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A MESSAGE FROM THE DIRECTOR

The National Center for Atmospheric Research (NCAR) is one of the world's premier scientific institutions, with an internationally recognized staff and research program dedicated to advancing knowledge, providing community-based resources, and building human capacity in the atmospheric and related sciences. After spending the first two decades of my career as a research scientist at NCAR, and serving the center in various leadership roles, I am extremely excited, honored and humbled to serve as the new Director. Moreover, I would like to extend my personal appreciation to Maura Hagan, who superbly led the Center during most of the past year. It was during her tenure that many of the accomplishments described in this 2013 NCAR Annual Report occurred.

In this Report, as well as the accompanying Laboratory Annual Reports, I invite you to learn more about how our staff are working synergistically and collaboratively with the broader community to produce impressive advances in our understanding of fundamental atmospheric processes and how the atmosphere interacts with and is influenced by other components of the Earth and Sun system. This progress is being driven, in part, by new technologies and their effective utilization at NCAR, including advanced observing facilities for field studies, increasingly powerful supercomputing capabilities, valuable research data sets that describe the Earth and the Sun, and widely used state-of-the-science community models that are providing improved capabilities for predictions of weather (including catastrophic events), air quality, hydrology, climate variability and change, and space weather. Moreover, educational and technology transfer activities at NCAR continue to encourage outstanding young scientists into the field and bring new research and technical achievements into the public and private sectors. Although only a small sampling of the many notable accomplishments of the past year, these aspects are well illustrated through the accompanying set of 10 highlights of our work in collaboration with the broader community.

NCAR's next strategic plan, due to be released in 2014, will extend this level of excellence with a compelling vision and strategy that emphasizes leadership in the development of observational and computational facilities and next-generation community models, as well as the aggressive pursuit of key integrative scientific challenges motivated by societal needs. Information about the probabilities of changes in temperature, precipitation, and availability of water, for instance, is not yet of a fine enough scale for effective use in regional adaptation and mitigation planning, and skill in predicting space-weather is not yet adequate for safeguarding satellite communications and the power grid. Community input into this plan has been invaluable, and we look forward to working with our community scientists to tackle the appropriate and ambitious research agenda that will be the centerpiece of the new plan.

For now, please enjoy this snapshot of NCAR competencies, facilities, and scientific accomplishments achieved in Fiscal Year 2013, and please accept my sincere thanks for your ongoing support and your hard work of the past year.

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With best wishes for 2014,

Jim Hurrell

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LARGEST AIR QUALITY STUDY IN DECADES LAUNCHES IN THE SOUTHEASTERN UNITED STATES

Elevated pollution levels, combined with abundant vegetation uniquely affect the climate and air quality in the southeastern United States. While elsewhere in the nation and world, effects of climate change have resulted in increased average temperatures, the Southeast has experienced a cooling trend. Additionally, the U.S. Southeast tends to have air quality issues resulting from chemical reactions occurring between organic compounds emitted from vegetation (biogenic volatile organic carbons or BVOCs) and human-made pollution. Wanting to better understand the dynamics of BVOCs and pollution in the atmosphere and the related effects on climate and air quality, the Southern Oxidant and Aerosol Study (SOAS) launched on June 1st, 2013 as part of an unprecedented 5-project air quality field campaign.

Included as part of SAS – the Southeast Atmosphere Study– SOAS addresses various components of air quality and chemical- and aerosol-constituent evolution over the southeastern United States. The largest U.S. air quality study in decades, SAS is jointly taken on by the National Science Foundation, the Environmental Protection Agency, the National Center for Atmospheric Research (NCAR), and 30 other U.S. and international research institutions. The atmospheric chemistry community, via the synergy and collaborative analysis of data from SAS, is poised to uncover the controlling processes of biosphere-atmosphere interactions that affect regional climate and air quality in the U.S. Southeast.

Atmospheric chemists have known for a decade that human-made emissions have the potential to interact with plant-emitted (biogenic) VOCs, turning these hydrocarbons into aerosols that may then affect air quality and human health. More typically, however, regions have either high pollution levels and low BVOC levels or high BVOC levels and less pollution, says Alex Guenther, an atmospheric chemist at NCAR and co-Principal Investigator on SOAS. This is less the case in the Southeast, where the aerosols resulting from the mixing of BVOCs and pollution also affect the region's climate.

Technicians evaluate the ISFS sampling tower in at the AABC site of the Southeast Atmosphere Study project, in the thick woods south of Tuscaloosa, Alabama (photo by Jim Moore).

“Black aerosols, which have been in the media quite a lot lately, are warming aerosols; they absorb incoming solar radiation, increasing global temperatures,” explains Guenther. “However, many of the lighter-colored aerosols, such as those composed of sulfates or organics, which form from reactions between BVOCs and pollution, have a cooling effect on the planet because they reflect some amount of incoming light back to space.”

Presence of high concentrations of light-colored aerosols is good from a climate perspective because it helps reduce average temperature, but bad from an air quality perspective, continues Guenther.

Many different kinds of VOCs are emitted to the atmosphere and their interactions with chemicals already in the atmosphere, such as water vapor, nitrogen, and ozone, and with each other, varies greatly, depending on the compound. In addition, VOC, when reacting in the presence of NOx from car emissions or other pollution sources, and sunlight can result in formation of ozone in the troposphere, the region of

the atmosphere just above the Earth's surface, which provides the air that people breath and to which plants are exposed.

Complicating things further, organic aerosols affect cloud formation and cloud opacity, both of which can, in turn, have impacts on incoming solar radiation (radiative forcing), potentially affecting the amount of greenhouse gases trapped in Earth's atmosphere. Moreover, because cloud formation is complex, many unknowns exist related to the specifics of aerosols' effects. Today's climate and atmospheric chemistry models have difficulty capturing these effects accurately. While models can replicate some atmosphere-aerosol observations, they don't achieve this at the level of detail that is required for a complete understanding of the chemical and atmospheric dynamics or to make accurate predictions of future air quality and climate.

Southeast Aerosol Research and Characterization (SEARCH) site sampling tower before instrumentation has been added (photo by Karsten Baumann).

To address some of these questions and improve observations that may be used to validate climate and chemistry models, the team of SAS/SOAS investigators will bring an unprecedented suite of filter sampling equipment and in-situ sensors to characterize the atmosphere and chemical processes across the Southeast U.S. this summer. From June 1-July 15, university and federal scientists will investigate why and how the Southeast has not warmed similarly to the rest of the continental United States. A combined investment of more than $20 million will include deployment of major measurement facilities, including the NSF/NCAR C-130 and NOAA P3 sampling across the region from the Mississippi River to the Atlantic Ocean, and from the Ohio River Valley to the Gulf of Mexico. Additionally, an Integrated sounding system (ISS) measuring boundary layer winds, moisture and temperature gradients, flux and chemical platform towers with instrumentation to take high resolution measurements from the surface up to 45 meters within the forest canopy and in the air above the forest will be deployed as part of these set of experiments.

Among the goals of SOAS – and SAS – are to develop a better understanding of the magnitudes, variations, and controlling processes for biosphere-atmosphere fluxes of oxidants and reactive carbon and nitrogen across spatial scales relevant to air quality and climate. The scientists expect to develop a better understanding of the chemical and physical processes that control the chemical reactions of BVOCs in the atmosphere. Additionally, study will determine how human-made emissions alter distribution of BVOC oxidation products, how aerosol formation affects clouds, and what the implications of oxidation are for ozone formation and reactive nitrogen.

For more information, see the SAS web site dedicated to the suite of SAS projects, including SOAS, deployment and measurement plans, as well as observation summaries and preliminary data products.

Arial view of the SEARCH site of the Southeast Aerosol Study project, near Brent, Alabama (photo by John Mak).

‹ A Message from the Director up Water Under the Bridge and Over the Road ›

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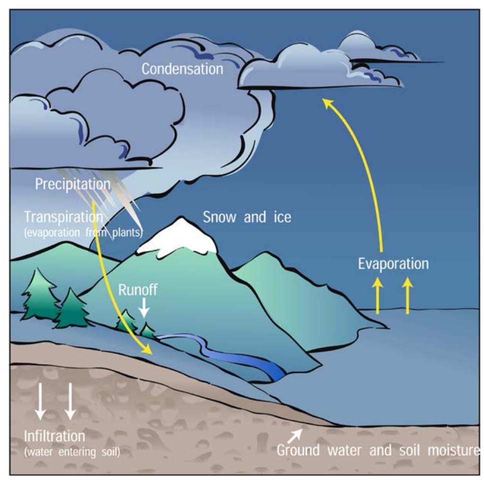
WATER UNDER THE BRIDGE AND OVER THE ROAD

Water is a precious commodity underpinning not only the U.S. economy, but also the quality of life here. The U.S. federal agencies managing the availability and distribution of this basic necessity face a variety of challenges every year in ensuring a high-quality, always-ready resource to meet public and private demands, and to manage highly changeable flood risks and drought responses around the nation. Recognizing that climate change is exacerbating these challenges, and to help managers better plan for and respond to climate change effects on water resources, the Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers (USACE), and National Center for Atmospheric Research (NCAR) are collaborating to improve our understanding of water resource-related climate effects. In addition, they are testing and improving some of the important management tools that the water resources community relies on to fulfill their federal missions to manage water resources in the best national interest.

"In 2010, Roy Rasmussen, who heads NCAR's Hydrometeorological Applications Program, talked to scientists at Reclamation about the effects of climate change on winter precipitation, snowpack, and runoff processes in Colorado's headwater basins, which is what launched this collaboration," says Martyn Clark, a scientist in the Hydrometeorological Applications Program who leads the water resource collaboration at NCAR.



Earth's water is always in circulation. It has been recycled in its different forms - as ice, liquid, or vapor -- for more than 3.5 billion years. The Sun's energy evaporates water from oceans and lakes into the atmosphere. Plants and animals also release water vapor as they respire. When atmospheric conditions are right, and cooling occurs, condensation of water vapor takes place and clouds form that can produce rain or snow.
Creditline: copyright University Corporation for Atmospheric Research

The Headwaters Research Program, led by Rasmussen, used a high-resolution, fully coupled atmospheric-hydrologic model to generate a detailed perspective on how the atmosphere interacts with the region's complex topography to control water availability under changing climate. Using projections of warmer, moister climate generated by global climate models, the research shows that Colorado's Headwaters region will receive greater than expected amounts of precipitation in winter, Clark says. This finding contradicts results from some Colorado River Basin climate change impact studies using less sophisticated methods for generating future hydro-climate conditions, methods that U.S. agencies, decision makers, scientists, and water managers are beginning to explore in preparation for developing plans related to regional-scale climate variation and change and its effects on water resources.

"The outcome surprised us, making us stop and think for a minute as to whether the methods used to assess climate change impacts on hydrology need to be reconsidered," Clark says.

Key scientists at Reclamation and USACE, the two chief water management agencies in the United States, became intrigued by Rasmussen's findings. Eager to work with NCAR to develop a better

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understanding of the issues and the implications for their missions, Reclamation and USACE designed and funded a partnership together with NCAR to understand how a modeler's methodological choices might affect the portrayal of climate change impacts on hydrology. Given the potential for any methodology to introduce biases into the model output, the group worked together to identify common or potential areas of weakness, focusing on “downscaling” issues and other relevant modeling and hydrologic questions.

Downscaling methods seek to extract local-scale information from global climate models and then use these data as input to regional-scale hydrologic models to examine effects of climate change on water resources. One commonly used approach, statistical downscaling, offers a number of benefits, including speed and ease of use; however, these statistical methods often cannot adequately capture the important subtle effects of climate change on terrestrial surface water hydrology.

“The statistical downscaling methods used by many water resource agencies can introduce artifacts in both precipitation occurrence and magnitude that affect projections of overall availability of water resources and flooding potential,” Ethan Gutmann, a scientist in NCAR's Hydrometeorological Applications Program.

Dynamic downscaling methods, on the other hand, use physically based regional- or local-scale numerical models to simulate more accurately regional-scale weather and climate dynamics. These methods, though, can be too computationally intensive and expensive to run and analyze for the large numbers of simulations needed to help inform water resources decisions, Gutmann says.

So, despite the shortcomings, water managers asking questions about climate change effects have in the past often relied on statistical downscaling methods because of their speed and ease of implementation, and because they have appeared to estimate the meteorological means in temperature and precipitation, at monthly time-scales reasonably well. Values at finer time scales or for extremes in the hydrologic cycle like floods and droughts are not so well estimated.

Eager to characterize and understand the shortcomings and their possible effects on water management decisions, and having the hope of developing better methods, USACE and Reclamation have extended their collaboration with NCAR to a new climate change project. That project seeks to improve both climate downscaling methods and hydrologic modeling approaches by creating a hybrid methodology that relies on both statistical downscaling and dynamical modeling.

“We have been developing this innovative downscaling approach using an atmospheric model of intermediate complexity that provides a good representation of natural processes and feedbacks,” says Gutmann. “This method provides physically meaningful representations of local-scale changes, and it can be applied to hundreds of different GCMs and emissions scenarios.”

“Many projections of changes in water resources are based on a single hydrological model that may not account for the uncertainty of simulating hydrologic processes,” explains Clark. “Our modeling approaches seek to improve the fidelity of hydrologic simulations over the contiguous U.S., as well as better characterizing model uncertainty.”

The group is working on developing new methods for dealing with weaknesses in climate impact methods, especially, new downscaling methods and novel hydrologic modeling approaches, Clark explains. Substantially improving climate impact assessment methods are critical to ensuring that when water mangers make long-term water resource plans that these plans are developed using robust research assumptions and planning tools.

“Our collaboration with NCAR and Reclamation is a vital component of the very active program at USACE to characterize the specific impacts of climate variability and change on our water management missions and on the roughly half-trillion dollar investment in water infrastructure USACE has made just since the 1960s," says Jeff Arnold, senior scientist and co-director of the USACE Responses to Climate Change programs. “This collaborative work to understand shortcomings in existing methods and to develop new tools for rapid deployment is significantly helping us prepare for the diverse climate change threats to surface water supplies and to plan possible responses and future investments.”

"Agencies are looking for ways to mainstream actionable climate science into water management

decisions, all while the climate science community continues to produce new sources of information that must be reconciled with planning activities," says Levi Brekke, Water and Climate Research Coordinator in Reclamation’s Science and Technology Program. "Reclamation and its partners are taking leading roles to develop an understanding on how these new sources of information and how they may be considered in water planning and management.”

‹ Largest Air Quality Study in Decades Launches in the Southeastern United States | up | Exploring the Atmosphere Where Satellites Fly ›

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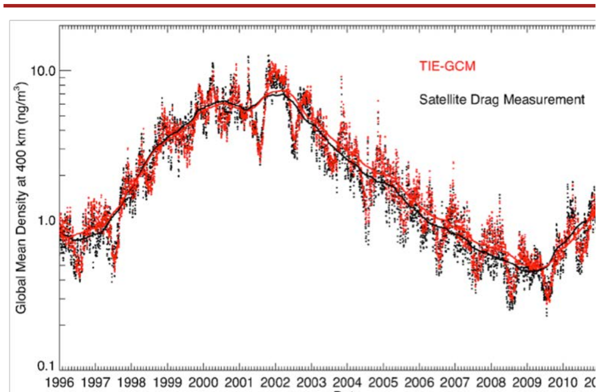
EXPLORING THE ATMOSPHERE WHERE SATELLITES FLY

Satellites are critical to many of the technological capabilities that global society has come to depend on. Global positioning systems provide essential navigation for land, sea, and air transportation, weather satellites collect data critical for predicting severe weather on Earth, and communications satellites broadcast television and radio transmissions into living rooms worldwide. However, society often takes satellite capability for granted. Characteristics of the atmosphere – for example, atmospheric mass – in regions where satellites orbit can have notable effects on satellite function. Scientists in the National Center for Atmospheric Research's High Altitude Observatory (HAO) are using models to improve their understanding and ability to predict abrupt changes in the upper atmosphere that can affect satellites' ability to perform as expected.

Satellites achieve a stable orbit by maintaining a velocity that allows the vehicle, pulled by the planet's gravitational force, to fall toward Earth at a rate equivalent to that at which the Earth's curvature moves away from the forward-moving satellite. But changes in atmospheric density affect satellite velocity. Moreover, changes in density are not uniform across regions of the atmosphere. Because these changes vary in space and time, those on the ground must sometimes manually adjust satellite velocity, as well as manage internal satellite warning systems related to avoiding collisions, and re-entry predictions, says Liying Qian, a scientist in HAO studying this problem.

"The atmosphere in the Earth's thermosphere, which exists roughly 90 to 600 kilometers above the Earth, is nearly a vacuum. Many space vehicles fly in the upper thermosphere and encounter drag from this very thin atmosphere. Perturbations on their orbits occur when mass density changes in this region," explains Qian. "Understanding changes in mass density in this region is critical, particularly because density changes can crop up unexpectedly, having important and often undesired outcomes on satellite flight."



The figure above compares modeled and measured global mean mass density at 400 km. Each dot shows a daily value of the mean density. Red dots show simulations by the NCAR TIE-GCM, while the black shows measurement through analysis of atmospheric drag on orbiting objects. The red and black lines show the 365-day centered running mean of global mean mass density.

At or below 150 kilometers, the Earth's gravitational pull requires that satellites have some means of constant propulsion to maintain their orbit, while above 600 kilometers atmospheric drag is minimal. In between these regions, the ability to predict changes in mass density would improve Earth-based satellite control during times when the thermosphere's neutral density experiences disruptions.

Disruptions occur because of changes in the amount of incoming solar radiation, for example from solar flares, or from geomagnetic disturbances caused by the effects of solar winds, as well as the natural dynamics occurring within the thermosphere. Increased solar activity may, for example, increase the amount of extreme-ultraviolet radiation in the upper atmosphere, exciting or ionizing the thermosphere's constituents. Some of the fast moving, charged

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particles expelled from the Sun's upper atmosphere in solar winds, can break through the Earth's protective magnetosphere, which sits above the thermosphere, causing regional changes. All of these events can affect the density of the thermosphere. In addition, the thermosphere is affected by processes occurring in lower atmospheric regions. For example, gases such as carbon dioxide, methane, water vapor, and ozone from the troposphere or stratosphere, the layers of atmosphere closest to Earth, can affect the density and dynamics of the overlying atmosphere.

To both gain an improved understanding of the atmospheric dynamics at this altitude and to better predict changes due to space weather or effects of changing climate and chemical composition of the lower atmosphere, among other questions, Qian and her colleagues turned to NCAR's Thermosphere Ionosphere Electrodynamic General Circulation Model (TIE-GCM). The TIE-GCM models the Earth's atmosphere from approximately 97 to 600 kilometers, but the scientists wanted to know how well the model performed as compared to reality, information that is critical for estimating expected and actual satellite orbits and necessary for improving scientists' ability to predict density changes.

Qian and the team generated model runs, replicating commonly occurring external forcing events – that is, events that influence or force changes to occur to the characteristics of the thermosphere, such as the effects of solar flares and geomagnetic storms. They then compared this output to observations collected from the CHAMP (Challenging Minisatellite Payload) satellite. Among the instruments loaded onto CHAMP are accelerometers, which provide information that can be used to derive effects of satellite drag.

By comparing the model output with observed atmospheric phenomena, the scientists gained information about how well the model did at predicting changes in the thermosphere's density. In addition, the comparison provided insights into the variability and driving mechanisms related to density changes, such as time of day, effects of space weather and solar cycle variations, and changes at varying altitudes.

"By assessing the observations and the modeled output, we gained new knowledge about thermospheric dynamics and factors that affect density changes, which provides valuable knowledge for improving satellite operations," says Qian. "A number of challenges still await us, such as how lower atmospheric forcings affect annual and semi-annual variation of the thermosphere's density, among other questions."

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NCAR-WYOMING SUPERCOMPUTING CENTER GRAND OPENING 2013

In October 2012, the NCAR-Wyoming Supercomputing Center (NWSC) simultaneously opened its doors to the public and launched its Educational Visitor Center. With funding provided by the National Science Foundation, the center exhibits let visitors explore science topics such as extreme weather, climate change, energy, water resources, supercomputing, energy efficient technologies, and human health. Each area represents work that is pursued at the National Center for Atmospheric Research and the University of Wyoming (UW), and also showcases the technology employed at the NWSC to realize these goals.

Wyoming school group stand in front of the NCAR-Wyoming Supercomputing Center.

The visitor center helps meet a key goal of the NWSC facility project and the NCAR- UW partnership: ensuring that the NWSC has a broad impact on the public. An active public visitor program is one means of achieving this end. In addition, the education and outreach goals are specifically designed to address the challenges facing students and educators pursuing science, technology, engineering, and math (STEM) education.

Currently, relatively few American students pursue studies in STEM fields, making STEM education for both students and teachers increasingly a national priority. The NWSC exhibit serves as a nexus for STEM events tackling this problem. For example, 192 Wyoming middle and high school students came to the NWSC to learn about science and supercomputing as part of the UW's Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP). In addition, the NWSC traveling display has been used in events such as the NSF-sponsored "Change the World: Science & Engineering Careers Fair" in Virginia, in September 2013.

Display content developed by UW, the Laramie County Public Library, NCAR's Computational and Information System Laboratory, and Spark (the education/outreach team of NCAR's managing body, the University Corporation for Atmospheric Research) includes a variety of STEM topics. Exhibits zero in on topics ranging from climate and computer science to meteorology, to questions unique to the U.S. West and its resources and the effects of science on society, to the green design of the NWSC itself. Visitors can view topical videos or animated films, or view displays featuring multiple Q&A activities or science and technical content. Some exhibits feature touchscreen technology that lets viewers play interactive games.

The center has exceeded initial estimates for community interest, total visitors, organized group tours, and school group visits. Since opening, the center has hosted more than 3,000 visitors – roughly the equivalent of 5% of the population of Cheyenne, Wyoming, where the NWSC is located. Since January 2013, when school groups first

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began visiting, an average of 2-3 school groups have visited each month, with groups ranging in size from 12 to 226 visitors. This is in addition to visit from 33 non-school groups.

A young visitor explores the NWSC's computing capabilities at a touchscreen exhibit.

UW, NCAR, and NSF are all happy with the outcome of the NWSC Visitor Center. Just more than a year old, it has yielded rich opportunities for outreach and education about NCAR and UW science, as well as scientific computing, mathematics, and engineering.

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SCIENTISTS LAUNCH INTERNATIONAL STUDY OF OPEN-FIRE COOKING AND AIR QUALITY

Expanding its focus on the link between the atmosphere and human health, the National Center for Atmospheric Research (NCAR) is launching a three-year, international study into the impact of open-fire cooking on regional air quality and disease.

The study will break new ground by bringing together atmospheric scientists, engineers, statisticians, and social scientists who will analyze the effects of smoke from traditional cooking methods on households, villages, and entire regions.

Cooking over an open fire in Ghana. (Photo Courtesy of Global Alliance for Clean Cookstoves)

Researchers will combine newly developed sensors with computer and statistical models to look at what happens to human health when traditional cooking methods are used. They will also evaluate whether newer, more efficient cookstoves could reduce disease and positively affect regional air quality.

The project brings together a diverse team of pollution, climate, and health experts from NCAR, the University of Colorado Boulder, University of Ghana School of Public Health, and Ghana Health Services. Funding comes from the National Science Foundation, NCAR's sponsor.

The researchers will focus primarily on northern Ghana, where they will examine possible links between air pollutants and such diseases as meningitis. Their findings are expected to provide information to policymakers and health officials in other developing countries where open-fire cooking or inefficient stoves are common.

"Often when you visit remote villages in Ghana, they're shrouded in haze for many miles from all the fires used for cooking," says NCAR scientist Christine Wiedinmyer, an atmospheric chemist overseeing the project. "Given that an estimated three billion people worldwide are cooking over fire and smoke, we need to better understand how these pollutants are affecting public health as well as regional air quality and even the climate."

Wiedinmyer and her colleagues will use a novel combination of local and regional air quality measurements—including specialized smartphone applications that are more mobile than traditional air quality sensors—and cutting-edge computer models of weather, air quality, and climate. The researchers and student assistants will also survey villagers to get their views on possible connections between open-fire cooking and disease as well as their interest in adopting different cooking methods.

Cooking fires in developing countries are a leading source of carbon monoxide, particulates, and smog. These can cause a variety of symptoms, ranging from relatively mild ailments, such as headaches and nausea, to potentially life-threatening conditions, including cardiovascular and respiratory diseases.

The fires also emit carbon dioxide and other heat-trapping gases that, when mixed into the global

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atmosphere, can affect weather patterns and warm the climate. As regional temperatures warm, that in turn can act to increase the level of air pollution, thereby potentially leading to greater health risks.

The project builds on other NCAR projects studying links between the atmosphere and human health. These include the development of specialized forecasts of weather conditions associated with the beginning and end of outbreaks of meningitis in Africa.

“We’re excited about the opportunity to continue working with our collaborators in Ghana and to help alleviate a major health problem across the Sahel of Africa,” says NCAR’s Mary Hayden, a medical anthropologist. “Bringing together an international transdisciplinary team of social scientists with climatologists, atmospheric chemists, and engineers to tackle the problem is the first step in addressing thesecomplex human-environmental problems.”

‹ NCAR-Wyoming Supercomputing Center grand opening 2013 up Observing a Quieter Sun ›

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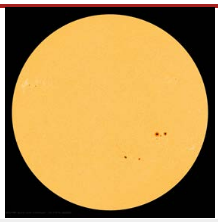
OBSERVING A QUIETER SUN

Since the dawn of the Space Age in the 1950s, solar maxima have coincided with strong upticks in sunspot activity but the current cycle, Cycle 24, which was expected to peak in Spring of 2013, has been unusually quiet. Solar activity remained at a moderate level, making it one of the weakest cycles in the past 100 years, as evidenced by the low number of sunspots appearing on the Sun's surface. With fewer and smaller sunspots, weaker magnetic fields that are associated with the sunspots, and less outgoing (radiative) energy, many wonder what might be causing the Sun's quiescence.

Some have suggested that the decline in solar activity may be a result of the 100-year Gleissberg Cycle. Others have speculated that sunspots and solar activity may be changing, with these changes potentially marking the beginning of a new Maunder Minimum. Because of the close connection between Earth and Sun, scientists are interested in better understanding the Sun's variable output, particularly when the star is not acting in a manner that people have come to expect.



Sunspot activity is mostly seen in the Sun's Southern Hemisphere in this October 15 2013 image taken by the Atmospheric Imaging Assembly telescope that flies on NASA's Solar Dynamics Observatory satellite.

"Cycle 24 is different from recent cycles. You need to go back almost a century, to 1928, to find a cycle as weak as this," says Giuliana de Toma, a scientist at the National Center for Atmospheric Research's High Altitude Observatory (HAO). "Weak cycles have happened before, but this is the first time we have had an opportunity to observe a weak cycle with modern instrumentation, which makes Cycle 24 very interesting."

Since the 1950s, the Sun's activity has been high, with the largest cycle in the historical record (Cycle 19) occurring during this time frame. But beginning with Cycle 23 in 1996, things started to change. While still an above-average cycle, Cycle 23 was noticeably weaker than the preceding ones and had fewer very large sunspots. Then, with Cycle 24, solar activity declined even more. Sunspots of all sizes have decreased in number, with large sunspots particularly scarce.

"This does not make Cycle 24 anomalous" says de Toma. "Weak cycles have fewer sunspots, and especially fewer of the largest sunspots – this is why weak cycles are weak."

A possible explanation for the recent decline in solar activity is that the Sun is near the minimum of a "Gleissberg Cycle." While regular sunspot observations began in the 18th century, scientists turn to cosmic rays as a proxy to understanding solar activity that occurred prior to having a direct observational record. Isotopes (Berrylium-10 and Carbon-14), which provide insight on the variation in cosmic radiation incident on Earth, indicate that the amount of radiative energy emitted by the Sun seems to change over a period of about 80-100 years. Known as the Gleissberg cycle, this pattern is believed to be of solar origin. While this theory is consistent with the fact that sunspot cycle patterns were similarly weak at the beginning of the 1800 and 1900, given the brevity of a direct solar observational record, scientists are unsure if this is a real phenomenon and, if real, what might cause such modulation in solar activity every 100 years. If valid, a Gleissberg Cycle might explain why the Sun is currently quieter.

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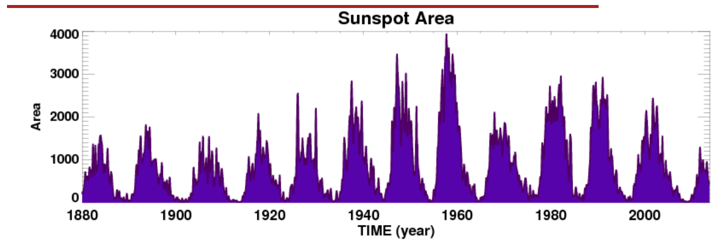
Matt Penn and Bill Livingston at the Solar National Observatory have put forward the suggestion that the Sun may be entering a period of inactivity. They reported a decline in magnetic field and darkness of sunspots, independent of the current weak solar cycle. According to their analysis, observations taken with the McMath-Pierce telescope located at the Sonoran Desert-based Kitt Peak Solar Observatory show that sunspots are becoming less dark at a worrisome rate of about 2% a year since the early '90s. If true, in extrapolating this trend forward in time, the Sun will experience a new Maunder Minimum by the year 2022.

The Maunder Minimum, which lasted from 1645 to 1715, was a period when sunspots rarely appeared. While little is known about the causes of the Maunder Minimum, one interesting aspect of this period is that it coincided with lower than average temperatures in Europe and North America. However, this was also a period of high volcanic activity that likely contributed to the observed cooling. Despite happening only once in the hundreds of years that humans have been counting sunspots, by using cosmic rays as a proxy of pre-historic solar activity, the Maunder Minimum is not a unique occurrence.



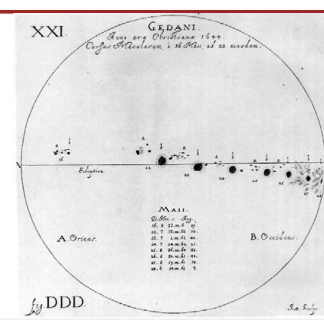
This image shows a record of sunspot area measures going back to solar cycle 12 in 1898. Areas are measured in millionth of solar hemisphere and averaged over three solar rotations.

So is the Sun on course for a long period of low activity? The decline found in the McMath-Pierce data occurs mostly in the early years, when only a very few measurements were collected. This decline has not been confirmed by other observations, in spite of the fact that other groups have looked for similar trends in different data sets. To better understand the recent slowdown in solar activity, de Toma and her colleagues at the California State University, Northridge examined the solar observations collected at the San Fernando Observatory (SFO) with the Cartesian Full Disk Telescope (CFDT1) that goes back to 1986. This data set includes more than 20,000 sunspot observations and is the longest record of accurate photometric sunspot measures, that is, accurate measurements of sunspot brightness.

"While the total area and number of sunspots have decreased in Cycles 23 and 24, the relationship between the area and brightness of the sunspots has not changed," de Toma says. "We do not find that sunspots are getting less dark during the 27-year period spanned by the SFO observations. Sunspots are not different now than they were in Cycle 22, when activity was high."

This evidence suggests that while the Sun's quiet has not been seen within recent history, it does not imply that the Earth will experience a Maunder Minimum, or that sunspots are disappearing.

The quiet solar maximum provides astrophysicists with a unique opportunity to hone their understanding of the solar dynamo and their ability to predict the strength of upcoming solar cycles. As for predicting a Maunder Minimum, this is still out of our reach, according to de Toma.



A drawing by Johannes Hevelius created in 1644, one year before the start of the Maunder Minimum, shows the passage of a large spot across the solar disk, which occurred over eight consecutive days.

"We still do not know how and why the Maunder Minimum started, so we cannot predict when another one will occur," she says. "We know from drawings made by Johannes Hevelius in the 17thcentury that there were large sunspots on the Sun shortly before the Maunder Minimum stated, so the lack of large spots is not an omen of an incoming Maunder Minimum."

In addition to the intellectual challenge, another benefit of this weaker solar activity is that fewer coronal mass ejections occur during these quieter cycles. This results in quieter space weather, which can affect communications and electrical grids on Earth, as well as space missions.

"That said, space weather does not go away when the Sun is quiet. Powerful solar eruptions can still occur. The 1859 Carrington flare, which caused the strongest geomagnetic storm on record, occurred during a normal cycle, not a very active one" cautions de Toma. "Indeed, in July 2012 we observed the fastest coronal mass ejection ever recorded, which blasted away from the Sun at a record speed of about 3,000 kilometer-per-second – luckily, it was not directed toward the Earth."

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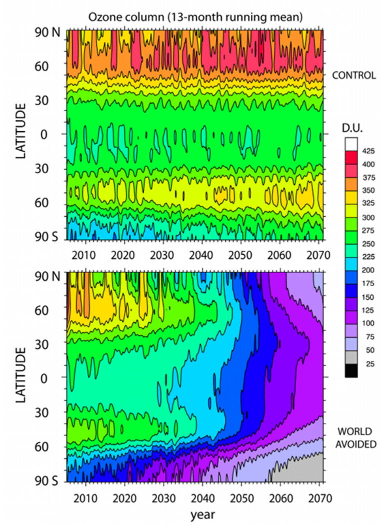
STUDYING A WORLD AVOIDED: THE EFFECTS OF THE MONTREAL PROTOCOL

Put into force in 1989, the Montreal Protocol (and its subsequent amendments) is an international treaty that protects the world's ozone layer by reducing global emissions of ozone-depleting substances (ODS). To understand the effects of this treaty and the response of the stratosphere to ODS reduction, Rolando Garcia, Douglas Kinnison, and Daniel Marsh, scientists at the National Center for Atmospheric Research (NCAR), used the *Whole Atmosphere Community Climate Model* (*WACCM*) to assess the "World Avoided" through implementation of the Protocol. They modeled the effects of uncontrolled emissions of ODS on stratospheric ozone and climate in the 21st century.

"We wanted to build on existing work about what the world has avoided by enacting the Montreal Protocol," says Rolando Garcia, a senior scientist in NCAR's Atmospheric Chemistry Division. "We also wanted to see how long it might have taken to reverse the effects of uncontrolled ODS emissions if action to address the problem had not been taken before the mid-2050s."

Work led by Paul Newman at NASA's Goddard Space Flight Center motivated the NCAR scientists. Newman and his collaborators simulated the effects of the Montreal Protocol using the Goddard Earth Observing System (GEOS) model, which showed a complete collapse of the protective ozone layer by 2050. Using a newly released version of WACCM, Garcia, Kinnison, and Marsh expanded on the work of Newman and colleagues by looking into the effects of unrestrained ODS emissions on both the chemistry of the atmosphere and the global climate. The latest version of WACCM can now be run coupled to a deep ocean model, which allowed the NCAR scientists to calculate the response of Earth's climate to the addition of ODS. Greatly increased concentrations of ODS would have a notable effect on global average temperature because these compounds are also potent greenhouse gases (GHG). While much less abundant than carbon dioxide, methane, or nitrous oxide, ODS are very effective GHG because they absorb outgoing infrared radiation in the "atmospheric window," the range of infrared wavelength where carbon dioxide and other GHGs are largely "transparent," explains Garcia.



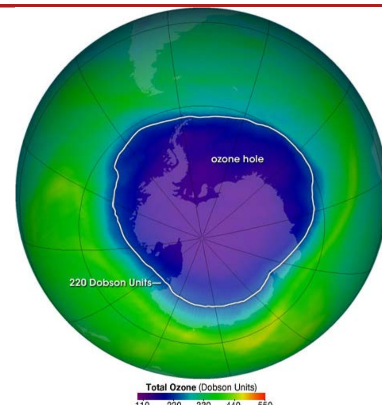
Evolution of the total ozone column in the control (top figure, which shows expected ozone column amounts between 2005 and 2070) and world avoided (bottom figure, which shows ozone concentrations expected in a world lacking the Montreal Protocol) simulations. Ozone column amounts are given in Dobson Units (DU) – higher DU values indicate a higher amount of protective stratospheric ozone. The time series have been smoothed with a 13-month running mean to suppress the annual cycle and emphasize long-term changes. **From Garcia et al, 2012.**

In running the World Avoided experiment, Garcia and his colleagues were able to confirm Newman's finding that, if ODS emissions had continued to grow at the rate observed prior to the adoption of the Montreal Protocol (3% per year), the ozone layer would have collapsed globally by the mid-21st century.

"This is an important finding, because the agreement of climate-chemistry models running similar experiments indicates that independent model implementations of currently accepted stratospheric chemistry lead to essentially the same results," Garcia says.

The WACCM calculations also showed that by 2070 ODS emissions alone would have increased global average temperature by an amount equivalent to what is expected to occur under a moderate greenhouse gas emissions warming scenario, the "Representative Concentration Pathway" 4.5 (RCP4.5). This scenario prescribes changes in GHG that would produce a radiative imbalance of 4.5 Watts per square meter (Wm^{-2}) with respect to pre-industrial conditions by the end of the 21st century. By comparison, the radiative imbalance due to uncontrolled growth of ODS calculated with WACCM is about 4 Wm^{-2} near the end of the 21st century, which is almost as large as thatdue to the change in non-ODS GHG under the RCP4.5 scenario. Consequently, the global temperature increase by the late 21st century would have been about twice as large in the World Avoided scenario as that calculated under RCP4.5 alone.

Finally, the scientists used WACCM to model how quickly the Earth's protective ozone layer might have recovered if reductions of ODS emissions began only by the mid-2050s. They chose this date because it coincided with the collapse of the ozone layer in their calculations – a catastrophe that would have forced the world to deal immediately with the resulting impacts. The scientists found that the ozone layer in the Tropics and middle latitudes recovered relatively quickly, within a few years of the complete cessation of ODS emissions. However, in the polar regions substantial ozone depletion was sustained into 2070, the end point of the model simulations. In addition, global warming did not abate significantly by 2070 in these calculations.



This NASA image shows regions of the ozone hole over Antarctica with total ozone of 220 Dobson Units or lower on October 4, 2004; data were acquired by the Ozone Monitoring Instrument on NASA's Aura satellite.

The reason for this disparity has to do with the atmospheric lifetime of the chemical species involved. At lower latitudes, ozone is destroyed mainly by chlorine and bromine compounds derived from short-lived ODS, such as methyl bromide, which has an atmospheric lifetime of less than a year. Once emissions cease, the atmospheric burden of methyl bromide from human sources disappears in just a few years. On the other hand, ozone loss at high latitudes depends on chlorine and bromine released from long-lived species like CFC-11, CFC-12, and Halon-1301, whose atmospheric lifetime ranges from 45 to more than 100 years. In this case, removal is a slow process, lasting on the order of a century. These long-lived compounds are also responsible for much of the greenhouse warming due to ODS. As a consequence, the rise in global temperature in 2070 is almost as large in the calculation where ODS emissions are curtailed in mid-21stcentury as in the full World Avoided scenario.

"Our experiment provides new perspectives on the effects of the Montreal Protocol on global ozone depletion, as well as on climate," Garcia says. "As regards climate change, it is also useful to bear in mind that while the impact of the long-lived ODS may last about 100 years, carbon dioxide is 'eternal' as far as human lifetimes are concerned."

Some of the atmospheric carbon dioxide will be absorbed by the oceans on the relatively short time scale of 1,000 years. After that, carbon removal is a geological process and takes place on time scales of hundreds of thousands of years. In terms of taking effective action for dealing with climate change, was the Montreal Protocol a good thing? Ironically, perhaps not, suggests Garcia.

"Without the agreement, the world today would be heating up more rapidly, which might have encouraged us to do something, right now, about climate change," Garcia says.

The paper by Garcia et al, "World avoided" simulations with the Whole Atmosphere Community Climate Model is available online.

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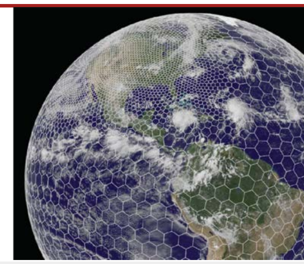
SPANNING THE GLOBE WITH A HIGH-RESOLUTION WEATHER FORECAST MODEL

Starting in June 2013, scientists around the world began downloading software that can simulate and forecast weather on a global basis. The debut of the Model for Prediction across Scales (MPAS) marked the first time that researchers everywhere could freely gain access to global-scale weather modeling tools that offer a level of detail previously available only in models spanning a particular region. The model is being jointly developed by NCAR and the U.S. Department of Energy's Los Alamos National Laboratory, with NCAR focusing on the atmospheric component and LANL the oceanic component.

MPAS follows in the highly successful footsteps of the Weather Research and Forecasting model (WRF), which was created by a multiagency partnership in the late 1990s and early 2000s. NCAR's version of this model, the Advanced Research WRF (ARW), has been used as an open-access tool by more than 2,000 scientists in over 150 nations. NCAR provides free, downloadable ARW software as well workshops and tutorials that focus on the model and how to get the most out of it. Many hundreds of research papers have drawn on ARW simulations. The model has also proven its mettle as a forecasting tool during field campaigns focused on hurricanes, tornadic thunderstorms, and other types of extreme weather.



The variable-mesh MPAS grid can be customized to feature higher resolution where added detail is desired (as illustrated here for North America).

Despite its high value and widespread use, WRF faces an obstacle common to many other weather models: the tyranny of the latitude-longitude grid. Such models slice the atmosphere into blocks, or grid cells, that are typically many kilometers wide and a few hundred meters tall, bounded by north-south and east-west lines. However, because longitudinal lines converge toward the North and South Poles, the grid cells are not quite rectangular. At higher latitudes, they become increasingly narrow, and special computational techniques are needed to keep the model's atmosphere working in a realistic way.

MPAS gets around this roadblock through the use of what is known as an unstructured Voronoi mesh (see illustration). Instead of a grid with rectangles that taper toward the poles, the MPAS mesh features a latticework of shapes—mostly hexagons, but with a few five- and seven-sided cells—that intersect in a seamless way across the entire globe. The resulting structure bears some resemblance to the shape of C60, the buckminsterfullerene (or "buckyball") molecule. But while that molecule has just 32 faces (as does a standard soccer ball), the MPAS grid can have millions of cells.

Along with eliminating the problems caused by polar convergence, the meshed grid of MPAS has another benefit: it can be easily telescoped to provide higher resolution in those regions where extra detail is desired. Traditional model grids can also be nested in this way, but the abrupt transitions along the sharp edges of a nest can be computationally problematic. In MPAS's variable mesh, the transition from coarse to fine resolution is seamless.

One of the most in-depth projects for MPAS thus far is a set of runs carried out after the installation

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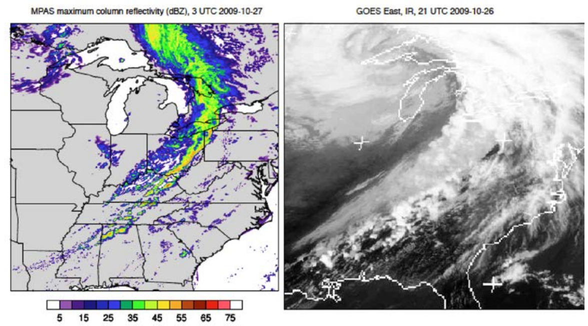
of NCAR's Yellowstone supercomputer in late 2012 at the new NCAR-Wyoming Supercomputing Center. These runs were part of NCAR's Accelerated Scientific Discovery (ASD) program, which allows a select set of computing-intense research projects to be carried out before a newly installed supercomputer is made available for more general use.



A broken line of supercell thunderstorms that produced tornadoes across parts of the eastern U.S. on the afternoon and evening of September 26, 2009 (see satellite image at right) was well forecast by the high-resolution 3-km MPAS (left) based on conditions four days earlier.

Under the ASD project, MPAS was run in retrospective mode. The model produced 10-day forecasts for two periods from 2010, allowing the forecasts to be compared to actual weather observations and satellite images. In these tests, the model's variable mesh narrowed from 60 kilometers to as fine as 3 km in areas of special interest, such as where severe weather might be expected. Grids cells larger than about 10 km are too coarse to simulate individual showers and thunderstorms, so the presence of storms must be specified, or parameterized—somewhat like predicting the course of a football game based on general statistics from past games. Even a 3-km grid is still too coarse to track individual cloud elements, but it does allow for thunderstorms to form, grow, and die over time—essentially simulating each play of the football game, rather than relying on statistical clues.

The abilities of MPAS were especially evident in one of the retrospective ASD forecasts, issued from starting-point conditions for the evening of October 22, 2010. The model predicted that four days later, on the afternoon and evening of the 26th, a broken line of supercell thunderstorms would move through the Ohio Valley. That forecast closely matched reality, with supercells marching across the region and producing dozens of tornadoes from Alabama to Ohio.

A major test of the model was carried out during the 2013 Atlantic hurricane season. Ten-day forecasts were generated once a day from 1 August to 20 September using two versions of MPAS. One version featured a variable mesh that transitioned from 60-km resolution across most of the world to 15 km across the tropical Atlantic and neighboring land areas. The other version spanned the entire globe at 15-km resolution. Although it provided more overall detail, the full 15-km version also required five times more computing time and expense. One of the key aspects of this project was to see if the less expensive variable mesh would perform as well as the uniform mesh for tropical cyclones.

The answer came from the Eastern as well as the Western Hemisphere. In 2013, the North Atlantic experienced an unusually quiet season for tropical cyclones—there were only two hurricanes, the least since 1982—so the researchers had only a handful of cases to evaluate against the MPAS forecasts. However, researchers at the Taiwan Typhoon and Flood Research Institute ran a companion study from 1 August to 31 November, centering the variable-resolution MPAS grid over Taiwan. This provided a larger set of test data, since the northwest Pacific experienced a much busier tropical season in 2013, even apart from the catastrophic Supertyphoon Haiyan.

Together, the Atlantic and Pacific studies showed that accuracy didn't suffer in a significant way when the less computationally costly grid was used. In some cases, forecasts up to six days in advance were able to capture specific tropical cyclones reasonably well in both versions of MPAS (see graphic).

The versatility of MPAS makes it a potential candidate for what's known as a unified model, one that could be used economically in place of several other models at an operational forecasting center. Even finer-scale variable meshes will be explored in the near future. A major question is how MPAS will perform at resolutions below 1 km; at this level of detail, individual cloud features can be resolved, such as the air parcels entrained into a building thunderstorm. Another goal is to develop new techniques for bringing information on current weather into MPAS, in tandem with NCAR's Data Assimilation Research Testbed.

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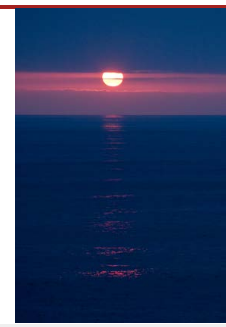
EXPLAINING THE RECENT PAUSE IN RISING GLOBAL SURFACE TEMPERATURES

Since 1998, globally averaged surface temperatures have remained relatively flat, despite continued warming of the climate system and carbon dioxide concentrations reaching a new high of 400 parts per million in 2013. Scientists are debating how and why the global atmosphere seems to be bucking the influence of steadily increasing greenhouse gases. As Kevin Trenberth and John Fasullo, scientists at the National Center for Atmospheric Research (NCAR) point out in a 2013 paper, the climate system's innate variability and dynamics make this a less-than-surprising reality.



The sun sets over the Pacific Ocean at Iquique, Chile. A number of studies, including one by NCAR's Kevin Trenberth and John Fasullo, indicate that the excess heat generated by anthropogenic emissions seems to be melting the Arctic sea ice and warming the world's oceans, with the deep ocean – below 700 meters – currently taking up a third of the excess heat.

While seasonal fluctuations don't seem out of the norm, with warmer-, wetter-, or sunnier-than-normal summers occurring one year, and cooler-, drier-, or cloudier-than-normal occurring the next, many people, write Trenberth and Fasullo, expect that human-made climate change will result in seasonal temperatures growing increasingly warm each year. However, natural variability within a dynamic system and people's experience with seasonal fluctuations should indicate that such an assumption is neither typical nor likely. Over the last several years, scientists including Trenberth, Fasullo, and NCAR colleague Jerry Meehl have used observations and models to show that "pauses" in global atmospheric warming lasting a decade or more can be expected, thanks in large part to the huge role of oceans in modulating Earth's climate.

Most climate scientists agree that the current warming "hiatus" does not indicate a stalling of the effects of a warming world. Instead, this heating hiatus, a result of natural variability, may be caused by fluctuating patterns linked to both the atmosphere and ocean, like the El Niño/Southern Oscillation that results in El Niño and La Niña events. For instance, the 1998 El Niño event caused notable changes in global weather patterns because heat came out of the oceans – thereby cooling the ocean – and invigorating weather systems, while recent La Niña events have reduced sea surface temperatures, resulting in cooler global average surface temperatures even as the ocean as a whole warms. In other words, the warming of the surface ocean often goes in the opposite direction to the global mean surface temperatures. Additionally, natural events such as volcanic eruptions and reduced solar activity caused by the Sun's recent quieter-than-average state can cause a reduction in the amount of incoming radiation.

A number of studies, including Trenberth and Fasullo's, indicate that the excess heat generated by anthropogenic emissions seems to be melting the Arctic sea ice and warming the world's oceans, with the deep ocean – below 700 meters – currently taking up a third of the excess heat. This appears to be related to the cool (negative) phase of the Pacific Decadal Oscillation (PDO) that has prevailed since the late 1990s. When the PDO is in its cool phase, there tends to be a net storage of heat in the global oceans—similar to El Niño, but on a longer time scale.

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The PDO switches from warm to cool (positive to negative) about every 20 to 30 years. Trenberth and Fasullo speculate that the record-strong El Niño of 1997–98 released so much heat from the ocean that the PDO's switch to a heat-storing negative mode may be having some type of compensating response. They caution that the dynamics that drive shifts in the PDO have not been conclusively determined, and climate models don't yet seem fully capable of predicting such shifts.

Trenberth believes an El Niño might be the trigger to push the current PDO in the other direction. If this happens, some of the "missing" atmospheric warming may once more be felt, potentially causing global temperature to rise at rates on a par with that experienced during the 1970s to 1990s and pushing global average readings to new record highs. This will likely cause global decision-makers some concern, given that even with the current hiatus in increasing land-surface temperatures, the first decade of the 21st century is the warmest since at least the 1850s, when instruments began regularly and reliably measuring weather phenomenon.

Even in the current global pause, the United States experienced by far the warmest year on record in 2012, accompanied by widespread and costly drought. The evidence suggests that global warming of the planet is continuing, explains Trenberth, it just gets manifested in different ways at times.

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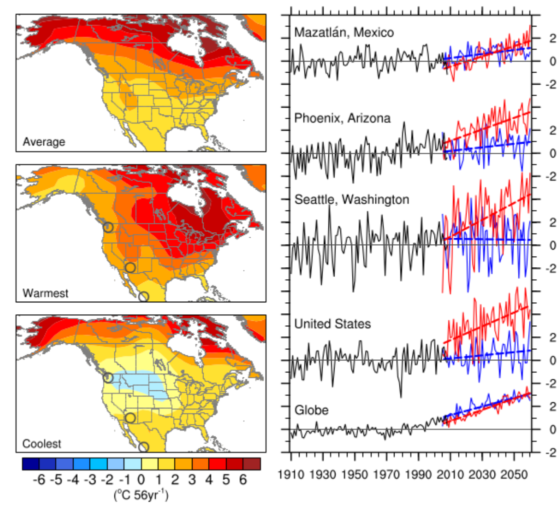
EFFECTS OF NATURAL VARIABILITY ON PROJECTIONS OF CHANGING CLIMATE: A STUDY IN NUANCE

Humans and their emissions have an undeniable effect on global, regional, and local climate; however, natural climate variability introduces shades of gray into the prediction of future effects of climate change. Extreme events such as “Snowmageddon,” the series of blizzards that hit the U.S. East Coast in 2009-2010, or even Colorado’s cooler-than-normal 2013 summer demonstrate deviations from typical climate patterns. These out-of-the-norm events indicate what happens when natural climate variability and human-driven climate change intersect, explains Clara Deser, a senior scientist at the National Center for Atmospheric Research.

While average global temperatures continue to rise due to human emissions, changes in temperature and precipitation will not occur uniformly across regions. How future climate change manifests locally will differ from the global averages predicted by models, with some localities experiencing cooling rather than warming trends, for example, because of the effects of natural climate variability.



These images show the range of future climate outcomes. The maps on the left show December–January–February (DJF) temperature trends during 2005–2060. The top panel shows the average of the 40 model runs; middle and bottom panels show model runs with the largest and smallest trends for the contiguous United States as a whole, respectively. The panel to the right shows DJF temperature anomaly time series for selected cities (marked by open circles in the left panels), the contiguous United States, and the globe (land areas only). Black curves show observed records from 1910 to 2008 (minus the long-term mean); red and blue curves show model projections for 2005–2060 from the realizations with the largest and smallest future trends, respectively, for each location or region. Dashed red and blue lines show the best-fit linear trends to the red and blue curves, respectively. For visual clarity, the model projections are matched to observations averaged over their common period of record 2005–2008. Thus, projected values at the end of the simulation (2060) should be regarded in relative terms.

“Climate models do a good job of projecting the effects of human-made (anthropogenic) climate change, but natural variability limits the accuracy of these projections,” says Deser. “In other words, natural variability is the ‘X Factor’ that determines how future weather and climate events will manifest in specific locations or regions, for example Denver or the western United States.”

Regional and global model projections provide researchers and decision makers with best guesses of climate dynamics and what might be expected in the future, however, local and regional climate variations from one model projection to the next is largely a consequence of the chaotic nature of large-scale atmospheric circulation patterns. Given this reality, uncertainty around projections of regional climate will remain even as models improve or as greenhouse-gas trajectories become more certain.

Consequently, regional leaders will have to rely heavily on knowledge of the local environment, infrastructure capacity, and societal needs to best manage change in an uncertain climate future. For instance, within the next five decades, a region might win the climate change lottery with residents and

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ecosystems experiencing average winter temperatures that are slightly cooler than today's. Alternatively, the effects of natural variability may leave residents of the region facing 4-degree warming in the next 50 years, or the result may be somewhere in the middle.

Given the breadth of climate possibilities, Deser and her colleagues explored these questions in a 2013 paper in *Nature Climate Change*. The scientists looked at a range of future-climate possibilities for North America, as well as specific cities (Seattle, Washington, Phoenix, Arizona, and Mazatlan, Mexico), factoring in natural variability. To test the variety of possible climate outcomes, Deser and her colleagues ran a global climate model 40 times, with each run beginning in 2000 and ending in 2060. For every run, only the atmospheric starting conditions changed (for example, air temperature or precipitation), while all other components – ocean, land, and sea ice characteristics, etc. – remained the same. The first time such a large set of climate change experiments has been run on a single state-of-the-art global climate model, the range of outcomes indicate the spectrum of possible future climate trends.

Next, to estimate future regional climate and climate change, the scientists took observed temperature and precipitation records from 1910 – 2010 for the three cities and the United States as a whole, extrapolating this information forward to 2060 using model projections. These projections took into account both the most and least extreme future climate trends for the locations considered.

Runs from the global climate model, Community Climate System Model version 3 (CCSM3), represented the spatial patterns and magnitudes of global and continental climate variability well on decadal and longer time scales, lending confidence to the model's projections, says Deser. The scientists found that regional climate outcomes varied widely for both precipitation and temperature, with some locations projected to experience either drying or moistening, and either warming or cooling, depending on the particular coin-toss of the natural variability.

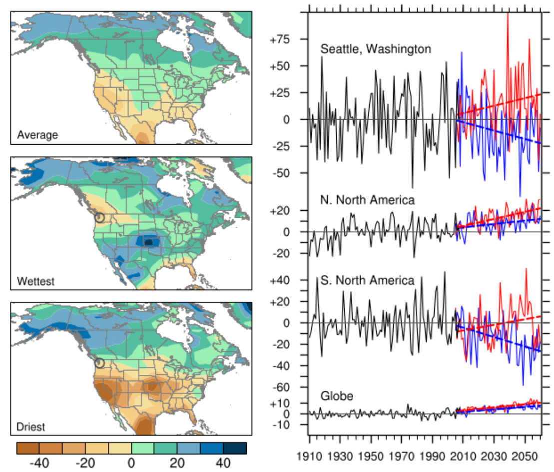

Figure a) shows DJF precipitation trends, expressed as a percentage of the model's ensemble-mean climatology for 2005–2060. The top panel shows the average of the 40 model runs, with stippling where the values are not statistically significantly different from zero at the 5% confidence level. The middle and bottom panels are based on the model runs with the wettest and driest trends for the southern half of North America (south of 42° N), respectively. In b) the DJF precipitation anomaly time series, is expressed as a percentage of the observed mean during 1910–2008 minus 100%. Northern and southern North American regions refer to averages north of 50° N and south of 42° N, respectively.

While it is well established that models – both global and regional – frequently disagree on projected climate outcomes, based on their research, Deser and her colleagues suggest that to a large degree this occurs because the effects of natural variability that ride on top of anthropogenic climate change are present within both the natural and modeled systems. Because of this, even when averaging a series of modeled regional outcomes, effects of natural variability within the chaotic system may not allow the narrowing of possible future regional climate outcomes in the next 50 years.

These findings make clear that a range of future climate outcomes should be expected, particularly on regional and local scales for the next 50 years, rather than a single trajectory determined solely by human influences, says Deser.

"The models aren't wrong – they provide insights on what to expect in the future and help untangle anthropogenic climate change from natural variability. But because of natural variability, local and regional decision makers will need to consider observed climate trends along with modeled climate projections to come up with common-sense options for managing effects of climate change," she says.

Next up, Deser and her colleagues are running another large set of climate-model simulations with the newest version of the model, the Community Earth System Model version 1 (CESM1); these runs begin in 1920 and end in 2080. They hope that comparing observations with CESM model runs over the historical period will facilitate identification of natural and anthropogenic components to past climate trends, as well

as those projected for the coming decades. Achieving this may help researchers, decision makers, and the public better understand nature's patterns and could also assist in explaining regions of cooling in the face of increasing global average temperatures.

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METRICS

The metrics featured below offer qualitative and quantitative measurements and assessments of the productivity, quality, and impacts that NCAR programs and activities have on our research community, our sponsors, and society in general.

NCAR-HOSTED COMMUNITY EVENTS

Each year, events are hosted by labs, divisions, and programs. These include colloquia, conferences, symposia, tutorials, and workshops.

A total of 292 events were hosted: 67 workshops, 195 tutorials, five symposia, two conferences, and 23 colloquia. Event sponsors included government entities NASA and Centers for Disease Control; non-profit organizations CUAHSI and The Cypress Institute; and universities including the University of Colorado and Seoul National University.

EDITORSHIPS

NCAR staff serve as publication editors. These positions recognize the appointee's leadership in the field and serve a critical role in developing a given field's future focus.

Seventy-five NCAR staff served in 101 different editorial roles on 81 different publications or journals. Publications included top-tier journals such as the *Environmental Research Letters*, and *Journal of Geophysical Research* .

EXTERNAL COMMITTEE SERVICE

NCAR staff are called upon to participate in and often lead external scientific, technical, policy, and educational committees. These committees are instrumental to advancing and promoting the work of the scientific and technical community.

This year, 167 NCAR staff served in a multitude of roles on 450 external committees for national and international scientific, education, and governmental organizations, including entities such as the Decadal Predictability Working Group, the Scientific Committee for International Partnerships in Ice Core Sciences, and the CEDAR Science Steering Committee.   Positions ranged from Science Advisor to Co-Organizer. More than 63 % served on more than one committee.

TALKS AND POSTERS

NCAR Staff give presentations about data, models, theories, hypotheses, reviews, and results around the world in talks and posters to audiences ranging from scientists and engineers to the general public.

More than 79,000 people were in the audience when 256 NCAR staff gave more than 1,100 talks across the country and around world, from Smyna, Tennessee to Santiago, Chile. Examples range from Doug Nychka's (CISL) talk on "Multi-Resolution Spatial Methods for Large Data Sets" in Raleigh, North Carolinato Paty Romero Lankao's (RAL) talk " Integrated Understanding of Urban Vulnerability and Risk" in Quito, Ecuador.

Atmospheric Research

NCAR Earth System Laboratory

Research Applications Laboratory

STRATEGIC PLANS

NCAR Strategic Plan

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Ninety-four NCAR staff made more than 130 poster presentations across the country and around world, from Galveston, Texas to Ancash, Peru. More than 18,000 people attended these events, which included from Cindy Bruyere's (MMM) poster "Exploring Genesis Potential Indices" in Kos, Greece and Andrew Monaghan's (EOL) poster "Climate change and the vector mosquito Aedes aegypti at the high altitude margins in Mexico" in Athens, Georgia.

STAFF COLLABORATION VISITS TO UNIVERSITIES

NCAR staff take leaves or visits to other institutions for two weeks or more for intellectual growth, professional development, collaboration with research community peers, community support, teaching, or sabbatical. Examples of work include teaching courses or workshops, lecturing, giving tutorials, working with graduate students on dissertation-focused research, student mentoring, collaborative research, and participating in the host institution's outreach to community colleges, minority-serving institutions, and high schools.

This year, 12 staff members took leaves at 12 different institutions, ranging from Montana State University to the University of Cambridge. Among the highlights: Phil Judge (HAO) , a Senior Scientist,visited the University of Montana to teach and work on the NASA IRIS mission.

TEACHING IN UNIVERSITY/COLLEGE CLASSROOMS

NCAR staff make important contributions through teaching appointments at institutions of higher education in positions ranging from Faculty Affiliate to Professor.

Teaching appointments at institutions of higher education currently number 81 . Seventeen percent of these appointments occur in 13 countries around the world; 83% took place in 20 U.S. states, including Howard University. The longest term is 28 years.

TEACHING OR TRAINING AT WORKSHOPS/TUTORIALS/COLLOQUIA

NCAR staff teach classes and offer training in workshops, tutorials, and colloquia to students ranging from model users, to scholars, to fellow researchers.

During this year, 60 staff members taught at a total of 97 workshops, tutorials, and colloquia. In all, 411 individual classes were taught, with an average class size ranging from five to 200 people. Twenty-seven percent of these events occurred in 14 countries around the world including Kenya; 73% took place in ten U.S. states, including New York. These were held in locations ranging from Ankara, Turkey to Fairbanks, Alaska. Examples range from Peter Sullivan's (MMM) presentation on "Waves in Marine Boundary Layers" in Monterey, California to Paty Romero Lankao's (RAL) "Low Carbon Cities in Asia Summer Course" presentation in Delhi, India.

CONTRIBUTIONS TO INDIVIDUAL GRADUATE STUDENT EDUCATION

NCAR staff serve as research advisors and committee members for graduate students around the world.

Of the 120 graduate students that have NCAR staff serving as graduate advisors or committee members, 31% hail from Colorado institutions; 40% attend schools in 28 other states. The remaining 29% study at schools in 25 countries around the world, including two students from the University of Utah who are advised by Jeff Anderson.

SPECIAL APPOINTMENTS

NCAR Affiliate Scientists: Select university and research-community scientists are invited to carry out long-term, highly interactive, collaborative work with UCAR scientists and are appointed as Affiliate Scientists with three-year terms. This appointment is particularly suitable for parties who desire an extended, close-working relationship on scientific problems of mutual interest. Currently, 35 hold appointments including Dr. Veronika Eyring of the German Aerospace Center . She is collaborating with NCAR scientists on the development of Earth System Models; Dr. Eyring collaborates with CGD in the NCAR Earth Systems Laboratory.

Emeritus/Emerita: Scientific and Research Engineering staff who have made significant contributions to NCAR through long and distinguished service in senior positions in research may be granted emeritus or emerita status. This designation confers a life-long honorary distinction. Approval of the President and the Board of Trustees is required. Currently the ranks of Emeritus/Emerita number 18 with the recent appointment of CISL scientist Annick Pouquet who is continuing her scientific contributions to the geophysical turbulence program.

K-12 OUTREACH

Staff across NCAR work directly with classes and groups of K-12 students by developing or delivering lectures, conducting tours, and leading or participating in field trips and other educational activities.

Thirty-six NCAR Staff worked with K-12 students from 34 schools. Activities included mentoring, lectures, tours and field trips reaching 16 different communities. Examples range from curriculum development with Boulder Valley School District to a weather station setup and installation,to classroom activities on the theme of weather, climate and climate change.

Among the highlights: Chris Golubieski (EOL) lead a weather station setup and installation at Fireside Elementary School; Joan Burkepile (HAO) participated in the Expanding Your Horizons (EYH) Workshop, a science, technology, engineering, and math STEM conference for middle school girls; and Synte Peacock (CGD) gave a talk on climate change geared for Wild Earth Day at Boulder Valley Schools.

EXTERNAL AWARDS

Each year a number of NCAR Staff are honored for their work and contributions to the Atmospheric and related sciences.

Twenty-three staff received special recognition for their work. Rit Carbone (EOL) received the American Meteorological Society's Cleveland Abbe Award. The award is for distinguished service to atmospheric sciences and is presented on the basis of activities that have materially contributed to the progress of the atmospheric or related sciences or to the application of the atmospheric or related sciences to general, social, economic, or humanitarian welfare. Wojciech Grabowski was granted by the President of Poland the title Professor of Physical Sciences. This honor, one of the highest scientific honors given out by the Polish government, comes after a two-year process of reviewing Dr. Grabowski's career and scientific achievements. Alicia Karspeck (NESL/CGD) received the 1st place Award for Outstanding Research Article in Biosurveillance in the Scientific Achievement Category from the International Society for Disease Surveillance. ISDS is a nonprofit organization dedicated to the improvement of population health by advancing the science and practice of disease surveillance. This award recognizes outstanding research articles in Biosurveillance.

This year, NCAR also received honors for its facilities. NCAR has taken top honors in the prestigious 2013 Green Enterprise IT (GEIT) Awards. The center's NCAR-Wyoming Supercomputing Center (NWSC) won first place in the "Facility Design Implementation" category for its sustainable approach in designing and building the new center. The GEIT Awards, bestowed by the Uptime Institute, showcase organizations for pioneering projects and innovations that significantly improve energy productivity and resource use in information technology. The Facility Design Implementation Award recognizes cutting-edge data center projects that demonstrate energy and resource efficiency in a new, operational data center.

The NWSC was also named the 2013 "'Green' Data Center of the Year" at the inaugural Datacenter Dynamics North American Awards. The NWSC received top honors in a category that recognizes the reality of designing and operating data centers in the context of environmental scrutiny.

FELLOWSHIPS

A fellowship is typically a special appointment granting support for a term in order to support advanced research or study.

Eight NCAR staff received fellowships in 2013. Among the highlights: Tanya Peevey ACD) was awarded the International Research Fellowship by the National Science Foundation. The purpose of the

Internatoinal Research Fellowship is to introduce scientists and engineers in the early stages of their careers to international collaborative research opportunities, thereby furthering their research capacity and global perspective and forging long-term relationships with scientists, technologists and engineers abroad. As an International Research Fellow, Tanya is studying transport and mixing within the DT, a current debate, and trying to understand its impact on the structure and dynamics of the UTLS. Her research focuses on the thermal tropopause in the upper troposphere lower stratosphere (UTLS) region of the atmosphere; specifically the double tropopause (DT) since it can impact concentrations of radiatively important species both in the troposphere and stratosphere thus changed Earth's climate due to the location of these species in the UTLS.

SCIENTIFIC AND TECHNICAL VISITS TO NCAR

Each year students, scientists, engineers, weather forecasters, and other professionals from around the country and world receive special visitor appointments from labs and programs across NCAR to collaborate with scientific, educational, or technical staff; conduct independent research; or participate in and/or oversee a professional project. Many receive financial support for their visits and some visitors temporarily join the NCAR staff.

This year, colleagues visited NCAR 863 times and hailed from 366 institutions, located in 45 different U.S. states and 41 different countries.

Visit Length - Number of Scientific and Technical Visits in FY13

1 day to 1 week: 182

8 days to 2 weeks: 108

>2 weeks to 2 months: 254

>2 months to 6 months: 172

> 6 months to 1 year or more: 147

Total: 863

Scientific and Technical Visit Types - FY13

Visits by Visitors on Payroll: 40

NCAR funded Visits: 355

Externally funded Visits: 468

Total: 863

PUBLICATIONS IN THE UCAR OPEN SKY INSTITUTIONAL REPOSITORY

NCAR's publication records are curated in the UCAR Open Sky Institutional Repository. OpenSky is the open access institutional repository supporting UCAR, NCAR, and UCP, extending free and open access to our scholarship for the benefit of research and education.

OpenSky is operated by the NCAR Library, with the goal of providing free and open access to the scholarship of UCAR, NCAR, and UCP. Founded on the principle that public access to the scholarly record is essential to the advancement of science and society, the vision of OpenSky is to support the broad mission of UCAR to foster science, support its community, and facilitate the transfer of knowledge.

In support of this vision, OpenSky will provide long-term storage, preservation, access to scholarly works and the products of scientific research created by UCAR, NCAR, and UCP authors.

A publication is an academic or technical work of writing containing original research results, reviews of existing results, or scholarship. "Refereed" publications undergo an editorial "blind" or anonymous process of peer review by one or more referees (who are experts in the same field) in order to check that the content of the paper is suitable for publication in the journal. A paper may undergo a series of reviews, edits and re-submissions before finally being accepted or rejected for publication. "Non-refereed" articles have been reviewed by editors or boards before being accepted for publication but have not gone through a formal blind review. Attached are NCAR's refereed lists for the period October 1, 2013 to September 30, 2013. Search for recent NCAR publications by author, date, keyword or status please go to the NCAR Publications database.

For excellent library resources please go the NCAR Library Web site.

641 Total Publications (download bibliography)

Refereed: 641
UCAR and Other: 70
UCAR and University: 191
UCAR only: 74
UCAR, University and Other: 306

UCAR Outstanding Publication award for FY13:

Bruce Lites (HAO) received the FY13 Outstanding Publication Award for “The Horizontal Magnetic Flux of the Quiet-Sun Internetwork as Observed with the Hinode Spectro-Polarimeter," The Astrophysical Journal 672, 1237-1253.

This highly cited paper produced a major paradigm shift in the understanding of the nature of solar magnetic fields by overturning a concept about these fields that had been accepted for 40 years. With data from the Solar Optical Telescope Spectro-polarimeter aboard the Hinode spacecraft, the authors demonstrated incontrovertibly, for the first time, the ubiquitous presence of large-scale horizontal magnetic fields in the photosphere of the quiet Sun. The result has important implications for our understanding of the emergence of magnetic flux through the solar photosphere and its connection with the convection-driven local dynamo at the solar surface. This research has been praised as “one of the most important publications in solar physics in the past 100 years.”

For a copy of the metrics data, click here. For questions on metrics, contact Helen Moshak (moshak@ucar.edu).

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DIRECTORS MESSAGE

The Advanced Study Program (ASP) helps NCAR and the scientific communities that it serves to prepare for the future by engaging in human, institutional and broad intellectual capacity building. ASP entrains a broad community of scholars, encourages the exchange of information and the development of new perspectives, and provides unique hands-on educational experiences and many opportunities for students, advisors, and early career scientists to collaborate with a wide variety of NCAR scientists and engineers engaged in research, modeling, and observational activities.

The two-year ASP Postdoctoral Fellowships encourage the development of early career scientists in the field of atmospheric and related sciences and direct attention to timely cutting-edge scientific areas. Approximately 10 new appointments are made annually for positions across NCAR. Fellows' research advances are reported separately in the NCAR Laboratory Annual Reports.

Through its remaining components, the Graduate Visitor Program (GVP), the Faculty Fellowship Program (FFP), and the Summer Colloquium, ASP promotes research activities, fosters graduate education, and develops partnerships between NCAR scientists and their colleagues in universities and other institutions.

Accomplishments

The ASP awarded 8 new postdoctoral fellowships in spring 2013. These new fellows have already begun to arrive and to participate in ASP activities, providing a boost to the ongoing program. Between the FFP and the GVP, the ASP supported 151 months of long-term visits to NCAR in FY13. Eight faculty members came to NCAR as part of the 2013 Faculty Fellowship Program while 24 GVP awards were given as a result of the 2013 GVP search. Most of the GVP awards also include an advisor visit.

The ASP continued its ongoing efforts to better serve diverse communities in FY2013 through the continuation of postdoc exchanges with Minority Serving Institutions (MSI).

Finally, the ASP supported the second Software Engineering Assembly (SEA) conference on scientific computing and software development that included participants from NCAR, other scientific agencies in

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the area and several MSI students.

More on all of these programs can be found in this report.

FY2014 Plans

ASP will continue to engage and develop the scientific workforce of the future through its core visitor and fellowship program elements that engage all graduate students and postdoctoral fellows in residence at NCAR, including monthly seminars, monthly informational socials, the annual ASP retreat and ongoing mentoring opportunities. Through the highly successful Thompson Lecture Series, ASP will bring two prominent scientists to NCAR for extended interactions with this cohort. Andrew Dessler, a professor at Texas A&M, will be visiting October.

The annual ASP Colloquium series will focus on the topic of Carbon-climate connections in the Earth System. As in the past two years, the colloquium will expand to three weeks from two to accommodate a revival of an NCAR tradition: the ASP Research Colloquium. The current format includes a one-week colloquium geared toward researchers engaged in the colloquium topic. Students will stay for three weeks to participate in lectures and hands-on activities.

ASP will support the NCAR Software Engineering Assembly's second conference and also provide organizational support for the activities of the Early Career Scientists Assembly (ECSA).

ASP will continue to promote diversity in the atmospheric sciences by supporting travel of NCAR scientists to give seminars at MSIs, supporting teaching opportunities of NCAR postdocs at MSI's and encouraging participation in ASP programs of individuals from underrepresented groups. ASP's Sean Moore will teach for a semester at the University of New Mexico, Albuquerque.

Additional details along with other ASP plans are included in this report.

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POSTDOCTORAL FELLOWSHIPS

ASP serves as a catalyst for burgeoning research that spans NCAR activities. The most important ASP component is the Postdoctoral Fellowship Program, which has been a part of NCAR for forty-five years and has sponsored over 450 postdoctoral scientists' research. The ASP appoints approximately 10 new postdoctoral scientists each year. During their two-year NCAR appointments, fellows benefit from the opportunity to work with NCAR scientists, from exposure to the breadth of science at NCAR, and from the independence they are encouraged to develop. Many former fellows now occupy prominent positions at UCAR universities or at NCAR, and many of the present collaborations between NCAR and university scientists derive from associations that developed in the postdoctoral program.

In FY13, the ASP appointed 8 new fellows (from over 110 applications) in a diversity of disciplines spanning the NCAR activities. In addition to the diversity of disciplines, the new fellows represent a diversity of population including gender and ethnicity. Also in FY2013, the ASP regular "socials" and other activities that often included an education or career development aspect. These activities not only brought members of ASP together, but also included any postdoctoral fellow or graduate student within the organization who wished to attend. For example, the ASP held a joint meeting at NCAR with the ASP fellows and the NS**F** Atmospheric and Geospace Sciences Post-Doctoral Fellows that included science discussions and career development talks **.**

The ASP aims to create a meaningful experience not only for ASP fellows, but for all fellows at NCAR. As part of this plan, NCAR/ASP is a sustaining member of the National Postdoctoral Association and we celebrated National Postdoc Day with a family picnic.

In FY2014, ASP plans to continue the core elements of the program, including monthly seminars, regular research reviews, regular socials, and the Thompson Lecture Series along with the annual research planning sessions and on-going mentoring that ASP postdocs receive.

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BUILDING PARTNERSHIPS WITH UNIVERSITY FACULTY

The ASP established the Faculty Fellowship (FFP) program in 2005 with the goal of funding medium-to long-term collaborative visits between the NCAR scientific staff and the university community. The program provides opportunities for university faculty to spend three to 12 months at NCAR, and for NCAR scientific staff to spend three to 12 months at a U.S. university. University faculty may also bring graduate students with them to NCAR. The FFP provides support for travel costs, temporary living per diem, and graduate student expenses.

In FY13, applicants submitted proposals and budgets for 3- to 12-month visits that occurred between 1 June 2013 and 31 May 2015. ASP received six viable applications. Five applicants were extended offers for visits that began in FY13. Included with the faculty visits will be three visits made by students. **We supported 44 months of faculty/scientist visits through this program in FY13.**

The program gives university faculty an opportunity to take advantage of their National Center in a meaningful and productive way, while providing unique research opportunities for the accompanying graduate students.

In additional to the incoming Faculty Fellowship Program visits, two NCAR Senior Scientists spent most of the year on one-year outbound FFP visits. Jeffrey Kiehl went to the University of California, Santa Cruz and Philip Judge went to Montana State University. Both spent their year teaching and collaborating with faculty and students during their visits.

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PROVIDING UNIVERSITY STUDENTS ACCESS TO THE RESOURCES OF NCAR

The Advanced Study Program provides university graduate students and their advisors with access to NCAR resources through the Graduate Visitor Program (GVP). The program, now in its seventh year, was created in response to multiple requests from NCAR scientific staff for graduate student support. It was also developed in response to university community requests for access to NCAR resources and facilities that are not available at a university. ASP recognized the need to establish a program that would sponsor a significant number of meaningful visits and collaborations with graduate students and their advisors. The GVP responds to that need.

The Graduate Visitor Program provides NCAR scientific staff with opportunities to bring graduate students to NCAR for three- to 12-month collaborative visits. These visits are undertaken with the endorsement and complementary support of the graduate students' thesis advisors. While residing at NCAR, the students conduct research in pursuit of their thesis requirements. The students receive support to cover their travel and living expenses in Boulder. Funding is also provided to allow the students' advisors to visit NCAR for a period of up to two weeks. The students' home institutions continue to pay the students' salary, benefit, and tuition expenses while they are in residence at NCAR.

The ASP made 24 awards in the GVP program as a result of our FY2013 GVP competition. ASP supported 107 months of GVP visits and 17 advisor visits in 2013.

The Graduate Visitor Program is becoming more popular every year. The ASP recognizes that students and their advisors are the bridge builders between NCAR and the university community. The ASP contends that the Graduate Visitor Program will seed significant and long-term collaborations. This program helps to extend NCAR capabilities by bringing students on-site to work on research of mutual interest and by providing NCAR scientific staff with the opportunities to participate in graduate student research and education. Through this program, NCAR increases its contribution to the education of the next generation of scientists, researchers, and faculty. In turn, the graduate students help invigorate NCAR and their home institutions. Finally, the Graduate Visitor Program provides opportunities to partner with universities and engage Ph.D. students from underrepresented groups in NCAR research activities. The ASP anticipates that the program will help diversify the future workforce at NCAR and in the geosciences professoriate and research communities.

GVP TESTIMONIALS, 2013

Samantha Tuhaus, Student at University of Michigan, WISE Recipient

I visited NCAR for about three months this past summer, and those three months were some of the most stimulating of my graduate career. I interacted with students from all walks of life. I broadened my perspectives on the world and meteorological research, which is an invaluable gift. Being in the GVP helped me get a boost in my research that I don't know if I would have received otherwise; NCAR presented me with personal and computational resources alike that were very helpful. I also made

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connections in other research departments and with outreach organizations like Global Learning and Observation to Benefit the Environment (GLOBE) and the Earth Science Women's Network (ESWN). The connections I developed during my time in the GVP will give me a head start when I begin my career.

Derek Posselt, Advisor University of Michigan

In addition to conducting research under the supervision of NCAR scientists, Ms. Tushaus also participated in the Warner Internship for Scientific Enrichment (WISE). During her two weeks participating in the WISE internship, Samantha participated in the GLOBE teacher training program. She is now certified as a GLOBE instructor, and has made contact with the local GLOBE coordinator in SouthEast Michigan. Samantha has been invited to engage project based learning at a local high school that serves a significant population of students traditionally underrepresented in the STEM fields.

Plans to continue the research performed under the ASP Graduate Visitor Program, combined with recent plans to engage in outreach to underserved student populations, has been formalized in a recently submitted proposal to the National Science Foundation.

I have been overall very pleased with the results of the NCAR GVP, and would consider it a privilege to have one or more of my students participate in this program in the future.

Tao Wang, Student Texas A&M

The visit not only helped my research, but it also helped me in expanding my social network with so many scientists. During the summertime, I got to meet so many visiting professors, scientists, etc. They come from basically all over the world. So I got to know them, talk to them, and work with some of them, too. This is so cool!

Alison Nugent, Student Yale University

The ASP graduate visitor program is a great opportunity to work at NCAR with a new advisor. It allowed me to explore new areas of research that I would not have been able to do otherwise. By spending time at NCAR and presenting my research to a new audience, I obtained invaluable advice and input which has significantly improved my course of research. Learning how to work with new people and making connections over science will certainly help me with my future career. My favorite part of the ASP graduate visitor program was the time I spent in Boulder. The friends and connections I made, the scenery and beauty of the countryside, and the spirit of Boulder are things I hold dear.

Anne Thompson, Advisor Penn State

ON-GOING IMPACT OF GRAD STUDENT ASP VISIT

The success of Ms. [Hannah] Halliday's time spent at NCAR was obvious in the September Houston deployment. She knew what to do; for the first time she obtained GOOD data! She will now have a path-breaking thesis, doing something no one else in our group nor *any* student on the NASA Science Teams with whom I work – has ever done. In summary, Ms. Halliday's visit to NCAR in ASP allowed her to obtain technical training in earth observations that will transform her thesis research, from routine to innovative! Her entire career path has been changed- from routine to potential for high-impact.

Benjamin Green, Student Penn State

When I first arrived at NCAR, I was worried about being out of place – after all, how often do graduate students get to spend an extended period of time interacting with such accomplished researchers? Thankfully, my fear was never realized: the entire NCAR community treated me with respect and made me feel welcome. These efforts by the community allowed me to establish strong professional relationships with several scientists, which have continued after my return to Penn State.

The supportive environment at NCAR has helped with my research. My research uses two numerical models with strong ties to NCAR: the Weather Research and Forecasting (WRF), and an in-house Large Eddy Simulation (LES). I found that it was much easier, and much more fruitful, to communicate face-to-face with model developers than it was to send e-mails from Penn State. In particular, my work with the LES would not have been possible had I not gone to NCAR.

Donald Hagen, Advisor, University of Missouri

Student's name: **James Keehn**

Our research group has substantial measurement data on aircraft emissions into the atmosphere at ground level near airports and at cruise altitudes. We are weak in knowing the fate of emissions after they transport more than a few kilometers from the source. A goal of my student James Keehn's participation in ASP was to gain some atmospheric modeling experience. Visiting the National Center for Atmospheric Research (NCAR) over the summer allowed him to get hands-on experience in learning to use the WRF model as well as the opportunity to learn about the atmospheric and computational sciences in general. He went to many seminars and colloquia on subjects that are relevant to his research while working at NCAR. These types of presentations are generally not available here at MS&T. He also had the opportunity to attend a week-long training session for the WRF model. Moreover, when he arrived he was given a computer that already had a lot of the software, libraries, etc. that he needed. When he had questions, there were several people available who were glad to help out. This simplified and shortened the learning process for the WRF model considerably, and allowed him to install and run the model at S&T when he came back with a greater level of confidence. Lastly (but certainly not least!), he had the opportunity to work with and to meet many scientists with whom he would be might interact with in the future. All in all, the Advanced Study Program was an excellent way to jump-start his research.

Christopher Nunalee, North Carolina State University, WISE Recipient

My experience as an NCAR-ASP graduate visitor was truly a rewarding experience. Not only did my scientific research background gain new breadth, but also added depth through interaction with NCAR scientists. I was privileged to meet with several well-known scientists in my field who inspired many new angles to addressing my core dissertation research questions in addition to interesting new ideas for future work. In addition, detailed discussions with the program managers of the Research Applications Laboratory thoroughly increased my understanding of how applied research is carried out, from conception to execution. I feel that these involvements have greatly improved my scientific merit and also my ability to carry out unique, high-impact atmospheric research. I anticipate these properties to be very beneficial when considering future career prospects. Lastly, through the NCAR-GVP program I was provided the opportunity to apply for, and fortunately receive, the Warner Internship for Scientific Enrichment. This added experience has given me a powerful appreciation for community outreach and instilled in me the motivation to inspire young students to consider careers in science.

Leiqiu Hu, Student University of Kansas

It was an efficient summer. My training is more in remote sensing than atmosphere, while I need work closely to the urban climate modelers to expand my understanding of urban climatology through the observation and modeling. With the guidance of Dr. Andrew Monaghan and other scientists in NCAR, I got many valuable suggestions for my future research and finished one paper and one co-author paper during the summer, which is a big part of my dissertation. Moreover, I had the chance to attend WRF tutorial with the convenience in Boulder. It greatly improved my understanding of climate modeling.

Hannah Halliday, Student Penn State

The graduate visitor program was excellent experience for me, and I'm very pleased that I got to be a part of it. I had a really wonderful group to work with and got some really fantastic instrument training while I was in Boulder. My favorite part of the program was that I was given freedom to work on whatever it was that I needed while I was there, and I wasn't tied down with busy work. I was free to really get involved and spend time working on and thinking about whatever was needed. I also really appreciated being given an office space to make myself home in, and the staff was extremely friendly and helpful as I got set up.

Additionally, I had a really wonderful experience working with the scientists and engineers in ACD. My main goal during the visit was to get instrumentation experience I don't have access to at Penn State, and this was a complete success. During the three months we got a couple of instruments up and running, I worked closely with a postdoc while she prepared for a field campaign, and then I eventually ended up in Alabama helping out with a separate project for a couple of weeks. I still have a ton to learn about the instruments and the science, but I could not have been better set up to start working on my own once I was done. I also made some terrific professional contacts, including one that looks like it has the potential to be very productive and helpful while I get my degree.

Laura Slivinski, Student Brown University

Through the GVP, I was able to visit NCAR for 3 months over the summer. I appreciated the opportunity to visit for a fairly long period of time; this gave me enough time to see a project almost completely to its end. I am now currently working on finishing a paper with my supervisor at NCAR on this project. This will help my dissertation to be more well-rounded, as I will now have a chapter on this project as well as my main thesis project. I also very much appreciate how much this visit has helped my career. I now have several contacts at NCAR who have been helpful during the application process for the ASP post doc. In addition, they have introduced me to other people (at different labs and companies) who I was able to get informational interviews with about their careers. This has, and will continue to be, very helpful during the job search process.

Xitian Cai, Student University of Texas at Austin

The thing I like about the graduate visitor program is that the program not only provides visitors opportunities to work with host scientists at NCAR, but it also serves as a platform that allows people from all over the world to come here to share our experiences and exchange our ideas. This would inspire more ideas and facilitate collaboration between different institutes, which would eventually advance the atmospheric sciences.
I have visited NASA and NOAA labs for similar periods of time before my visit to NCAR. However, I like NCAR ASP the most. The program is well established; my paperwork was very smooth; and the program manager and staff are very efficient and patient.

Andy Monaghan, NCAR Scientist

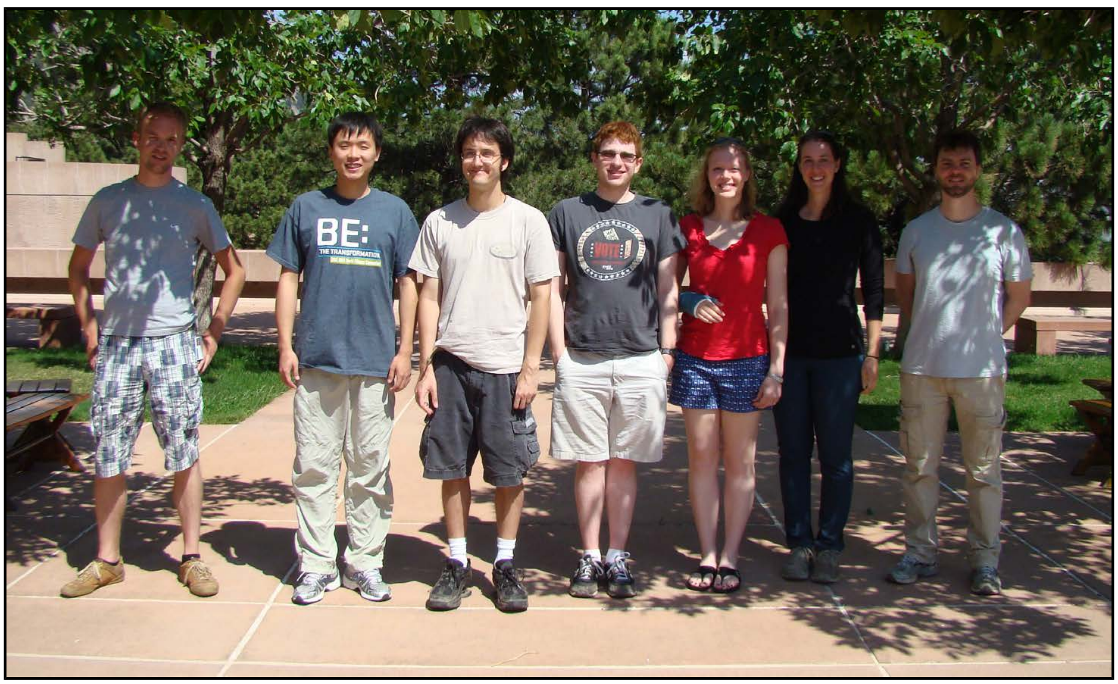
I want to thank you and the ASP program for funding the visits that led to these [four] papers. The work would not have resulted without the valuable person-to-person interactions enabled by the visits. Additionally, the visits helped us build and strengthen collaborations with these early career researchers and their institutions.

Xubin Zeng, Advisor, University of Arizona

My Ph.D. student, Ms. Kerrie Geil, worked with Dr. Mike Barlage at RAL and also interacted with other NCAR scientists at RAL and CGD. This visit helped her to better understand and use the WRF/Noah model for regional climate modeling. She also helped to address the energy/water/snow balance in the model that will be of interest to the broad WRF/Noah community. Besides the science benefits, interactions with NCAR scientists also gave her the inspiration for her future career. It was a wonderful and mutually beneficial visit. Thanks much to the NCAR Graduate Visitor Program!

Amir Aghadouchak, Advisor University of California, Irvine

My graduate student had a great experience at NCAR. She worked closely with two NCAR scientists, and with their help, she developed a new statistical model for anlaysis of climatic extremes. She has two draft manuscript with myself and her NCAR mentors that will be submitted for publication soon. This clearly emphasizes the fact that her NCAR experience has had a significant impact on her research.



Picture of the GVP students after the Annual ASP Hike

‹ Building Partnerships with University Faculty | up | ASP Summer Colloquium ›

ASP SUMMER COLLOQUIUM

For several decades, the ASP has hosted at least one 2-week colloquium every summer on an emerging science topic of interest to the NCAR community. The colloquia are designed for graduate students in new or rapidly developing areas of research for which good course materials may not yet be available. In recent years, the colloquia have had both a lecture component and a hands-on tutorial component. NCAR Scientific staff members in partnership with one or more university collaborators write proposals for colloquia topics, and in the event that their proposal is selected, organize the colloquium curriculum with logistical support provided by the ASP.

In 2013, the summer colloquium was titled "Carbon-Climate Connections in the Earth System."

The 2013 ASP summer colloquium examined the global carbon cycle, with specific attention paid to its representation in Earth System models. The event was three weeks long and was attended by 25 Ph.D. students. The program during the first and third weeks included lectures, hands-on tutorials, and student projects. During the middle week, an additional 60 scientists joined the group for a workshop that was supported in part by US CLIVAR, the Ocean Carbon and Biogeochemistry program, the Carbon Cycle Science Interagency Working Group, and the USDA. The teaching part of the colloquium presented information on modeling the terrestrial and ocean carbon cycles. Hand-on sessions emphasized modeling concepts through the application of simple models. Student projects involved analysis of models contributing to the Coupled Model Intercomparison Project, phase 5 (CMIP5). The researcher workshop explored topics at the frontier of carbon cycle science.

Several key modeling challenges were identified and explored during the colloquium:

1. **Remineralization / Decomposition**
   Microbial respiration converts organic carbon and nutrients back to inorganic forms. This constitutes a loss of carbon from terrestrial soils, and also returns nutrients to bioavailable pools. In the ocean, rates of microbial respiration of sinking organic matter controls remineralization depth, which determines carbon sequestration potential. While microbial respiration is common to land and ocean systems, the environmental dependence of respiration rates is poorly understood in both systems. Given that the underlying reactions are similar, we might expect land and ocean system to exhibit similar responses to changes in analogous environmental variables. The colloquium explored how to circumvent barriers of language, framing of questions, and channelized funding streams that prevent collaboration between terrestrial and ocean scientists studying respiration pathways.
2. **Nutrient limitation**
   The representation of nutrient limitation on land is a leading-order uncertainty in projections of carbon sink dynamics. Representation of nutrient limitation in land models is relatively new, while it is fundamental to ocean ecosystem models. This is due in part to faster biomass turnover in the ocean, somewhat better observational constraints on nutrient cycles, and homogenization of the marine nutrient reservoir by circulation and mixing. While timescales and substrates differ markedly between the land and ocean, many concepts are transferrable. We explored how to compare processes and conceptualizations of nutrient limitation between terrestrial and marine systems. There is a clear need for more observational studies examining mechanistic controls on nutrient budgets, and including experimental manipulation to better constrain model formulations.
3. **Ecology and physiology**
   The community composition of terrestrial and ocean ecosystems determines their carbon cycling characteristics. Ecosystems are comprised of organisms with physiological capacities and constraints; these `traits' determine functional role and success in competition for limiting resources. Models seeded with a spectrum of organisms with different traits can generate realistic biogeography on the basis of universal distribution and local selection in ocean ecosystems; concepts of universal distribution and local selection are just beginning to be explored in terrestrial

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models. However, the realism and extensibility of these models into the future is predicated on accurate understanding and depiction of the feasible trait space. Traits result from resource allocation; since resources and physiological capacities are finite, trait space is characterized by tradeoffs. The key to developing robust representations of trait spaces lies in accurately understanding physiological tradeoffs and the criteria organisms employ for optimization. Research on this topic should involve collaboration between physiologists and modelers. Optimization of traits at both ecological and evolutionary times scales should be considered.

4. **Disturbance and trophic coupling**
   Intermittent events, while rare, are often dominant forces structuring ecosystems. In nonlinear systems, episodic forcing can lead to outcomes different from those of the same integral forcing applied uniformly in time. Mortality, for instance, is a key loss term from terrestrial and ocean ecosystems. It tends to happen intermittently, but models often impose a constant loss. In the marine ecosystem, trophic coupling is a leading order control on phytoplankton biomass and export, and models show dramatically different behavior with subtle parameter changes. We need improved approaches to modeling disturbance events like mortality, particularly for terrestrial ecosystems which have long response timescales associated with perturbations. A major observational effort is required to provide improve data constraints for grazing parameterizations in the ocean. Additionally, the behavior of models with multiple trophic levels needs to be more carefully evaluated.
5. **Physical climate setting**
   In the Earth System modeling framework, carbon cycle models are embedded in climate models, which typically consist of coupled GCMs. The climate models provide the physical setting in which ecosystem codes operate. Since many ecosystem processes are sensitive to physical climate variables, it can be difficult to attribute particular features of model behavior to a particular component model. Ideally, ecosystem models could be evaluated in different physical settings, thereby providing better insight into the ecological process representation, as well as the physical climate models themselves. There is a clear need for modeling frameworks that permit interoperability of subcomponents. Note that this does not mean a common coupling infrastructure (i.e. the ability to run an ocean model with different atmospheres), but rather modularity to permit swapping out process-level parameterizations. Representation of disturbance impacts, discussed above, will require that extremes in the physical climate (i.e. hurricanes and drought) be resolved. This mainly pertains to land; the analogy in the ocean might be mesoscale eddies. It is unclear at this point how nonlinear ecosystem responses to disturbance induced by a mesoscale eddy field feeds back to alter large-scale distributions.

By far the best part of the colloquium was interactions with the strong group of students. A sense of deep curiosity and enthusiasm permeated the whole event. Indeed, some of this persists as both personal and professional relationships developed at the colloquium continue to blossom.

Organizers:

Matthew C. Long and R. Quinn Thomas (NCAR), Naomi M. Levine (USC)
Curtis Deutsch (UCLA), Galen A. McKinley (Wisconsin), Annalisa Bracco (Georgia Tech)

Group Photo of the collloquium students and organizers

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SUPPORTING DIVERSITY IN THE ATMOSPHERIC SCIENCES

The ASP continued its ongoing efforts to better serve diverse communities in FY2013 primarily through its postdoc exchange initiative.

In FY2008, a Memorandum of Agreement (MOA) was signed between NCAR and four Historically Black College and University (HBCU) partner universities:

* Howard University
* North Carolina Agricultural and Technical University
* Hampton University
* Jackson State University

The MOA focuses on these areas of mutual agreement:

* Graduate student research and internship opportunities
* Faculty exchange and internship opportunities and faculty training.
* NCAR scientists serving as visiting faculty to increase instructional capacity and curricular breadth/
* Participation of NCAR scientists on graduate student committees.
* Collaborative research that results in proposal submission

The ASP has been working to renew this MOA in FY13 while adding two new collaborators: Texas Southern University and The University of Texas, El Paso.

In support of the Memorandum of Agreement referenced above, the ASP recruited two of its postdoctoral fellows to spend time teaching, conducting research, and collaborating with faculty and students at The University of New Mexico, Albuquerque (UNM) and The University of Texas, El Paso (UTEP). Sean Moore spent the semester at UNM during the fall of 2012 teaching "Global Climate Change" to 40 undergraduates at UNM. Shanlin Wang spent Spring 2013 at UTEP teaching "Energy Use & Climate Change to 8 graduate students. In both cases, the postdocs spent about 40 hours per week preparing for their courses and in each case, the students were expected to produce projects. Both visits established a scientific relation where none previously existed between NCAR and the Minority Serving Institution (MSI).

Dr. David Gutzler of UNM writes of Sean's visit:

> I think our curriculum and our students have greatly benefited from having Sean Moore teach a class here last semester. I hope we have an opportunity to host another postdoc if you continue that aspect of your program.

Dr. Barry Benedict wrote of Shanlin's visit:

> Dr. Shanlin Wang made a very positive contribution to UTEP, the Mechanical Engineering Department, and the Environmental Science and Engineering (ESE) Ph.D. program during her stay here.
>
> She did an excellent job teaching ESE 6312 (Climate Change). I presented some material in

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one of her class sessions. I also know most of the students in her course from having them in one or more of the ESE courses I teach. They told me they were impressed with her breadth of knowledge, approach to teaching, and commitment.

I must also admit that we did not take full advantage of her time here. I should have assured that she made contacts more widely on campus. If we are fortunate enough to have another such Post-Doc, we will be very intentional about our efforts to integrate her (or him) more fully into our efforts.

In our collective opinion, Dr. Wang has a very bright future, and I look forward to seeing her future career and works. I do hope she benefited from her time here. I know we did.

The ASP plans to send another student to an MSI during the Fall Semester of 2014.

Shanlin Wang teaching at UTEP, Spring 2013

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CISL DIRECTOR'S MESSAGE

CISL Director Al Kellie

Welcome to the FY2013 CISL Annual Report. This collection of highlights from our service, science, and education portfolios includes an overview of CISL's broader impacts on the research community.

To start the fiscal year, CISL officially opened the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming on 15 October 2012. To commemorate the grand opening with a ribbon-cutting ceremony, UCAR President Dr. Tom Bogdan was joined by National Science Foundation Director Dr. Subra Suresh, Wyoming Governor Matt Mead, former Wyoming Governor Dave Freudenthal, and University of Wyoming Vice President Dr. Bill Gern. This event marked the official unveiling of the Yellowstone supercomputer, which began operations with Accelerated Scientific Discovery (ASD) projects. An important feature of CISL's services for many years, ASD provides very large allocations of computational resources to a small number of experienced scientists to boost their potential for discoveries through high-capability simulations. The NWSC provides petascale computing, data analysis, and visualization resources combined with exascale data management capabilities to support greater model resolution, increased model complexity, better statistics, longer simulation times, and more predictive power. This facility is carefully designed to continue serving the scientific community at the highest level for decades.

CISL is gratified that the arrival of NWSC and Yellowstone were instrumental in the support for climate scientists' ambitious agenda of Community Earth System Model (CESM) and Community Climate System Model (CCSM) simulations for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). These researchers' coordinated climate model experiments were completed in time to address pressing climate change issues for world leaders, and CISL now provides high-performance access, end-user support, accurate data use metrics, and helps publish the resulting data products. At a rate averaging 75 terabytes per month in FY2013, more than 2,000 scientists downloaded these data products from the Earth System Grid (ESG) science gateway at NCAR.

The Regional Integrated Science Collective (RISC) in CISL's Institute for Mathematics Applied to Geosciences (IMAGe) made some groundbreaking progress and produced numerous other important advances in regional climate modeling. RISC pioneered a new data bias correction method using distribution-mapping techniques to develop a daily observational data product that includes uncertainty estimates. This new product improves on existing data products by providing not only gridded daily observations but also estimates the uncertainty associated with interpolated fields. This product, called MICA, is being developed in a transparent, modular, and reproducible form to facilitate adoption throughout the community.

The Data Assimilation Research Testbed (DART) project in IMAGe made a swift transition to petascale

computing this year. DART was carefully prepared and tested in advance, and it ran on Yellowstone without modification for all applications. Considerable effort was made to find the most efficient ways to use DART on Yellowstone for large models, and a novel multiple-component assimilation interface to the coupled CESM models was completed and tested. This CESM coupler advances ensembles of all five component models using separate instances of DART for the atmosphere, land, and ocean models to assimilate observations into the ensemble. This fully coupled multiple-component assimilation allows scientists to better understand the relationships between the different coupled model components. Finally, a new interpolation mechanism was developed and tested to reduce memory usage for assimilations in ever-larger models.

Among CISL’s FY2013 advances in education, I want to call your attention to a new type of “data analytics” training program that multiplies our ability to broaden participation in the Earth System sciences. Developed in collaboration with a professor of statistics at the University of Wyoming, “Data analytics for the Geosciences using R” is a new type of workshop where experts train statistics instructors who can spark the interest of future scientists and engineers. Targeting math, science, and statistics professors, the workshop particularly encouraged attendance by faculty at community colleges who teach introductory statistics and teachers of Advanced Placement statistics at regional high schools. Breaking the tradition of teaching introductory courses using simple methods and small data sets, this new approach encourages instructors to immerse students in expansive real-world datasets with uncertain values and missing data. Using data sets that are rich in clues about how nature works and relevant to students’ interests can stimulate the curiosity and imagination of future scientists and engineers.

This annual report offers many more highlights of the breadth and excellence of CISL’s programs. These highlights include external recognition of the NWSC supercomputing facility, as it won two national awards in 2013: the Uptime Institute’s Green Enterprise IT first-place award for Facility Design Implementation, and the Datacenter Dynamics North American ‘Green’ Data Center award for demonstrated sustainability in the design and operation of facilities.

CISL provides far more than balanced, easy-to-use computational and data environments designed for the evolving requirements of the Earth System sciences. CISL also develops and delivers high-quality science and education programs to help secure the future of our scientific enterprise and the communities we serve. As you read this report, I hope you share our excitement about our recent progress. It is my pleasure to present our FY2013 CISL Annual Report.

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CISL SERVICES

From CISL's web page for services and support, users can access CISL's help desk and consulting services, as well as complete information about HPC systems, storage systems, data analysis and visualization systems, data collections, user documentation, and training. CISL has a proud tradition of providing world-class supercomputing and data services to its user community. The quality of these services is and will remain a core value of the laboratory. However, the makeup of these services is not static: they continually change in concert with rapid changes in the underlying technologies and the scientific demands of our users. CISL:

- Maintains and operates the physical facilities and cyberinfrastructure needed to support the atmospheric and related sciences.
- Curates, manages, and archives a rich set of data collections to which it provides free and open access.
- Creates essential widely used software cyberinfrastructure such as data analysis and visualization tools and frameworks for modeling and science gateway construction.
- Provides user support and training for all of these services.
- Strives to better integrate its resources and services with regional and national cyberinfrastructure and services, and with the organizations that maintain them, such as the Front Range GigaPoP (FRGP), the Front Range Consortium for Research Computing (FRCRC), and NSF's eXtreme Science and Engineering Discovery Environment (XSEDE).

In FY2013 CISL put the data-centric petascale Yellowstone supercomputing environment into production at the NWSC, including the 1.5 petaflops IBM iDataPlex supercomputer, the 11.9 petabyte GLADE central disk storage system, two data analysis and visualization systems, the HPSS tape archive, and high-speed wide-area networking. Through the Accelerated Scientific Discovery program which first ran on Yellowstone in December 2012, 11 large-scale scientific projects have extended the research frontiers of weather phenomena, climate change, space weather, solar physics, and more. The award-winning NWSC facility has been systematically tuned to approach its designed energy efficiency levels, and at end-FY2013 it achieved an average PUE below 1.2. The NWSC Visitor Exhibit was completed in early FY2013 and has attracted over 3,000 visitors in its first year of operation, hosting a number of student STEM education programs such as Wyoming's GEAR UP and the Wyoming Cowboy Challenge.

CISL's software CI capabilities continued to make important advances in FY2013 as well, including the deployment of a novel multiple-component interface between the Data Assimilation Research Testbed (DART) and the CESM that enables climate predictability experiments; a major new release of the NCAR Command Language (NCL) that included a major overhaul of its display model; and improvements to the Visualization and Analysis Platform for Ocean, Atmosphere, and Solar Researchers (VAPOR), such as adding support for ocean modeling data and refactoring VAPOR's architecture to facilitate third-party code enhancement. All of these tools are heavily used -- for instance, in FY2013, VAPOR's user community increased to over 5,000 users and NCL's software was downloaded over 22,000 times.

This work is funded as specified in the following individual reports.

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CISL FACILITIES

The NCAR Wyoming Supercomputing Center won top honors in the "Design Implementation Category" of the 2013 Green Enterprise IT Awards. Aaron Andersen is holding the plaque and is bookended by Terry Autry (RMH Group), Ken Dabbs (H+L Architecture), and Mike Pask (Saunders Construction), all key members of the design and construction team. Also shown are John Ford, John Sabey, and Pitt Turner, sponsors of the award.

CISL's first computing imperative is to provide world-class supercomputing facilities for its user community. A foundational element of CISL's mission is to deploy and operate the physical and virtual computational facilities needed to support the atmospheric and related sciences. Consistent with NCAR's environmental mission, CISL regularly enhances the capability and capacity of NCAR's supercomputing facilities while maximizing their efficiency and usability. FY2013 was focused on the work required to tune and optimize the facility as computing entered initial production. NWSC will be home to many generations of supercomputing systems for the Earth System sciences.

At the NWSC, Yellowstone was accepted in very early FY2013 and entered full production in January. In Boulder, the Bluefire system was decommissioned, and the Mesa Lab Computing Facility (MLCF) completed the transition to a colocation facility. The MLCF now hosts computer systems for divisions and programs across UCAR as well as hosting a BlueGene/Q system in collaboration with the Colorado School of Mines. This work gives CISL access to different architectures that are critical in determining the best path for future large procurements.

NSF Core funding supports this work along with other funding as described in the following sections.

‹ CISL Services up NCAR-Wyoming Supercomputing Center ›

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NCAR-WYOMING SUPERCOMPUTING CENTER

In partnership with the University of Wyoming (UW), the State of Wyoming, Cheyenne LEADS, the Wyoming Business Council, and NSF, NCAR transitioned into operation of the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming during FY2013. NWSC is designed to meet the rapidly growing high-performance computing (HPC) needs of Earth System scientists and to encourage broader participation in this scientific enterprise. Earth System scientists need petascale computing, data analysis, and visualization resources combined with exascale data management capabilities to support greater model resolution, increased model complexity, better statistics, more predictive power, and longer simulation times. NWSC has been designed and built with a focus on sustainability and energy efficiency consistent with NCAR's and UW's strong commitment to environmental stewardship.

Gary New stands in front of the NCAR Wyoming Supercomputing Center front entrance with the award recognizing the facility as the 2013 "Green Data Center of the Year" from the inaugural Datacenter Dynamics North American Awards.

NWSC is fully aligned with NSF's vision for future cyberinfrastructure and will directly contribute to the creation of a national-scale petascale computing capability. The facility will be a peer with other NSF facilities and will serve as a "stepping stone" for Earth System science investigators to fully utilize the largest systems available such as NCSA's Blue Waters. CISL's first strategic imperative is to provide HPC facilities for the Earth System sciences: "A foundational element of CISL's mission is to deploy and operate the physical and virtual computational facilities needed to support the science community. Essential to this mission is the design, construction, and operation of a new data center capable of meeting future scientific computing challenges in the atmospheric sciences."

CISL accepted Yellowstone at the beginning of FY2013, and the system was then used for 11 Accelerated Scientific Discovery projects. During this early period, a number of system issues were identified and improved, then full production work on Yellowstone was initiated in January FY2013. During FY2013, the NWSC was recognized nationally and internationally and won the "Facility Design Implementation" category of the 2013 Green Enterprise IT (GEIT) Awards. Later in the year, the NWSC was named the 2013 "Green Data Center of the Year" at the inaugural Datacenter Dynamics North American Awards.

The operational expenses for NWSC during FY2013 were met using NSF core funds.

‹ CISL facilities up Mesa Lab Computing Facility ›

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MESA LAB COMPUTING FACILITY

NCAR's Mesa Lab Computing Facility (MLCF) has served high performance computing in the atmospheric sciences since the mid-1960s. CISL continued to invest considerable effort in maintaining MLCF while the NCAR-Wyoming Supercomputing Center (NWSC) was under construction. MLCF has been repurposed to house the majority of the enterprise-class IT equipment for NCAR and UCAR so it continues providing significant value to researchers for many years into the future.

In a collaborative arrangement with the Colorado School of Mines, CISL is hosting an IBM BlueGene/Q system in the MLCF. The system shown provides CISL with early access to another variation of water-cooled computing systems as well as access to an architecture that may provide useful information about future computer architectures and modeling valuable to the Earth System sciences.

While MLCF infrastructure can't support modern large-scale HPC systems, the facility is fully capable of supporting conventional Information Technology (IT) equipment for NCAR divisions and UCAR programs. With the decommissioning of the IBM Bluefire system in January 2013, the Mesa Lab Computing Facility (MLCF) was fully transitioned to its new colocation role. At present, the MLCF hosts servers and services for NCAR divisions and UCAR programs ACD, CGD, CISL, COSMIC, F&A, Globe, HAO, IIS, JOSS, and RAL.

During FY2013 an engineering study examining the cooling infrastructure for the MLCF was completed. This study further informed a statement of work that will be used to refurbish the MLCF. Additionally, a battery monitoring system was installed that promises to reduce the cost of battery replacements because only truly weak or failing batteries will be replaced. Finally, a facility monitoring software package was installed at MLCF that allows staff at MLCF and at NWSC to monitor the health of the cooling and electrical systems at both locations.

During FY2013 CISL was approached to participate in a joint project with the Colorado School of Mines (CSM). It involved hosting an IBM BlueGene/Q system in exchange for NCAR user access to a percentage of the CSM system. Working through the details of this type of partnership was complex: several agreements and direct NSF approval was required. After NSF approval, the BlueGene/Q was installed and acceptance testing began during summer FY2013.

Funding for the MLCF is supported by UCAR overhead funding out of the communications pool.

‹ NCAR-Wyoming Supercomputing Center up CISL computing services ›

CISL COMPUTING SERVICES

CISL's world-class supercomputing and data services continually change in concert with underlying technologies and scientific demands. CISL continues to provide and has significantly improved support for data-intensive computing. Beyond the basic bandwidth and latency CISL has continued to enhance capabilities such as data management, data analytics, improved workflow, as data is one of the key products enabling scientific discovery. The challenges of managing data are becoming the challenge for our scientific research community. Fundamental CISL computing services include:

- **Hardware cyberinfrastructure resources:** CISL's current hardware environment features Yellowstone, a 1.5-PFLOPS high-performance computing resource at the NCAR-Wyoming Supercomputing Center (NWSC). The Yellowstone environment encompasses a petascale high-performance computing (HPC) resource, an 11-PB centralized file system and data storage resource, and two integrated data analysis and visualization resources.

- **User services:** CISL places paramount importance on providing high-quality support to our user community. User support efforts include a broad range of activities including HPC training, on-call support for specialized campaigns, help desk, and consulting services. Four allocation communities are now served: NCAR, NSF-funded researchers at U.S. universities, the Climate Simulation Laboratory, and University of Wyoming researchers through the Wyoming-NCAR Alliance. Allocations for the new Wyoming community began in FY2013. NCAR is one of only a small number of institutions with the resources and support services necessary to conduct high-end climate research, model development, and campaigns such as real-time weather forecasts for the MPEX field experiment in early 2013. As a discipline-specific computing center, CISL is able to provide the capabilities and skill sets required to support important field and computational campaigns with on-demand resources that include those driven by unfolding natural disasters.

- **Enterprise architecture (EA):** CISL develops effective business practices and information technology (IT) infrastructure to support them. CISL's Director of Operations and Services leads UCAR's cross-organizational IT coordination. This effort initiated a UCAR-wide Enterprise Architecture team to govern and evolve the necessary infrastructure for IT in the organization. The first major effort began in FY2013 with the recommendation that UCAR move to Google Apps for Government as a complete cloud-based suite taking advantage of cloud-based e-mail, calendar and collaborative tools.

Funding for these activities is indicated at the end of each of the following sections.

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HARDWARE CYBERINFRASTRUCTURE

CISL fulfills its computing imperative to provision computing, storage, data analysis, visualization, networking, and archival systems customized to support the atmospheric and related sciences by delivering robust and reliable resources and services in an end-to-end research environment. For over 1,700 users in a wide variety of disciplines, CISL provides:

- High performance production computing.
- Data storage and archival environments.
- Local and wide-area network connectivity.
- Data analysis and visualization systems.

CISL also actively participates in projects designed to provide advanced services and tools to enable Earth System science for a diverse community of users, including:

- Collaboration on national and regional supercomputing initiatives.
- Science gateways for climate, environmental, and astrophysical research initiatives.
- Experimental computing systems.

The Yellowstone supercomputing system has been producing significant scientific results for the research community since early FY2013.

CISL put the data-centric Yellowstone supercomputing system into production in FY2013. Early system access was provided through the Accelerated Scientific Discovery (ASD) program. For Yellowstone, 11 ASD projects used more than 100 million core-hours from December 2012 through April 2013, pursuing challenges in high-resolution climate modeling, cloud physics and turbulence, and modeling of the heliosphere. Additional special campaigns in FY 2013 took advantage of Yellowstone's computational

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capacity to support field campaigns and improve model forecasts. CISL also witnessed the end of HPC computing at the venerable Mesa Lab Computing Facility with Bluefire being decommissioned at the end of January 2013.

NCAR's supercomputers are managed by CISL under the UCAR/NSF Cooperative Agreement and are supported by NSF Core funds including CSL funding.

‹ CISL computing services   up   Yellowstone data-intensive computing environment ›

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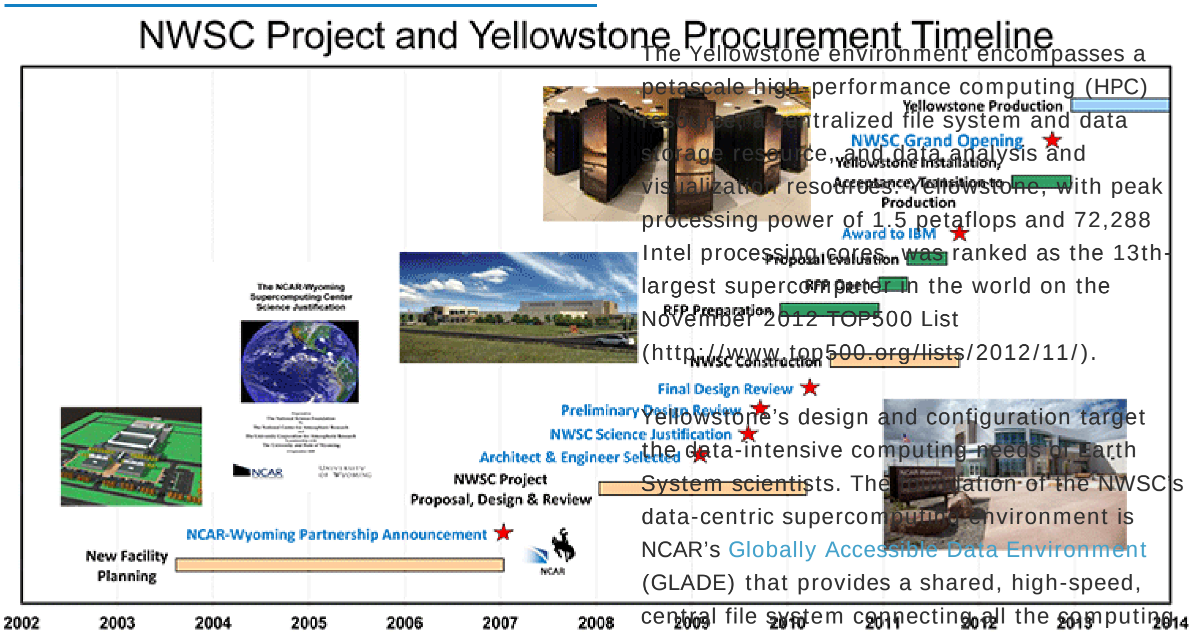
YELLOWSTONE DATA-INTENSIVE COMPUTING ENVIRONMENT

FY2013 saw the largest change in computational capacity and capability in NCAR history with the acceptance of Yellowstone, its data storage systems, and related data analysis equipment. Yellowstone provides 30 times more capability than NCAR's previous largest system, Bluefire. Placing Yellowstone into production service on 20 December 2012 culminated nearly a decade of work by CISL in planning, designing, and constructing the new NCAR-Wyoming Supercomputing Center (NWSC), which held its grand opening on 15 October 2012.



The FY2013 opening of the NCAR-Wyoming Supercomputing Center and showcasing of its inaugural supercomputer, Yellowstone, culminated nearly a decade planning, design, construction and implementation.

The Yellowstone environment encompasses a petascale high-performance computing (HPC) resource, a centralized file system and data storage resource, and data analysis and visualization resources. Yellowstone, with peak processing power of 1.5 petaflops and 72,288 Intel processing cores, was ranked as the 13th-largest supercomputer in the world on the November 2012 TOP500 List (http://www.top500.org/lists/2012/11/).

Yellowstone's design and configuration target the data-intensive computing needs of Earth System scientists. The foundation of the NWSC's data-centric supercomputing environment is NCAR's Globally Accessible Data Environment (GLADE) that provides a shared, high-speed, central file system connecting all the computing and support systems required for scientific workflows. This design improves scientific productivity and reduces costs by eliminating the need to move or maintain multiple copies of data. GLADE provides an aggregate data storage capacity of nearly 11 petabytes and is capable of transferring data at speeds exceeding 90 gigabytes per second.

Rounding out the resources of Yellowstone's environment are the Data Analysis and Visualization (DAV) systems Geyser and Caldera. Specially configured for DAV tasks and equipped with NVIDIA graphics processing units (GPUs), Geyser and Caldera share GLADE filesystems with Yellowstone. The 16-node Geyser cluster, with 1.0 terabyte of memory per node, was designed for intense data synthesis and analysis tasks. The 16-node Caldera cluster, with two GPUs per node, was designed for computationally intensive parallel data analysis and visualization tasks.

Also part of the Yellowstone environment is a 16-node computational cluster equipped with two Intel Xeon Phi co-processors per node. This system, named Pronghorn, was installed in the second half of FY2013 and provides a testbed for research and code development work targeted at applying the Phi co-processor to accelerating the performance of atmospheric science applications.

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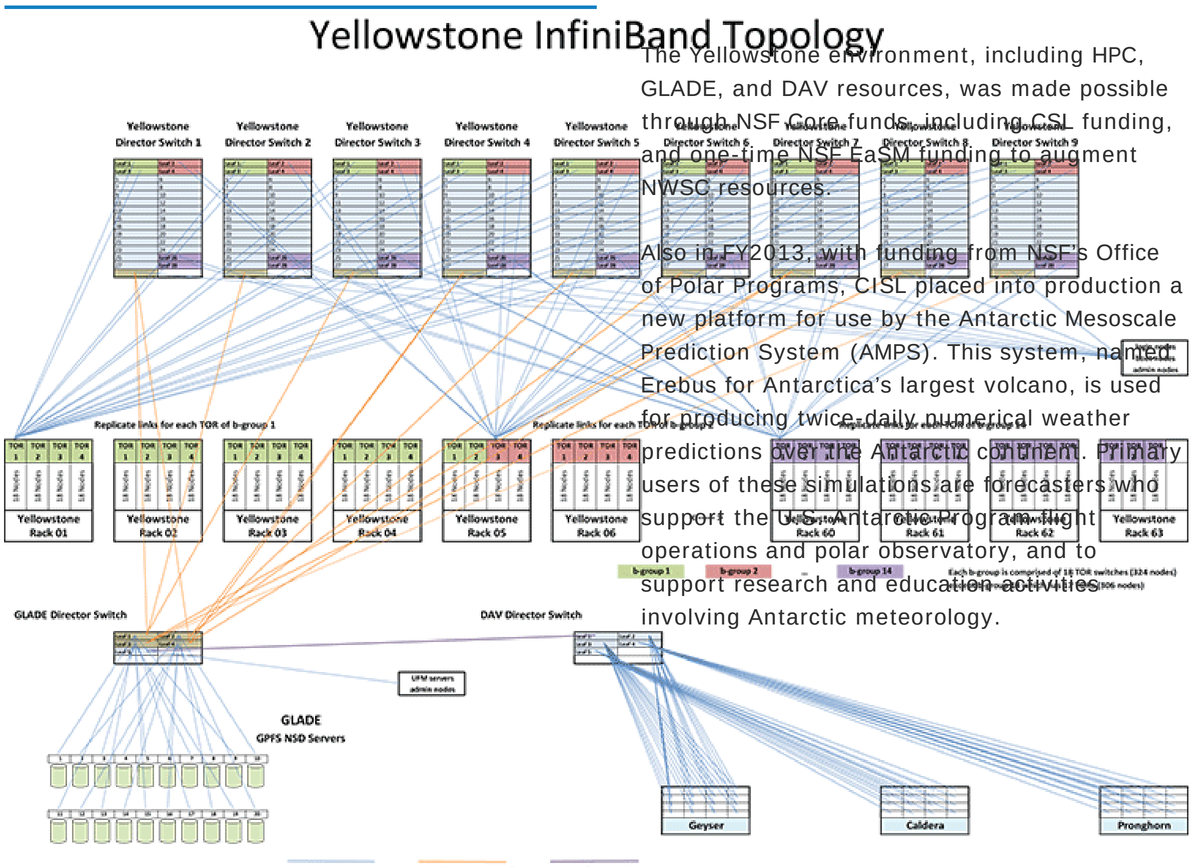
CISL's commitment to a data-intensive computing strategy extends beyond the Yellowstone environment and includes a full suite of science gateway and data portal services. CISL continues to lead the community in developing data services that can address the future challenges of data growth, preservation, curation, and management. CISL also leads in supporting NSF's new requirement for data management plans. Our disk and tape-based HPSS storage systems provide an efficient, safe, and reliable environment for hosting datasets. CISL has streamlined and improved its data services through the data-centric design of the Yellowstone environment.

As it has always been with the early adoption of new technologies, production deployment of Yellowstone was not without difficulty. Yellowstone was one of the first petascale systems to use Intel's E5-2670 (Sandy Bridge) processor and PCIe Gen3 and FDR InfiniBand technology. Much of CISL's efforts during FY2013 were focused on establishing and improving a stable user environment. In partnership with IBM and Mellanox, CISL worked to address operational and administrative processes, monitoring, system resource manager issues, application performance and scaling issues, and to identify deficiencies in packet routing on multi-tier InfiniBand topologies. Additionally, while being an early adopter of emerging technologies has distinct advantages for applying the best computational tools to NCAR's science and for producing close vendor-customer partnerships, there are potential pitfalls.

Not only was Yellowstone comprised of newly introduced technology, it was also deployed at an unprecedented scale, and an issue arose with Yellowstone's InfiniBand interconnect. A combination of an early-production manufacturing issue with the electro-optical converters in the FDR cables and the nuances of packet routing algorithms on Yellowstone's multi-tier quasi fat-tree topology (which had been previously untested at such a scale) resulted in poorer stability and performance from the fabric than had been anticipated. Improvements were made in the routing algorithm during FY2013, more are planned in the upcoming year, and CISL, IBM, and Mellanox have developed a plan for replacing over 4,600 optical InfiniBand cables at the start of FY2014. CISL anticipates that, together, these efforts will further improve the stability and performance of Yellowstone in FY2014 and beyond.



A schematic diagram of a small portion of Yellowstone and its InfiniBand interconnect. In all, the Yellowstone InfiniBand fabric is comprised of over

The Yellowstone environment, including HPC, GLADE, and DAV resources, was made possible through NSF Core funds, including CSL funding, and one-time NSF EaSM funding to augment NWSC resources.

Also in FY2013, with funding from NSF's Office of Polar Programs, CISL placed into production a new platform for use by the Antarctic Mesoscale Prediction System (AMPS). This system, named Erebus for Antarctica's largest volcano, is used for producing twice-daily numerical weather predictions over the Antarctic continent. Primary users of these simulations are forecasters who support the U.S. Antarctic Program flight operations and polar observatory, and to support research and education activities involving Antarctic meteorology.

4,600 optical cables and over 4,500 copper cables (nearly 60 miles).

PRODUCTION SUPERCOMPUTING STATUS

FY2013 heralded a new era of CISL supercomputing services with the grand opening of the NCAR-Wyoming Supercomputing Center, the commissioning of the Yellowstone computational and storage resources, and the decommissioning of former supercomputing systems at the NCAR Mesa Laboratory.

As described in last year's annual report, an aggressive installation and acceptance testing schedule was set for the Yellowstone environment, targeting production use of the system by the end of FY2012. As FY2013 began, Yellowstone was not yet ready for production science. The triune partnership of CISL, IBM, and Mellanox that developed during the delivery, installation, and initial acceptance testing of the systems in the summer of 2012 continued its aggressive focus into the fall on expeditious isolation and resolution of system, operational, and stability issues. The rapid pace of identifying and resolving issues resulted in the systems being declared production ready on December 20, 2012, allowing CISL to open the new NWSC resources to the full user community. Work continued through FY2013 on additional system software, stability, and application performance issues and on planning the optical cable replacement project.

The Yellowstone procurement defined a data-centric architecture for systems deployed within the NWSC, where NCAR's Globally Accessible Data Environment (GLADE) would provide a common, high-speed, high-capacity foundation for high performance computing (HPC) and data analysis and visualization (DAV) resources. This environment was designed to optimize scientific workflows and minimize data movement between computation, data subsetting, and analysis tasks, with additional support for direct data movement activities between the NCAR HPSS archive and GLADE storage.

The visitor-facing end panels of Yellowstone, CISL's new 1.5-petaflops supercomputer, installed in the NCAR-Wyoming Supercomputing Center.

The computational and data storage resources deployed at the NWSC during FY2013 are often collectively referred to as Yellowstone for simplicity, but are actually an integrated set of HPC, DAV, and centralized filesystem and data storage (GLADE) resources. The table below provides the detailed specifications for each of the computational resources of the NWSC environment.

High Performance Computing

Yellowstone is the production HPC resource at the NWSC. Based on the NWSC-1 procurement's benchmarks, Yellowstone has 30 times more sustained throughput capacity than the 77-teraflops IBM POWER6 system Bluefire, NCAR's previous largest production system. Yellowstone consists of 63 IBM iDataPlex racks equipped with rear door heat exchangers, 9 Mellanox SX6536 FDR InfiniBand switch racks, and two 19-inch racks containing login and administrative nodes

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and the system's administrative Ethernet switch. Yellowstone's computational component contains 4,518 IBM dx360 M4 nodes with 72,288 compute cores having a peak computational capability of 1.5 petaflops and a total of 145 terabytes of memory. Yellowstone is comprised of computational, login, and administrative nodes, a full fat-tree FDR InfiniBand interconnect, and a private administrative Ethernet network.

As part of the Yellowstone procurement, CISL, IBM, and Intel partnered to deploy Pronghorn, a small Intel Xeon Phi coprocessor system. Pronghorn was deployed in mid-FY2013 as an exploratory system to help CISL and NCAR examine and evaluate the applicability of the Intel Xeon Phi coprocessor to climate, weather, and other related science simulations.

Data Analysis and Visualization

DAV in scientific workflows place special needs on the underlying hardware that are different from computational resources. The DAV production resource at NWSC is designed to offer two purpose-focused clusters: a large-memory node cluster (Geyser) to be used primarily for single- and multi-tasked data analysis applications and a GPU-computation/visualization cluster (Caldera) dual purposed for visualization as well as for GPU computation and computationally assisted data reduction and analysis.

Caldera is comprised of 16 IBM dx360 M4 nodes each containing a pair of NVIDIA Tesla graphics processing units. Geyser has 16 IBM x3850 X5 nodes each containing an NVIDIA Quadro 6000 graphics processing unit and a terabyte of memory.

Geyser and Caldera share a Mellanox SX6512 FDR InfiniBand director switch. Six FDR links from the SX6512 director switch to GLADE provide a theoretical aggregate bidirectional I/O bandwidth of 84 gigabytes/second to the DAV resources.

Globally Accessible Data Environment

For the data-intensive science served by Yellowstone, GLADE is the heart of the system, providing the NWSC's primary high-performance centralized filesystems and data storage. The filesystems are implemented with IBM's General Parallel File System (GPFS) with a sustained aggregate I/O bandwidth exceeding 90 gigabytes/second and a usable capacity of 10.9 petabytes. GLADE's usable capacity will be expanded to 16.4 petabytes in mid FY2014.

GLADE is comprised of 20 GPFS Network Storage Device (NSD) servers, 6 GPFS quorum, metadata, and cluster management servers, 4 I/O aggregator servers for data staging with the NCAR HPSS archive and to and from the internet, 76 IBM DCS 3700 storage subsystems, and a Mellanox SX6512 FDR InfiniBand switch that provides I/O connectivity with other FDR InfiniBand switches in the HPC and DAV resources. Two NSD servers and four DCS3700 storage subsystems are dedicated to managing the home filesystem, while the remaining 18 NSD servers manage the project and scratch filesystems, which are striped across the remaining 72 DCS3700 storage subsystems. NSD servers are configured in pairs for high availability and filesystem resiliency, and each NSD server is twin-tailed to four DCS3700 storage subsystems, providing load balancing across controllers and multi-pathing for resiliency.

	Yellowstone	Caldera	Geyser	Pronghorn	Erebus (AMPS)
Peak FLOP Rate (TF)	1503.6	21.8	14.4	37.7	28.0
Total Number of Nodes	4518	16	16	16	84
Primary Node Architecture	IBM dx360 M4	IBM dx360 M4	IBM x3850 X5	IBM dx360 M4	IBM dx360 M4
CPU Type	Intel Xeon E5-2670	Intel Xeon E5-2670	Intel Xeon E7-4870	Intel Xeon E5-2670	Intel Xeon E5-2670
CPU Microarchitecture	Sandy Bridge	Sandy Bridge	Westmere EX	Sandy Bridge	Sandy Bridge

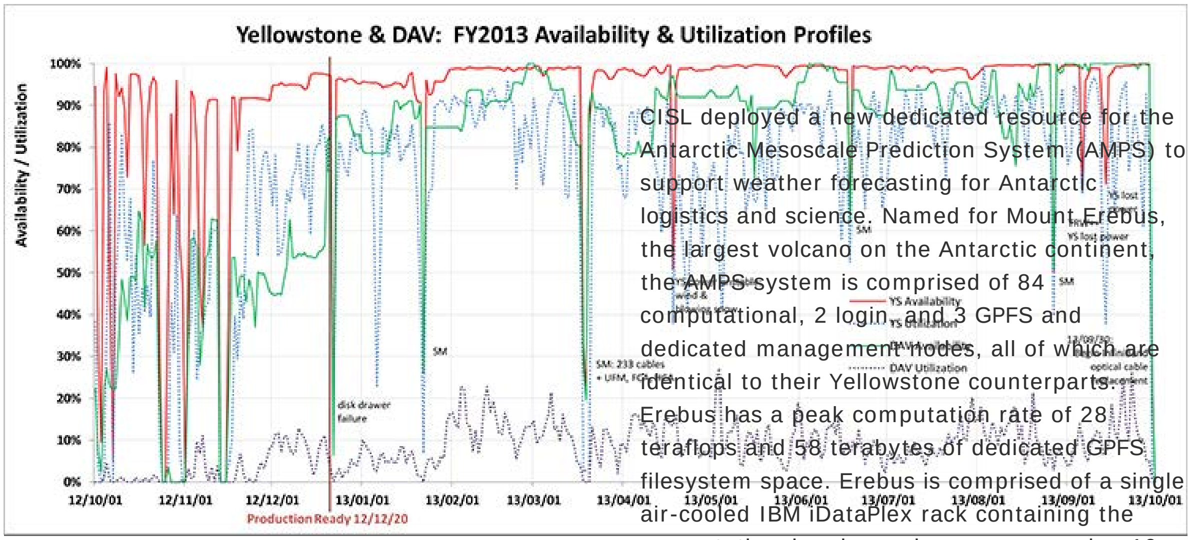
	EP	EP		EP	EP
CPU Frequency (GHz)	2.6	2.6	2.4	2.6	2.6
CPU Count per Node	2	2	4	2	2
Core Count per Node	16	16	40	16	16
Node Memory Capacity (GB)	32	64	1024	64	32
Node Memory Type	DDR3-1600	DDR3-1600	DDR3-1066	DDR3-1600	DDR3-1600
Interconnect Network	InfiniBand 4x FDR	InfiniBand 4x FDR	InfiniBand 4x FDR	InfiniBand 4x FDR	InfiniBand 4x FDR-10
Interconnect Topology	3-tier full fat tree	1-tier full fat tree	1-tier full fat tree	1-tier full fat tree	2-tier full fat tree
Network Ports per Node	1	1	2	1	1
System Bisection Bandwidth (GB/sec)	31,095	108.6	103.9	108.6	407.3
Accelerator Peak Double-precision FLOP Rate (GF)	-	515.2	515.2	1011	-
Accelerator Count per Node	-	2	1	2	-
Accelerator Memory Capacity (GB)	-	6	6	8	-
Accelerator Memory Type	-	GDDR5	GDDR5	GDDR5	-
Number of Compute Racks	63	0.5	2	0.5	1

Initially, every new system introduced into the NCAR HPC computing environment is substantially dedicated to use by a select set of Accelerated Scientific Discovery (ASD) projects. By the mid-October 2012 grand opening of the NWSC facility, and despite the system not yet being considered production ready, investigators began production ASD simulations. These ASD codes, some of which utilized the full system, helped to identify operational and performance-at-scale issues within the hardware and the resource management and parallel-runtime software (theretofore not exercised at that scale). During this initial production period of December 2012 through March 2013, the ASD projects consumed nearly 100 million core hours.

Production deployment of a computational resource as large and complex as Yellowstone is challenging. Yellowstone incorporated emerging hardware and software technologies at a previously untested scale during its initial deployment. CISL worked hand-in-hand with IBM and Mellanox to assess, diagnose, and isolate issues, address hardware issues, and deploy software and firmware fixes. Throughout FY2013, system administration and consulting services staff in CISL’s Operations and Services Division were wholly focused on stabilizing and refining the user environment and working with end users to improve application resiliency and performance.

Since entering production, Yellowstone has averaged 98.4% availability and 79.5% user utilization, while the DAV resources (Geyser and Caldera) have had an average availability of 91.4% and user utilization of 9.6%.

In addition to the Yellowstone systems, with funding from the NSF Office of Polar Programs,



The availability and utilization profiles for the HPC (Yellowstone) and DAV (Caldera & Geyser) resources during FY2013; showing the stabilization of the system during the fall of 2012.

CISL deployed a new dedicated resource for the Antarctic Mesoscale Prediction System (AMPS) to support weather forecasting for Antarctic logistics and science. Named for Mount Erebus, the largest volcano on the Antarctic continent, the AMPS system is comprised of 84 computational, 2 login, and 3 GPFS and dedicated management nodes, all of which are identical to their Yellowstone counterparts. Erebus has a peak computation rate of 28 teraflops and 58 terabytes of dedicated GPFS filesystem space. Erebus is comprised of a single air-cooled IBM iDataPlex rack containing the computational nodes and an accompanying 19-inch rack containing the remainder of the system's resources.

With the production deployment of Yellowstone, Caldera, Geyser, Pronghorn, Erebus, and GLADE, CISL continued to deliver on its computing imperative for hardware cyberinfrastructure. CISL's efforts remained substantially focused on providing robust, reliable, and secure high-performance computing resources in a production research environment, and supporting this environment for more than 1,500 users at NCAR, UCAR member universities, and the University of Wyoming in a wide variety of disciplines related to the atmospheric sciences. CISL resources empowered the research community to pursue more innovative investigations, and CISL itself provides the organizational focus, capabilities, and skill sets to support these investigations along with the field and computational campaigns of other NCAR laboratories.

CISL's production supercomputing environment is designed, administered, and managed to provide data-centric computational resources that are balanced to meet the needs of its numerical simulation and data-analysis communities. Additionally, CISL strives to provide the most effective and useful combination of computational and data storage capability and capacity, augmented by scientific data analysis, visualization, and archival services. CISL works to provide equitable access to these computing and storage resources while achieving high reliability, minimizing job wait times, and maximizing resource throughput and utilization. These objectives require CISL to continuously monitor system usage and performance and to continuously work to balance resource allocation with priority-based intelligent job scheduling, a well-tuned job queue structure, and single-job resource limits.

In addition to deploying new cyberinfrastructure resources, supporting all user communities, and maintaining production supercomputing services, CISL also retired equipment during FY2013. On February 1, CISL decommissioned the previous production system, Bluefire, and its test system Firefly. These IBM POWER6 systems had been the primary computational systems at NCAR for over four and a half years. Also, the Cray XT5m system, Lynx, was retired at the end of the fiscal year.

This work is made possible through NSF Core funds, including CSL funding, and NSF Special Funds were used for the AMPS resources.

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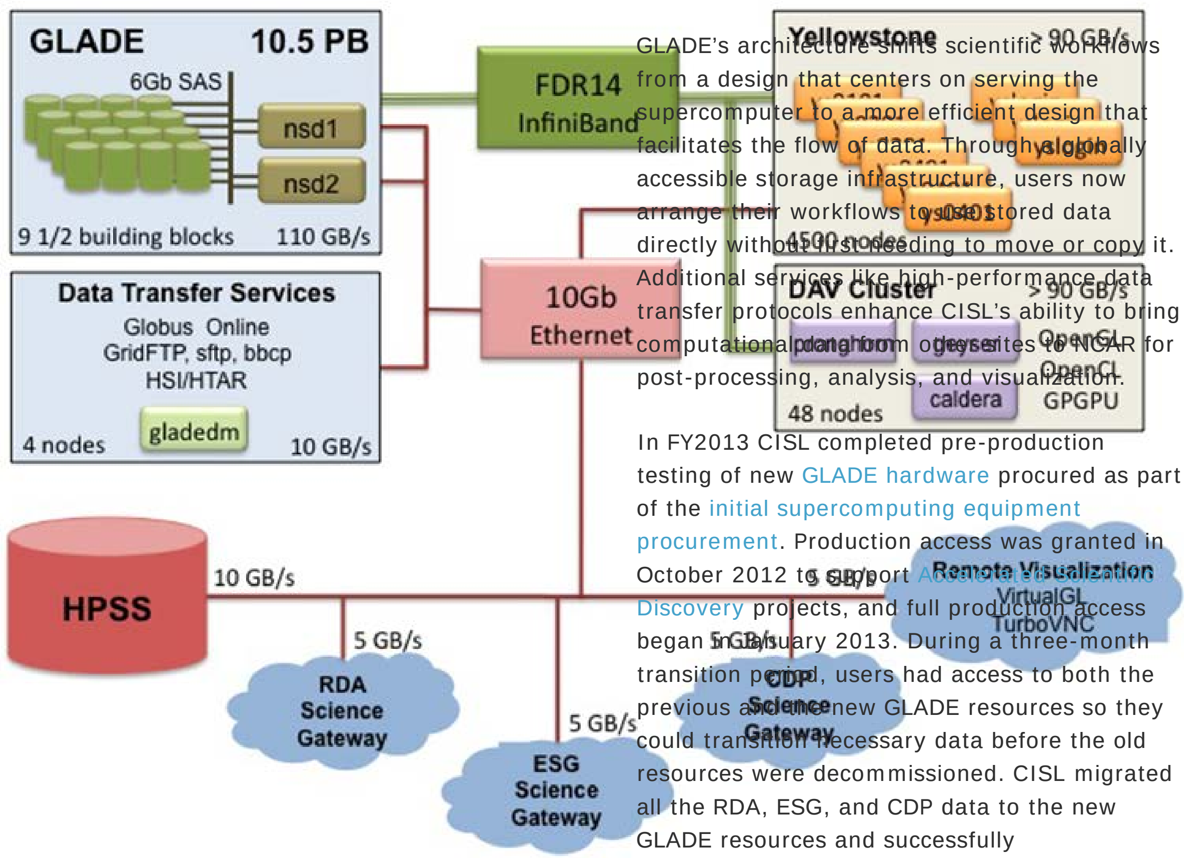
GLOBALLY ACCESSIBLE DATA ENVIRONMENT

The GLobally Accessible Data Environment (GLADE) provides centralized high-performance file systems spanning supercomputing, data post-processing, data analysis, visualization, and HPC-based data transfer services. GLADE provides computation, analysis, and visualization work spaces common to all CISL HPC resources. Project space is allocated through NCAR's allocation panels, while scratch and user space is available to all users of NCAR HPC resources. GLADE also hosts data from NCAR's Research Data Archive (RDA), NCAR's Community Data Portal, and the Earth System Grid which curates CMIP5/AR5 data.



This illustration shows the I/O network connecting the GLADE storage resource to Yellowstone, Geyser, Caldera, and Pronghorn along with access to the science gateways supporting the RDA, ESG, and CDP.

GLADE's architecture shifts scientific workflows from a design that centers on serving the supercomputer to a more efficient design that facilitates the flow of data. Through a globally accessible storage infrastructure, users now arrange their workflows to use stored data directly without first needing to move or copy it. Additional services like high-performance data transfer protocols enhance CISL's ability to bring computational data from other sites to NCAR for post-processing, analysis, and visualization.

In FY2013 CISL completed pre-production testing of new GLADE hardware procured as part of the initial supercomputing equipment procurement. Production access was granted in October 2012 to support Accelerated Scientific Discovery projects, and full production access began in January 2013. During a three-month transition period, users had access to both the previous and the new GLADE resources so they could transition necessary data before the old resources were decommissioned. CISL migrated all the RDA, ESG, and CDP data to the new GLADE resources and successfully decommissioned the old GLADE resources on 1 April 2013.

This work supports CISL's computing imperative for hardware cyberinfrastructure by provisioning storage and networking systems customized to support efficient workflows for the atmospheric and related sciences. Specifically, GLADE facilitates typical user workflows plus special efforts like supporting data flows for the IPCC AR5. GLADE also advanced CISL's computing imperative for facilities by demonstrating high-performance data services that were critical for the next-generation resources that now operate at NWSC. By using GLADE-enabled workflows, users are well prepared for a smooth transition to NWSC's new environment. GLADE

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equipment was purchased with NSF Special funds, and it is supported by NSF Core funds including CSL funding.

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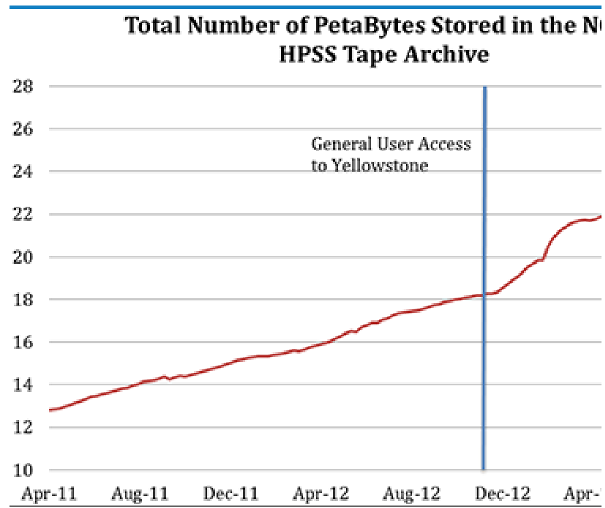
ARCHIVAL SYSTEMS



This chart shows recent growth of the HPSS tape archive. Since Yellowstone was opened to general users, the growth rate has increased to 1 petabyte per month.

NCAR originally selected IBM's High Performance Storage System (HPSS) technology to integrate NCAR resources with NSF TeraGrid supercomputers, data archives, and data analysis facilities around the country. XSEDE is the NSF's follow-on program, and it continues using HPSS technology. The deployment of HPSS at NCAR enables a homogeneous storage solution for XSEDE, allows potential data archive connectivity directly with XSEDE Wide Area Network (WAN) filesystems, and provides data archive services for the High-Performance Computing (HPC) system Yellowstone.

A business continuity plan for selected archive data was executed after the production deployment of the core HPSS services at NWSC in FY2013. The plan isolated critical data from the CISL Research Data Archive (RDA) at the Mesa Lab. Additional copies of this data are available at NWSC thus satisfying the geographical separation requirement. Capitalizing on the delayed deployment of production HPC equipment at NWSC, CISL developed a new archive deployment strategy in July 2012. The new strategy delayed the release of the next archive RFP by two years. This strategy provides CISL time to develop RFP requirements based on real-life experience with the NWSC HPC environment. The delay also allows CISL time to develop new policies for refining data management practices in the future. The release of the NWSC Archive RFP is now scheduled for January 2015 with deployment in 2016. To fill the two-year gap, CISL will exercise options to extend the AMSTAR subcontract period of performance. New tape technology increasing the total HPSS capacity by at least 60% over the existing tape technology will be included in the Augmentation of the Mass Storage Tape Archive Resources (AMSTAR) subcontract extension. This is scheduled to be executed in early FY2014. The subcontract extension will meet NCAR's projected needs through 2016. That is when the equipment from the NWSC Archive RFP is expected to be deployed.

This effort supports CISL's computing imperative for hardware cyberinfrastructure by deploying a production HPSS instance that supports NWSC. The NCAR HPSS is managed by CISL under the UCAR/NSF Cooperative Agreement and is supported by NSF Core funds and CSL funding.

‹ Globally Accessible Data Environment up Data analysis and visualization environment ›

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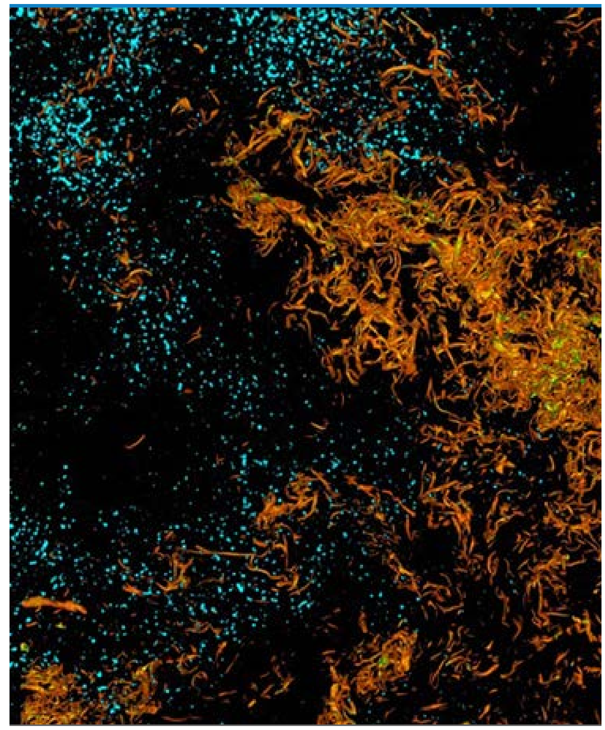
DATA ANALYSIS AND VISUALIZATION ENVIRONMENT

The Data Analysis and Visualization Lab enhances scientific workflows by providing UCAR's research community with state-of-the-art systems tailored for the specialized needs of interactive data post-processing, analysis, and visualization. This lab also supports the research community by developing algorithms for relevant visualization and analysis methods and by producing animations and imagery on behalf of scientific staff.



This image depicts a small subregion from a high-resolution ($2,048^3$) simulation of inertial particles interacting with a turbulent field. Particle "clustering" or "preferential concentration," has been linked to the acceleration of precipitation in cumulus clouds by increasing the collision frequency and the coalescence rate of the cloud droplets. The simulation, conducted as part of the Accelerated Scientific Discovery (ASD) program on Yellowstone, generated over 50 terabytes of data, which was post-processed and visualized on Geyser using CISL's VAPOR software.

During FY2013, the Data Analysis and Visualization (DAV) environment transitioned from standalone systems to become a much more tightly integrated part of the larger Yellowstone environment consistent with its design goals of providing an end-to-end data-centric environment for computation, analysis, and visualization within a scientific workflow. The DAV resources of the Yellowstone environment, Caldera and Geyser, are comprised of systems with binary compatibility with Yellowstone itself and a dedicated 84 Gbps pathway to the same GLADE filesystems as Yellowstone, but are equipped with NVIDIA graphics co-processors. Caldera is comprised of 16 IBM dx360 M4 nodes identical to Yellowstone's, but each node is equipped with two NVIDIA M2070Q graphics processing units and 64 gigabytes of memory. Caldera is designed especially for applications performing parallel graphics, parallel data reduction and analysis, and GPU-assisted computation. Geyser is comprised of 16 IBM x3850 X5 nodes, with an NVIDIA Quadro 6000 graphics adapter and one terabyte of memory per node. Geyser is designed especially for more traditional interactive large-dataset reduction and analysis and visualization work. The DAV resources are also used for data subsetting and curation of Research Data Archive holdings. The predecessor DAV systems, Mirage and Storm, were decommissioned in March 2013.

In addition to supporting CISL's computing imperative for hardware cyberinfrastructure (CI), the DAV environment also supports CISL's software CI computing imperative by developing and supporting software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. Additionally, the DAV Lab advances CISL's science frontier in understanding large and heterogeneous data sets by developing new methods and tools to extract and visualize information from such data sets.

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The DAV environment and services are supported by NSF Core funds including CSL funding.

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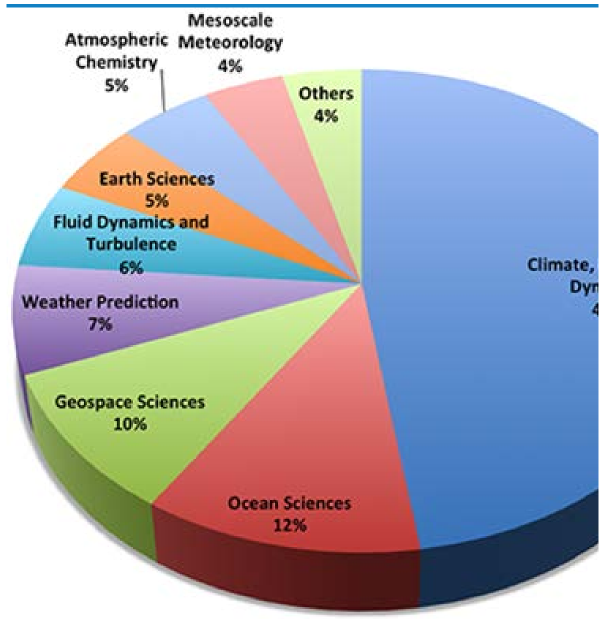
USER SERVICES



The petascale Yellowstone system was used by various Earth System science disciplines in FY2013. User Services staff provide computational and data management support services tailored to needs of this research community.

CISL has a strategic commitment to provide robust, accessible, and innovative services and resources to researchers in the atmospheric and related sciences, including the broad university community, Climate Simulation Laboratory (CSL) users, NCAR researchers, and with the arrival of Yellowstone, University of Wyoming users. As part of that commitment, CISL works to provide its users with responsive and knowledgeable support services. CISL's success in supporting scientific goals and enabling scientific impact depends in equal measure on understanding the needs and research objectives of its user community, and on integrating CISL's resources, capabilities, and services in response to those needs. Our success can be measured in part by the high demand for current and future CISL resources in FY2013.

NCAR is one of only a small number of institutions with the resources and support services necessary to conduct high-end climate research, model development, and campaigns such as the Accelerated Scientific Discovery (ASD) projects that inaugurated the Yellowstone system and real-time weather forecasts for the MPEX field experiment in mid-2013. As a discipline-specific computing center, CISL is able to provide the capabilities and skill-sets required to support important field and computational campaigns with on-demand resources that include those driven by unfolding natural disasters.

In FY2013, CISL user services continued to support users during the transition from the Bluefire system in the Mesa Lab Computing Facility to the petascale Yellowstone environment at the NCAR-Wyoming Supercomputing Center. In the transition effort, the CISL Help Desk absorbed additional user support tasks from the Computing Production Group and Database Services Team. The Consulting Services Group dedicated considerable effort to acceptance testing for Yellowstone and to organizing and streamlining the software environment for users making the transition from Bluefire to Yellowstone.

This work supports CISL's computing imperative to provide hardware cyberinfrastructure customized for the atmospheric and related sciences. This ongoing service for users is supported by NSF Core funds including CSL funding.

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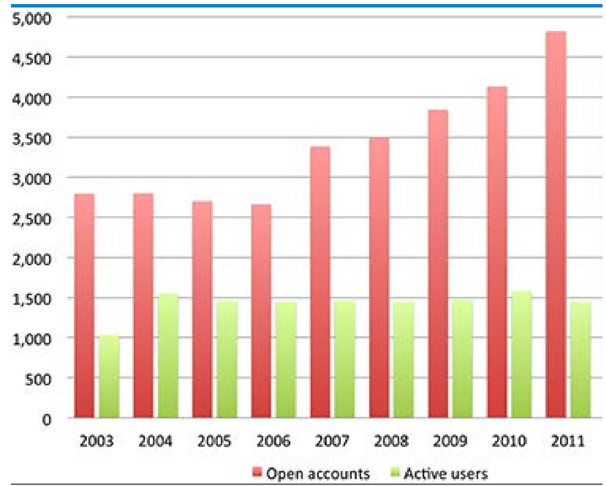
USER COMMUNITY OVERVIEW

CISL's success in supporting scientific goals and enabling scientific impact depends in equal measure on understanding the needs and research objectives of its user community, and on integrating CISL's resources, capabilities, and services in response to those needs. In FY2013, that user community included more than 1,700 users at more than 130 universities and other institutions who benefited from using CISL's high-performance cyberinfrastructure (CI) and services. These active users represented more than half of the more than 3,200 users who had computing or storage accounts during that year.

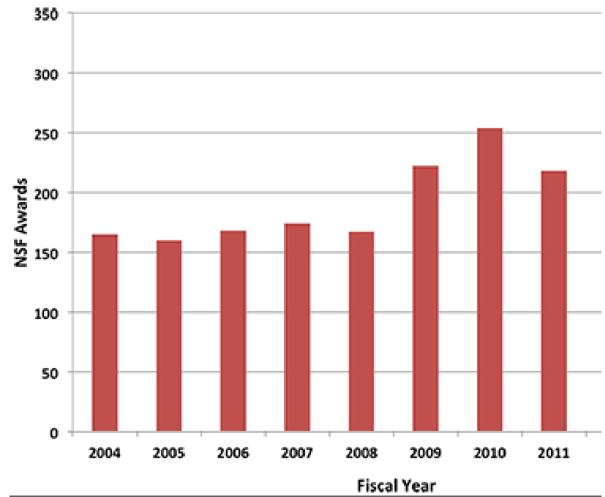


CISL's active HPC user community (including HPSS and MSS users) has remained consistently high over the past 10 years. The decrease in open accounts in FY2013 resulted from account closures with the decommissioning of Bluefire.

A discipline-specific approach to supercomputing allows us to tailor system design and services for our user community and to satisfy the highly specialized technical requirements of scientific applications such as climate system models. A well-defined workload allows CISL and NCAR scientists to optimize the most heavily used models and applications on current and future systems. It also ensures that model development and research in Earth System processes can occur in a controlled yet responsive environment where researchers can prepare complex models and perform the computationally demanding tests required to validate them.

The size, breadth, and disciplinary pursuits of the CISL user community offer perspectives on the scientific impact enabled by CISL's HPC, data analysis, and archival resources. This user community reported more than 300 publications and 33 dissertations and theses resulting from CISL HPC support in FY2012 (the timeframe of our most recent survey). Approximately 80% of CISL's HPC users run NCAR-provided climate and weather applications.

Scientifically, our user community spans more than 15 areas of interest in the atmospheric and related sciences. In geographic scope, the user community for CISL's HPC environment spans hundreds of different universities and collaborating institutions, primarily in the U.S. as defined by our HPC mission. In serving the NSF research community, CISL allocations to university researchers have supported the scientific objectives of more than 150 different NSF awards each year for the past decade. In FY2013, active projects supported 331 unique NSF awards.



CISL allocations to university researchers have supported the scientific objectives of more than 150 different NSF awards each year for the past decade. In FY2013, active projects supported 331 unique NSF awards.

This work is a crucial part of CISL's computing imperative to provide hardware cyberinfrastructure customized for the atmospheric and related sciences. This ongoing service for users is supported by NSF Core funds including CSL funding.

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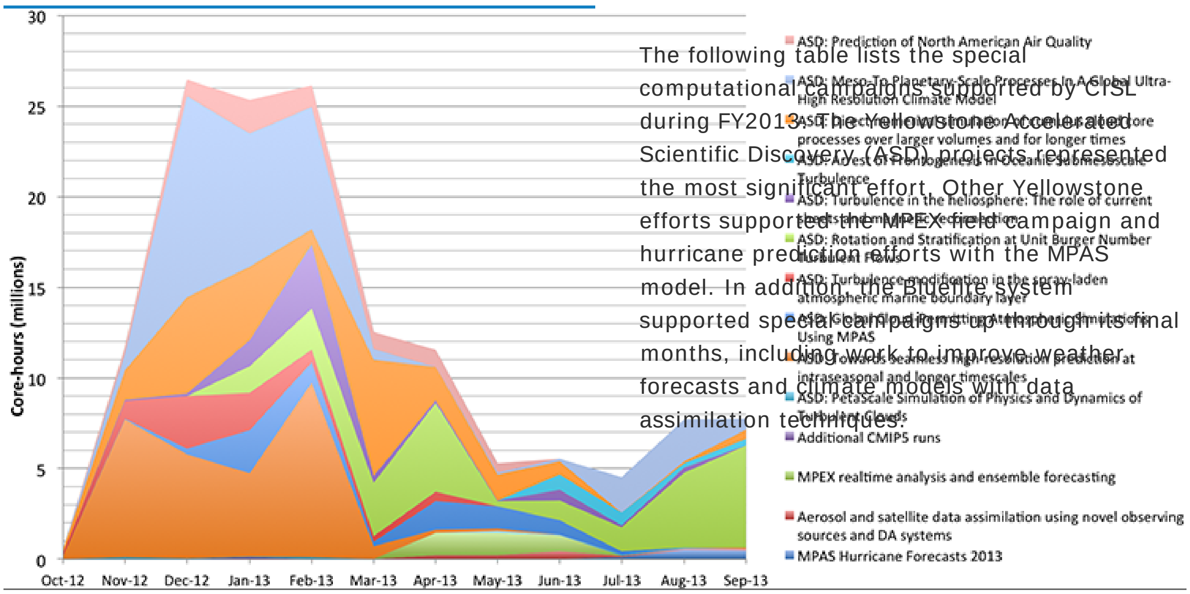
SPECIAL COMPUTATIONAL CAMPAIGNS

The CISL production supercomputing environment supports special computational campaigns for ongoing and short-term computational projects, all via a priority-based and near-real-time job scheduling mechanism. These campaigns are managed to minimize the impact on the production computing delivered to NCAR, university, and CSL scientists.



The following table lists the special computational campaigns supported by CISL during FY2013. The Yellowstone Accelerated Scientific Discovery (ASD) projects represented the most significant effort. Other Yellowstone efforts supported the MPEX field campaign and hurricane prediction efforts with the MPAS model. In addition, the Bluefire system supported special campaigns up through its final months, including work to improve weather forecasts and climate models with data assimilation techniques.

This chart shows the monthly usage of Yellowstone for special computational campaigns during FY2013. CISL works to accelerate scientific discovery through numerical simulation by providing a portion of the Yellowstone system to special campaigns.

FY2013 Special Campaigns	Principal Investigator	Begin	End
ASD: Toward seamless high-resolution prediction at intraseasonal and longer timescales	J. Kinter	1-Dec-12	31-Oct-13
ASD: Direct numerical simulation of cumulus cloud core processes over larger volumes and for longer times	L. Collins	1-Dec-12	31-Oct-13
ASD: Community computational platforms for developing 3-D models of Earth structure	T. Jordan	1-Dec-12	31-Oct-13
ASD: Turbulence in the heliosphere: The role of current sheets and magnetic reconnection	M. Shay	1-Dec-12	31-Oct-13

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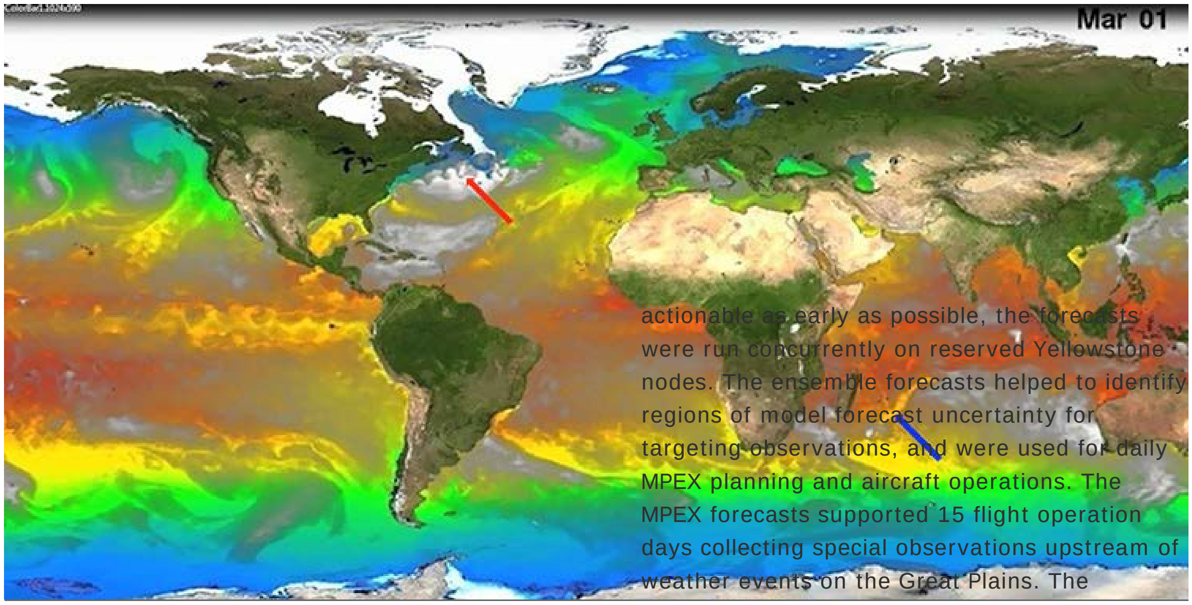
ASD: Arrest of frontogenesis in oceanic submesoscale turbulence	B. Fox-Kemper	1-Dec-12	31-Oct-13
ASD: Turbulence modification in the spray-laden atmospheric marine boundary layer	D. Richter	1-Dec-12	31-Oct-13
ASD: Rotation and Stratification at Unit Burger Number Turbulent Flows	A. Pouquet	1-Dec-12	31-Oct-13
ASD: Meso- To Planetary-Scale Processes In A Global Ultra-High-Resolution Climate Model	J. Small	1-Dec-12	31-Oct-13
ASD: Global Cloud-Permitting Atmospheric Simulations Using MPAS	W. Skamarock	1-Dec-12	31-Oct-13
ASD: Prediction of North American Air Quality	G, Pfister	1-Dec-12	31-Oct-13
ASD: Petascale Simulation of Physics and Dynamics of Turbulent Clouds	A. Wyszogrodzki	1-Dec-12	31-Oct-13
MPEX realtime analysis and ensemble forecasting	G. Romine	1-May-13	30-Jun-13
Aerosol and satellite data assimilation using novel observing sources and DA systems	C. Schwartz	1-Mar-13	31-Aug-13
MPAS Hurricane Forecasts 2013	C. Davis	1-Aug-13	31-Oct-13
Additional CMIP5 runs	G. Meehl	1-Dec-12	28-Feb-13
Testing ensemble data assimilation system for MPAS (Bluefire)	S.-Y. Ha	1-Nov-12	31-Dec-12
Improving severe weather forecasts with hybrid variational/ensemble data assimilation (Bluefire)	C. Schwartz	1-Sep-12	31-Dec-12

The largest ASD effort performed a multi-decadal run of a very-high-resolution coupled general circulation model. In particular, the CESM was used for a 60-year climate simulation under present-day (year 2000) greenhouse gas conditions, coupling a 25-km-resolution land surface and atmosphere based on the Community Atmosphere Model (CAM5), and 10-km-resolution sea ice and ocean models based on the Parallel Ocean Program (POP2) – perhaps the longest run with CAM5-enabled CESM at this resolution of ocean and atmosphere. The simulation was more computationally intensive than many previous high-resolution simulations largely because of the computational cost of adding prognostic aerosol equations in the CAM5 model. The experiment ran on 23,404 cores of Yellowstone and consumed 25 million CPU-hours over three months. The simulation output is now being examined by climate scientists specializing in atmospheric, oceanic, and sea-ice processes. Preliminary results show that the high-resolution simulation captures more cases where the ocean drives atmospheric variability than previous low-resolution runs. There is a better seasonal cycle of polar sea-ice in the high-resolution model, and also hints that some of the large-scale climate modes are better captured. To support further analysis and research, the data are available to the community via NCAR's Earth System Grid gateway.

In support of the Mesoscale Predictability Experiment (MPEX) field program, NCAR staff in the MMM division conducted near-real-time weather forecasts with the Weather Research and Forecast Model (WRF-ARW) from May through June 2013. Two 48-hour ensemble forecasts were run each day using a 3-km horizontal grid resolution. For the output to be



Snapshot showing latent heat flux (gray scale, see legend) overlaid on sea surface temperature from year 14 of the high-resolution CESM run. Warmest ocean temperatures are red, followed by yellow, green, and blue is coldest. Note the influence of Gulf Stream meanders on a cold-air outbreak in the Northwest Atlantic (red arrow) and a cold temperature wake beneath a tropical cyclone in the Indian Ocean (blue arrow). Neither feature has been well simulated by lower-resolution climate models.

actionable as early as possible, the forecasts were run concurrently on reserved Yellowstone nodes. The ensemble forecasts helped to identify regions of model forecast uncertainty for targeting observations, and were used for daily MPEX planning and aircraft operations. The MPEX forecasts supported 15 flight operation days collecting special observations upstream of weather events on the Great Plains. The sampling areas flown by the Gulfstream V aircraft were routinely based on guidance from the NCAR ensemble system, such that the success of the field campaign can in part be attributed to the timely forecast products made possible by the computing services provided by CISL.

These special computing campaigns serve CISL's computing imperative to provision on-demand and real-time services support for hardware cyberinfrastructure. This work is made possible through NSF Core funds, including CSL funding.

‹ User community overview   up   Help desk and consulting ›

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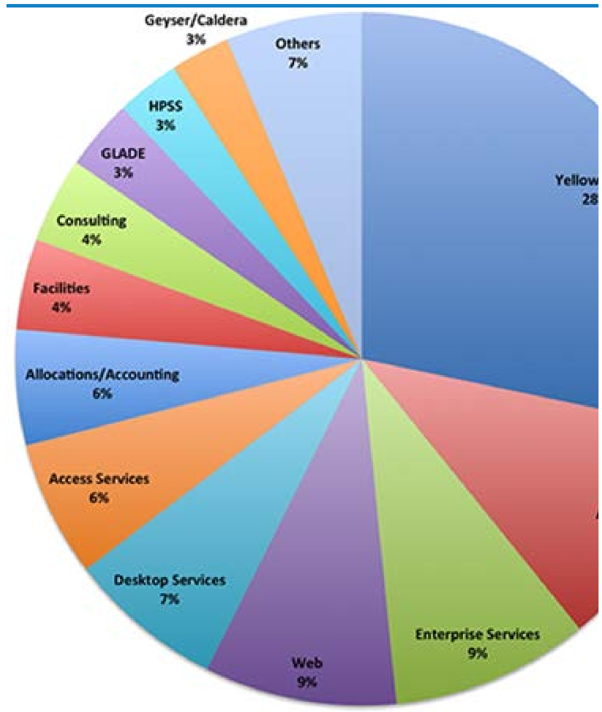
HELP DESK AND CONSULTING

CISL's strategic commitment to provide robust, accessible, and innovative information services and tools to our customers includes end-to-end services for NCAR's supercomputer users with both 24x7 frontline user support and consulting services for providing in-depth expertise. CISL's User Services Section unites four functions – the CISL Help Desk, Consulting Services, Documentation, and Accounts and Allocations – under the User Services Section to streamline and fully coordinate user-oriented procedures and support activities.



In FY2013, CISL staff fielded more than 13,000 help requests to the CISL Help Desk, which are grouped into the general categories shown here. (CISL's Network Engineering and Telecommunications Section (NETS) fielded an additional 1,370 help requests not shown here.)

During FY2013, CISL user services staff shepherded the user community through the major transitions associated with moving to the Yellowstone system at the NCAR-Wyoming Supercomputing Center (NWSC). The Help Desk team completed the transition of tasks from the Computer Production Group and the Database Services Team as those groups were phased out. For the Consulting Services Group, user support efforts in FY2013 focused on helping the user community make full use of the system's capability.

CISL's consulting experts devoted considerable effort in FY2013 to implementing the key elements of the Yellowstone user environment to ensure the most seamless transition possible for users. In addition, CISL's consulting staff provided expertise and customized, one-on-one service for:

- Special campaigns, including the Accelerated Scientific Discovery (ASD) projects, on the Yellowstone system.
- Transitioning from the IBM Power 575 cluster Bluefire and the Mesa Lab GLADE disk resource.
- Benchmarking, testing, and troubleshooting related to the Yellowstone HPC environment.

The Consulting Services Group also continued to:

- Support users of NCAR flagship models such as the Community Earth System Model (CESM) and the Weather Research and Forecasting model (WRF) on the Yellowstone system.
- Teach training courses for users of CISL's supercomputing, storage, and data analysis and visualization resources.
- Augment CISL support for the NSF's Decadal and Regional Climate Prediction Using Earth System Models (EaSM) program.

CISL tracks user support activity for this growing community using an ExtraView trouble ticket system. In FY2013, the ticket system recorded 13,141 tickets to the CISL Help Desk. A large portion of the increased

volume was linked to the arrival of Yellowstone and use of the ticket system to track error conditions on the many hardware components. The average number of log entries per ticket was 4.73, and communication with users was highest on complex cases. Of the total tickets submitted, the Help Desk team closed 2,519 tickets in an average of 4.14 days (median, 0.75 days), or 210 per month on average. In the same interval, Consulting Services staff resolved 2,268 more complex requests with an average response time of 16.9 days (median, 5.04 days).

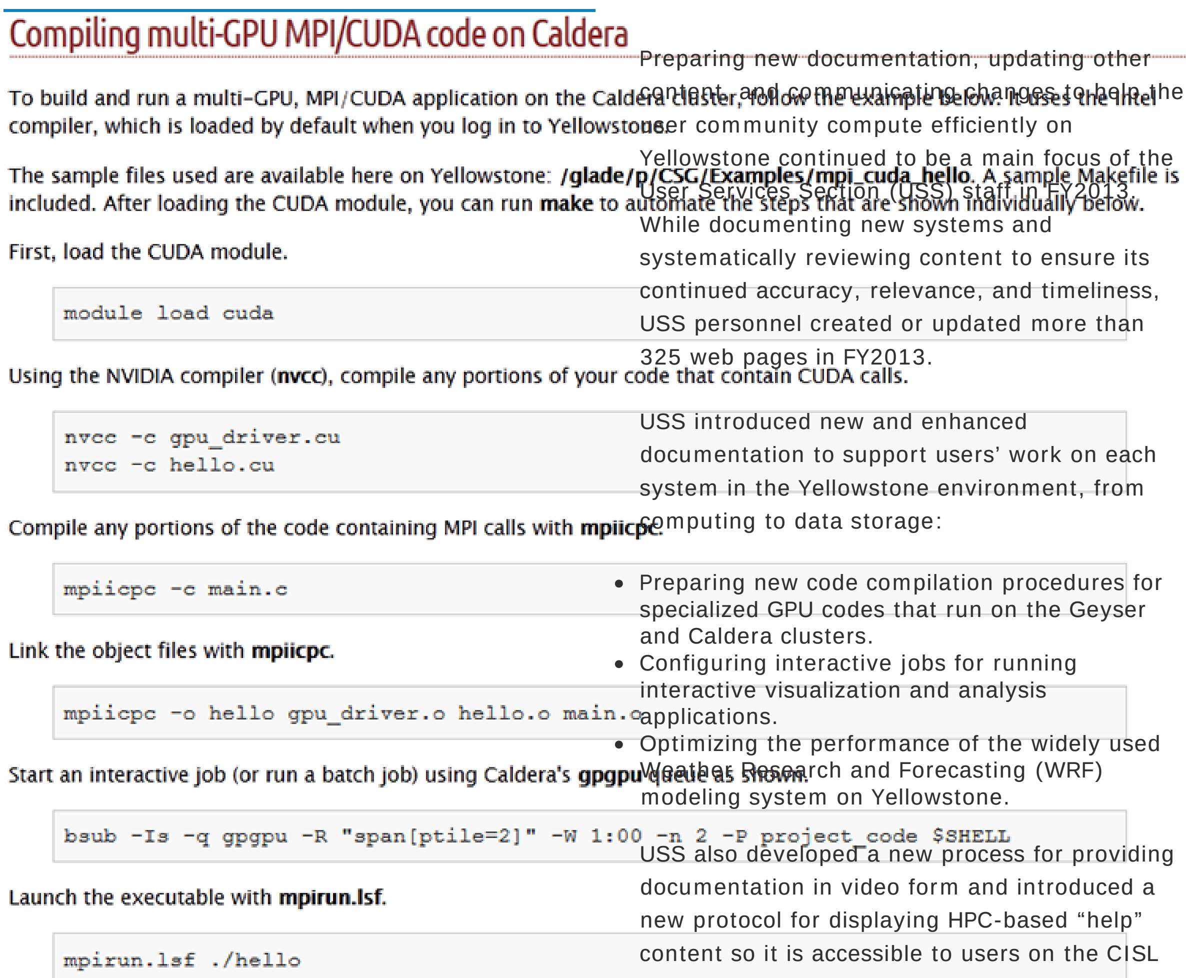
An additional 708 user support tickets were fielded related primarily to managing allocations and accounting, with an average response time of 6.4 days (median, 1.0 days). In FY2013, more than 900 new users joined the CISL computing community, with 492 university projects active during the year on CISL resources, along with a new set of NCAR and large-scale Climate Simulation Laboratory (CSL) projects.

This work supports CISL's computing imperative to provide hardware cyberinfrastructure customized for the atmospheric and related sciences. This ongoing service for users is supported by NSF Core funds including CSL funding.

‹ Special computational campaigns up User documentation ›

USER DOCUMENTATION

Up-to-date documentation remains vital to users' success with complex, high-end computing systems. It has been particularly important in supporting users who transitioned from working with the Bluefire, Mirage, and Storm systems – which were decommissioned in mid-FY2013 – to the data-centric Yellowstone environment. Integration of the new Yellowstone HPC and Geyser/Caldera analysis and visualization clusters presented new opportunities and required changes in thinking and procedures for users who were accustomed to the Bluefire environment.



Compiling multi-GPU MPI/CUDA code on Caldera

To build and run a multi-GPU, MPI/CUDA application on the Caldera cluster, follow the example below. It uses the Intel compiler, which is loaded by default when you log in to Yellowstone.

The sample files used are available here on Yellowstone: **/glade/p/CSG/Examples/mpi_cuda_hello**. A sample Makefile is included. After loading the CUDA module, you can run **make** to automate the steps that are shown individually below.

First, load the CUDA module.

```
module load cuda
```

Using the NVIDIA compiler (**nvcc**), compile any portions of your code that contain CUDA calls.

```
nvcc -c gpu_driver.cu
nvcc -c hello.cu
```

Compile any portions of the code containing MPI calls with **mpiicpc**.

```
mpiicpc -c main.c
```

Link the object files with **mpiicpc**.

```
mpiicpc -o hello gpu_driver.o hello.o main.o
```

Start an interactive job (or run a batch job) using Caldera's **gpgpu** queue as shown.

```
bsub -Is -q gpgpu -R "span[ptile=2]" -W 1:00 -n 2 -P project_code $SHELL
```

Launch the executable with **mpirun.lsf**.

```
mpirun.lsf ./hello
```

This section of a new documentation page from the CISL website shows users how to compile multi-GPU code to run on the Yellowstone environment's Caldera cluster. Such documentation helps users work efficiently on new systems featuring GPU processors.

Preparing new documentation, updating other content, and communicating changes to help the user community compute efficiently on Yellowstone continued to be a main focus of the User Services Section (USS) staff in FY2013. While documenting new systems and systematically reviewing content to ensure its continued accuracy, relevance, and timeliness, USS personnel created or updated more than 325 web pages in FY2013.

USS introduced new and enhanced documentation to support users' work on each system in the Yellowstone environment, from computing to data storage:

- Preparing new code compilation procedures for specialized GPU codes that run on the Geyser and Caldera clusters.
- Configuring interactive jobs for running interactive visualization and analysis applications.
- Optimizing the performance of the widely used Weather Research and Forecasting (WRF) modeling system on Yellowstone.

USS also developed a new process for providing documentation in video form and introduced a new protocol for displaying HPC-based "help" content so it is accessible to users on the CISL website.

USS continued its efforts, initiated in FY2012, to increase awareness of the many training and information assets that are available to users. Significant updates or additions to documentation and training resources are publicized routinely in the CISL Daily Bulletin, an important tool for keeping the user community informed. In the "Daily B" and via an online form, USS actively solicits user feedback to ensure that it is

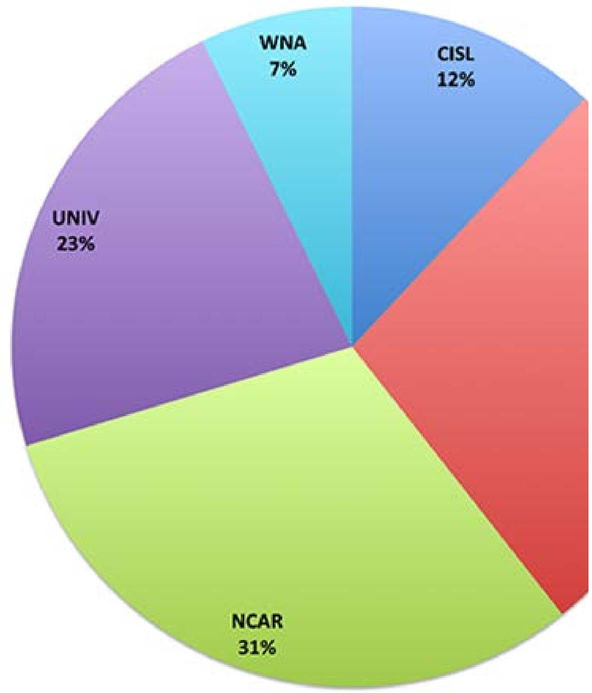
meeting the community's documentation needs. Unique page views grew to more than 144,600 in FY2013, a substantial 35% increase over the 107,300 unique page views in FY2012.

This work supports CISL's computing imperative to provide hardware cyberinfrastructure customized for the atmospheric and related sciences. This ongoing service for users is supported by NSF Core funds including CSL funding.

‹ Help desk and consulting   up   Allocating supercomputing resources ›

ALLOCATING SUPERCOMPUTING RESOURCES

CISL works to provide equitable and efficient access to reliable computing resources for several distinct communities of researchers in the atmospheric and related sciences, including the broad university community, Climate Simulation Laboratory (CSL) users, NCAR researchers, and with the arrival of Yellowstone, University of Wyoming researchers. CISL manages several allocation processes to distribute resources and ensure access by the most meritorious projects, and in FY2013, Yellowstone and its 30-fold increase in computational capacity supported the growing user community with rapid turnaround for their research efforts. As with past system procurements, CISL dedicated the first months of Yellowstone to a small set of large-scale Accelerated Scientific Discovery (ASD) projects selected from university and NCAR submissions.



The actual FY2013 core-hours delivered by Yellowstone to CISL's major user communities aligned well with the percentages targeted by the allocations process. The large 12% portion identified as CISL represents early user access and use by CISL and IBM staff to evaluate performance and troubleshoot system problems early in the system's deployment.

About 28% of Yellowstone is available to the CSL at NCAR; in FY2013, the current CSL projects, reviewed in March 2012, engage researchers funded or supported by a U.S. university, U.S. federal or state agency, or U.S. not-for-profit research laboratory in conducting large-scale simulations of Earth's climate system in support of the objectives of the U.S. Global Change Research Program. CISL provides approximately 29% of Yellowstone to U.S.-based researchers with NSF awards in the atmospheric or related sciences. A comparable portion of Yellowstone is also allocated to NCAR researchers in support of the computational needs of the NCAR laboratories. NCAR activities included the first nine NCAR Strategic Capability (NSC) requests, which were reviewed by a panel of NCAR computational scientists and approved by the NCAR Executive Committee. University requests are reviewed twice per year by the CISL HPC Advisory Panel (CHAP). In October 2012 and May 2013 combined, the CHAP reviewed 45 requests for 113 million core-hours on the Yellowstone system. University researchers submitted more than 200 small allocation requests during FY2013, indicating growing interest in the new system. CISL also offers the university community access to the Janus cluster, which was deployed as part of a collaboration between the University of Colorado and NCAR.

The new Wyoming-NCAR Alliance (WNA), which targets geosciences collaborations among the University of Wyoming, NCAR, and institutions in other EPSCoR states, convened the Wyoming Resource Allocation Panel (WRAP) in January and June 2013. Along with the first WRAP-reviewed

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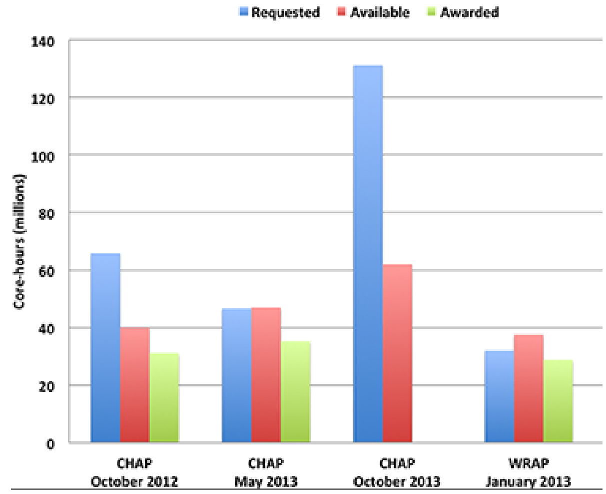
projects from May 2012, the WNA established 16 large projects for 73 million core-hours, along with 13 small allocations.

This work supports CISL's computing imperative to provide hardware cyberinfrastructure customized for the atmospheric and related sciences. This ongoing service for users is supported by NSF Core funds including CSL funding. The Janus cluster is supported by NSF MRI Grant CNS-0821794 to the Front Range Consortium for Research Computing (FRCRC), with additional support from the University of Colorado and UCAR non-federal funds. The Wyoming Resource Allocation Panel (WRAP) is supported by funding from the University of Wyoming.



The FY2013 allocation opportunities showed the user communities' growing demand for the Yellowstone system. Core-hours available to the University community reflect reduced availability due to the ASD period and prior allocations made in anticipation of Yellowstone's arrival.

‹ User documentation up Earth System Model support ›

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EARTH SYSTEM MODEL SUPPORT

To support NSF grant winners from the Decadal and Regional Climate Prediction Using Earth System Models (EaSM) program, CISL partnered with the NCAR Earth System Laboratory (NESL) to offer enhanced data and modeling support to this community, and CISL provides a coordinated EaSM entry point for this service.

This figure is an image of two Research Data Archive datasets that support the NSF-funded EaSM projects. The NCAR Community Earth System Model has global 3D atmospheric and surface data grids coverage, with simulations for 20th Century (1950–2005) and three concomitant Representative Concentration Pathway future scenarios spanning 2005–2100. The NCAR Nested Regional Climate Model combines the strength of NCAR’s Weather

Following guidance from NCAR scientists, a selection of global and regional model outputs have been identified and are available as datasets in the Research Data Archive (RDA). The NCAR Community Earth System Model (CESM) output data offers users access to global files and capabilities to select time, space, and parameters from the global fields. The data are available for a 20th Century run (1950–2005) and three concomitant Representative Concentration Pathway (RCP) future scenarios spanning 2005–2100. The NCAR Nested Regional Climate Model data output covers the North Atlantic Ocean and the U.S. with greater fidelity than CESM and for periods 1995–2005, 2020–2030, and 2045–2055. At this time the data files are available and in the near future data service capabilities similar to CESM will be added. The CESM collections have had a fair amount of user activity: 16 unique users have downloaded files with a total size of 10 terabytes, and 10 unique users have submitted 50 requests for customized subsets. To fill these requests CISL has processed 28 terabytes of data to produce 0.5 terabyte of needed products, indicating the value of server-side data processing in advancing research work.

In FY2013, the CISL Consulting Services Group (CSG) and NESL development teams for CESM and NRCM continued to offer user support for EaSM awardees. Through EaSM support, CSG is able to provide individualized help for porting and installing community codes at or outside NCAR. This assistance encompasses guidance for carrying out initial functionality tests and a validation run, assistance in determining the successful validation of the model on the targeted platform, suggestions for appropriate

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Research and Forecasting (WRF) model and the Community Climate System Model to make climate change simulations for the North Atlantic Ocean and USA in periods 1995–2005, 2020–2030, and 2045–2055.

load-balancing layouts to achieve optimal efficiency and throughput, and help in resolving problems that arise as part of these efforts.

The EaSM support effort received one-time NSF funding to augment NWSC resources and is receiving NSF Core funding.

‹ Allocating supercomputing resources up Enterprise architecture ›

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ENTERPRISE ARCHITECTURE

CISL's Enterprise Architecture Team began investigating a replacement for calendaring software used throughout UCAR, NCAR, and UCP. This effort produced a recommendation to revamp much of UCAR's IT infrastructure by moving to cloud services via Google Apps for Government.

Enterprise Architecture (EA) is the name of the discipline of translating an organization's vision and strategy into effective business practices and information technology (IT) infrastructure to support those practices. EA is a relatively young and still-evolving discipline, but it has been adopted by a wide variety of public and private organizations. The U.S. Government has developed a set of reference models called the Federal Enterprise Architecture.

Under the auspices of the UCAR Information Technology Council (ITC), co-chaired by Anke Kamrath (OSD director) and Shawn Winkelman (Finance and Administration IT Director), and at the direction of the UCAR President's Council, a UCAR-focused Enterprise Architecture Team (EA Team) was formed at the beginning of FY2013. The team meets weekly to discuss IT topics of significance to the institution and recommend courses of action.

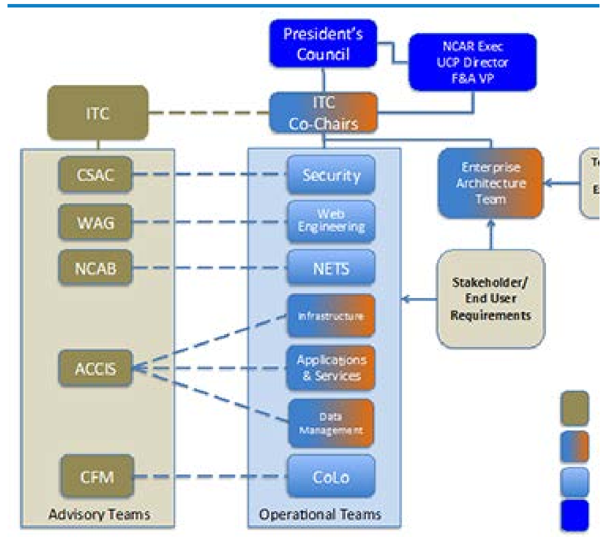
One of the first topics of discussion for the EA Team was a report from the ITC subcommittee ACCIS (Advisory Committee for Central Infrastructure Services) recommending a replacement for the Meeting Maker calendaring system in place at UCAR. The report advised the adoption of either Google Calendar or Zimbra. After investigating the recommended solutions and considering the broader implications of adopting them, the EA Team recommended that UCAR adopt the full Google Apps For Government suite of Software-as-a-Service, which includes Google Calendar, Gmail, Google Drive, and several other cloud-based software services. This recommendation was endorsed by the ITC co-chairs and accepted by the President's Council, resulting in the establishment of a project team to manage the adoption. The project is ongoing, and as of end-FY2013, proposals have been received from a number of Google Apps integrators to assist UCAR with the transition. Contract negotiations and award are anticipated in early FY2014, with rollout to follow over the next 90-120 days.

The EA Team continues to monitor and advise the Google Apps project, but also continues to discuss topics of broad relevance to UCAR IT such as planning for IPv6 networking, desktop virtualization, Bring Your Own Device strategies, and Identity Management.

Development of an EA for UCAR supports the Science and Collaboration Fabrics of the CISL Strategic Plan, and is a joint effort between CISL/OSD and Finance and Administration IT. This effort is supported by UCAR indirect funds.

‹ Earth System Model support | up | Enterprise systems overview, process, and governance ›

ENTERPRISE SYSTEMS OVERVIEW, PROCESS, AND GOVERNANCE



This diagram illustrates the revamped IT Governance model that incorporates new ITC Co-chairs Anke Kamrath and Shawn Winkelman. The new governance model includes an Enterprise Architecture team lead by Aaron Andersen with four additional members, two from CISL and two from UCAR IT.

Enterprise systems at UCAR are managed by a number of groups distributed across the organization, notably the Finance and Administration IT group and CISL's Enterprise Services Section (ESS) and Network Engineering and Telecommunications Section (NETS). Some of the services provided by these systems are relaying inbound and outbound e-mail for the ucar.edu domain, security monitoring of network traffic, enterprise calendaring, and providing wide-area network links for UCAR and partner organizations.

Governance of UCAR-wide IT infrastructure is provided by the Information Technology Council (ITC) co-chaired by Anke Kamrath (OSD Director) and Shawn Winkelman (Finance and Administration IT Director). During FY2013 the co-chairs revamped the governance model and incorporated the Enterprise Architecture discipline as a founding model along with the formation of an Enterprise Architecture Team. A major activity of the ITC in FY2013 was drafting a new strategic plan for IT across the institution. To this end, the ITC convened a summit meeting and designated a number of working groups to address specific focus areas, with the acknowledgment that topics would overlap between working groups. The working groups met independently and reported back to the ITC, which, with the assistance of the Enterprise Architecture Team and other IT managers, is compiling the final plan at end-FY2013, for broader review and approval in early FY2014.

A number of CISL staff participate in enterprise systems governance in multiple ways, supporting the Service and Collaboration Fabrics of the CISL Strategic Plan. Staff include members of the Enterprise Architecture Team, the Network Coordination and Advisory Board (NCAB), the Advisory Committee for Central Infrastructure Services (ACCIS), the Web Advisory Group (WAG), the Computer Security Advisory Committee (CSAC), and the ITC. CISL staff also provide engineering support for all of these committees plus the Colocation Facilities Management Committee. These activities are primarily supported by UCAR indirect funds.

‹ Enterprise architecture | up | Network engineering and telecommunications ›

NETWORK ENGINEERING AND TELECOMMUNICATIONS

Networking infrastructure is essential technology vital to UCAR's ability to function and prosper in a rapidly evolving scientific and technical environment. Networking infrastructure enables business processes, scientific investigations and analysis, communication, global collaborations, and educational and outreach missions to flourish. Network infrastructure is literally the backbone of all other IT infrastructure and services. A sound and reliable network infrastructure is critical to building stable IT infrastructure at the higher levels. It is the goal of the networking infrastructure to provide this fast, robust, and flexible infrastructure to support all other IT services.

Networking is a critical component of cyberinfrastructure. Networks are interconnected and interoperate at the campus, metropolitan, regional, national, and international levels. Networking is a global endeavor. Being well connected has become a requirement for successful business operations but is especially important for a national research center such as UCAR. Networking provides a vital service enabling all functions at UCAR. UCAR's scientific mission is enabled and supported by networking. UCAR's business operations, including interactions with funding agencies, also depend on networking. Collaborative science would not happen today without networks just as UCAR's business operations would not function.

The Network Engineering and Telecommunications Section (NETS) plans, engineers, installs, operates, maintains, develops strategy, and performs research for NCAR and UCAR's state-of-the-art data networking and telecommunications facilities. NETS provides a vital service to NCAR's research communities by linking scientists to supercomputing resources. These activities are essential for the effective use of NCAR/UCAR's scientific resources, and they foster the overall advancement of scientific inquiry. This work supports CISL's computing imperative to provision hardware cyberinfrastructure for the atmospheric and related sciences. It also supports CISL's computing frontier of center virtualization by providing infrastructure for science gateways and other Grid-based technologies.

NETS pursued these **LAN** projects in FY2013:

- UCAR network infrastructure re-cabling
- MFS – infrastructure/SPICE/HAO Trailer move
- FLA/FL4 Fiber
- CGD ML 312 remodel
- ML-Security Camera upgrade
- ML 29 CSM supercomputer infrastructure installation
- WASP inventory system
- NWSC Infiniband cabling design support
- RAL FL2-2076 Switch Cable Upgrade
- FL0 Power Down
- NWSC Grand Opening
- ArcGIS
- Plookup
- ITC Strategic Plan participation (networking, collaboration, security, collocation)
- Telecommunications
  - Single Number Reach (SNR)
  - Eliminated chargebacks for long distance calls
  - Softphones
  - Cisco Unified Attendant Console (CUAC) upgrade
  - Call Manager Upgrade - 7.1 to 8.5 and then 8.6
  - New hire, visitors, terminations PeopleDB matching
  - ML Room 2B 034 remodel and NETS shop relocation

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- CG1 structural repair
- Cellular phone support
  - NWSC
  - FLA
  - FL4
- Network monitoring
  - CISL Nagios centralization transition
  - Netflow - Icmynetflow
  - Archibus
  - Internet2 Network Performance Workshop
  - Extraview
    - Upgrade
    - Converted to MySQL from Oracle
- Multicast support activities
- Business continuity
  - Everbridge Emergency Notification System (ENS) testing
  - CISL IT Business Continuity Emergency Plan
- UPS, grounding, wireless networking, IPT, Collocation Facilities Management (CFM)
  - Wireless 802.11*i* guest network certificates
  - Eduroam
  - 802.11n campus-wide upgrade
  - ML 29 infrastructure rework
  - IPT server replacement
  - Spring and Fall power downs
- Cisco end-of-service and GigE upgrades
- NETSDB replacement and redundancy
- Participated in the CISL Change Control project team
- UIS database project (PeopleDB)
  - Contact list conversion
- Telecommunication closet cooling
- CISL NOC move coordination
- Vidyo® expansion

NETS pursued these **MAN** projects in FY2013:

- Boulder Point-Of-Presence (BPOP)
- Boulder Research and Administration Network (BRAN)
  - BRAN Fiber Distance Table
- Boulder Valley School District fiber partnership
- BoulderFiber collaboration
- Remote-working and home-access
- EOL SPOL wireless
- I2 Dynes project
  - CU-Boulder
  - CSU
- ML/FL wireless upgrade

NETS pursued these **WAN** projects in FY2013:

- Front Range GigaPoP (FRGP)
  - 910 colocation relocation
  - All Ethernet (no ATM, T1, etc.)
  - Google peering
  - Netflix cache
  - Deploy C4900M
- UCAR Point of Presence (UPoP)
  - NEON
  - NREL
  - State of Wyoming
- National LambdaRail (NLR)
- Internet2
- Bi-State Optical Network (BiSON)
  - Windstream/McLeod fiber relocation
  - Boulder BiSON single point of failure resolution
  - Colorado School of Mines (CSM) NSF CC-NIE BiSON proposal
  - CSM BiSON hardware configuration design
- XSEDE
- Western Regional Network (WRN)
- NOAA Research Network (NWAVE)
- The Quilt Project – National Regional Networks Consortium
  - Jeff Custard Executive Committee

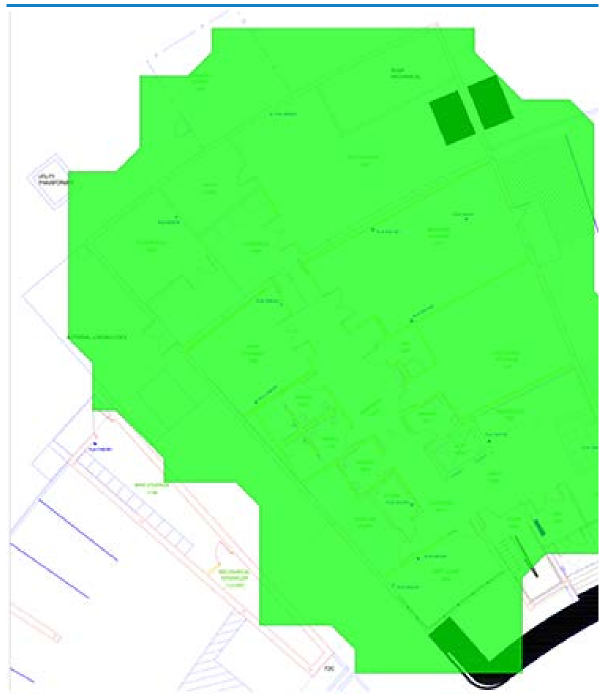
- SC ’12 SCinet Participation
- Westnet Meeting Support
  - January 2013
  - June 2013

In FY2013, NETS will continue to provide support and enhancements for all of these essential networking services. NETS activities are primarily supported through UCAR Communications Pool indirect funds.

Detailed project descriptions appear below for four of these projects: Wireless (802.11n, Eduroam, Guest Wireless Certificates), Earth Observing Laboratory S-Band Polarization Radar (S-Pol), FLA/FL4 Cellular, Vidyo.

Wireless (802.11n, Eduroam, and Guest Wireless Certificates)

NETS took on three separate but related local area wireless projects this year. The first was to upgrade, optimize, and document all UCAR wireless access points to the current 802.11n standard which supports a significant increase in the maximum net data rate from 54 Mbit/s to 300 Mbps. This project was successfully completed this year.



An example of the wireless coverage as mapped by the Ekahau software system used by NETS.

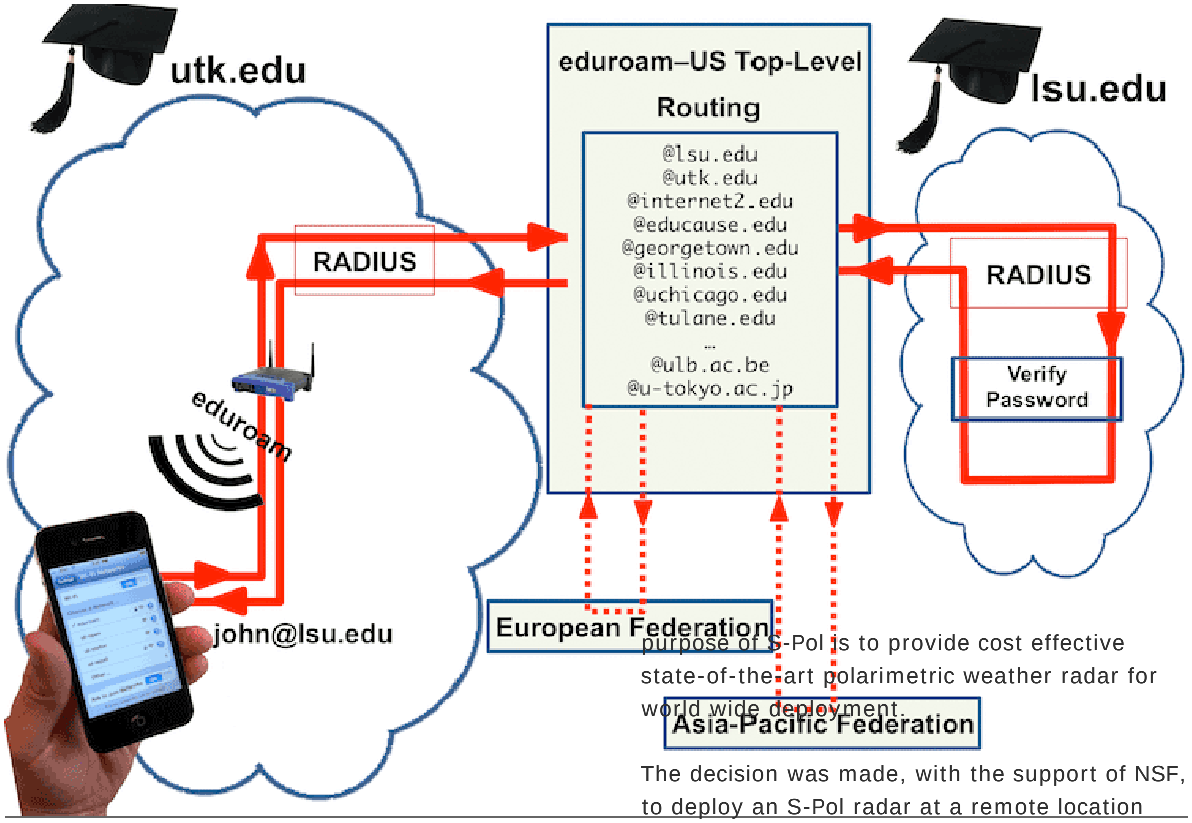
Eduroam (**edu**cation **roam**ing) is the secure, world-wide roaming access service developed for the international research and education community. Eduroam allows students, researchers and staff from participating institutions to obtain Internet connectivity across campus and when visiting other participating institutions by simply opening their laptop or wireless device. NETS deployed Eduroam at UCAR to support visitor wireless requirements more effectively and efficiently. In addition, Eduroam allows UCAR users with Eduroam certificates to connect to remote Eduroam enabled wireless system across the country and world. Eduroam is now available in 54 countries and 119 institutions in the United States. Eduroam is a valuable tool to enhance and enable the evolving mobile workforce.

NETS deployed guest wireless certificates to enable long term visitors to have access to the UCAR Guest Network in a secure fashion for up to four years. This also enables UCAR users who Bring Your Own Device (BYOD) to have secure wireless access to the UCAR Guest Wireless network.

These three wireless projects are valuable extensions and expansions to the wireless service at UCAR that support local UCAR users as well as the multitude of visitors that UCAR supports.

S-Pol

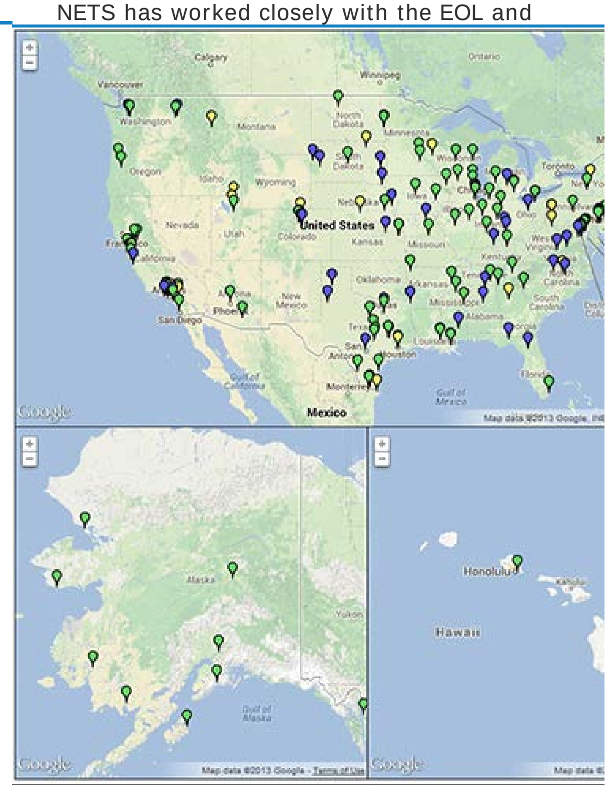
The S-Pol radar was developed at NCAR/ATD to replace the CP-2 radar which served the research community for nearly 20 years. The



A diagram of how Eduroam works for users across the U.S. and the world.

purpose of S-Pol is to provide cost effective state-of-the-art polarimetric weather radar for world wide deployment.

The decision was made, with the support of NSF, to deploy an S-Pol radar at a remote location near Firestone, Colorado, to fill a National Weather Service (NWS) gap in radar coverage. NETS has worked closely with the EOL and Facilities Management team since this project's inception to identify an acceptable location, investigate wide area network solutions, and install and deploy the necessary infrastructure and hardware to support the wireless solution agreed upon. NETS is also providing design, construction and ongoing LAN support at the site.



This is a map showing the current U.S. deployments of Eduroam, which is constantly growing.

This has been a very successful collaboration that will support core science and community services.

Vidyo

The Vidyo Project is a joint effort between UCAR F&A Multimedia, NETS, and CISL to build a desktop videoconferencing system to support UCAR desktop videoconferencing requirements following a key recommendation from the UCAR Collaborative Technology Advisory Group (CTAG). The Vidyo product was chosen by consensus of the collaborators, was evaluated as part of a pilot to determine if it was the appropriate tool for this purpose and would scale to a larger and production deployment.

Following the successful pilot project, Vidyo has been deployed and is used throughout UCAR. Vidyo is utilized extensively for one to one, one to many, and many to many interactions. Vidyo has proven to be a valuable tool for distributed meetings such as the FRGP monthly meeting

involving attendees from around the state of Colorado, remote management of the NWSC, and remote work applications.

Jeff Custard from NETS has led this effort throughout working closely with the other collaborators and the users to ensure a successful deployment. NETS has invested in and deployed Vidyo room systems in two major conference rooms and multiple offices. There are approximately 161 users with 273 installations on various client end point devices across four separate tenants including CISL, NETS, MMS, JOSS.

(Clockwise from top) Bryan Anderson, Jerome Martinez, Del Harris, and Paul Dial install the Mesa Lab side of the S-Pol wireless WAN system on the top of Tower B.

Image of the Firestone end of the S-Pol installation.

This diagram shows the components of a Vidyo system that make up the UCAR deployment and how they integrate.

‹ Enterprise systems overview, process, and governance
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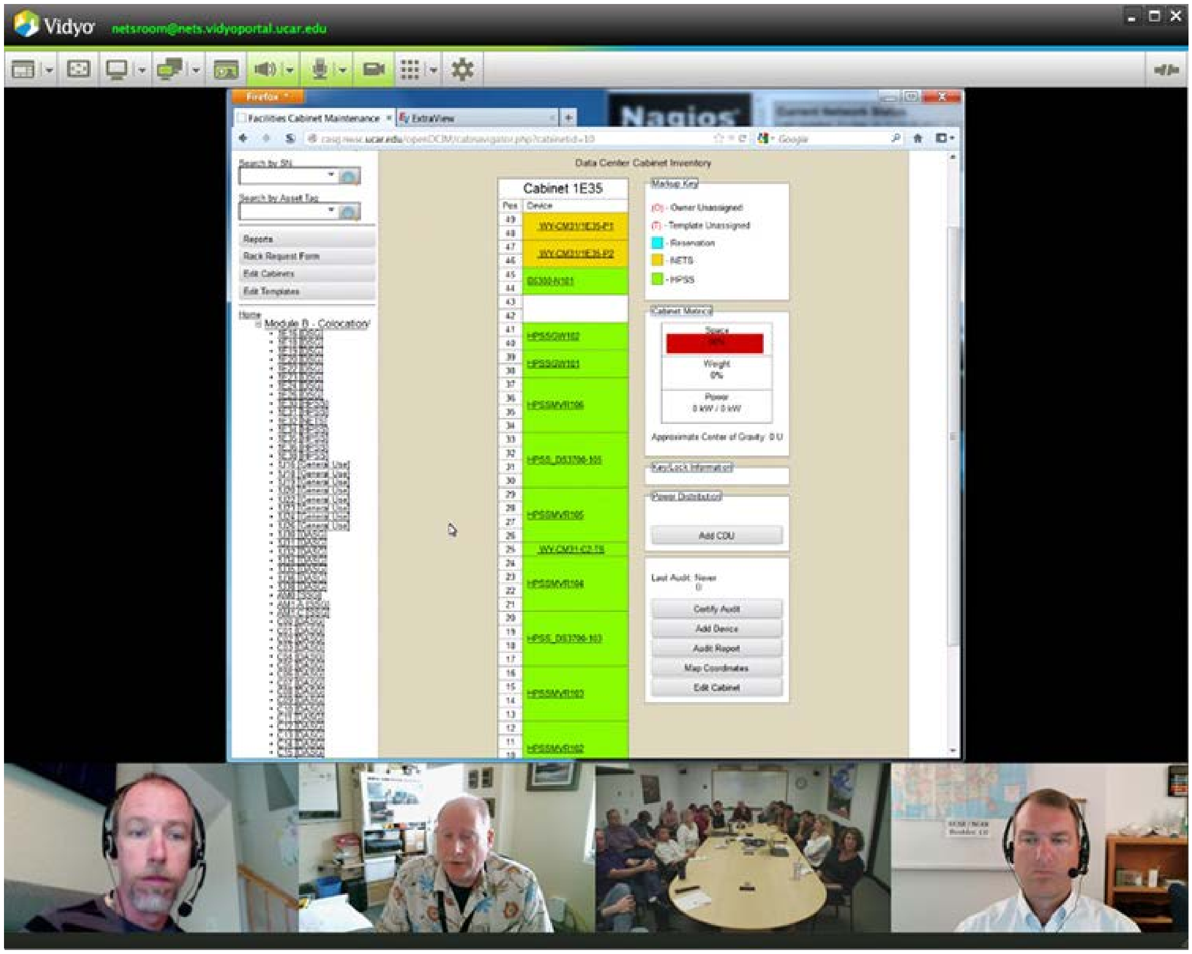
Cybersecurity ›



This image shows an example of a collaboration including two remote participants, David Mitchell from home, and Jim Van Dyke from the NWSC interacting with NETS. Jim is presenting on the DCIM software used at the NWSC.

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CYBERSECURITY

This is the infrastructure cluster that supports security monitoring at the NWSC. These computer systems work together to collect and analyze large volumes of network traffic. When necessary, alarms are issued for abnormal activity.

UCAR manages and maintains a large and diverse set of compute, data, email, web, and network servers that form the core information technology (IT) within the institution. Not only are these systems valuable monetarily, they comprise vital scientific research tools and business continuation systems used throughout UCAR and the university communities. To pursue the scientific mission of the organization without hindering the free exchange of information, CISL is committed to maintaining a security posture that appropriately balances usability with the security of the systems.

Providing secure information technology systems within CISL and across UCAR supports CISL's computing imperatives to provision hardware and software cyberinfrastructure for the atmospheric and related sciences. Cybersecurity is also critical to CISL's computing imperative for data curation and to its computing frontier of center virtualization. The security strategy we employ must be balanced by the goals of openness and ease of access. CISL proactively strives for zero security incidents on its systems, and CISL responds and reports an incident analysis if one occurs.

It is vital to the organization that we take appropriate measures to ensure the confidentiality, integrity, and availability of intellectual property, data, and systems. Appropriate measures balance the needs for availability and usability with those for integrity and confidentiality.

During FY2013, the following activities were vital to the continued security of IT systems at UCAR:

- Coordinated consistent security policies and procedures across UCAR by the Computer Security Advisory Committee (CSAC), with the goal of maintaining the appropriate balance between reasonable protection and pursuit of the institution's scientific mission.
- Consulted with various internal groups on how best to implement computer security for their applications and needs.
- Continued to expand the capabilities of the four-person Security Engineering Group (SEG) though numerous professional development activities.
- Continued to encourage UCAR staff to engage with SEG early in the process of developing or purchasing systems that will be accessible across the UCAR network security perimeter, or that will require UCAS token or password authentication.
- Maintained UCAR-wide token authentication using one-time password (OTP) tokens.
- Continued to provide ongoing information to UCAR system administrators about newly found compromises for a wide variety of relevant operating systems and applications.
- Engaged in collaborative efforts with peer and XSEDE centers to share cybersecurity information, best practices, and incident notification.
- Expanded the capabilities and uses for our Kerberos authentication infrastructure.
- Upgraded both security hardware and software to increase capabilities.

Earth Observing Laboratory
High Altitude Observatory
National Center for Atmospheric Research
NCAR Earth System Laboratory
Research Applications Laboratory

- Collaborated with peers to develop and refine policies and procedures for secure operation of high-performance computing resources at NWSC.
- Enhanced our network and host monitoring tools to support increased traffic loads and provide redundancy using our other campuses.

Cybersecurity at NCAR is supported by a combination of NSF Core funding and UCAR Communications Pool indirect funds.

‹ Network engineering and telecommunications up Distributed services and web engineering ›

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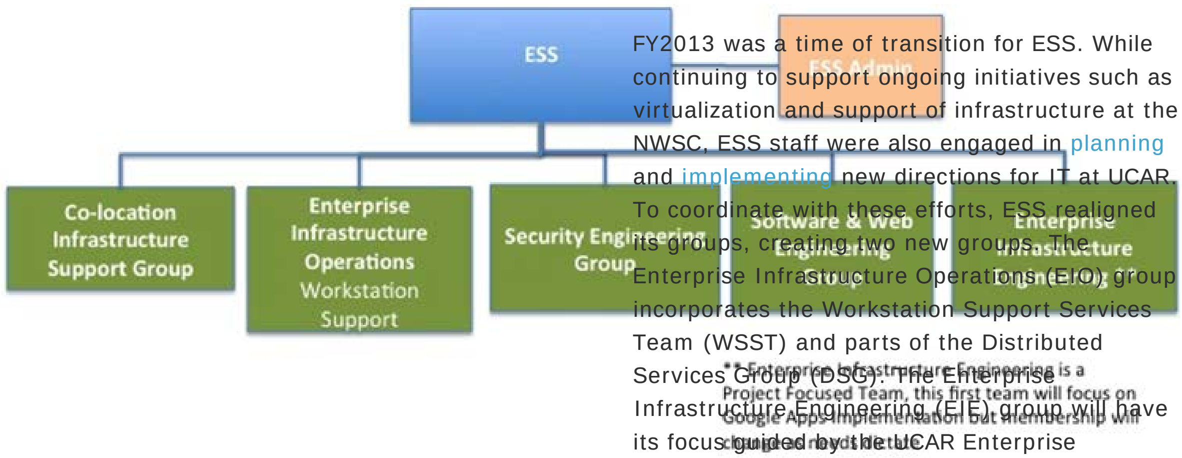
DISTRIBUTED SERVICES AND WEB ENGINEERING

The CISL Enterprise Services Section (ESS) provides the hardware and software infrastructure – including development, deployment, configuration, monitoring, and maintenance – for a variety of Information Technology (IT) services used across UCAR. Examples of these services include organization-wide DNS and DHCP, incoming and outgoing e-mail via SMTP, web content hosting, development and production instances of the Drupal web Content Management System (CMS), and distributed software revision control systems, among others. ESS also provides systems administration support for other CISL groups such as the Data Support Section and the Visualization and Enabling Technologies Section.



The Enterprise Services Section was restructured to create capacity and alignment around the Enterprise Architecture model. The initial focus of the Enterprise Infrastructure Engineering team will be transitioning UCAR to the Google Apps for Government cloud services.

FY2013 was a time of transition for ESS. While continuing to support ongoing initiatives such as virtualization and support of infrastructure at the NWSC, ESS staff were also engaged in planning and implementing new directions for IT at UCAR. To coordinate with these efforts, ESS realigned its groups, creating two new groups. The Enterprise Infrastructure Operations (EIO) group incorporates the Workstation Support Services Team (WSST) and parts of the Distributed Services Group (DSG). The Enterprise Infrastructure Engineering (EIE) group will have its focus guided by the UCAR Enterprise Architecture efforts, and its membership will be flexible over time. The initial composition of EIE targets the deployment of Google Apps For Government at UCAR.

ESS's Security Engineering Group (SEG), Infrastructure Support Group Boulder (ISGB), and Web Engineering Group (WEG) will continue their roles. Leadership of the WEG has changed, with the new group head transferring from CISL's Visualization and Enabling Technologies Section.

ESS provides enterprise services in support of the Service, Innovation, and Collaboration Fabrics of the CISL Strategic Plan. Support comes from NSF Core and CSL funding, as well as from UCAR indirect funds because the services provided are available to all UCAR/NCAR labs and programs.

‹ Cybersecurity up CISL data services ›

Earth Observing Laboratory
High Altitude Observatory
National Center for Atmospheric Research
NCAR Earth System Laboratory
Research Applications Laboratory

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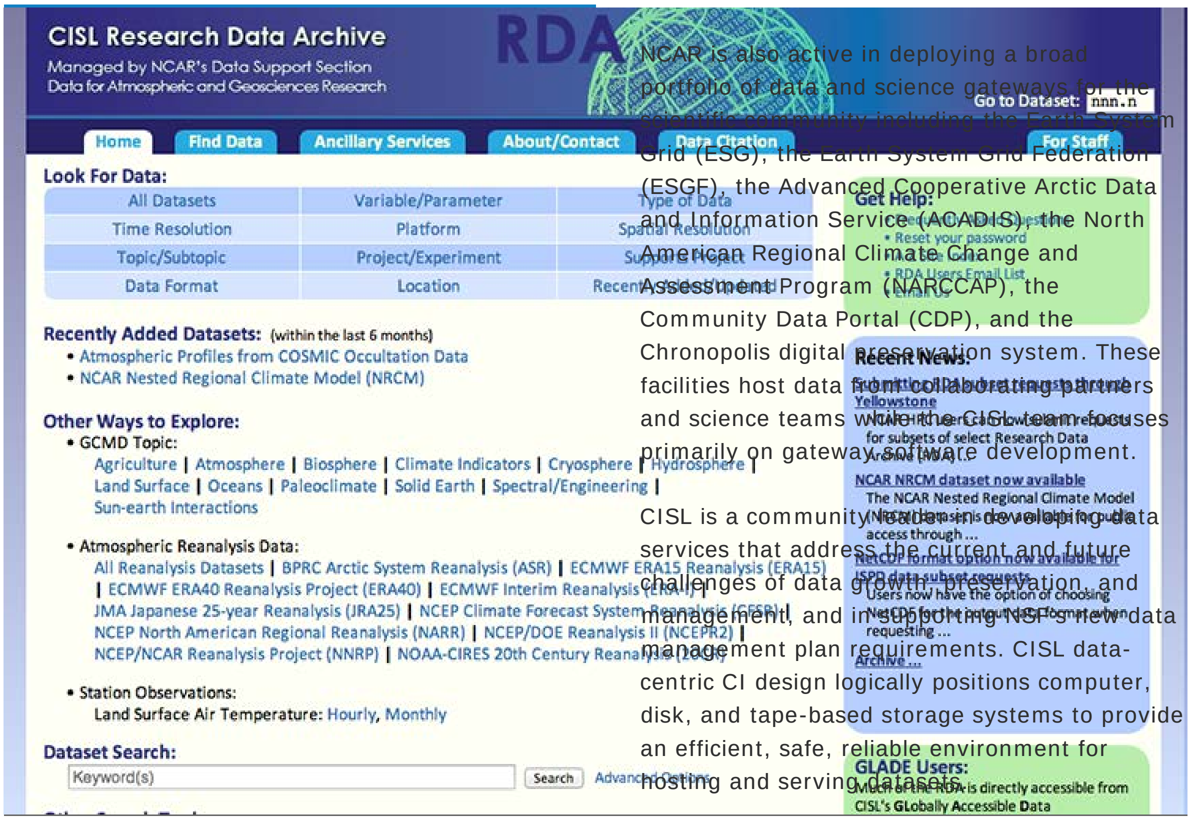
CISL DATA SERVICES

CISL has over 40 years of experience curating and providing data services to the atmospheric and related sciences community. The Research Data Archive (RDA) provides observational, analyzed, and model-generated datasets that support studies in climate, weather, and increasingly, other related disciplines. RDA development is designed to serve the research needs at NCAR and its associated university community, but since it is an open data access resource, the worldwide community also uses it.



NCAR is also active in deploying a broad portfolio of data and science gateways for the scientific community including the Earth System Grid (ESG), the Earth System Grid Federation (ESGF), the Advanced Cooperative Arctic Data and Information Service (ACADIS), the North American Regional Climate Change and Assessment Program (NARCCAP), the Community Data Portal (CDP), and the Chronopolis digital preservation system. These facilities host data from collaborating partners and science teams while the CISL team focuses primarily on gateway software development.

CISL is a community leader in developing data services that address the current and future challenges of data growth, preservation, and management, and in supporting NSF's new data management plan requirements. CISL data-centric CI design logically positions computer, disk, and tape-based storage systems to provide an efficient, safe, reliable environment for hosting and serving datasets.

The Research Data Archive (RDA) entry page emphasizes three ways to "find" data: a simple keyword text search, a faceted search using a standard metadata vocabulary, and direct links to featured and the most popular datasets. These different options match up with the variety of ways a broad community prefers to discover data within the RDA's more than 600 datasets and 1.5 TB total collection size.

The RDA is known for essential reference datasets and long-term preservation. The CDP system is designed to support the data management needs of individual researchers or larger projects, and it allows them to manage their own data and user communities easily. The ESG system is used to manage large-scale climate simulation data and serves the needs of data managers who provide CCSM, CESM, NARCCAP, and CMIP5/IPCC products to the global community. The ACADIS system – a joint endeavor with NCAR's Earth Observing Laboratory (EOL), UCAR's Unidata Program, and the National Snow and Ice Data Center (NSIDC) at CU – supports Arctic researchers with tools and support for comprehensive data management, including the development of NSF data management plans, self-publishing, federation with other repositories, digital citation, and long-term preservation. ACADIS and other projects utilize the Chronopolis digital preservation system, which

provides geographic replication of important datasets along with continuous bit-integrity auditing.

This work is funded as specified in the following individual reports.

‹ Distributed services and web engineering up Research Data Archive ›

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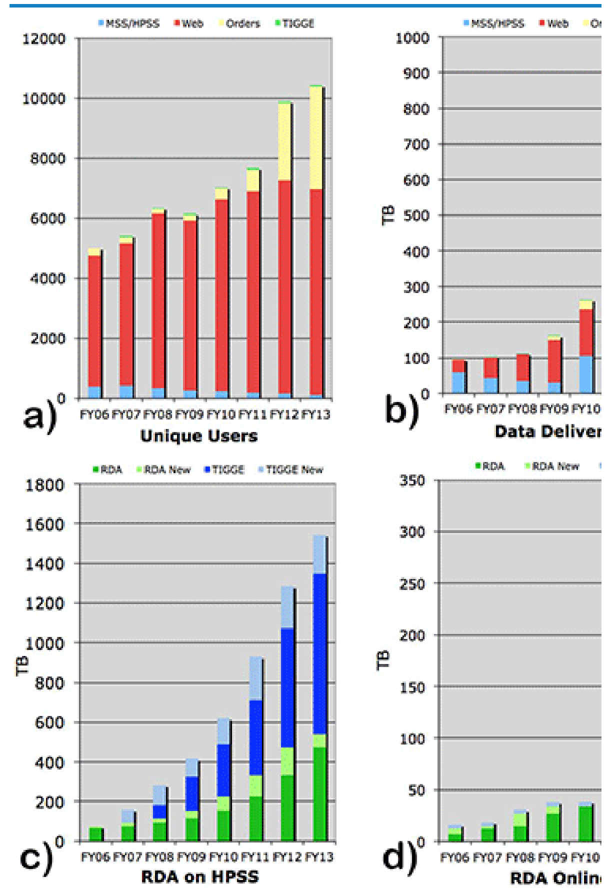
RESEARCH DATA ARCHIVE



These charts show the data access and growth metrics for the Research Data Archive (RDA) during FY2006-FY2013. a) The number of unique RDA users specified by access pathway: the NCAR HPSS, publicly available web servers, one-time special requests (orders) prepared for individual users, and TIGGE. b) The amount of data delivered to customers, by access pathway. c) The amount of data in the HPSS archive, showing annual growth and not including backups. d) The amount of data on public web servers, showing annual growth. Charts a) and b) indicate the RDA's significance to the community, and charts c) and d) show the annual progress toward building more valued content into the RDA.

The Research Data Archive (RDA) is a key part of CISL's computing imperative for data curation. It provides a rich information resource through a large and growing collection of datasets that support scientific studies in climate, weather, Earth System modeling, and increasingly, other related sciences. The RDA is developed to serve the research needs at NCAR and in the associated UCAR community, but since it is an open resource, the global community also uses it. RDA activities can be viewed from two different perspectives: user data access and archive content development, both of which are equally important.

In FY2013, over 10,000 unique persons were provided about 900 terabytes of data through various primary access pathways: the NCAR HPSS, public servers on the web, one-time special requests prepared for individuals, and the THORPEX (THe Observing system Research and Predictability EXperiment) Interactive Grand Global Ensemble (TIGGE) archive (see charts a and b). The number of unique users increased modestly from 2012 to 2013. One-time requests (subsetting and format conversion) increased and full file downloads over the web decreased. This is an expected trend: improved server-side data subsetting allows more users to acquire the specific the data they need. CISL is making it easier for them to access terabyte-sized archives on their own. Orders were prepared for over 3,400 individuals, and they received 300 terabytes of data. Web users form the largest group, with 6,800 people downloading 520 terabytes of data. There are fewer users of the HPSS (99 requesting 40 terabytes) and TIGGE (49 requesting 36 terabytes) services. The newest and most-used RDA collections are directly available from GLADE to the DAV and supercomputer environments. We currently cannot estimate the metrics for this pathway, but it is substantial because the access from the tape-based archive system has dropped and anecdotally our local users are pleased. These metrics indicate that the RDA is an important growing data resource for a broad community.

The RDA content expanded by over 60 terabytes in FY2013 (see chart c). TIGGE is part of the RDA, but it

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is shown separately because it alone added about 195 terabytes. The complete RDA is now over 1.5 petabytes, and over 324 terabytes of it is readily available via GLADE (chart d), a 16-terabyte increase relative to the previous year. TIGGE is shown separately, and although it is capped at a rolling three-month archive, it is about 50 terabytes. NCAR users can access the portion of the RDA not available on GLADE directly from the HPSS, and the Data Support Section provides automated procedures to assist outside users with data access from HPSS.

The RDA is constantly changing. Curation extends and adds to existing datasets, and stewardship improves the documentation, creates systematic organization, applies data quality assurance, and develops user access. Many routine tasks and background infrastructure developments are necessary to maintain the RDA. Major accomplishments for FY2013 include:

- Operated and maintained the TIGGE archive and access on a 24×7 basis.
- Successfully transitioned the RDA from the Mesa Laboratory Computing Facility to the NCAR-Wyoming Supercomputing Center (NWSC) infrastructure with no downtime for data users.
- Updated many ongoing observational, operational model, and reanalysis dataset collections.
- Implemented automated systems that use CISL HPC and GLADE to give users better access to terabyte-sized datasets. More than 3,000 individual data requests were processed to create user-defined custom products, including spatial, temporal, and parameter subsets, and in many cases data format conversions.
- Enhanced access for NCAR HPC users by implementing a command line structured tool to get metadata and extracted data from multi-terabyte datasets in the RDA. This effectively places the desired data subset in a user’s personal working directory and removes one data processing step from the scientist’s workflow.
- Added NCAR Nested Regional Climate Model (NRCM) data to the RDA. This supports NSF grant winners from the Decadal and Regional Climate Prediction Using Earth System Models (EaSM) program.
- Provided all RDA upper-air data sources and the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) to support ECMWF Re-analysis for Climate (ERA-CLM).
- Added a 30-kilometer interim Arctic System Reanalysis (ASR) Project dataset to the RDA. This was surprisingly popular with users. Final data at 30 kilometers and 20 kilometers will be added when they become available.
- Implemented Thematic Realtime Environmental Distributed Data Services (THREDDS) Data Server (TDS) for several popular GRIB-formatted datasets, creating metadata and data access with scientific tools using standard interoperable protocols such as Open-source Project for a Network Data Access Protocol (OPeNDAP).
- Developed and implemented a system for assigning and maintaining DOIs on RDA datasets.

The RDA is nationally and internationally respected for its staff, data management practices, consulting services, and ability to positively affect outcomes in the data arena. This position is advantageous to building collaborations that continually strive to provide better scientific data resources and access.

RDA maintenance and development within CISL are almost entirely supported by Core funding. A small NOAA grant supplements development of ICOADS.

‹ CISL data services | up | CISL data infrastructure enhances CMIP5 data effort ›

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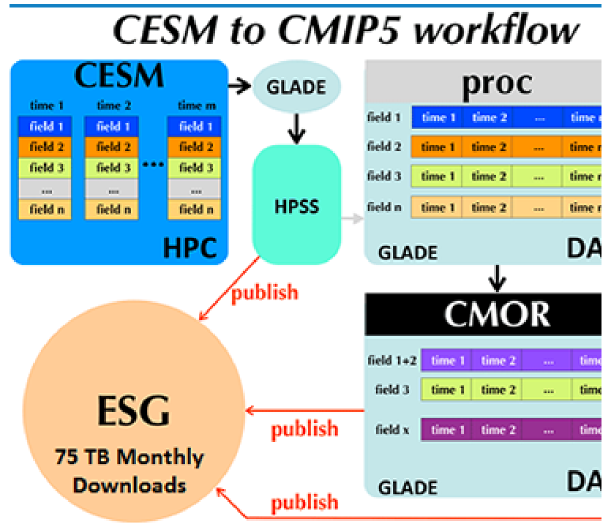
CISL DATA INFRASTRUCTURE ENHANCES CMIP5 DATA EFFORT

Climate scientists using CCSM and CESM have completed the extremely ambitious climate change simulations for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). CMIP5 describes a set of coordinated climate model experiments designed to address questions about climate change that arose from the previous IPCC assessment report (AR4). CISL infrastructure, including data storage systems and user access software, supports ongoing international community access to the global set of experiments contributed by CCSM and CESM simulations.



CISL infrastructure supports CMIP5 data modeling, processing, storage, and international community access. The CMIP5 data archive is heavily used, and the ESG-NCAR Data Node serves an average of 75 terabytes of CMIP5 data monthly.

The Globally Accessible Data Environment (GLADE) is a centralized high-performance file system that is the hub of activity for data receipts from models running on NCAR's HPC equipment, data products prepared on the Data Analysis and Visualization (DAV) cluster, and user access through web-based servers. This configuration has improved data workflow efficiency because it eliminates excessive data transfers between storage systems and simplifies data access and usage on multiple systems. The NCAR CCSM and CESM CMIP5 data products are available to the international IPCC-AR5 community via the NCAR Earth System Grid gateway (ESG-NCAR) and Data Node which access the GLADE file system. The ESG-NCAR gateway and Data Node are federated with the Earth System Grid Federation (ESGF) distributed data system, allowing researchers to access the full set of CMIP5 data products generated by the many participating modeling organizations for model output comparison.

Publication of the 150-terabyte CMIP5 data collection was completed in FY2012. CISL efforts in 2013 primarily provided production high-performance access to this high-use data collection. Specific efforts included providing end-user support through the ESG-NCAR help desk to address more than 100 CMIP5-related inquiries, upgrading the metrics capture system to provide accurate data use metrics, and working closely with NESL/CGD staff to publish new and updated CMIP5 and related data products. Looking to the future, CISL also initiated exploratory work related to enhancing the performance of the modeling-to-data-publication workflow described above. More than 2,000 individual scientists have downloaded CMIP5 data from ESG-NCAR in FY2013. CMIP5 data access is a significant portion of overall ESG-NCAR data download volume, representing an average of 75 terabytes monthly.

International community access to the CCSM and CESM CMIP5 data products is supported by NSF Core funds.

‹ Research Data Archive | up | Science gateway services in production ›

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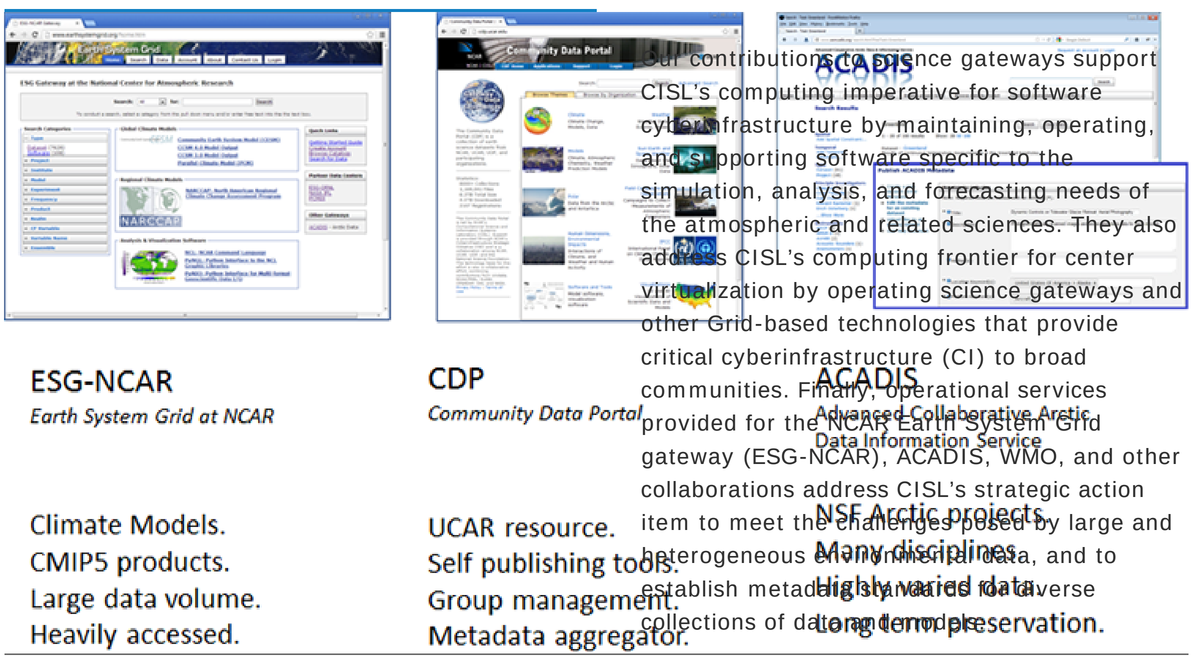
SCIENCE GATEWAY SERVICES IN PRODUCTION

CISL builds and operates science gateways that provide sustainable access to shared cyberinfrastructure for diverse scientific communities. Our projects and initiatives span climate science, regional climate change, Arctic science, solar science, digital preservation, and international efforts to develop metadata and knowledge infrastructure. Many of these efforts are tied to major interagency, national, and international initiatives, including, for example, the World Meteorological Organization (WMO), the Intergovernmental Panel on Climate Change (IPCC), the International Polar Year (IPY), the World Climate Research Program (WCRP), and the Library of Congress' National Digital Information and Infrastructure Preservation Program (NDIIPP). Most of these projects use open source, web portal infrastructure called the Science Gateway Framework (SGF). CISL's contributions to this suite of science gateway services is supported through NSF Core funding and augmented by special funding as noted below.



This figure shows three prominent science gateway and data portal services operated by CISL. These services provide access to shared data management cyberinfrastructure for diverse scientific communities from petascale "big head science" to small individual investigator-based projects. Combined, these gateways and portals serve over 1,000 active users monthly with annual downloads of nearly 1.5 petabytes.

Our contributions to science gateways support CISL's computing imperative for software cyberinfrastructure by maintaining, operating, and supporting software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. They also address CISL's computing frontier for center virtualization by operating science gateways and other Grid-based technologies that provide critical cyberinfrastructure (CI) to broad communities. Finally, operational services provided for the NCAR Earth System Grid gateway (ESG-NCAR), ACADIS, WMO, and other collaborations address CISL's strategic action item to meet the challenges posed by large and heterogeneous environmental data, and to establish metadata standards for diverse collections of data and models.

Earth System Grid gateway at NCAR (ESG-NCAR)

CISL operates the ESG-NCAR gateway that provides data discovery and access services for global and regional climate model data, knowledge, and software. The ESG-NCAR gateway participates in the Earth System Grid Federation (ESGF), which is a globally distributed petascale data management environment for CMIP5/IPCC-AR5 and U.S. climate science. The ESG-NCAR gateway supports community access to data products from many of NCAR's modeling efforts, including IPCC-AR4, IPCC-AR5, PCM, AMPS CESM, and the NARCCAP data products. The ESG-NCAR gateway is heavily used, has over 33,000 registered users, and each month delivers over 90 terabytes of scientific data to the community.

In FY2013, the ESG-NCAR gateway capabilities were extended primarily to support simpler end-user data product access, streamlined account registration workflow, and to improve the overall performance of data publication and capture metrics. CISL also provided considerable end-user support through the ESG-NCAR help desk by answering over 150 end user inquiries. We continued to apply and refine our Agile software development process in FY2013, releasing and deploying 21 software versions. This process allows us to provide high-value features quickly to our community and gain insights and feedback frequently to improve usability and quality. In March 2013 we delivered a rebuilt metrics capture and storage sub-system that provides highly accurate use and download metrics from the various gateway data access systems (TDS data node, GridFTP service, and direct gateway downloads including NCL and HPSS tape-based collections.) Other notable enhancements include streamlining the OpenID registration process and handling federated identities, refactoring many URLs to RESTful forms, upgrading bulk download features, and enhancing error reporting. In FY2013 CISL completed migrating the ESG-NCAR and related data services to the NWSC facility. CISL continued to work closely with NESL and other data managers to process and publish data products from CESM, CCSM3/4, AMPS, and NARCCAP. Over 800 terabytes and nearly 1 million files were published to ESG-NCAR during FY2013, raising the full volume of ESG-NCAR to 2.3 petabytes and 3.3 million files.

NSF Core funds support the operational ESG-NCAR gateway as well as special funding from the National MultiModel Ensemble (NMME) project.

Advanced Cooperative Arctic Data and Information Service (ACADIS)

ACADIS is a collaboration between CISL and NCAR's Earth Observing Laboratory, the National Snow and Ice Data Center, and Unidata. ACADIS is a community data service that provides project data management planning, data archival, preservation, and access for all projects funded by NSF's Arctic Science Program (ARC). CISL's contributions to ACADIS include the ACADIS gateway, which provides an end-to-end service where NSF-supported data providers can publish their data collections and make them available to the broad community of researchers. Accomplishments in FY2013 include a significant reimplementation of metadata sharing technology including the addition of OAI-PMH ISO record output and re-engineered Thredds Catalog, OpenSearch feed, and OAI-DIF harvesting subsystem. The ACADIS gateway is now harvested by the Arctic Data Explorer (ADE), NASA's Global Change Master Directory (GCMD), and the USA National Weather Service (NWS) Global Information System Center (GISC) nodes via the WMO Information System (UN/WMO WIS). Other FY2013 improvements include data entry user interface improvements for faster data entry, new REST services for data upload (in progress), automated ingest of EOL metadata holdings, a service for Citation and DOI generation, and a Chronopolis-based data preservation service. The ACADIS gateway supports a community of over 120 principal investigators and receives an average of 40 provider-self-published datasets monthly.

The ACADIS project is supported by NSF Core and NSF Special funds.

Community Data Portal (CDP)

The CDP offers a broad range of scientific data collections that includes observations, climate, atmospheric chemistry, space weather, field programs, models, analyses, and more. Many programs and projects at NCAR, UCAR, and UCAR Community Programs (UCP) are represented in the portal. CDP provides a self-publishing model that offers data management tools directly to projects and PIs. Data discovery is enhanced worldwide by automatically sharing these metadata with other portals and international centers. Roughly 2,100 registered CDP users are discovering, accessing, and using 8,000 collections representing over 6.3 terabytes of managed data holdings. The CDP has been actively used for over 10 years. In FY2013 we began the process of identifying high-use data collections that we will migrate to the actively enhanced ESG-NCAR science gateway so we can better address the future needs of the community of data providers and users. In FY2013 we continued to provide operational support and critical bug fixes for CDP.

CDP is supported by NSF Core funding.

North American Regional Climate Change Assessment Program (NARCCAP)

This project shares regional climate simulation data with a community of over 800 users via the ESG-

NCAR gateway. NARCCAP is an international program that supports regional climate assessments for the U.S. and Canada. The assets are nine high-resolution regional model outputs forced by various global models and provided by multiple PIs. The core software CI is now mature, and the archive continues to grow as experimental runs are completed and published via the ESG-NCAR gateway. Nearly doubling in FY2013, NARCCAP-published data volume grew from 18 terabytes to 33 terabytes in managed holdings. CISL contributed by supporting operations, data publication, and user interface bug fixes and enhancements.

CISL’s contributions to NARCCAP are supported by NSF Core funding.

Chronopolis: Federated Digital Preservation over Space and Time

There is a critical and growing need to organize, preserve, and make accessible the increasing number of digital holdings that represent vital intellectual capital, much of which is precious and irreplaceable. Chronopolis is a strategic collaboration among the San Diego Supercomputing Center (SDSC, lead organization), NCAR/CISL, the University of California Library System, and the University of Maryland. It is aimed at developing national-scale digital preservation infrastructure that has the potential to broadly serve any community with digital assets for science, engineering, humanities, and more. In addition to community collections, Chronopolis CI is being used to provide pilot digital preservation services for the NCAR Library and the ACADIS project.

In FY2013, Duracloud was added as a data provider and the Chronopolis consortium now provides data preservation for Duracloud customers. CISL continued to provide operational support of the NCAR storage node and managed replication of over 28 terabytes of new data collections bringing the total volume of managed holding to 52 terabytes.

This gateway data preservation service is supported by the Chronopolis project.

Grid Asteroseismic Modeling Portal (GridAMP)

GridAMP provides a web-based interface for an international community of astronomers to run and view simulations that derive the properties of Sun-like stars from observations of their pulsation frequencies. GridAMP is developed through collaboration between CISL and the NCAR High Altitude Observatory (HAO).

CISL’s GridAMP portal has been transferred to Aarhus University in Denmark. Since its debut in 2009, this community modeling portal has become an essential resource for scientists worldwide who are involved in the analysis of data from NASA’s Kepler Space Telescope. The GridAMP portal will continue to serve this community at http://amp.phys.au.dk under the auspices of the recently established Stellar Astrophysics Centre in Denmark.

In March 2013, CISL supported the successful transfer of the operational GridAMP portal to Aarhus University. The transfer was accomplished in only three days with minimal downtime. The rapid transfer was made possible by using CISL’s Virtual Machine technology. The operational portal is running normally in its new home, and CISL continues to provide administrative support for the project.

The GridAMP project is supported through NSF Core funding and XSEDE.

WMO Information System (WMO-WIS)

CISL contributes to developing the World Meteorological Organization (WMO) Information System (WIS). Under the auspices of the United Nations, the WMO is designing, developing, and deploying WIS as a next-generation globally federated information system for weather, climate, hydrology, oceanography, and many other disciplines. CISL plays a strong role in the management and technical direction of WIS and has contributed ideas, strategies, and services developed through our work with CDP, ESG, ACADIS, and TIGGE. CISL staff have served on several WIS committees, recently including the Expert Team on WIS Centres (ET-WISC) ,the Task Team of Data Centres (TT-DC), and the Task Team on WIS Centre Audit Certification (TT-CAC). At the request of the U.S. National Weather Service (NWS), CISL attended the WMO WIS Centre Audit for NWS. CISL data collections are now being harvested by GISC-Washington

into WIS as part of production operations. In addition, CISL operates the U.S. archive and portal for the WMO THORPEX Interactive Grand Global Ensemble (TIGGE), an international weather forecast multimodel intercomparison collaboration with the European Centre for Medium-range Weather Forecasts (ECMWF) and the China Meteorological Administration (CMA). In tandem with this important global effort, CISL serves on the WMO GIFS-TIGGE (Global Interactive Forecast System) Working Group. In FY2013, CISL extended the Science Gateway Framework capabilities to support OAI-PMH access to WMO-ISO metadata records for ingest into the WMO Global Information System. CISL science gateway metadata is now harvested by the U.S. National Weather Service (NWS) Global Information System Center (GISC) nodes via the WMO Information System (UN/WMO WIS) as noted in the ACADIS section above.

CISL's WMO-WIS efforts are supported by NSF Core funding.

‹ CISL data infrastructure enhances CMIP5 data effort up CISL software cyberinfrastructure ›

CISL SOFTWARE CYBERINFRASTRUCTURE

CISL develops and supports software infrastructure (SI) specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. This software infrastructure includes data assimilation frameworks; data analysis and visualization software for climate, weather, and turbulence applications; and software for accessing, comparing, and exploring data through science gateways. In general, CISL balances its use of core funds to ensure the stability and long-term support of existing SI with opportunities to further expand and develop these capabilities via grants. The prioritization criteria used in maintaining this balance of funding sources includes the SI's importance to NCAR's ongoing mission, dependencies of other SI on its continuation, and in the case of capabilities under development, the proposed SI's relevance to CISL's and NCAR's strategic plans.

‹ Science gateway services in production up Data Assimilation Research Testbed software ›

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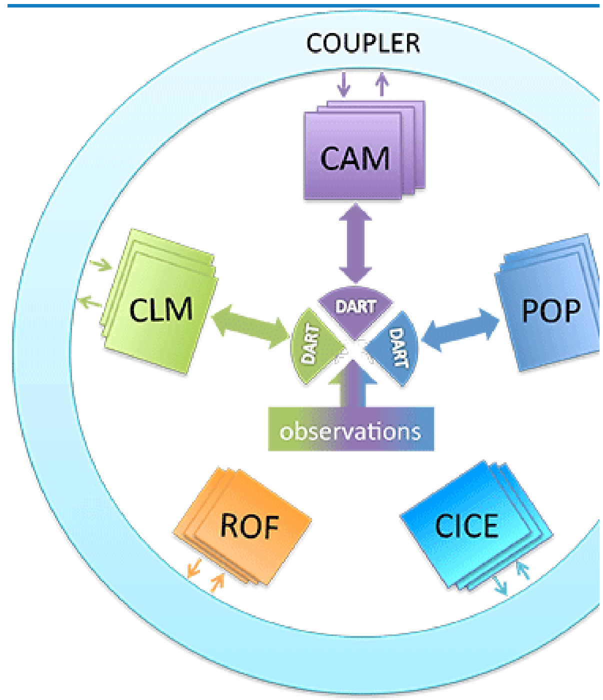
DATA ASSIMILATION RESEARCH TESTBED SOFTWARE

Data assimilation is providing rapid advances in geophysical studies. The Data Assimilation Research Section (DAReS) of IMAGe develops and maintains the Data Assimilation Research Testbed (DART), a software facility for ensemble data assimilation. DAReS also provides support to a growing community of NCAR, university, and government laboratory partners who apply ensemble data assimilation methods with DART.



A schematic depiction of the multiple-component CESM assimilation capability with DART. The CESM coupler advances ensembles of all five component models. Separate instances of DART are run for the atmosphere (CAM), land (CLM), and ocean (POP) models to assimilate observations of each model into the ensemble. This fully coupled multiple-component assimilation produces more consistent analyses than previous disjoint systems, allowing scientists to better understand the relationships between the different coupled model components. This is an important intermediate step toward building a fully coupled cross-component assimilation in which observations from any component model can impact the other models.

DART software was carefully tested prior to the delivery of Yellowstone and ran without modification for all applications when Yellowstone was delivered. Considerable effort was made to find the most efficient ways to use DART on Yellowstone for large models including CESM and WRF.

During FY2013, DART's interfaces to a number of large geophysical models were built or improved. A novel multiple-component assimilation interface to the coupled CESM models was completed and tested (see figure). A prototype interface to the new spectral element dynamical core Community Atmosphere Model (CAM-SE) was completed along with initial assimilation tests. DART interfaces to the WRF/CHEM model and the Global Ionosphere Thermosphere (GITM) model from the University of Michigan were recoded to improve performance.

DART interfaces to new observation sets were also completed including a general capability to do vertical interpolation in log-pressure that improved assimilation results in atmospheric models that extend above the troposphere. Forward operators for Carbon Monoxide retrievals from the MOPITT and IASI satellite instruments were also completed and tested in WRF/CHEM. Measurements of leaf area index from MODIS and brightness temperature from AMSR-E for snow cover can now be assimilated in land surface models.

As models increase in size, the current DART software requires a proportional increase in memory per process. A new distributed mechanism for doing general interpolation on model grids using MPI2 one-sided communication has been developed and tested. This capability is essential for reducing memory usage to allow assimilation for larger models.

CISL's data assimilation research supports CISL's computing imperative for software cyberinfrastructure.

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Further, developing and supporting the capabilities of the DART facility is specified as a strategic action item in the CISL Strategic Plan. Data assimilation research in IMAGe is supported by NSF Core funding, National Oceanographic Partnership Program Grant G0776112, and NSF Grant CNS1035250.

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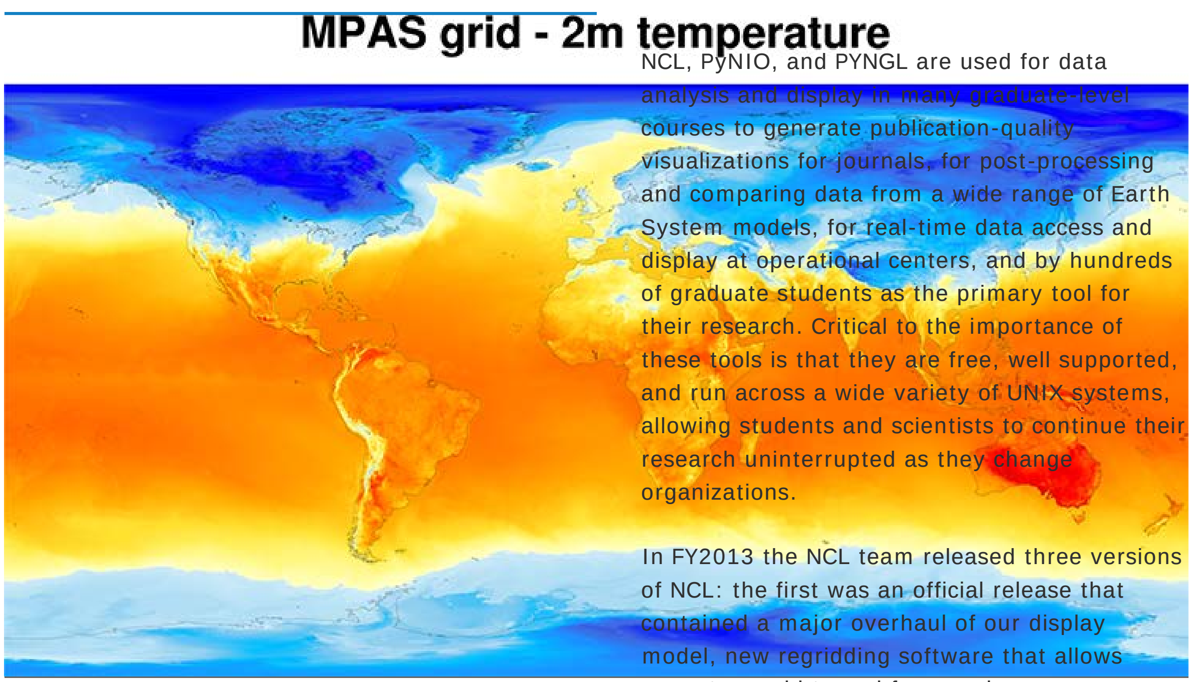
NCL DATA ANALYSIS AND VISUALIZATION SOFTWARE

The NCAR Command Language (NCL) is a data analysis and visualization environment developed primarily at CISL in deep collaboration with a number of core scientific groups. NCL enables scientists to easily and effectively read, analyze, and visualize their geoscientific data on platforms ranging from personal laptops to high performance computers. PyNIO and PyNGL are Python modules based on NCL's file input/output and visualization capabilities, thereby offering NCL's software components to a wider and more mainstream user base. The NCL and Python tools have been embraced broadly across the international Earth System sciences community spanning research, education, operational, military, government, and commercial organizations including the Bureau of Meteorology in Melbourne, Australia, IPMet in Brazil, CERFACS and Météo-France in Toulouse, Max-Planck-Institut für Meteorologie in Hamburg, and MeteoSwiss in Zürich.



This visualization shows temperature on a 65-million-cell MPAS grid. The MPAS grid is an unstructured centroidal Voronoi mesh that's being used and/or introduced into the Community Atmosphere Model (CAM) in the Community Earth System Model (CESM), and into a subset of the Advanced Research WRF (ARW) model. This image was created using a new faster mesh-fill algorithm in NCL, which took just over an hour to generate. Using an older fill algorithm took multiple hours on a 2-million-cell grid, and wouldn't even work on the 64-million-cell grid because of precision issues.

NCL, PyNIO, and PYNGL are used for data analysis and display in many graduate-level courses to generate publication-quality visualizations for journals, for post-processing and comparing data from a wide range of Earth System models, for real-time data access and display at operational centers, and by hundreds of graduate students as the primary tool for their research. Critical to the importance of these tools is that they are free, well supported, and run across a wide variety of UNIX systems, allowing students and scientists to continue their research uninterrupted as they change organizations.

In FY2013 the NCL team released three versions of NCL: the first was an official release that contained a major overhaul of our display model, new regridding software that allows users to regrid to and from various topographically rectangular and unstructured grids using several interpolation methods, and a new "advanced file structure" that allows for support of new features introduced in the NetCDF-4 and HDF-5 data formats. The second and third releases were mainly bug fix releases. For future releases of NCL, work is underway to integrate a SIParCS project for importing scientific visualizations into a Google Earth display engine, and on a "quick-look" tool tailored for visualizing cross-sections of NCAR model data. For the Python work, the display model is being overhauled for PyNGL as well, and a new collaborative project with U.S. universities, labs, and other organizations is underway for creating an open source, community-based "atmospheric and oceanic

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sciences" Python library called aoslib. A three-year joint project (ParVis) with Argonne National Laboratory and several other organizations to parallelize components of NCL for ultra-large climate datasets (ParNCL) reached its final year, and a beta version was released in summer 2013. In support of combined NCL and ParVis objectives, the NCL contouring software was overhauled to introduce a faster "mesh fill" algorithm as shown in the figure above, and a SIParCS project was sponsored to compare the parallelization of Fortran algorithms using OpenMP versus OpenCL/CUDA.

There were 22,511 downloads of NCL, PyNGL, and PyNIO software in FY2013 by 6,132 unique users. Our email lists had 3,805 total postings in FY2013 on 1,318 unique subjects.

This work advances one of NCAR's goals to support, enhance, and extend the capabilities of the university community and the broader scientific community both nationally and internationally. It also addresses CISL's strategic imperative for software cyberinfrastructure through developing and supporting software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. Specifically, this effort fulfills CISL's strategic action item to continue the support and development of community data analysis and visualization software. Our core development and maintenance of NCL and Python tools is primarily supported by NSF Core funding, while the ParVis project is supported by the U.S. Department of Energy Office of Science's Biological and Environmental Research Division under grant DE-SC0005358.

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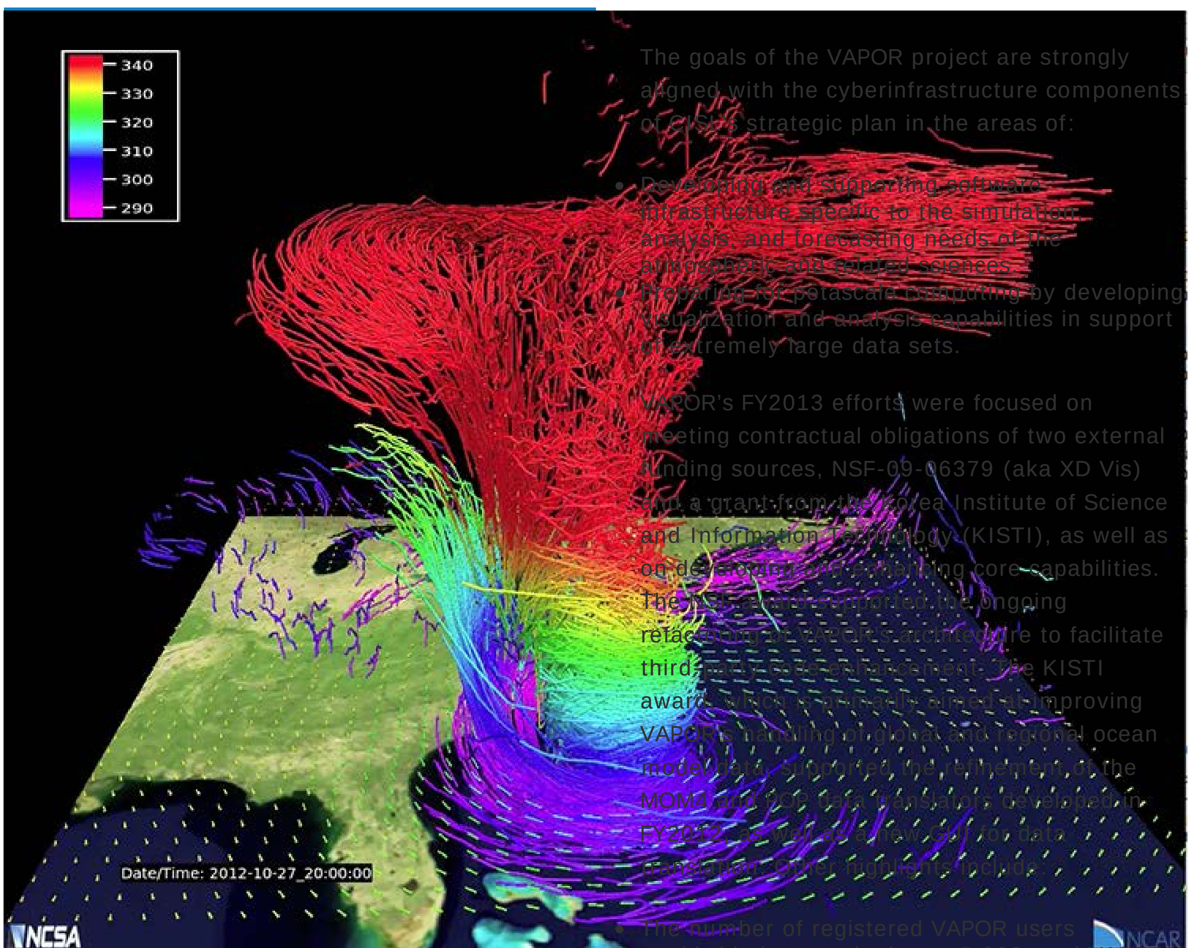
VAPOR VISUALIZATION SOFTWARE FOR VERY LARGE DATASETS

The Visualization and Analysis Platform for Ocean, Atmosphere, and Solar Researchers (VAPOR) project is an open source software development effort aimed at improving the ability of researchers in the Earth System sciences to analyze and interpret results from some of the largest numerical simulation outputs. The genesis of this work was an NSF-ITR research grant that supported CISL as well as collaborators at the University of California at Davis and the Ohio State University. VAPOR has transitioned into production from a research project, and it has become a strategic priority for CISL. Though VAPOR's origins are strongly rooted in geophysical turbulence, recent work on VAPOR has focused on expanding its capabilities to support the needs of the broader Earth System sciences community, particularly in the areas of numerical weather prediction and ocean modeling. Development of VAPOR is closely guided by a steering committee comprised of Earth scientists from around the world that sets development priorities, dictates software requirements, and serves as friendly users for testing and evaluating new software features. VAPOR's unique features include its use of a multi-resolution model that permits exploration of some of the largest simulation outputs using only desktop computing resources, a feature set and user interface that is focused on the needs of the Earth System sciences community, and a strong emphasis on supporting quantitative data analysis.



The goals of the VAPOR project are strongly aligned with the cyberinfrastructure components of CISL's strategic plan in the areas of:

- Developing and supporting software infrastructure specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences.
- Preparing for petascale computing by developing visualization and analysis capabilities in support of extremely large data sets.

VAPOR's FY2013 efforts were focused on meeting contractual obligations of two external funding sources, NSF-09-06379 (aka XD Vis) and a grant from the Korea Institute of Science and Information Technology (KISTI), as well as on developing and enhancing core capabilities. The NSF award supported the ongoing refactoring of VAPOR's architecture to facilitate third-party code enhancement. The KISTI award, which is primarily aimed at improving VAPOR's handling of global and regional ocean model data, supported the refinement of the MOM4 and POP data translators developed in FY2012, as well as a new GUI for data translation. Other highlights include:

- The number of registered VAPOR users worldwide has reached over 5,000, and VAPOR

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This image shows wind trajectories, colored by temperature, from a 0.5-km WRF simulation of Hurricane Sandy. With a computational grid size of 9,120 x 9,216 x 48 grid points, and generating over 100 terabytes of data, this storm prediction model is the largest known to date. The ability to effectively visualize these unprecedentedly large model outputs demonstrated VAPOR's ability to handle Big Data in the Earth sciences.

was cited by nearly 20 scholarly journals in FY2013.

- VAPOR's user documentation was overhauled and modernized.
- Imagery generated by VAPOR users appeared in the November 2012 issue of *Science*.
- Release 2.2 of VAPOR was completed in February, and over 1,700 copies of the software have been downloaded to date. Major new features for version 2.2 include parallel data translation on Windows, GPU rendering of terrain-following and stretched grids, support for ROMS, MOM4, and POP ocean model data, numerous usability improvements, and completion of the NSF XD Vis award deliverables.
- A third year of funding to support further ocean model data enhancements was won from KISTI.

This project is supported by NSF Core funds, NSF-09-06379, and a grant from KISTI.

‹ NCL data analysis and visualization software | up | Science gateway cyberinfrastructure development ›

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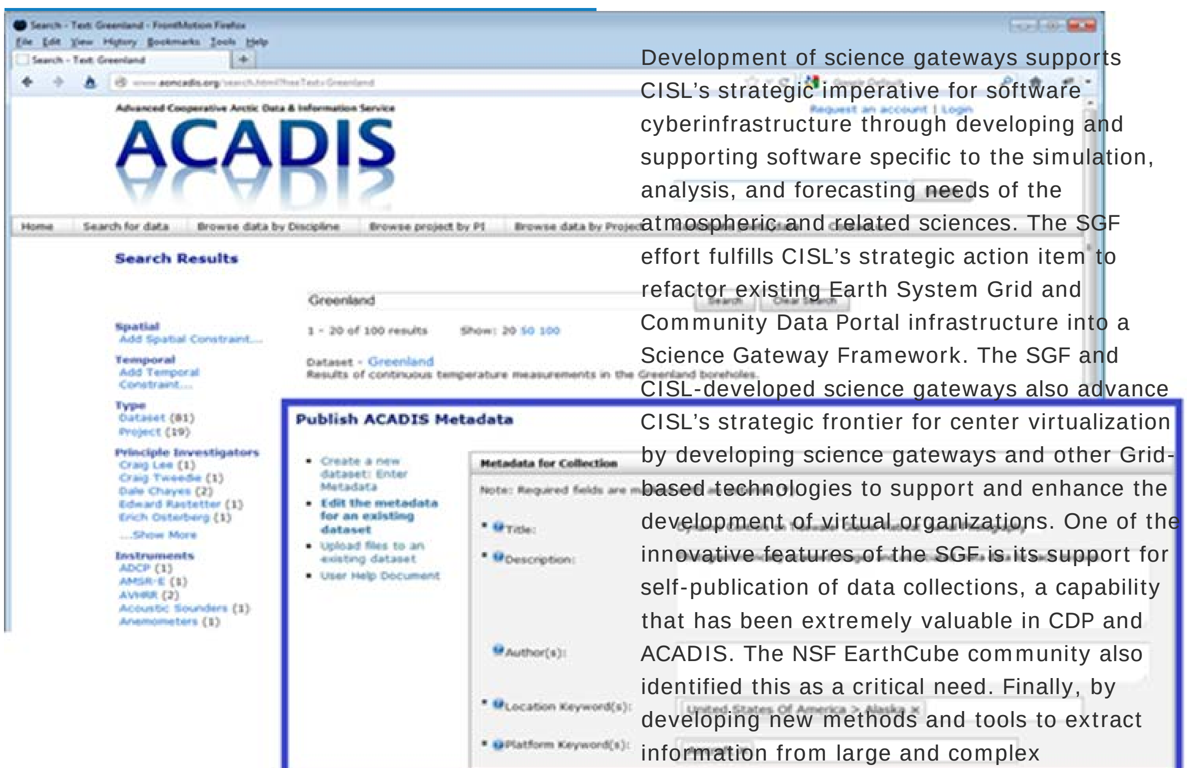
SCIENCE GATEWAY CYBERINFRASTRUCTURE DEVELOPMENT

Science gateways facilitate scientific communities' access to shared cyberinfrastructure. A science gateway typically provides a specific community with some level of integrated, web-based data and knowledge management, secure data access, and data sharing. CISL is engaged in a number of efforts in this area, including developing the Open Source Science Gateway Framework (SGF) that serves as a foundation for the ESG, ACADIS, and CDP science gateways. These science gateways provide sustainable data services that support national and international science efforts such as the World Climate Research Programme Coupled Model Intercomparison Project (WCRP CMIP) effort, the IPCC AR5 process, the CESM, and more. The SGF provides services for user community management, data and metadata publication, search and discovery, metadata federation, security, data access, and more.



The ACADIS Gateway is built on the Science Gateway Framework (SGF) and enables individual PIs and science teams to manage their own data in a sustainable, cost-effective way. The SGF-based ACADIS Gateway provides the services needed to enable a diverse community to self-manage and provide access to their data products.

Development of science gateways supports CISL's strategic imperative for software cyberinfrastructure through developing and supporting software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. The SGF effort fulfills CISL's strategic action item to refactor existing Earth System Grid and Community Data Portal infrastructure into a Science Gateway Framework. The SGF and CISL-developed science gateways also advance CISL's strategic frontier for center virtualization by developing science gateways and other Grid-based technologies to support and enhance the development of virtual organizations. One of the innovative features of the SGF is its support for self-publication of data collections, a capability that has been extremely valuable in CDP and ACADIS. The NSF EarthCube community also identified this as a critical need. Finally, by developing new methods and tools to extract information from large and complex heterogeneous data sets, this work supports CISL's science frontier for understanding large and heterogeneous data sets.

In FY2013, SGF software capabilities were extended to support community access to sustainable self-publishing tools and services, enhance broad data discovery, improve interface usability, support catalog federation with other systems, and capture broad and accurate usage metrics. In November 2013 we launched a new data entry interface for fast and easy metadata authoring. In March 2013 we delivered a rebuilt metrics capture and storage subsystem that provides highly accurate use and download metrics from the various gateway data access systems (TDS data node, GridFTP

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service, and direct gateway downloads including NCL and HPSS tape-based collections). Also in FY2013, we re-implemented the metadata sharing subsystem and added OAI-PMH ISO record output. This work area included enhancements to THREDDS catalogs, OpenSearch feed, and OAI-DIF harvesting capabilities. Other notable enhancements include streamlining the OpenID registration process and the handling of federated identities, refactoring many URLs to RESTful forms, upgrading bulk download features, and enhancing error reporting. We continued to apply and refine our Agile software development process in FY2013, releasing and deploying 21 software versions. Early and frequent release has led to higher-quality feature development, lower defect rates, and faster feedback cycles from our user base. The SGF supports the production ESG-NCAR, CDP, and ACADIS science gateways and services.

The SGF project is supported through NSF Core funding and is augmented by special project funding from ACADIS.

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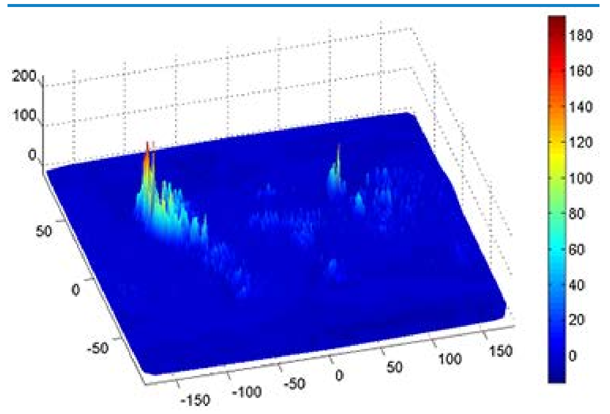
CISL SCIENCE

CISL research activities support scientific computation, numerical methods, geophysical modeling, and the analysis of geophysical data and model experiments. These activities are chosen to lead the geophysics community in adopting new computational methods and mathematical tools to improve research. Diverse scientific disciplines often share common tools and numerical methods. The kind of mathematical, computational, and physical sciences housed in CISL focus on general mathematical tools, models, and algorithms that have broad application across NCAR. Hallmarks of this research are innovative and standout contributions that not only have relevance for the overall NCAR scientific program, but also are significant in their specific area of mathematical, physical, or computational science.

The figures shown here illustrate some of the diversity of scientific research in CISL and also suggest some unifying themes. Numerical methods have always been an important component for making geophysical models run more efficiently on evolving computing environments and for handling both resolved and unresolved processes in models. The project highlighted in the first figure is an example of using a new numerical approach (radial basis functions) to model the electrical properties of the atmosphere. Here the emphasis is on a physical model capturing processes at multiple scales.



Vertical current density at ground (nA/m²).

The Earth's electric system is an important geophysical between link between solar processes, the upper and lower atmosphere, and cloud system dynamics. In the past however, its role has not been represented in global climate models because they could not resolve the many spatial scales involved in describing the Earth's currents and electrical fields. Challenges include representing dipole current sources from thunderclouds and the effect of topography at smaller scales than a typical atmospheric model can resolve. Another problem is accounting for the variation of the conductivity of the atmosphere and Earth over many orders of magnitude. This figure illustrates some initial research to model these electrical linkages. In the left panel is the current density derived from a 3D electrostatic model of the lower atmosphere (<70km), using sources from electrified clouds obtained by satellite data (right panel). This physical model is one of the first constructed for these processes and is based on a new numerical method known as radial basis function-generated finite differences that allows for complete geometric flexibility of the domain, yet is computationally efficient due to the sparse structure of the matrices.

At other the end of research activities is the analysis of observational data – 911 call records – and the connection between weather and human health. The second example illustrates the use of Bayesian statistical methods to estimate patterns in heat stress for the Houston metropolitan area. Finally, data assimilation is an additional area of research that is pursued in CISL. It combines observations and numerical models to improve estimates of a physical process or to quantify differences between model predictions and observations. All of these projects are challenged by large computational problems and data sets. CISL's research in computational science supports these projects and additional efforts at NCAR to simulate the Earth's climate system. Hallmarks of all these areas of research – numeric, data analytics, data assimilation, and computational sciences – are the development of tools and methods that have relevance beyond their specific

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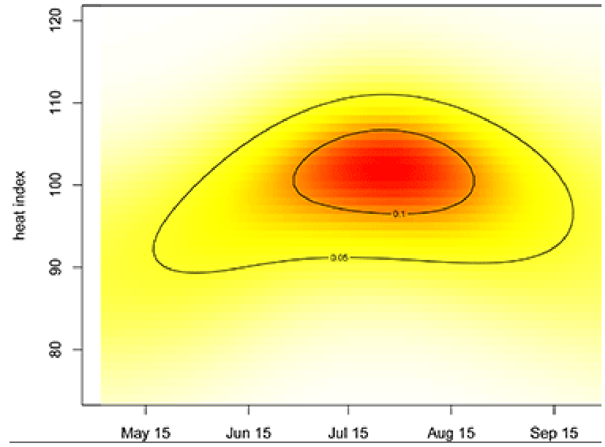
applications. While CISL research is motiviated by specific scientific problems, it also produces useful outcomes applicable to other areas.

Additional notable accomplishments and examples CISL's scientific diversity in FY2013 include:

- A six-month reanalysis was completed that couples the atmosphere, ocean, and land components of the NCAR climate model. The value of assimilating observations into this system is the ability to compare these results to assimilation for each model component alone. The comparison will help to identify significant transfers of energy, momentum, and water within the system. The use of DART in this project is novel and represents a unique capability in climate modeling.

- The impact of extreme heat events on Houston has been modeled statistically and related to the demographic and urban landscape of the city. This model is the first of its kind to quantify the uncertainty in the relationship of temperature and emergency calls over location and season.



The color shading depicts an estimate of how the frequency for 911 calls in Houston, Texas depends on the day of year and temperature (with reference contours at 0.1 and 0.05). This statistical surface is estimated from 911 call records, U.S. census demographic information, and daily weather. Note that the increased call intensity is associated with a higher heat index and with days that are closer to the middle of the summer. This suggests a seasonal effect that is partly independent of the temperature. This research is a part of the highly interdisciplinary SIMMER project, featuring scientists from across NCAR, the university community, and public health professionals from the city of Houston and from partners in Canada. By understanding the link between extreme heat and public health endpoints such as 911 calls, this research is aimed at providing public health professionals with important scientific information for planning and mitigation purposes. In this case, for example, this figure highlights the times of year and temperatures they can expect a high volume of heat-related 911 calls to occur.

- A numerical method that supports nonhydrostatic dynamical motion of the atmosphere was successfully implemented in the primary model for the atmosphere used by CESM. Nonhydrostatic models are important for simulating motion at the scale of clouds but require very short spatial scales in the vertical dimension. This approach deals with the differences in the horizontal and vertical scales using a mix of explicit and implicit time stepping. Moreover, the implementation focusing on the flux form of the physical equations facilitates scalability of code and conservation in the simulated processes.

- An exploration of computational accelerator technology focusing on the numerical core for atmospheric models demonstrated the potential of these micro-architectures. These results are important for evaluating next-generation supercomputing architectures that make heavy use of accelerator technology.

- A prototype data preprocessing tool has been developed to convert simulation model output fields to time series. This "transpose" processing operation has been a bottleneck, and the prototype based on parallel libraries affords a factor of 30 speedup.

The activities outlined in this report advance the imperatives and frontiers of CISL's research strategy. Moreover, the breadth of this research aligns with CISL's strategic imperative to produce scientific excellence. For CISL's interactions with the scientific community, a robust visitor program and a popular summer internship program provide numerous opportunites for collaboration and for dissemination of these results. Another scientific imperative addressed by CISL research is meeting the challenges of Earth System modeling as it moves to the petascale and exascale. Thus, research is pursued on adaptive numerical methods and multiscale models, both areas addressing the need for higher-resolution geophysical simulations. A companion to this effort is work in computational science for taking advantage of massively parallel supercomputers and new kinds of processors. Set against these computational goals is the creation of new analysis tools to interpret complex multifactor geophysical simulations and heterogeneous observational data. These are addressed in CISL research by focusing on the impacts of

regional climate change and data assimilation.

This work is funded as specified in the following individual reports.

‹ Science gateway cyberinfrastructure development up Integrating geophysical observations and numerical models ›

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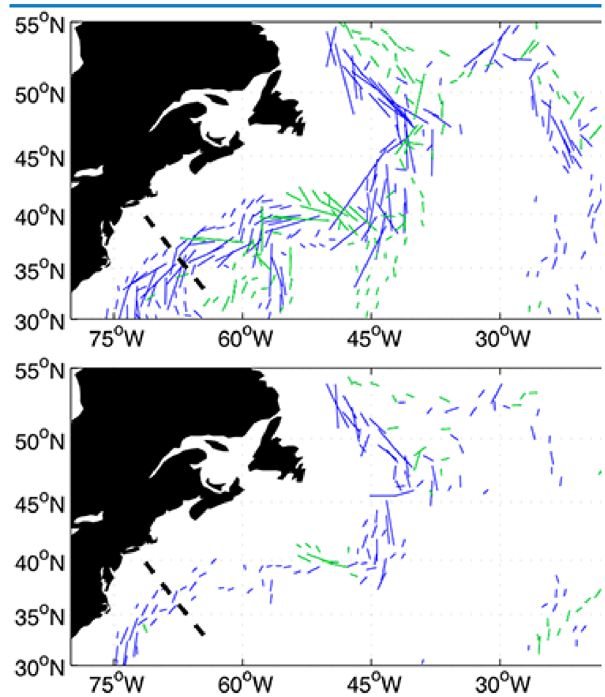
INTEGRATING GEOPHYSICAL OBSERVATIONS AND NUMERICAL MODELS

CISL's strategy to support progress in the computational geosciences is to bring in new ideas from other scientific disciplines to anticipate emerging technology trends and the evolving NCAR scientific mission. Because it combines expertise in computer science, applied mathematics, and statistics, CISL is a successful interdisciplinary computational science laboratory.

The interdisciplinary research within CISL serves several purposes. In addition to its direct contributions to NCAR science programs, it also engages the larger computational science and mathematics communities to use problems from the geosciences as testbeds, examples, and proofs-of-concept. In this way, the research capacity in CISL provides an interface between NCAR and other NSF communities. Moreover, many scientists in CISL leverage their work through collaboration with external groups at universities and national laboratories. Apart from the specific research by CISL groups, interdisciplinary science is also supported by CISL workshops, the IMAGe Theme-of-the-Year, and SIParCS interns. CISL's in-house scientific activities described in the following sections facilitate this outreach by integrating it into the research.



The deep western boundary current is an important feature of ocean circulation that is predicted by theory and confirmed with observations. This figure shows how combining observations and the POP ocean model using the Data Assimilation Research Testbed (DART) improves the representation of this feature. The upper plot shows results using data assimilation, and the lower plot is based on an unconstrained model run. The lines indicate strength and direction (blue=southward, green=northward) of the currents at depths below 2,500 meters. The assimilation results successfully produce a stronger and more accurate current. This improvement is likely due to a better vertical profile of ocean temperature and salinity that in turn results from the data assimilation method's effective incorporation of observations.

These are some highlights from CISL's FY2013 research that demonstrate how successfully observations and models are being integrated:

- Statistical methods were developed and applied for analyzing the Earth's magnetosphere. A key contribution is combining model experiments at different resolution to give a unified view of how model performance depends of the values of several parameters.
- DART/WRF was used to explore the impact of a variety of observations on analyses and forecasts of hurricane intensity for cases in the Atlantic and Pacific oceans.
- Analysis has begun for a high-resolution (10-km) downscaling experiment based on the WRF parent NARCCAP run.

Funding for these activities is indicated at the end of each of the following sections.

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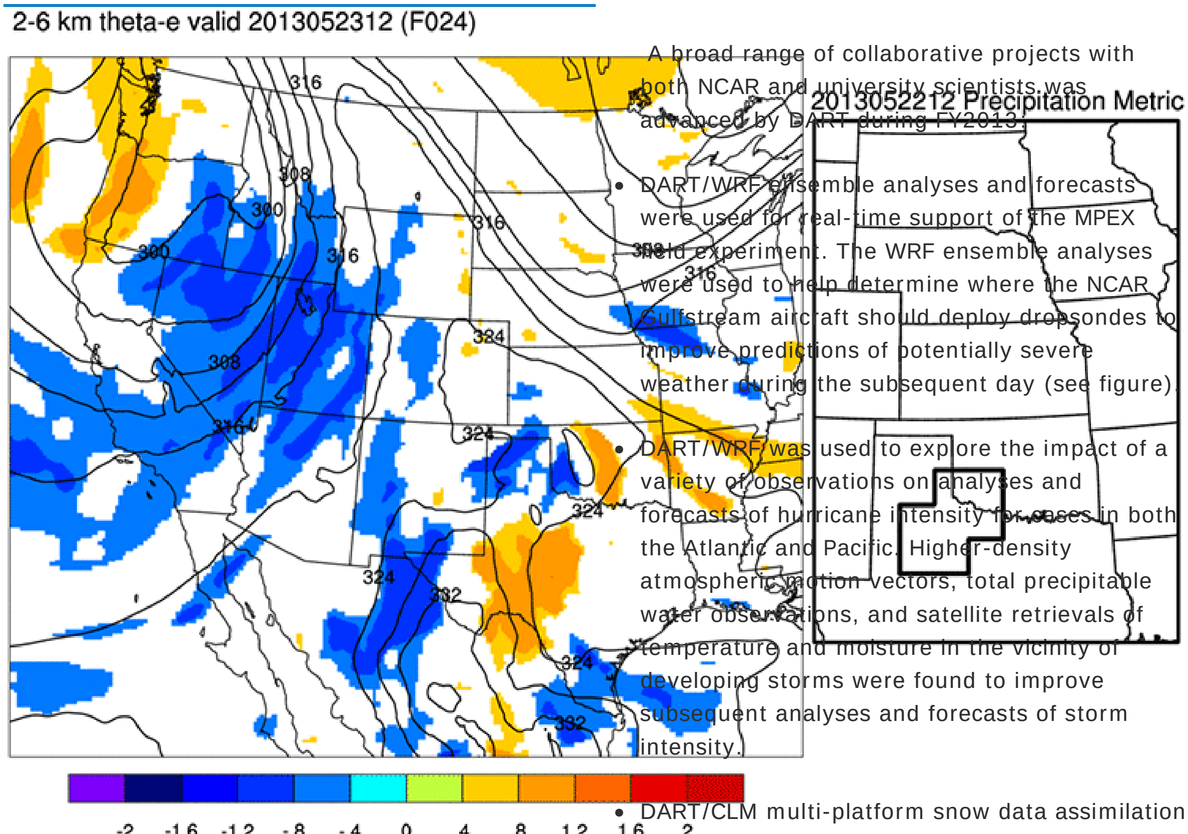
DATA ASSIMILATION RESEARCH

Data assimilation is providing rapid advances in geophysical studies. The Data Assimilation Research Section (DAReS) of IMAGe performs fundamental research on ensemble data assimilation methodologies for application across a wide range of geophysical problems. DAReS develops and maintains a software facility for ensemble data assimilation called the Data Assimilation Research Testbed (DART). DAReS also provides support to a growing community of NCAR, university, and government laboratory partners who are applying ensemble data assimilation methods.



Ensemble sensitivity analysis using DART/WRF forecasts during the MPEX field campaign was one tool used to guide deployment of dropsondes by the NCAR Gulfstream research aircraft to improve subsequent forecasts. The left panel shows where DART/WRF forecast precipitation in the box (right panel) is sensitive to the mid-tropospheric equivalent potential temperature. Warm colors mean that higher temperatures imply increased forecast precipitation. Additional observations in regions with large sensitivity are anticipated to reduce the uncertainty in the subsequent ensemble forecasts of precipitation in the boxed region.

A broad range of collaborative projects with both NCAR and university scientists was advanced by DART during FY2013:

- DART/WRF ensemble analyses and forecasts were used for real-time support of the MPEX field experiment. The WRF ensemble analyses were used to help determine where the NCAR Gulfstream aircraft should deploy dropsondes to improve predictions of potentially severe weather during the subsequent day (see figure).
- DART/WRF was used to explore the impact of a variety of observations on analyses and forecasts of hurricane intensity for cases in both the Atlantic and Pacific. Higher-density atmospheric motion vectors, total precipitable water observations, and satellite retrievals of temperature and moisture in the vicinity of developing storms were found to improve subsequent analyses and forecasts of storm intensity.
- DART/CLM multi-platform snow data assimilation including AMSR-E brightness temperatures in addition to MODIS snow cover fraction observations has been applied for both snow-covered and bare-soil areas. Due to the novel decomposition of the CLM grid structure, future work will involve incorporating land cover/land use information into the observation metadata to support more accurate forward observation operators.
- A six-month fully coupled multiple-component assimilation with DART and CAM, and POP and CLM was completed. The resulting ensemble reanalyses were compared to products that were

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produced by single-component model assimilations. This is a fundamentally new capability, and exploration of the analyzed fluxes is expected to help increase understanding of the coupled climate system.

- Both observing system simulation experiments and real data assimilation tests were performed with DART/WACCM. Assimilated data included tropospheric observations from the NCAR/NCEP reanalysis and temperature retrievals from the SABER and AURA/MLS satellite instruments in the middle and upper atmosphere. In particular, assimilating SABER observations was shown to improve forecast fits to the independent AURA/MLS observations.

CISL's data assimilation research advances CISL's strategic imperative to produce scientific excellence. Specifically, this work leads the mathematics and geophysical communities in ways that accentuate the contributions of mathematical methods and models to scientific progress in the geosciences. Further, DAReS research advances CISL's science frontier for understanding large and heterogeneous data sets by assimilating strategic, heterogeneous, and nonlinear observations into Earth System models.

Data assimilation research in IMAGe is supported by NSF Core funding, National Oceanographic Partnership Program Grant G076112, and NSF Grant CNS1035250.

‹ Integrating geophysical observations and numerical models   up   Multiscale modeling of geophysical and astrophysical turbulence ›

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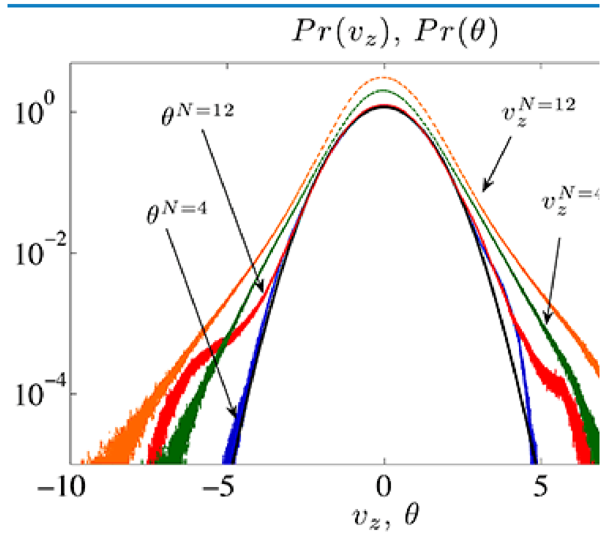
MULTISCALE MODELING OF GEOPHYSICAL AND ASTROPHYSICAL TURBULENCE

Processes that drive climate and create weather occur at many spatial and temporal scales. A challenge for traditional modeling is to represent behavior at scales that are physically relevant but too small to be resolved explicitly in a model. One solution is to simulate simpler processes in great detail and study the patterns and physical relationships by which scales are connected. This takes advantage of NCAR's rich scientific expertise in turbulence and climate processes and a national center's perspective when building collaborations among geophysicists, statisticians, and computational scientists. In addition to numerical models, statistical models are being developed from observational data to quantify how field correlations change at different distances and locations.



Normalized histograms (in semi-log) shortly after the peak of dissipation, for fluctuations of temperature θ and vertical velocity w, for stratified turbulence with Froude number Fr≈0.1 (N=4) and Fr≈0.03 (N=12), where N is the Brunt-Vaisala frequency. A normal distribution is shown (inner black curve) as a reference.

We are studying the dynamics of turbulent flows undergoing strong rotation and/or stratification, and the problems that are linked with the implied multiscale coupling. FY2013 has been mostly devoted to pursuing these last topics, moving on to the dynamics in the presence of forcing. A new topic that is still developing is the study of mixing in rotating stratified turbulence. To support this work, a Lagrangian particle module has been added to GHOST and is in the final stages of testing for parallelization using MPI, and hybrid parallelization will be pursued next year.

Long-time properties of dissipative non-rotating 2D flows

The main aim of this work is to study the conditions in a decaying flow under which behavior arises that is associated with an inverse cascade (approximately constant negative flux, and the corresponding self-similar spectrum with the appropriate scaling law). Results from an ensemble of 10 runs with $4{,}096^2$ grid points were computed and analyzed. When ensemble-averaged and time-averaged, inverse energy cascade behavior was observed in the absence of external mechanical forcing. The energy source for this behavior comes from the modal energy around the energy containing scale at t=0. The results shed some light into connections between decaying and forced turbulence, and into recent controversies in experimental studies of two-dimensional and magnetohydrodynamic turbulent flows

Inverse cascade in rotating turbulence

Rapidly rotating turbulent flows are characterized by the emergence of columnar structures that are representative of quasi-two-dimensional flow behavior. It is known that when energy is injected into the fluid at an intermediate scale, it cascades toward smaller as well as larger scales. This study analyzed the

flow in the inverse cascade range at a small but fixed Rossby number. To resolve the inverse cascade range with reasonably large Reynolds number, the analysis is based on large-eddy simulations that include the effect of helicity on eddy viscosity and eddy noise. Thus, we model the small scales and resolve explicitly the large scales. Shear and helicity are observed jointly in the atmosphere at large scale in some instances and that, under strong rotation for example, atmospheric flows can be described by the quasi two-dimensional quasi geostrophic approximation. Two new direct numerical simulations of the inverse cascade phenomenon in rotating turbulence have now been performed on grids of $2{,}048^3$ points using XSEDE resources.

Stratified flows

The evolution of stably stratified flows, under the Boussinesq approximation, was considered in the decaying case for relatively high stratification and moderate Reynolds numbers, with particular emphasis on the role of helicity (velocity-vorticity correlations). Helicity, which is not an invariant of the non-dissipative equations, was shown to undergo a substantially slower decay than in the unstratified case, and a type of large-scale "cyclostrophic" balance is invoked to explain this behavior. The ensuing decay rate of energy for stratified flows with high helicity is thus considered with a phenomenological model in a way similar to what is done for unstratified but rotating flows. It is shown that decay can be particularly slow, $t^{-1/3}$, as in the case with strong rotation. Results are published in the paper: Rorai, Cecilia, D. Rosenberg, A. Pouquet, and P. Mininni, 2013: "The role of helicity in the dynamics of stratified turbulence," *Phys. Rev. E*, **87**, 063007.

The forced case

Two direct numerical simulations of the dynamics of forced stratified turbulence have been performed on grids of $2{,}048^3$ points using XSEDE and NCAR/ASD resources. We concentrate on how the Ozmidov scale, at which the wave period and the eddy turnover times are comparable, is resolved or not in such flows, may alter the overall dynamical interactions between gravity waves and turbulent eddies. The flows are forced isotropically at large scale in the momentum equation. We find that for both flows, the potential energy settles at ≈10% of the total energy, and the energy dissipation rates also both settle at ≈3% of their nominal value. Furthermore, the waves with zero frequency, or slow modes, grow immediately in time at the expense of other modes. The production of helicity (velocity-vorticity correlations) is rather weak, and its distribution among scales is relatively flat, as observed as well in the nocturnal planetary boundary layer. Energy spectra of the different fields, and in terms of parallel and perpendicular wave numbers were analyzed in detail.

Turbulence comes in bursts in stably stratified flows

There is a clear distinction between simple laminar and complex turbulent fluids. But in some cases, as for the nocturnal planetary boundary layer, a stable and well-ordered flow can develop intense and sporadic bursts of turbulent activity that disappear slowly over time. Similarly, in the ocean, intermittency of the vertical velocity is associated with frontogenesis. This phenomenon is not well understood and poorly modeled, yet it is central to our understanding of weather and climate dynamics. We presented a simple model showing that in stably stratified turbulence, the stronger bursts occur when the flow is expected to be more stable. The bursts are generated by a rapid nonlinear amplification of energy stored in waves, and bursts are associated with energetic interchanges between vertical velocity and temperature (or density) fluctuations. Direct numerical simulations on grids of $2{,}048^3$ points confirm this somewhat paradoxical result of measurably stronger events for more stable flows that is displayed both in the temperature and vertical velocity as well as in their derivatives.

The inverse cascade in rotating stratified flows

We examined the inverse cascade of kinetic energy to large scales in rotating stratified turbulence as occurs in the oceans and in the atmosphere, while varying the relative frequency of gravity to inertial waves. Using direct numerical simulations with grid resolutions up to $1{,}024^3$ points, we found the most efficient range for the transfer of energy from three-dimensional to two-dimensional modes, where resonances disappear. In this range, the cascade is faster than in the purely rotating case, and thus the interplay between rotation and stratification helps create large-scale structures. The ensuing inverse

cascade follows a −5/3 spectral law with an approximately constant flux. This inverse cascade becomes negligible when stratification is dominant.

Funding

These research and service activities are supported by NSF Core funding, and by additional funding from NSF-CMG Grant 1025188. We also gratefully acknowledge DOE INCITE award TUR020, and NSF TeraGrid/XSEDE grant TG-PHY10029.

‹ Data assimilation research up Statistics for geophysical data and model experiments ›

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STATISTICS FOR GEOPHYSICAL DATA AND MODEL EXPERIMENTS

From its unique position within CISL and IMAGe, the Geophysical Statistics Project (GSP) has been a leader in research and training emphasizing the synergy between the geosciences and the statistical sciences. In addition to basic methodological and theoretical statistical research for scientific problems arising in the geosciences and at NCAR, GSP is focused on developing algorithms and tools to harness multi-core and high-performance computing environments to enhance capabilities for analyzing large datasets, and in particular, those involving spatial and spatial-temporal dependence. Further, GSP has a strong interdisciplinary training component supporting graduate students and postdoctoral visiting scientists. These young researchers are immersed in research activities that not only focus their skills as applied statisticians but also expose them to important geophysical applications.

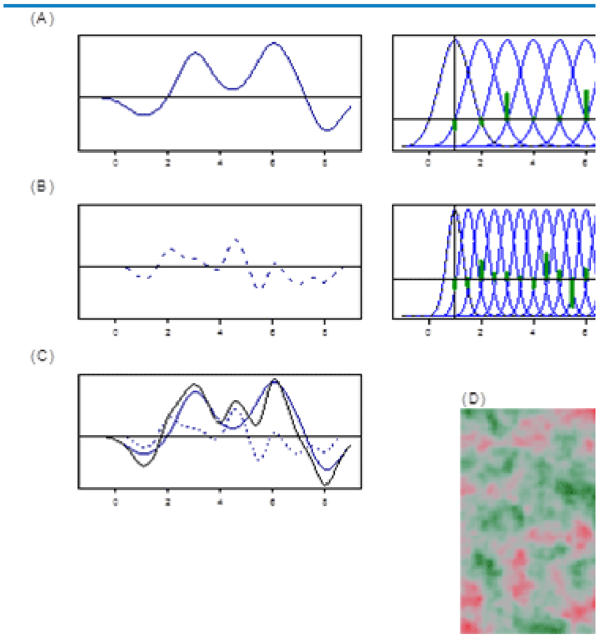

Illustration of the multi-resolution lattice Kriging method. This panel illustrates how a one-dimensional curve is constructed from random coefficients applied to multi-resolution, bump-shaped basis functions and gives an example of a two-dimensional simulation. Row (A) shows a random function (left plot) found by adding together the eight basis functions (right plot) with random weights (green bars). Note that when added together, these regularly spaced bumps blend together to give a curve where the individual bumps are not recognizable. Row (B) is a similar operation but uses 16 basis functions at half the scale. The random curves in (A) and (B) have variation at different spatial scales, and these curves are added together to give the solid black curve in (C). The sum in (C) shows variation at both spatial scales and thus has more complex structure than either (A) or (B). The image in (D) is a simulation of a random image, or spatial field, using similar concepts. Approximately 5,000 multi-resolution bump-shaped functions are used. The simulated field in (D) turns out to be a useful representation of what one expects in many different types of geophysical data observed over space. Moreover, this representation suggests a method (lattice Kriging) to go from irregularly observed spatial data to a complete spatial field. Most importantly, this method can handle large geophysical data sets and produce error bounds for the predicted values of a field where there are no observations.

GSP also has an active visitor program providing research opportunities for visiting faculty members from across the nation and abroad. Our goal is to foster collaboration between graduate students, postdocs, the permanent and visiting GSP and IMAGe staff, and more broadly, NCAR scientists. These programs – as well as the research and training aspects of GSP that emphasize the interaction between statistics and the geosciences – embody the tenets of integration, innovation, and community building within the CISL Strategic Plan. This program advances CISL's strategic imperative to produce scientific excellence by leading the scientific community in adopting new computational methods and mathematical tools that enhance scientific research. More specifically, GSP supports CISL's science frontier of developing innovative statistical design and analysis techniques to improve the efficiency and accuracy of model development and testing.

During FY2013, GSP researchers have been involved in numerous projects that include:

- Designing and analyzing computer experiments that focus on regional climate models and models of

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the upper atmosphere and the magnetosphere.
- Developing methodology for analyzing extremes of weather and climate.
- Developing stochastic weather-generators.
- Estimating impacts of climate and climate change on public health.
- Building software tools for the analysis of large spatial datasets.

In addition, GSP continues to develop theory and methodology for analyzing spatial and spatial-temporal data (including large datasets, nonstationary covariance models, and multivariate spatial observations) as well as general methodology for computational statistics and Bayesian hierarchical models.

This project is made possible through NSF Core funding, as well as grants through NSF's Division of Mathematical Sciences (DMS0707069), NSF's Division of Atmospheric Sciences (ATM0934488), NSF's Collaboration in Mathematical Geosciences (AGS0934488), and the National Aeronautics and Space Administration (NNX10AK79G).

‹ Multiscale modeling of geophysical and astrophysical turbulence up Integrated regional climate science ›

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INTEGRATED REGIONAL CLIMATE SCIENCE

In collaboration with a broad range of public and private laboratories and universities, the mission of the Regional Integrated Science Collective (RISC) is to generate high-quality regional-scale scenarios of projected climate change, then develop tools and methods for analyzing impacts, vulnerability, and adaptation options. RISC's placement in IMAGe shows the close ties between evaluating climate models and quantifying uncertainty using statistics. RISC also reaches out to the broader decision-making and policy communities by integrating mathematical analyses into a more immediate and pragmatic realm. RISC has responsibility for serving large and multifaceted numerical experiments, so it is well aligned with CISL's mission of data support to the climate science community.

A centerpiece of RISC's activity has been its leadership of the North American Regional Climate Change Assessment Program (NARCCAP). NARCCAP is systematically investigating the uncertainties in regional-scale projections of future climate. It is unique in its balanced design that allows for isolating the influence of individual regional and global models on the resultant climate simulations. The overall goal of NARCCAP is to produce high-resolution (50 km) climate change scenarios using six regional climate models (RCMs) nested within four atmosphere-ocean general circulation models (AOGCMs) forced with the A2 SRES emission scenario, over a domain covering the conterminous U.S., northern Mexico, and most of Canada. The project also includes an evaluation arm whereby the participating RCMs are forced by reanalysis data sets. The resulting regional climate model runs and time slices form the basis for multiple high-resolution climate scenarios that can be used in climate change impacts assessments in the U.S. and Canada. This year, work related to NARCCAP has entailed completing archiving of data and applying the data sets to a number of climate and impact analyses.

Further analyses and data products development using NARCCAP

RISC's activities include developing a number of data products and services to support NARCCAP data users. These products and services will also be useful for future anticipated high-resolution regional climate simulations such as those to be developed in North American CRODEX. Seth McGinnis has been collaborating with CISL's VETS group and NOAA's NCPP project to help guide the development of next-generation data services that will enable users of output from Big Data projects like NARCCAP to access only the data they need, avoiding the problem of downloading large volumes of unwanted data. These new service capabilities include spatial and temporal subsetting, file spanning, aggregation, and format conversion.

Simulation data bias correction

Having identified bias correction as an important need of NARCCAP users, especially for impacts analysis, RISC has been working to bias-correct NARCCAP output using distribution-mapping techniques. This work breaks new ground by applying the methods to daily data rather than monthly or seasonal climatologies. Seth McGinnis and Doug Nychka have been collaborating to develop a gridded daily observational data product with uncertainty by applying kriging to station data (see figure). This new product will improve on existing products by covering North America outside CONUS at the daily time scale, and by including an estimate of the uncertainty associated with the interpolated field, which comes as a natural product of using geostatistical methods. Uncertainty based on observational coverage in particular is a new and valuable feature. This product, called MICA, will be developed in a transparent, modular, and reproducible fashion. It will also explore the use of supercomputing facilities on smaller but highly parallelizeable

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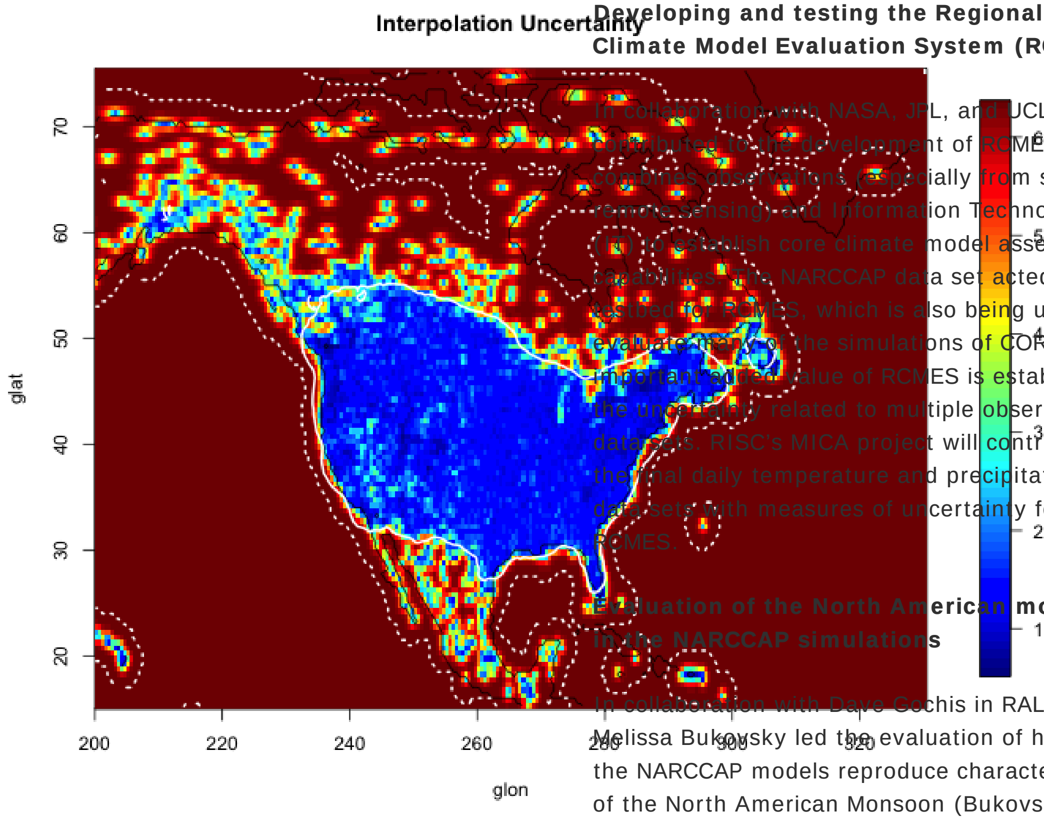
analysis problems. The resulting data will be used to validate the NARCCAP simulations, and may be used by NEON as well.



The uncertainty (in degrees C) associated with an observed daily maximum temperature field interpolated from station locations to a regular grid using the fastTPS() method from the "fields" library for R. Solid and dotted white lines indicate the boundaries of regions where the number of stations within interpolation range is 50 or more and 1 or more, respectively.

Developing and testing the Regional Climate Model Evaluation System (RCMES)

In collaboration with NASA, JPL, and UCLA, RISC contributed to the development of RCMES, which combines observations (especially from satellite remote sensing) and Information Technology (IT) to establish core climate model assessment capabilities. The NARCCAP data set acted as the testbed for RCMES, which is also being used to evaluate many of the simulations of CORDEX. An important added value of RCMES is establishing the uncertainty related to multiple observations datasets. RISC's MICA project will contribute the final daily temperature and precipitation data sets with measures of uncertainty for use in RCMES.

Evaluation of the North American monsoon in the NARCCAP simulations

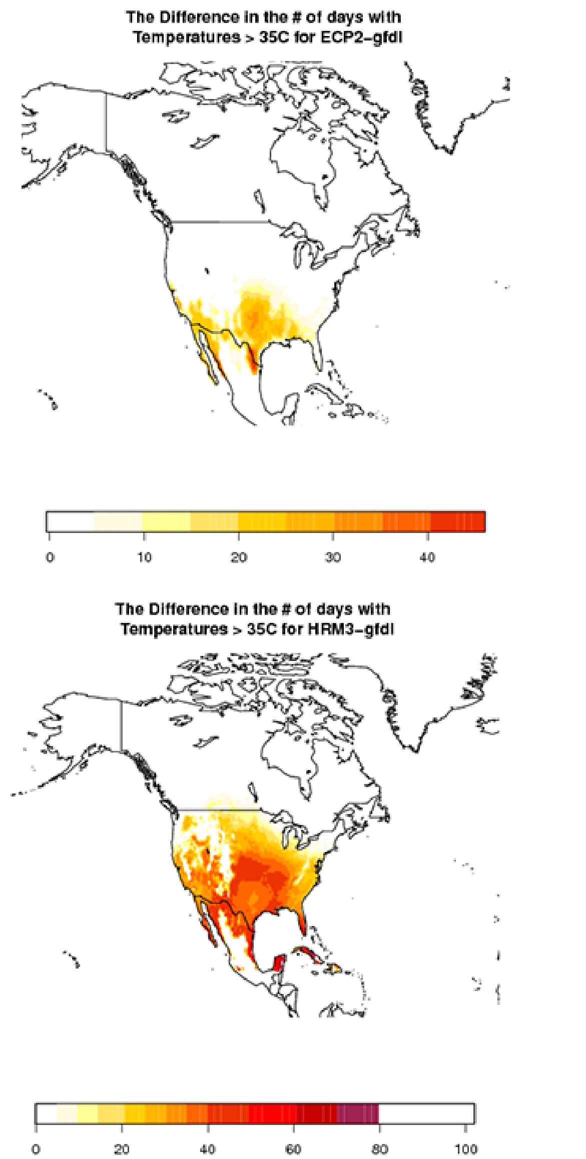
In collaboration with Dave Gochis in RAL, Melissa Bukovsky led the evaluation of how well the NARCCAP models reproduce characteristics of the North American Monsoon (Bukovsky et al., 2013, *J. Climate*). Findings include the fact that the quality of the driving conditions from the global climate models have a dominant effect on how well the regional models perform.

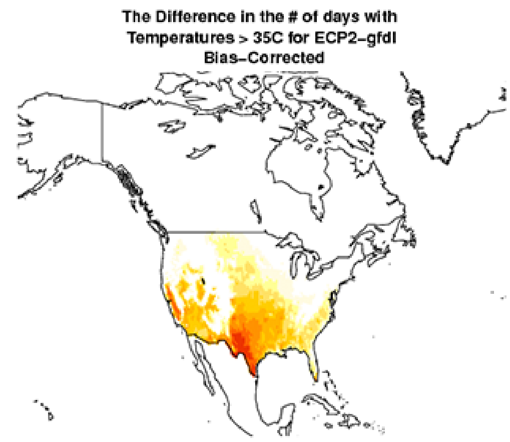
Heat stress and exposure to heat

RISC scientists are collaborating with scientists from the IAM group in CGD to produce analyses of the combined distribution of heat and population based on the NARCCAP simulations and downscaled population distributions. This will give an indication of how many people are exposed to different levels of heat stress. As part of this project, RISC is exploring how bias correction of NARCCAP data (see above) affects the measure of change in number of days over 35° C, future compared to current (see figures below).

Developing and providing climate information including uncertainty measures for adaptation research

RISC is currently engaged in three different research projects concerning adaptation to climate change at local and regional scales. These projects include one funded from NSF EaSM, "Informing Climate-Related Decisions with Earth System Models," led by RAND; and two funded through the DoD Strategic Environmental Research and Development Program (SERDP), "Decision-Scaling: A Decision Framework for DoD Climate Risk Assessment and Adaptation Planning," led by U.





Changes in number of days with maximum temperatures above 35º C calculated from simulations by two different regional models (ECP2, top, HRM3, bottom) driven by the same global model (GFDL). Left panels are based on raw simulation data. Right panels are based on bias-corrected simulation data.

Massachusetts, and “Understanding Data Needs for Vulnerability Assessment and Decision-making to Manage Vulnerable DoD Installations to Climate Change,” led by PNNL. All three concern decision making and more specifically, risk management under various conditions of uncertainty, including that of climate. All three projects rely to some degree on the use of the NARCCAP simulations in various resource management contexts. The EaSM project specifically considers ecological and water resources in the U.S. East and West, while the two SERDP projects consider a range of resources and climate conditions relevant to U.S. military bases in the Southeast, Mid-Atlantic, Texas, the Front Range of Colorado, and Southern California, such as heat stress, flooding, changes in available water resources, etc. The analysis of changes in snowpack, number of days of snow cover, and so on are relevant to a number of resources, particularly water resources. These results were analyzed by Rachel McCrary and are being used in one of the SERDP projects for the location along the Front Range of Colorado as well as in the EaSM water resource segment in California. In the work on the U.S. Naval Academy (Annapolis), particular work concerning future changes in the incidence of moderate to severe flooding is ongoing. RISC has estimated the change in sea level rise for the mid-21st century using the method of Tebaldi et al., (2011) as well as increased level of storm surges.

WCIASP

RISC also maintains and develops the Weather and Climate Impacts Assessment Science Program (WCIASP). WCIASP has three primary thrusts: investigating uncertainty in climate change research, studying extreme weather and climate events and their impacts, and supporting the Climate and Health Workshop series. WCIASP funds projects throughout NCAR, particularly in CGD, RAL, and other sections in IMAGe.

Funding

RISC is supported by NSF Core funding as well as interagency support for NARCCAP and the use of

NARCCAP results for adaptation planning from NSF, NOAA grant NA11OAR4310111, NASA grant 1450579, Commercial RAND Corporation grant 9920110075, and DoD grants 12007064A and 189743.

‹ Statistics for geophysical data and model experiments | up | Scalable algorithms for massively parallel computers ›

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SCALABLE ALGORITHMS FOR MASSIVELY PARALLEL COMPUTERS

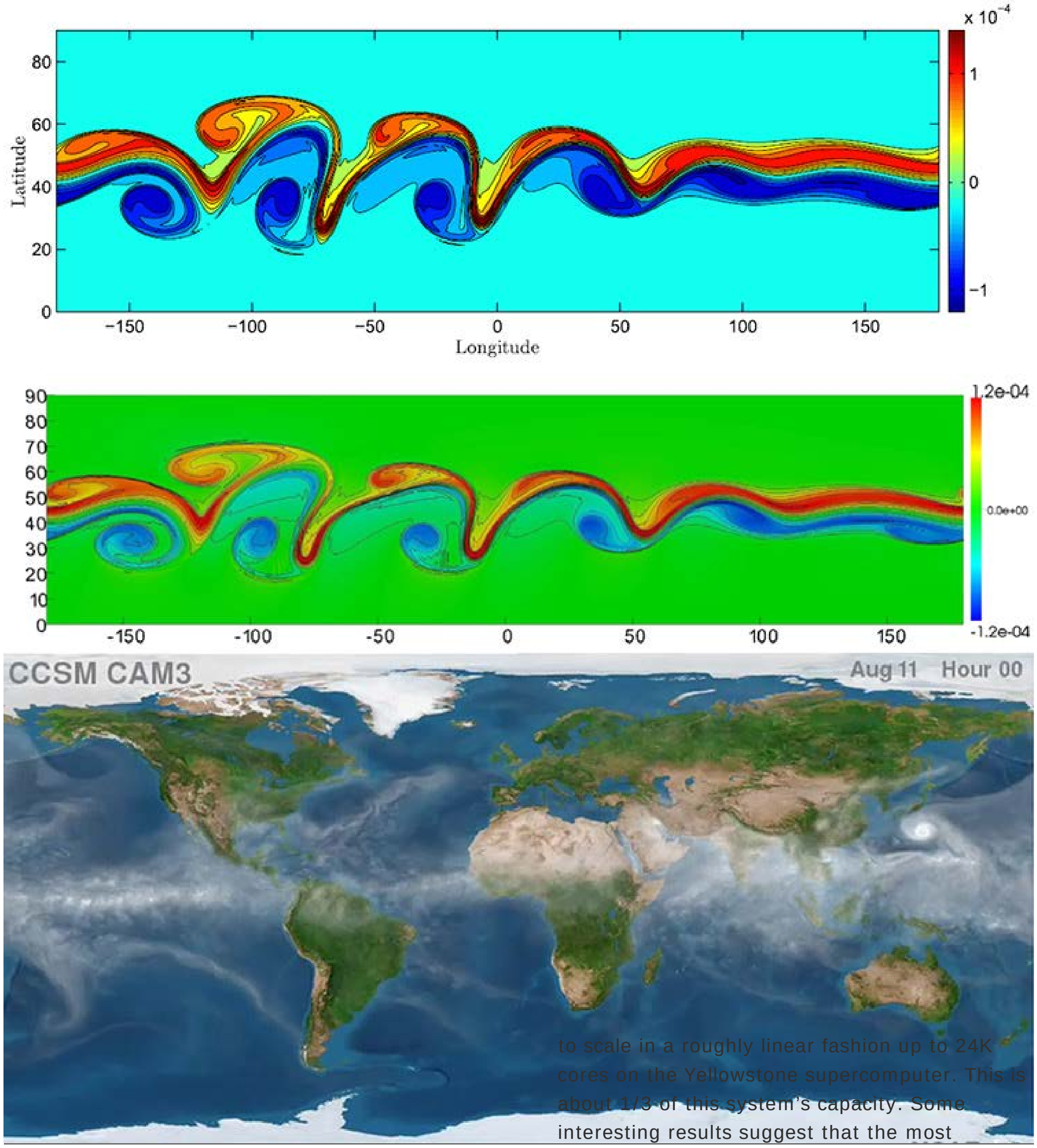
NCAR models of the Earth System and for solar physics motivate CISL's scientific research on algorithms, numerical methods, and computational performance. A priority in geophysical modeling is to increase resolution to resolve important processes and uncover unexpected interactions within the physical system. This goal must be pursued within the context of massively parallel computational resources. Given these two elements, CISL research focuses on areas to increase model resolution through methods that scale to large numbers of processing cores. It is well understood that to take advantage of the unique characteristics of large systems, improvements in simulation speed depend on better numerical algorithms and innovative computer science.

The figure above contrasts the results for two different numerical methods but also highlights the difference between mature, well-developed algorithms such as DG and newer approaches such as RBFs. Reflecting this difference, DG methods have already been migrated into prototype codes for CAM. RBFs are at an early stage where their numerical strengths and efficiencies are still being explored. Some highlights for research in this area include:

- Accurate and highly scalable numerical methods were developed to discretize partial derivatives in geophysical equations. The innovation is the use of a local set of radial functions to generate the differentiation weights without being tied to a regular mesh. Moreover, these computations are well suited to take advantage of graphics accelerators and other kinds of coprocessors.

- An efficient numerical scheme was developed for transporting tracers in the spectral element dynamical core for climate models. Tracer transport is important not only for atmospheric chemistry but to also to simulate the motion of dust and other constituents in the atmosphere. The conservative semi-Lagrangian scheme (SPELT) in this work is not only efficient for handling many tracers simultaneously but is also designed for a multi-resolution mesh of varying size quadrilaterals. Both of these features are important for next generation atmospheric models.

- The Community Earth System Model was shown



A comparison of a meshless and high order numerical method with a more traditional gridded method. The relative vorticity in the radial basis function (RBF) solution (top) approaches the fidelity of that in the discontinuous Galerkin (DG) solution (middle) with approximately four times less degrees of freedom needed, resulting in a lower computational expense for the test case described in section 2.2.2. This standard test case is a simple caricature and an efficient test for the more complex flow simulated by a full-scale atmosphere model. The bottom figure is a frame of a high-resolution simulation from the NCAR Community Atmosphere Model (CAM) emphasizing the patterns of clouds.

to scale in a roughly linear fashion up to 24K cores on the Yellowstone supercomputer. This is about 1/3 of this system's capacity. Some interesting results suggest that the most efficient size is about 15K.

This work is funded as specified in the following individual reports.

‹ Integrated regional climate science
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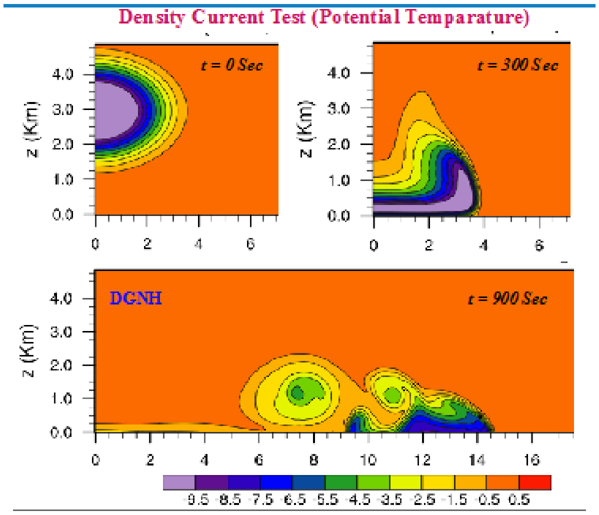
HIGH ORDER METHOD MODELING ENVIRONMENT

The High-Order Method Modeling Environment (HOMME) is a hydrostatic framework to investigate using high-order element-based methods to build conservative and accurate dynamical cores. Currently, HOMME employs the Spectral Element (SE) and Discontinuous Galerkin (DG) methods on a cubed-sphere tiled with quadrilateral elements. HOMME can be configured to solve the shallow water or the dry/moist primitive equations with explicit time-stepping. The objective of this project is to extend HOMME to a framework capable of providing the atmospheric science community with a new generation of atmospheric general circulation models (AGCMs) for the CESM (Community Earth System Model). Currently the SE version of HOMME is the default dynamical core for NCAR's Community Atmosphere Model (CAM), and HOMME-SE can efficiently scale hundreds of thousands processors on a supercomputer.



Potential temperature perturbations for the Straka density current problem, where the evolution of a cold bubble in a neutrally stratified atmosphere (25.6 x 6.4 km^2 (x,z)-domain) is considered. The bubble sinks from its initial position and hits the ground at 300 sec, resulting in generation of the Kelvin-Helmholtz-type rotors at time 900 sec. A third-order DG-NH model at a resolution of 100 m is used for the simulation.

With the ever-increasing computing resources available to modelers, it is now possible to develop high-resolution (cloud-resolving) global models at non-hydrostatic (NH) scales. For a typical NH global model, the vertical resolution is on the order meters while the horizontal resolution is on the order of a few kilometers. Extending the hydrostatic HOMME framework for the NH model development was a major research effort in FY2013. However, this necessitated incorporating the NH system (compressible Euler system) of equations and redesigning the vertical grid system of the HOMME framework. A major computational challenge is to find an efficient time-stepping scheme for the NH model. The fast-moving meteorologically insignificant sound waves in the NH governing equations largely determine this time-step restriction. The maximum stable time step for explicit time discretizations is dictated by the Courant–Friedrichs–Lewy (CFL) stability limit. At a higher resolution (smaller grid spacing), the CFL limit requires extremely smaller time steps – as small as a fraction of a second – and is not practical for global NH models simulating climate.

Although fully implicit methods with relaxed stability restrictions are available at the cost of complex elliptic solvers, it is not obvious how such methods could be efficiently implemented in HOMME. However, the stringent CFL limit associated with vertical high resolution can be remedied by treating the vertical component of the equations an in implicit manner and the horizontal components explicitly, using a dimension-splitting procedure. This semi-implicit method is often called "horizontally explicit vertically implicit (HEVI)." This scheme seems to be very attractive for HOMME because existing horizontal discretization based on the SE/DG method and the time integration schemes can be utilized. In FY2013, a new time-stepping scheme based on the HEVI approach has been developed for NH models based on the DG method.

To evaluate the time-stepping scheme, a

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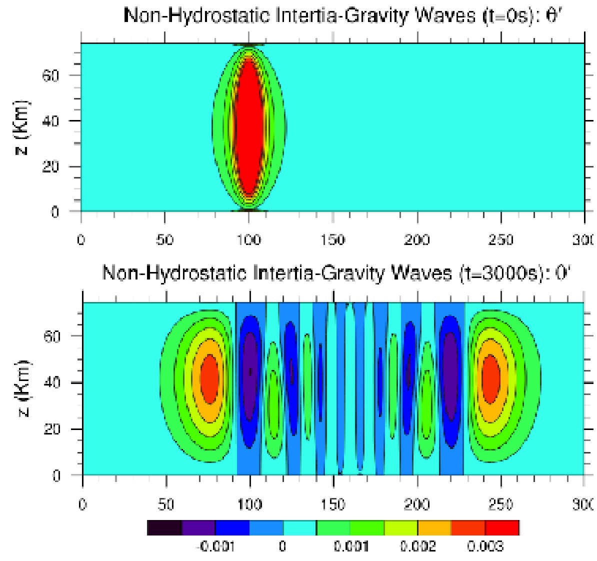
prototype NH Euler model in 2D (x-z plane) based on the DG method has been used as a testbed that essentially mimics the vertical aspects of a fully 3D model. The vertical discretization for the DG-NH parallel model relies on terrain-following height (z) coordinates, with an explicit or HEVI time-stepping scheme. Several benchmark tests have been performed. The first figure above shows the evolution of a sinking cold bubble (Straka density current test) at 100-meter grid spacing. The 2D model employs a consistent diffusion mechanism to smooth the solution as seen in that figure. In the second figure, the DG-NH model combined with a HEVI time-stepping scheme is tested for the inertia-gravity wave test. Because of the implicit treatment of the vertical components of the Euler system, the CFL restriction is only limited to horizontal grid spacing (dx), which is eight times larger than the vertical grid spacing (dz = 165 m). The second figure shows the results with a HEVI scheme, and is very close to the results with an explicit time-stepping scheme. The new time-stepping scheme is being implemented in the HOMME framework for NH development.



Potential temperature perturbations for non-hydrostatic inertia-gravity wave test in a channel. The initial solution is shown in the upper panel, and the lower panel shows the numerical solution after 3,000 seconds. For this test, the grid-spacing in x-direction is 8 times larger than that of the z (vertical) direction. The DG-NH model employs HEVI time-stepping scheme where the CFL stability limit is not constrained by the high vertical resolution.

This work supports CISL's science imperative to develop mathematical research codes that improve modeling. Specifically, it fulfills the strategic action item to further develop the HOMME dynamical core. Primary support for HOMME is provided by NSF Core funding. The validation of the HOMME dynamical core and HOMME/DG development are supported by the U.S. Department of Energy under grants DE-F402-07ER64464, DOE/BER program DE-SC0001658, and DOE BER SciDAC 06-13194.

‹ Scalable algorithms for massively parallel computers   up   Developing meshless numerical methods for accelerator-based computer architectures ›

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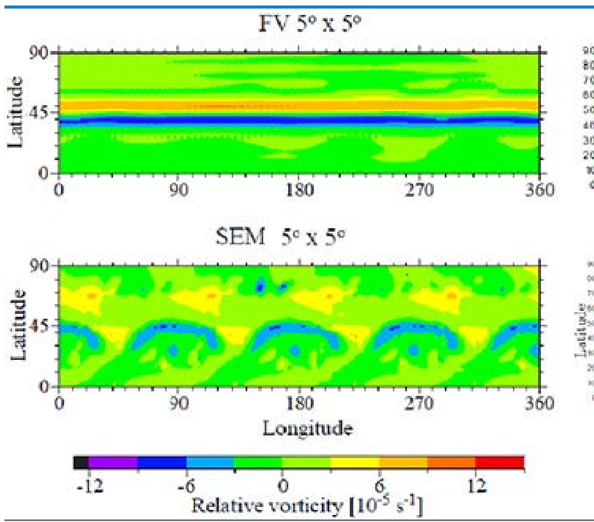
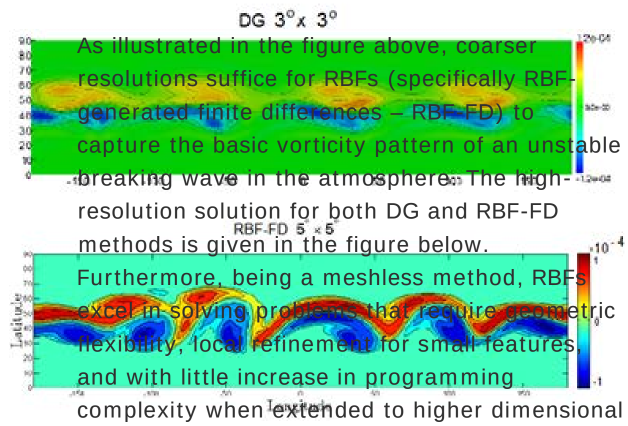
DEVELOPING MESHLESS NUMERICAL METHODS FOR ACCELERATOR-BASED COMPUTER ARCHITECTURES

While computer architectures have advanced rapidly in recent years, numerical schemes currently used for geoscience modeling have not kept pace with these technological developments. Radial basis functions (RBFs) offer a novel numerical approach for solving partial differential equations to high accuracy. Compared to other methods such as spectral element methods (SEM), discontinuous Galerkin (DG), or finite volume (FV), relatively coarse RBF discretizations suffice for obtaining matching or even higher accuracies.





The relative vorticity at day 6 for the evolution of the highly unstable atmospheric wave test case with resolution of 5 by 5 degrees for an SEM and FV model, and the RBF-FD model. The DG model has a resolution of 3 by 3 degrees. Both the SEM and DG model show the artificial wavenumber four pattern for the cubed-sphere.

As illustrated in the figure above, coarser resolutions suffice for RBFs (specifically RBF-generated finite differences – RBF-FD) to capture the basic vorticity pattern of an unstable breaking wave in the atmosphere. The high-resolution solution for both DG and RBF-FD methods is given in the figure below. Furthermore, being a meshless method, RBFs excel in solving problems that require geometric flexibility, local refinement for small features, and with little increase in programming complexity when extended to higher dimensional spaces.

After being initiated in FY2012, the RBF-FD method for approximating the derivatives in PDEs was further developed in FY2013. The RBF-FD approach has allowed the RBF method to become computationally cost-effective in terms of scalability, memory, and runtime for solving systems of PDEs. The localized and accurate nature of the RBF-FD method:

- Leads to matrices that are 99.8% empty.
- Allows it to scale as O(N) per time step, with N being with the total number of nodes.
- Makes it highly suitable for parallelization on accelerator-based computer architectures.

With the successful university collaborations of FY2013, the IMAGe Computational Mathematics Group together with Florida State University, Boise State University, University of Minnesota, University of California at Davis, University of Colorado at Boulder, NOAA National Severe Storms Lab, and Uppsala University in Sweden

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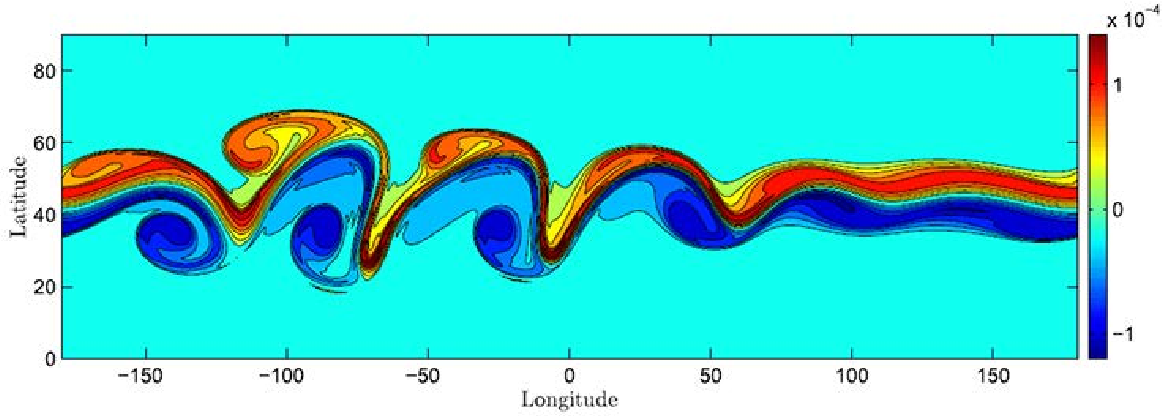

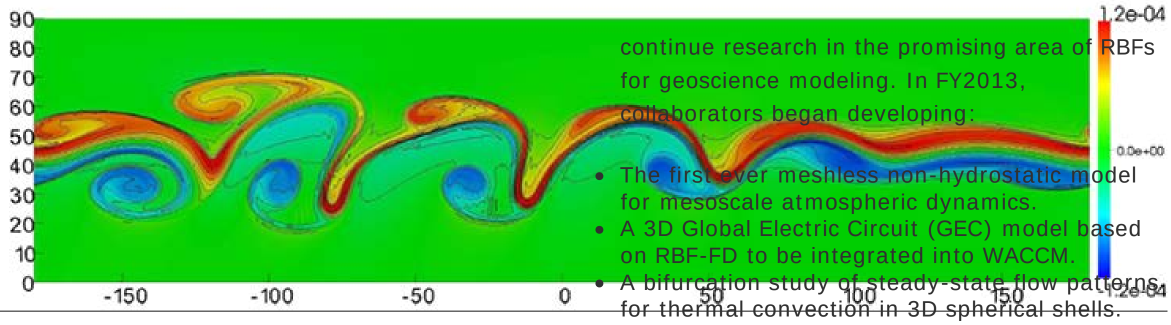

The relative vorticity in the RBF-FD solution (top) approaches the fidelity of that in the DG solution (bottom) with approximately four times less degrees of freedom needed, resulting in a lower computational expense for the test case described in the previous figure.

continue research in the promising area of RBFs for geoscience modeling. In FY2013, collaborators began developing:

- The first ever meshless non-hydrostatic model for mesoscale atmospheric dynamics.
- A 3D Global Electric Circuit (GEC) model based on RBF-FD to be integrated into WACCM.
- A bifurcation study of steady-state flow patterns for thermal convection in 3D spherical shells.

This work advances CISL's scientific efforts to develop scalable algorithms for massively parallel and accelerator-based computer architectures. This development effort at NCAR is supported by NSF grants DMS-0934317 and OCI-0904599.

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‹ High Order Method Modeling Environment up Scaling Earth System models ›

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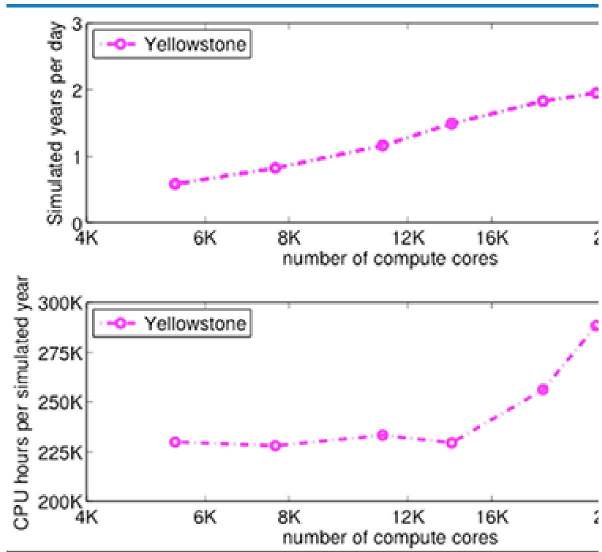
SCALING EARTH SYSTEM MODELS

During the Accelerated Scientific Discovery program on Yellowstone, a 65-year ultra-high-resolution CESM simulation was run with 23K cores over the course of three months. This configuration of CESM combined CAM-SE (atmosphere) and CLM3.5 (land surface) models at 0.25°-resolution with 0.1°-resolution POP (ocean) and CICE (sea ice) models. The figure illustrates the simulation rate and scaling efficiency of this configuration of high-resolution CESM. The top panel of the figure shows the simulation rate in years per wall-clock day (SYPD) as a function of processor count, while the bottom panel is the cost to perform the simulation in thousands of CPU-hours per simulated year. Interestingly, the least expensive core count on which to run high-resolution CESM (14,276 cores) achieves a simulation rate sufficient to perform climate experiments within a reasonable time.



Simulation rate and CPU hours per simulated year of high-resolution CESM running on Yellowstone.

These are important advances because significant improvements in the scalability of CESM allows the research community to utilize high-resolution simulations to advance our understanding of the Earth System.

This work advances CISL's strategic imperative to produce scientific excellence, and it prepares a foundation for petascale and exascale computing. This work is supported by NSF Core funds.

‹ Developing meshless numerical methods for accelerator-based computer architectures | up | Highly scalable codes for turbulent flows ›

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HIGHLY SCALABLE CODES FOR TURBULENT FLOWS

Simulating geophysical processes with numerical models is vital to understanding complex relationships in the Earth System. Model development depends on efficient numerical methods, and as models become more complex, their algorithms must be continually improved. This activity leverages the scientific development of weather and climate models at NCAR and its links to geophysical communities for disseminating software. CISL identifies numerical methods research that will address outstanding or anticipated modeling problems. Much of this research is built on software testbeds.

The Turbulence Numerics Team (TNT) generally focuses on simplified physical fluid systems that retain the full multiscale properties and complexity of geophysical and astrophysical systems in an effort to understand the detailed scale interactions that characterize turbulence in them. Accurate numerical methods are required when examining the small-scale statistical properties of such complex flows. Pseudo-spectral codes thus retain a great usefulness, both for examining high-Reynolds-number flows and for testing numerous modeling parameterizations in detail. In this spirit, the Geophysical High-Order Suite for Turbulence (GHOST) code was developed originally by P. Mininni in collaboration with D. Gómez (U. Buenos Aires). GHOST has since been extended to include several methods for parametrization (a regularization procedure, and a helical spectral model for both eddy viscosity and eddy noise) as well as adding a variety of new PDE solvers, including those for rotation, magnetohydrodynamics (MHD), and Hall MHD. Considerable work was invested in recent years to hybridize the parallelization of GHOST using MPI and OpenMP, and to test the scaling and characterize in detail the behavior of the code on large-core-count multiprocessor systems. This code is available to the community upon request.

Development continued on the hybrid version of the GHOST code in FY2013. Further, a parallel scalability of GHOST on GPUs is being developed. Also, the Lagrangian particle solver, in collaboration with Alain Pumir (ENS, Lyon) has been tested for accuracy.

Research and service activities of TNT are supported by NSF Core funding, and by additional funding from NSF-CMG Grant 1025188. We also gratefully acknowledge DOE INCITE award TUR020, and NSF TeraGrid/XSEDE grant TG-PHY10029.

‹ Scaling Earth System models | up | Computational research and development ›

COMPUTATIONAL RESEARCH AND DEVELOPMENT

Meeting the grand challenges in simulating the Earth System will require more than just migrating standard algorithms to larger computational platforms. New hardware, parallel computational approaches, and more efficient algorithms will all be needed to reach the resolution and complexity levels needed to support scientific breakthroughs in modeling. The research in this section focuses on CISL's mission to anticipate new computational technologies and determine their fit for geoscience applications. These activities also adapt software tools and numerical methods to emerging technologies.

CISL research activities support scientific computation, numerical methods, geophysical modeling, and the analysis of geophysical data and model experiments to improve research through new computational methods and mathematical tools. Diverse scientific disciplines often share common tools and numerical methods. The types of mathematical, computational, and physical sciences housed in CISL focus on general mathematical tools, models, and algorithms that have broad application across NCAR and are also significant in their specific area of mathematical, physical, or computational science. The activities outlined in this section reflect the breadth and quality of this scientific research.

CISL derives its research priorities from the computational science challenges in the NCAR strategic plan with emphasis on innovation and collaboration. Based on these priorities, CISL focuses its applied scientific research and development activities in these areas:

Evaluating many-core and accelerator-based architectures: The Technology Development Division's ASAP group is evaluating the scalability and performance of key benchmarks derived from atmospheric and related models on various many-core architectures, including GPUs and Intel's Xeon Phi architecture, using a variety of languages, compilers, source-to-source translation tools, and directive-based methods.

Accelerating data analysis: TDD is conducting research to develop end-to-end parallel data analysis and visualization technologies intended to accelerate scientific discovery on large or complex data sets.

Accelerating applications algorithmically: Goals for the next generation of global atmosphere models include accommodating regional grid refinement, resolving fine-scale convective processes that occur on scales on the order of a few kilometers, taking relatively large implicit or semi-implicit time steps, and conserving physical quantities such as mass and energy to machine precision. We are developing several novel numerical methods to tackle these challenges.

This work is supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

‹ Highly scalable codes for turbulent flows   up   Evaluating many-core and accelerator-based architectures ›

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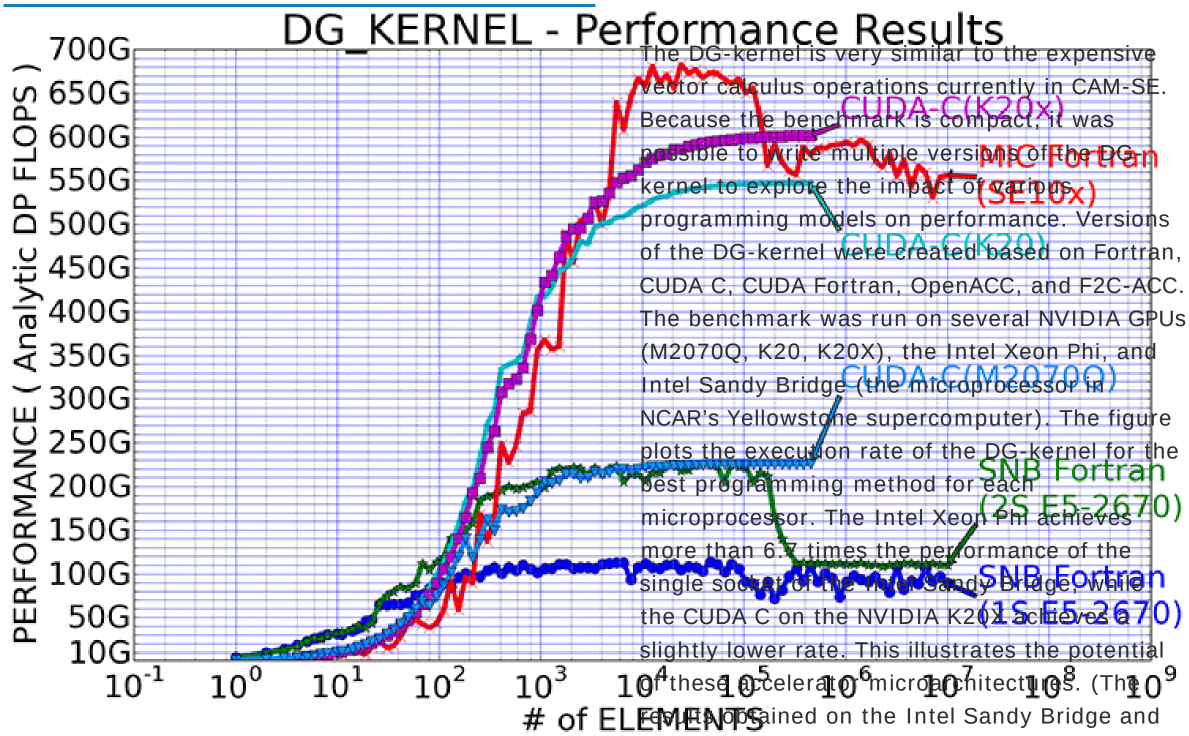
EVALUATING MANY-CORE AND ACCELERATOR-BASED ARCHITECTURES

In FY2013, CISL's Technology Development Division (TDD) committed two new software engineers within the Application Scalability and Performance (ASAP) Group to explore the use of accelerator technology within existing weather and climate model codes. This group is evaluating the two main accelerator architectures: general-purpose graphics processing units (GPGPUs) from NVIDIA and Intel's Xeon Phi processor, using both a small computational kernel DG-kernel and larger applications.

The work with the DG-kernel benchmark performs a gradient operation from the discontinuous Galerkin (DG) version of the High Order Methods Modeling Environment (HOMME). The current released version of the Community Atmosphere Model (CAM) is based on the HOMME dynamical core.



Performance of DG-kernel on NVIDIA GPU (M2070Q, K20, K20X), Intel Sandy Bridge (SNB), and Intel Xeon Phi (SE10x).

The DG-kernel is very similar to the expensive vector calculus operations currently in CAM-SE. Because the benchmark is compact, it was possible to write multiple versions of the DG-kernel to explore the impact of various programming models on performance. Versions of the DG-kernel were created based on Fortran, CUDA C, CUDA Fortran, OpenACC, and F2C-ACC. The benchmark was run on several NVIDIA GPUs (M2070Q, K20, K20X), the Intel Xeon Phi, and Intel Sandy Bridge (the microprocessor in NCAR's Yellowstone supercomputer). The figure plots the execution rate of the DG-kernel for the best programming method for each microprocessor. The Intel Xeon Phi achieves more than 6.7 times the performance of the single socket of the Intel Sandy Bridge, while the CUDA C on the NVIDIA K20X achieves a slightly lower rate. This illustrates the potential of these accelerator microarchitectures. (The results obtained on the Intel Sandy Bridge and Xeon Phi resulted from an extended collaborative effort between Intel, NCAR, NREL, and TACC.)

Members of ASAP and the Community Software Engineering Group within NESL have successfully ported the entire CESM1.2.0 application to the Stampede system at TACC which contains Intel Xeon Phi cards. While CESM currently utilizes the Intel Xeon Phi cards on Stampede, it is not currently competitive with the use of the Sandy Bridge CPUs due to issues with the Intel MPI stack, the flexibility of the job launcher, and I/O from the Xeon Phi cards. In collaboration with researchers from the Barcelona Supercomputing Center, ASAP developed a methodology to identify poorly performing segments of code within very large codebases. Using this technique, small segments of code within CESM were identified and were subsequently optimized producing a factors of 4 speedup on the Sandy Bridge, and a 10x speedup on Xeon Phi architectures.

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In mid-September 2013, NCAR's Technology Development Division hosted, for the third year, the "Programming Weather, Climate, and Earth System Models on Heterogeneous Multi-core Platforms Workshop." This workshop brought 40 experts in the field of programming accelerators to NCAR to discuss the state of the art in programming weather and climate models on many-core systems. This workshop allows teams at numerical weather prediction centers and national laboratories, who often work in isolation, to share experiences and compare best practices.

This work on the use of accelerators is supported by NSF Core funds.

‹ Computational research and development   up   Accelerating data analysis ›

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ACCELERATING DATA ANALYSIS

NSF and other agencies now broadly recognize "Big Data" as a paramount challenge across science and engineering. Models such as the Community Earth System Model (CESM) have seen dramatic improvements in their performance and in the associated volume of data they produce. The recent CMIP5 endeavor (Coupled Model Intercomparison Project Phase 5) resulted in approximately 1.4 petabytes of data, and the National Multimodel Ensemble Experiment is expected to generate 1.3 petabytes over a fairly short period. At the same time, we have not seen nearly the same progress from our processing, analysis, and visualization tools, which are generally single-threaded and sometimes limited to 32-bit addressing. In addition to emphasizing the hardware cyberinfrastructure (CI) side of the data analysis problem with NWSC resources, CISL is engaged in several activities aimed at exploring the requirements and developing new strategies for the software CI side of the equation.

As discussed in this annual report's NCL data analysis and visualization software section, the DOE-funded Parvis project is aimed at providing data and compute-parallel NCL capabilities to the broad community. The basic goal is to use very large machines to efficiently analyze supercomputer output. During FY2012, we advanced task-level parallelism via Swift, completed a full conversion of the ocean diagnostics package to NCL, and completed most of the development work needed to make the first community release of ParNCL in early FY2013.

CISL also began exploring the area of web-based services for supporting very large data collections. This work basically straddles NCL, Parvis, ESG, and other science gateways to provide a set of web-based visualization and/or analysis functions as integrated gateway services. Specifically, we developed a back-end processing system for NOAA's Live Access Server (LAS) based on the new 64-bit version of NCL. Such a service can be layered on top of, for example, CMIP5 data or much higher-resolution ocean model output. ParNCL can serve as the back-end processing engine and take advantage of using much larger-scale computers to service gateway users.

CISL was heavily involved in the CGD-led process of preparing CMIP5 data for publication into ESG and subsequent community use. The tools and workflows we have for this purpose are seriously inadequate, and we need new ones to support modern climate science. CISL has secured partial funding from NSF to engineer some new, fast, and efficient tools in this area. CISL's Application Scalability And Performance (ASAP) group has been exploring two approaches to address data analysis challenges. The first approach involves the creation of a prototype processing tool to explore the performance impact of converting data from the synoptic history files generated by CESM to a time series representation that is typically used for post-processing analysis. Currently the conversion from synoptic to time series is performed using inefficient netCDF Operators (NCO). The prototype, which uses the Parallel I/O (PIO) library, minimizes the number of calls to the disk subsystem. This prototype currently executes about 20 times faster than the NCO-based version. ASAP is also developing a method to evaluate the use of lossy data compression. Preliminary results of several different data-compression algorithms suggest that it may be possible to significantly reduce the amount of output data generated by climate simulations.

An FY2013 SIParCS project provided another opportunity to research web-based access to visualization and analysis of large collections of model output data stored on a centralized file server. The SIParCS intern prototyped a web service that allows a user to select from a set of model runs and, based on the options selected, produce a tailored suite of output diagnostics. For instance, the user might choose to compare two model runs over a selected time period. The service consists of a modular and extensible

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Python framework that achieves scalable performance using the Swift task-parallel scripting tool to control the parallel execution of the user-selected and parameterized elements of the diagnostic suite.

CMIP5, SIParCS, and data services R&D are supported by Core NSF funds. The new NSF-supported work in model data processing is supported by a special award under AGS-0856145. The Parvis project is supported by the U.S. Department of Energy Office of Science Biological and Environmental Research Division of the under grant DE-SC0005358. The SIParCS program supported the 10-week project by the intern, and her CISL mentor was suppored by NSF Core funds.

‹ Evaluating many-core and accelerator-based architectures | up | Accelerate applications algorithmically ›

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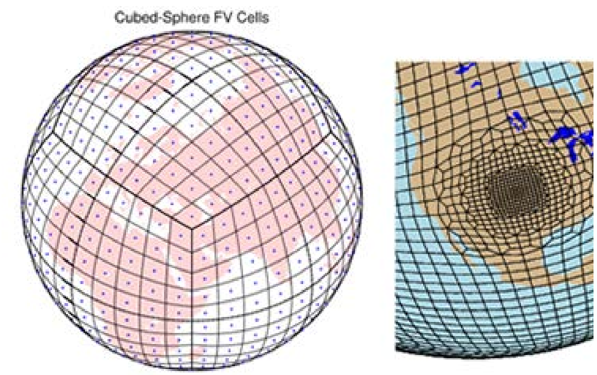
ACCELERATE APPLICATIONS ALGORITHMICALLY

For a production climate model such as the Community Earth System Model, multi-tracer efficiency is extremely important as it is a dominant computational factor for the entire simulation. However, with a growing number of tracers in today's atmospheric modeling applications, transport becomes very expensive. For example, more than *O*(100) tracers are used in the current chemistry version of CAM, and this number is likely to increase in future applications. A native SE transport scheme combined with non-oscillatory features is available in HOMME. Unfortunately, it is computationally prohibitive for a large number of tracers due to three communications per time step and a relatively small time step of the explicit Runge–Kutta-based approach.

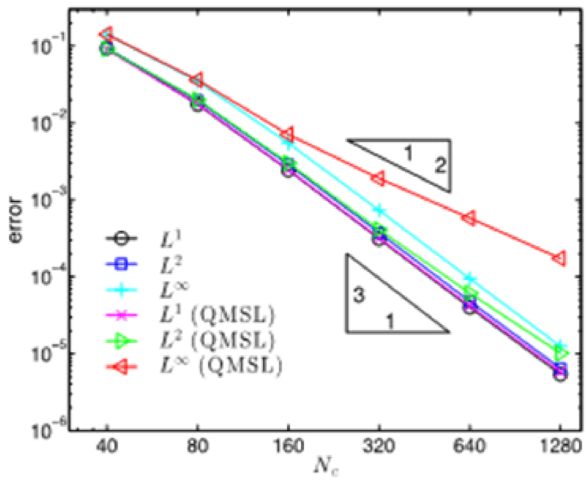


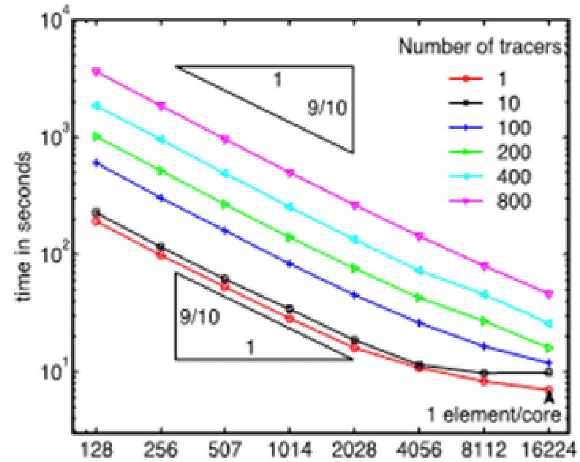
This figure shows a uniform-resolution cubed-sphere grid (left panel) and a variable-resolution cubed-sphere grid with regional high-resolution zones (right panel) where the grid cells are arbitrary quadrilaterals. Variable-resolution global grids are used for regional climate modeling. The conservative semi-Lagrangian scheme (SPELT) is multi-tracer capable and designed for any type of quadrilateral grid without impeding computational efficiency.

Recently HOMME/CAM (also called CAM-SE) has been further extended for variable-resolution arbitrary quadrilateral meshes to facilitate regional climate modeling (see figure above). Extending a regular transport scheme that relies on uniform mesh resolution and a wider halo region for reconstruction can be difficult or impractical on a variable resolution mesh. To address this issue, a new algorithm based on a Lagrangian method suitable for arbitrary quadrilateral mesh has been developed. The new algorithm "SPELT" (SPectral-Element Lagrangian Transport) employs a multi-moment compact reconstruction procedure. The resulting scheme has all the benefits of CSLAM (developed in FY2010) including accuracy, multi-tracer efficiency, and positivity preservation, while being compact and flexible for arbitrary quadrilateral meshes. In FY2013, the SPELT scheme has been implemented in HOMME, and the figure below shows the parallel efficiency and accuracy of the scheme.

This work advances CISL's science frontier in algorithmic acceleration by developing new algorithms and computational approaches to produce simulations capable of addressing grand challenges. Specifically, it fulfills a strategic action item to accelerate applications algorithmically by developing new numerical methods, AMR, new solvers, and new time integration schemes. This work is supported by NSF Core funding and by the DOE BER Program under award DE-SC0006959.

Reference: Erath, C.E. and R.D. Nair (2013): A





The left panel shows convergence of the SPELT scheme on an irregular GLL-type HOMME grid, where the scheme is third-order accurate. Parallel scalability of SPELT on the Yellowstone supercomputer up to 800 tracers is shown in the right panel. As the number of tracers increases, SPELT can be significantly more efficient than the native transport SE scheme in HOMME. A practical climate model uses hundreds of tracers for long-term integrations.

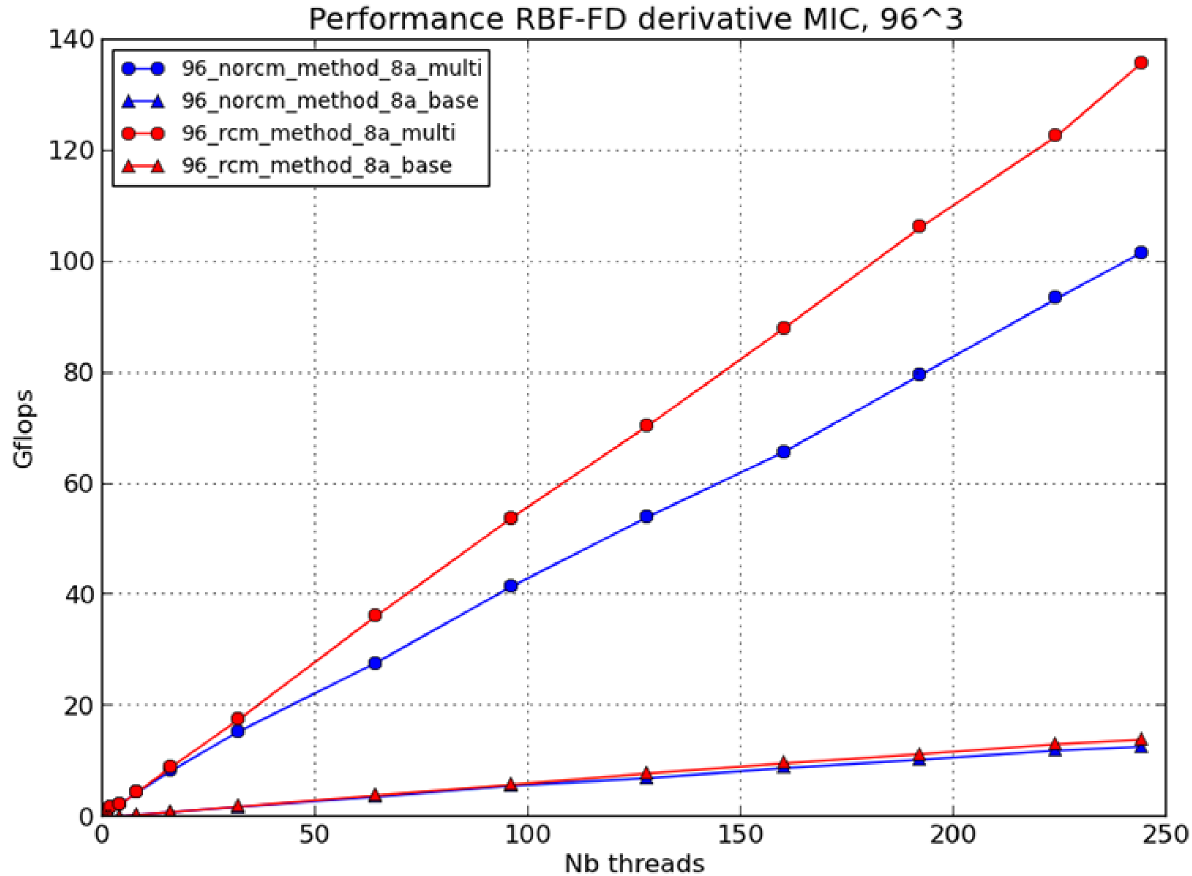
conservative multi-tracer transport scheme for spectral-element spherical grids. *Journal of Computational Physics*, **256**, 118–134.

Accelerating RBF-FD derivative calculations on MIC processors

Calculating derivatives in an RBF-FD formulation are computationally expressed as a sparse matrix/vector multiplication (SpMV). Using the full 61 nodes of an Intel Xeon Phi coprocessor and all four threads of each node, only a lowly 18 gigaflops is achieved when calculating a single vector of a single function. Bandwidth reduction has minimal effect since the cache is large enough to store both the matrix containing the differentiation weights and the solution vector.

The number of computations per byte transferred is increased by calculating four different derivatives of four different functions. With the use of a bandwidth reduction algorithm, as reverse Cuthill-McKee, the calculation is sped up by a factor of 8, and achieves more than 140 gigaflops as shown in the figure below. This effort is a joint collaboration with Florida State University and the University of North Carolina at Charlotte and is supported by NSF grants DMS-0934317 and OCI-0904599.

‹ Accelerating data analysis
up
Scientific data compression and visualizing large datasets ›



Performance on an Intel Xeon Phi coprocessor of derivative computation(s) for RBF-FD with 884,736 (96^3) nodes distributed quasi-randomly in a cube. Single derivative of a single function (base case, triangle) and four derivatives of four functions (multi case, circles). No bandwidth reduction (blue) and using reverse Cuthill-McKee (red).

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SCIENTIFIC DATA COMPRESSION AND VISUALIZING LARGE DATASETS

CISL is exploring a variety of hardware- and software-based approaches for addressing the challenges of the storage, visualization, and analysis of large data sets. CISL is also exploring two interrelated approaches to the challenges of large data sets. The first major software thrust in this area has been research, development, and experimentation with wavelet-based progressive-access data models for structured scientific data sets. Wavelets are the basis for numerous, ubiquitous multimedia compression technologies such as the JPEG 2000 image compression standard. However, unlike the "lossy" compression strategies used in consumer entertainment, our efforts are focused on level-of-detail techniques that offer perfect reconstruction of the original data while allowing the user to make speed/quality tradeoffs when performing interactive work. The second focus is to develop a method for determining how much information can be lost without impacting the results of typical climate analysis. The goals of all this work are to:

- Determine whether, and to what degree, scientific data sets can tolerate information loss.
- Investigate a variety of compression methods and their suitability for geoscience data.
- Develop user tools for data compression and improved, more general, progressive data access.

Exponential growth in transistor density is producing ongoing increases in computer processing power. These increases enable computational scientists to create numerical simulations of physical phenomena at unprecedented scales, thus generating extraordinary amounts of data. Yet while microprocessor performance continues to advance in accordance with Moore's Law, other computing technologies are improving at much more modest rates. In particular, storage and networking bandwidths have lagged behind. As a result, the challenge of storing, analyzing, managing, and sharing large simulation data sets is becoming ever more problematic. Moreover, large data visualization is a central component in preparing for petascale computing and enabling the understanding of large and heterogeneous data sets: this is a science frontier specified in CISL's strategic plan, which specifies these tasks:

- Deploy and investigate parallel visualization clusters.
- Partner with peer institutions and combine efforts to develop and enable large visualization of large data.

CISL continued development of VAPOR's open source progressive data access model, the VAPOR Data Collection (VDC). This year we began an effort to refactor the VDC API to better support the Earth sciences communities, particularly those with data adhering to the widely used NetCDF Climate Forecast (CF) Metadata conventions. The new "version 3"API will remove many of the constraints imposed by the old API and should facilitate great adoption by the earth sciences modeling communities.

CISL collaborates with members of NCAR Earth System Laboratory (NESL) are using an ensemble-based port validation methodology to evaluate the use of lossy data compression. Preliminary results, which have evaluated the VAPOR wavelet compression algorithm along with several other data-compression algorithms, suggest that it may be possible to significantly reduce the amount of output data generated by climate simulations.

This data compression and visualization research is supported by NSF Core funds, and the development of the parallel VDC API is supported by NSF Core funds and NSF Grant NSF-09-06379.

‹ Accelerate applications algorithmically up CISL Education, Outreach, and Training ›

CISL EDUCATION, OUTREACH, AND TRAINING

CISL designs education programs to integrate research and education and teach the technical skills that students and faculty need to make effective use of advanced cyberinfrastructure. These programs also promote diversity, enhance a culture of teaching and mentorship within CISL, and provide opportunities for collaboration with the university community. These objectives are accomplished through internship, visitor, workshop, and training programs.

A supercomputing laboratory in a national research center is a unique place to help integrate research and education between disciplines. CISL focuses on the computational and atmospheric sciences, and has a math institute dedicated to education and advancing research using applied mathematics and statistics. CISL's educational efforts are designed to complement and supplement programs at universities and other centers.

CISL manages two principal training thrusts: one for HPC systems and another for CISL-developed data analysis and visualization tools. NCAR and CISL also provide cyberinfrastructure resources and user support for community workshops, tutorials, and summer schools in the atmospheric and related sciences.

This work is supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

‹ Scientific data compression and visualizing large datasets up Integrating research and education ›

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INTEGRATING RESEARCH AND EDUCATION

As a supercomputing laboratory embedded in a national center focused on the atmospheric and related sciences, CISL provides resources to integrate research and education between the disciplines of the computational and atmospheric sciences. CISL's educational efforts are therefore designed to serve this function in a way that complements and supplements programs at universities and other centers.

CISL's Summer Internships in Parallel Computational Science (SIParCS) program offers graduate and undergraduate students significant hands-on opportunities in computational science, applied mathematics, and geostatistics to help build a workforce that can exploit petascale computers. CISL's Research and Supercomputing Visitor Program (RSVP) allows prolonged engagement and collaboration between our staff, the university community, and researchers at peer centers around the world. IMAGe's Theme-of-the-Year (TOY) is a series of year-long programs, each focused on a specific aspect of mathematics applied to the geosciences; it is designed to advance research, education, and collaboration between the mathematics and geosciences communities.

Topics such as multiscale modeling, data assimilation, and turbulence offer hands-on experience to young researchers. CISL budgets for approximately 10 SIParCS interns each year and actively seeks to improve the diversity of its workforce through the outreach performed by its Diversity Coordinator. The RSVP program is visitor-driven and generally operates on a first-come, first-served basis. For attendees from EPSCoR states and minority-serving institutions, CISL supplies RSVP travel support to CISL training classes and workshops such as students from MSIs attending the April 2013 Software Engineering Assembly Conference and Scalable Profilers Workshop. The TOY program establishes collaborations around potentially rewarding research activities and encourages contributions from talented young investigators in a variety of disciplines.

CISL's education imperative for integrating research and education is primarily supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

‹ CISL Education, Outreach, and Training up Summer Internships in Parallel Computational Science ›

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SUMMER INTERNSHIPS IN PARALLEL COMPUTATIONAL SCIENCE

The Summer Internships in Parallel Computational Science (SIParCS) program seeks to develop students with a background in computational science, applied mathematics, computer science, or the computational geosciences. The 11-week internships provide opportunities for exceptional students to gain practical experience with a wide variety of parallel computational science problems by working with the HPC systems and applications related to NCAR's Earth System science mission. The ultimate goal of SIParCS is to address shortages of trained scientists and engineers capable of using and maintaining these high-end systems to achieve the goals of 21st-century computational geoscience research. SIParCS supports NCAR's and CISL's core missions in education and directly contributes to CISL's strategic imperative to integrate research and education. CISL is teaching the mathematical and computational science concepts and skills that students will need to make effective use of advanced cyberinfrastructure.

The SIParCS class of 2013 brought 10 students from 8 different colleges and universities across the country to work on computational science and engineering projects. This photo shows the interns and their mentors, along with SIParCS Program Office staff.

The application process for the Summer 2013 SIParCS program ran from November 2012 to February 2013. A total of 55 students applied for 10 potential intern positions. The 11-week program began 20 May and ended 2 August, when each student gave a project presentation. The seventh annual SIParCS program included 10 students from eight U.S. colleges and universities, including two from Minority Serving Institutions and three from an EPSCoR state institution. Five of the 10 students were from underrepresented groups. Student research topics in 2013 covered diverse problems in applied mathematics, numerical algorithms, informatics science, software engineering, HPC system administration and computer science. Once again this year an engineering intern participated in the program and worked on a project at the NCAR-Wyoming Supercomputing Center (NWSC).

The 2013 SIParCS applicant-to-intern ratio was 5.5, indicating that the internship program continues to be competitive. Seven interns came from outside the Front Range region. Salary increases have increased the cost of the program relative to previous years, but maintained salary equity with the other internship programs within UCAR/NCAR/UCP. In response, the SIParCS program has aggressively sought partners to help fund positions. In 2013, of the 10 positions, seven were supported by CISL Core funds (including two by CISL Diversity funds and one partially by IMAGe base funds), one was partially funded by external partner University of Wyoming, one by an NSF special award and one by a DOE grant.

The ongoing development of the SIParCS program can be credited to CISL's comprehensive and aggressive outreach strategy. In addition to the program's already significant number of university

faculty points of contacts from across the country, the efforts of CISL's Diversity Coordinator have directly resulted in the addition of new MSI contacts and the participation of a student from one of these MSIs. The Diversity Coordinator's term contract has been extended with a continued goal of developing and supporting relationships with MSIs. With the current extensive network of contacts, these continued efforts will ensure the supply of high-quality and diverse applicants.

‹ Integrating research and education up IMAGe Theme Of the Year ›

IMAGE THEME OF THE YEAR

Dr. Melissa Lucash from Portland State University explains a point during her talk about evaluating climate change on Midwestern forests. The workshop included talks from scientists such as Dr. Lucash who depend on climate data products to focus discussion on statistical methods that meet the practical needs of climate science-related communities.

IMAGe's Theme Of the Year (TOY) is a series of activities that explores the opportunity to enrich both applied mathematics and the geosciences through a common scientific topic. TOY is designed to advance research and education between the mathematical and geosciences communities; it uses targeted projects for building interdisciplinary communities. The topics are selected by the IMAGe external advisory panel and coordinated by one or more visiting co-directors. The yearly TOY programs support CISL's education imperative to integrate research and education, sparking collaborations between the mathematics community and Earth System scientists. This year the theme was Climate Analytics; it was designed to give researchers a broad view of how data analysis and statistics are applied to observational and model output data in the geosciences.

The analysis and interpretation of observational geophysical data sets and model simulations are intrinsic to understanding the Earth's climate system. The term analytics is used here to reflect a growing science concerning "the discovery and communication of meaningful patterns in data." Although this field has its foundation in statistics, data mining, machine learning, and visualization, there is also an emphasis on the applicability to specific areas of science and engineering. For this work, climate analytics supports progress in modeling and predicting the Earth's climate system by uncovering complex and often-hidden structures and relationships in data. Offering insight into the sources and magnitudes and uncertainties as part of the variability in the data, climate analytics can provide powerful tools for tailoring data products to various needs.

The TOY co-directors for 2013 were Andrew Finley of Michigan State University and Caspar Ammann of NCAR's Research Applications Laboratory.

The capstone activity for this theme was the *Next Generation Data Products Workshop* held 15-19 July 2013. This workshop brought together members of the statistics, data science, and climate modeling communities to share ideas on improving the creation of data products. The workshop had 80 participants, and the format consisted of invited talks, a poster session, and several sessions for breakout discussion. Breakout group themes and reports are posted on the workshop website. This workshop created interest in a follow-on working group to evaluate and compare methods of data product construction for some common data sources.

Other elements of this theme included:

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- *The Second International Workshop on Climate Informatics*, 20-21 September 2012 supported an emerging community in machine learning and data mining for climate science.
- *Workshop on Massive Data sets in Environment and Climate*, 13-15 February 2013 was held in partnership with the NSF's Statistics and Applied Mathematical Sciences Institute.
- *Visualization on Climate Data*, 13-17 May 2013 was held in partnership with graduate educators and the NSF's Research Network named Statistics Methods for Atmospheric and Oceanic Sciences.
- Invited session at *International Meeting on Statistics and Climatology*, was held in Jeju, Korea on 24-28 June 2013. This conference is an important confluence for reporting research in the analysis of climate data.

Outreach activities of the Theme of the Year are supported by NSF Core funding.

‹ Summer Internships in Parallel Computational Science   up   Research and Supercomputing Visitor Program ›

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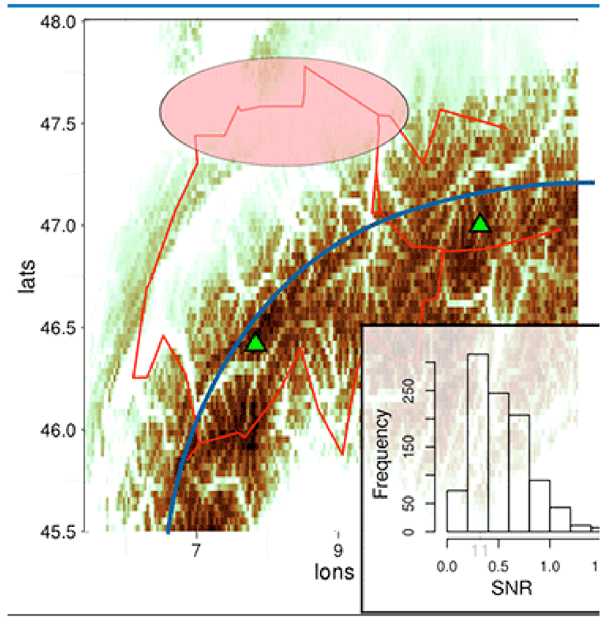
RESEARCH AND SUPERCOMPUTING VISITOR PROGRAM



A reassessment of several historical weather records in Europe (area marked with red ellipse) has shown that 1540 was by far the hottest and driest year in the last 500 years. However, tree ring records (green triangles) from south of (or close to) the alpine ridge (blue curve) show only a moderately warm year. In a collaboration between an RSVP-funded visitor and IMAGe staff, a Bayesian approach with a simple stochastic model for temperature and soil moisture in the northeastern and southwestern regions together with a deterministic model of tree ring growth was used to estimate the distribution of the likely signal-to-noise ratios (SNR, inset figure). These results show that the SNR of the tree ring data in this year is relatively low, which suggests that the seeming contradiction between these two datasets can be attributed to a limited temperature response of the trees: temperature stress typically limits tree growth. However, with sufficiently high temperatures, the trees reach a "complacent" regime, where growth no longer is temperature dependent. In contrast, this method does not support a hypothesized moisture limitation of growth response in that year.

The Research and Supercomputing Visitor Program (RSVP) is designed to bring university faculty, researchers, and students to NCAR to foster collaboration with CISL staff and to provide training opportunities for underrepresented groups. The program pays for travel and living expenses for stays of up to three months. These extended visits help establish stronger relationships that lead to long-term collaborations. For many visitors, this program represents a unique opportunity to interact with CISL and NCAR scientists and staff on topics ranging from high-performance computing and Earth System modeling to applied mathematics and statistics.

This program supports CISL's education imperatives of integrating research and education and broadening participation by being a key, integrative component of CISL's education, outreach, and training efforts.

RSVP has sponsored graduate students, junior faculty, senior faculty, and scientist visitors from around the U.S. and the world. Visitors in FY2013 focused on developing interactive tools for visualizing geophysical simulations with VAPOR, improved computer codes for representing atmospheric turbulence, improved data assimilation in the planetary boundary layer with DART/WRF, and simultaneous temperature and moisture reconstructions for paleoclimate research. The program also partially sponsored sabbatical stays for senior researchers in statistics, computational mathematics, turbulence, and data assimilation.

This program is made possible through NSF Core funding.

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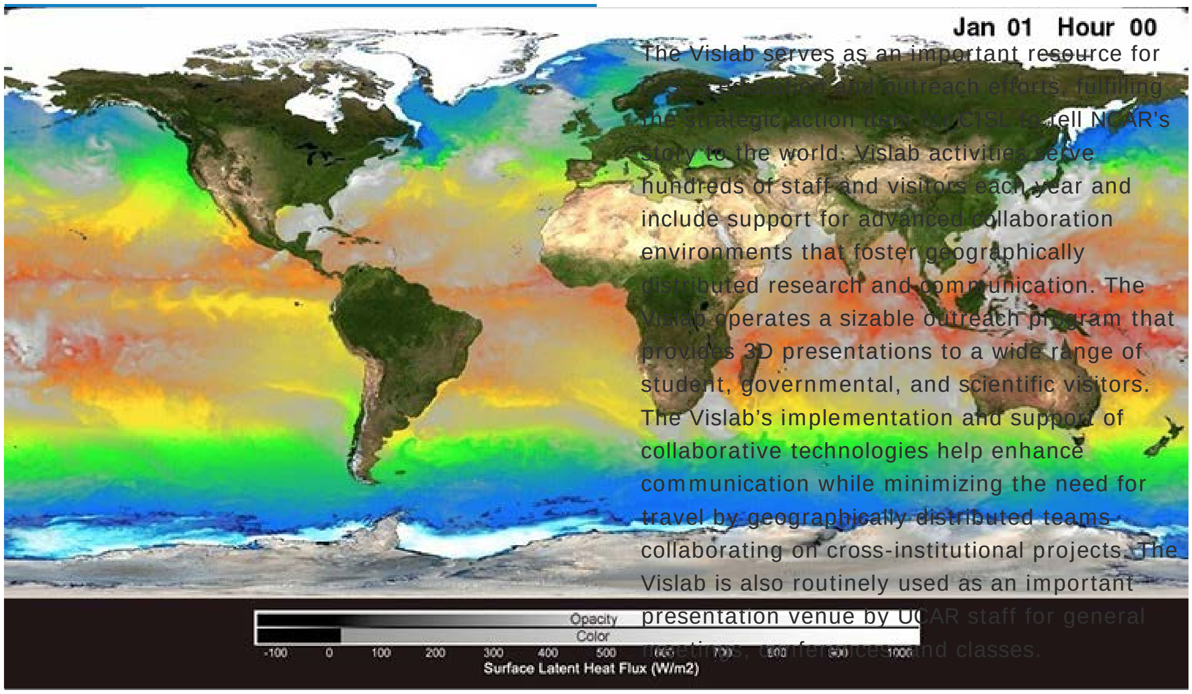
VISUALIZATION LABORATORY OUTREACH

CISL's Visualization and Enabling Technologies Section (VETS) operates the Vislab, a visual computing center that is used to conduct many of CISL's education, outreach, and collaboration efforts. The 1,000-square-foot facility supports video conferencing technologies, data analysis and visualization, and theater-style presentations in a widescreen, high-resolution, 3D format. The facility is equipped with a collaborative touch-screen interface, a high-definition 3D 1920×1080-resolution active stereo projector, and a 12×7-foot screen. This system displays imagery and presentation materials simultaneously from multiple sources including user laptops, digital media systems, and high-definition video conferencing platforms.



Vislab staff worked with CESM researchers to produce this snapshot showing latent heat flux (grayscale) overlaid on sea surface temperature generated from a CESM run on the Yellowstone supercomputer. An animation of this high-resolution run reveals Gulf Stream influences on cold-air outbreaks in the Northwest Atlantic and cold temperature wakes beneath tropical cyclones. These features are not well simulated by standard-resolution climate models.

The Vislab serves as an important resource for CISL's education and outreach efforts, fulfilling the strategic action item for CISL to tell NCAR's story to the world. Vislab activities serve hundreds of staff and visitors each year and include support for advanced collaboration environments that foster geographically distributed research and communication. The Vislab operates a sizable outreach program that provides 3D presentations to a wide range of student, governmental, and scientific visitors. The Vislab's implementation and support of collaborative technologies help enhance communication while minimizing the need for travel by geographically distributed teams collaborating on cross-institutional projects. The Vislab is also routinely used as an important presentation venue by UCAR staff for general meetings, conferences and classes.

The Vislab continued serving as a venue for demos to many high-level visitors and a meeting space for conferences and classes to help engage a broad and diverse community, increasing awareness and understanding of science, high-performance computing (HPC), and environmental issues. In collaboration with the UCAR Office of Government Affairs and UCAR's Science Education Program (SPARK), demos were provided to diverse visitors and groups including the Colorado Governor's Office, Chinese geoscientists, the NSF Division Director of Earth Sciences, Natural Resources Defense Council, and Nobel Prize Laureate Tom Cech, to name a few. The Vislab was also used by NBC, BBC, and the Weather Channel as an interview venue with NCAR staff.

In addition, HPC training classes addressing topics such as Fortran programming, Yellowstone supercomputer access, data analysis, and many others were offered through collaborations with the CISL

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Consulting Group and CISL's IMAGe division. In all, the Vislab supported approximately 100 meetings involving over 1,900 participants. Vislab staff continued to collaborate with Earth System science researchers from NCAR and the Southern California Earthquake Center to develop new and compelling visualizations including climate and earthquake simulations for Accelerated Scientific Discovery researchers.

The Vislab also continues to help CISL embrace green technologies and reduce its environmental footprint. Collaboration technologies for video, web, and telephone conferences were employed to support meetings and classes for approximately 200 remote users at NCAR Boulder campuses, NWSC, and other institutions around the country. Unplanned accomplishments this fiscal year include a collaboration with NIST technicians on a projector and display metrology project to help develop techniques for measuring immersive and 3D displays.

This project is supported by NSF Core funds.

‹ Research and Supercomputing Visitor Program | up | Geophysical Turbulence Program facilitating interdisciplinary studies ›

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GEOPHYSICAL TURBULENCE PROGRAM FACILITATING INTERDISCIPLINARY STUDIES

Research on turbulence has been a significant part of the NCAR scientific program since its beginning in the early 1960s. The original scientific leaders of NCAR recognized that to understand the dynamics of the atmosphere, the oceans, the climate, the sun, and solar-terrestrial interactions, understanding relevant turbulent processes would be essential. A number of scientific appointments in the first 10-15 years of NCAR's existence reflected this view and provided an in-house base from which to productively interact and collaborate with the world turbulence community. From these beginnings, a sustained emphasis on geophysical turbulence at NCAR has emerged in research, visitors, seminars, and workshops that continues to this day. Most of this emphasis manifests itself currently in the Geophysical Turbulence Program (GTP).

By design, GTP is an interdisciplinary group of about 40 members that spans many divisions and laboratories at NCAR with a few external affiliates. GTP encompasses research at NCAR on multiscale nonlinear processes with an array of applications in a broad variety of areas. GTP is also the outreach arm of this research. The broad goal of GTP is to promote research, education, and awareness of geophysical turbulence at NCAR and in the scientific community. The budget is used to bring visitors to NCAR to give seminars and interact with UCAR staff, on workshops, and, under special circumstances, for direct support of staff, in particular graduate students. GTP members meet as a group at least once annually to choose visitors to whom to offer support, and to select and develop workshop topics. Members also provide input to NCAR's Advanced Study Program on selection of Postdoctoral Fellows who have turbulence interests.

A highlight activity for this period is the sponsored workshop

Large-Eddy Simulations of Magneto-hydrodynamic turbulence May 20-23, 2013

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

CAPTION PLACEHOLDER

Large Eddy Simulations (LES) provide a means to model turbulent flows in extreme parameter regimes that are inaccessible to Direct Numerical Simulation (DNS). However, LES require some strategy to deal with the sub-grid scale (SGS) motions that cannot be explicitly resolved. This workshop explored combined LES/SGS modeling strategies for turbulent MHD flows in geophysical, heliophysical, and astrophysical applications.

GTP activities are mainly supported by NSF Core funding. Some of the collaborations with the university community also receive funds from NSF and can be co-sponsored by NCAR funds from its laboratories and programs.

‹ Visualization Laboratory outreach up Workforce training and development ›

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WORKFORCE TRAINING AND DEVELOPMENT

CISL has been preparing for the petascale computing era by training young researchers in the atmospheric and related sciences to effectively use high-performance cyberinfrastructure. CISL delivers educational content synchronously through workshops and training classes, and asynchronously through Internet-based content.

CISL's education imperative for workforce training and development is supported primarily by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

‹ Geophysical Turbulence Program facilitating interdisciplinary studies | up | Training users and interns in computing at NCAR ›

TRAINING USERS AND INTERNS IN COMPUTING AT NCAR

Dan Nagle, a consultant in CISL's Consulting Services Group (CSG), presented Fortran training classes during FY2013. CISL instructors provide a range of HPC training courses for users and interns.

CISL has been preparing for the petascale computing era by training young researchers to answer questions in the atmospheric and related sciences using high-performance cyberinfrastructure. CISL delivers educational content synchronously through workshops and training classes, and asynchronously through Internet-based content.

CISL instructors provided nine training classes in high-performance computing to approximately 350 local and national HPC users. Five CSG instructors presented the following courses in FY2013: Introduction to Yellowstone, Fortran 90, Parallel programming (with MPI and OpenMP), NCL, Version control, Python, and Preprocessing Fortran source with CoCo. In addition to the regular curriculum, CSG also coordinated the 2013 UCAR Software Engineering Assembly conference, which included two days of talks on scalable HPC profilers and optimization tools (Intel Trace Analyzer, Open/SpeedShop, TAU, VAMPIR, Scalasca, Eclipse, and GPU optimization). CSG staff also supported NCAR user training that is delivered by others: Weather Research and Forecasting (WRF) model workshops, Community Earth System Model (CESM) workshops, and the RAL-taught Gridpoint Statistical Interpolation (GSI) Data Assimilation System Community Tutorial.

CISL also leveraged its participation in the national XSEDE cyberinfrastructure to expand the training opportunities available to users by cross-posting XSEDE courses via CISL's website and Daily Bulletin.

CISL's education imperative for workforce training and development is supported primarily by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

‹ Workforce training and development up Training in geoscientific tools ›

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TRAINING IN GEOSCIENTIFIC TOOLS

Staff in CISL/TDD and NESL/CGD have collaborated for 13 years to provide a series of training workshops for the NCAR Command Language (NCL) – a free, interpreted language designed specifically for geoscientific data analysis and visualization. To date, a total of 68 workshops have been taught to 1,041 students at universities and research centers worldwide. Seven workshops were taught in FY2013 to 126 students. The NCL workshops are 3-1/2 days in length with morning lectures and intensive hands-on labs in the afternoons. Similarly, the VAPOR team has been offering tutorials on interactive 3D visualization and analysis with CISL's VAPOR package. VAPOR tutorials were held in FY2013 at AGU, EGU, the Korean Supercomputing Conference, and the annual WRF meeting held in Boulder.

In summer 2013, Guilherme Martins, a doctoral student in the Graduate Program in Earth System Science (CST) of the National Institute for Space Research (INPE) taught the two first-ever NCL workshops in Brazil, at the Universidade Federal do Rio Grande do Norte and Centro de Previsão de Tempo e Estudos Climáticos. The workshops were comprised of masters and Ph.D. students in meteorology.

The NCL and VAPOR hands-on labs are targeted toward students' specific needs by encouraging students to use their own datasets for analysis and visualization rather than canned datasets and examples. The instructors work with students individually during the labs, and by the end of the workshop most students have developed nearly complete NCL programs or VAPOR "sessions" that produce meaningful results from their data.

A core NCAR value is partnership with the university community. We proactively reach out to U.S. university students by offering at least one fully or partially funded NCL workshop at a U.S. university each year, and by covering all travel expenses for qualified students from EPSCoR universities and minority-serving institutions (MSIs) to attend workshops. (EPSCoR universities are located in states that are deemed to be underserved by federal research and education funding. The goal of the Experimental Program to Stimulate Competitive Research – EPSCoR – is to balance national research and education support by strengthening it in these states.)

In FY2013, we offered three U.S. university NCL workshops: one fully funded one at the University of Alaska at Fairbanks (an EPSCoR state), one fully funded one at the University at

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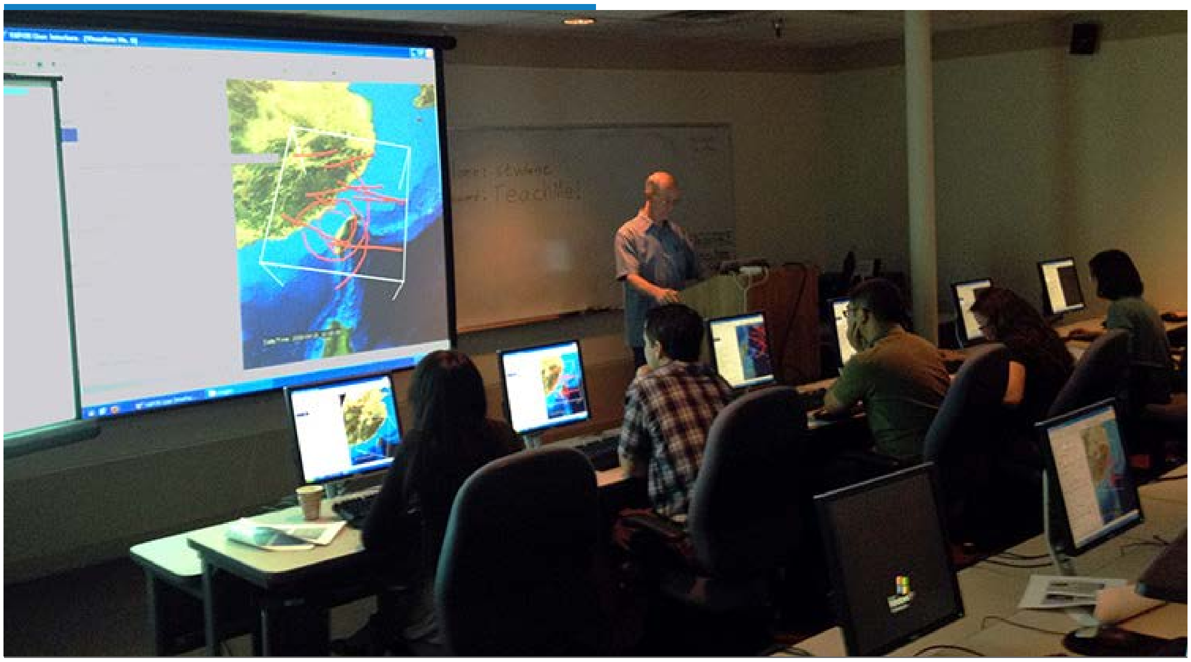
Albany – SUNY and one partially funded workshop at Harvard University. We provided full funding for five EPSCoR/MSI students to attend workshops in Boulder, Colorado in January and June 2013.

These workshops advance CISL's strategic education imperative to provide workforce training and development. The Korean Supercomputing Conference VAPOR tutorial was funded by the Korea Institute for Science and Information Technology. All other VAPOR tutorials and the NCL workshops were funded with core CISL funds.

Participants attending the May 2013 NCL workshop at the University at Albany – SUNY included students from Albany and North Carolina A&T State University, faculty members, and technical support staff.



In June 2013, approximately 40 students attended a hands-on, two-hour VAPOR tutorial held at the 14th Annual WRF User's Workshop in Boulder, Colorado.

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SUPPORT FOR COMMUNITY WORKSHOPS, TUTORIALS, AND SUMMER SCHOOLS

The 2013 conference Programming Weather, Climate, and Earth System Models on Heterogeneous Multi-core Platforms was held on 19-20 September 2013 at NCAR in Boulder, Colorado. The conference was attended by leading experts in the use of accelerator coprocessors in atmospheric and related science from as far away as India, China, and Switzerland, and included representatives from industry, academia, and national laboratories.

The third annual Programming Weather, Climate, and Earth System Models on Heterogeneous Multi-core Platforms was attended by 40 experts in the use of multi-core platforms in atmospheric and related modeling.

The purpose of the workshop was to provide a forum for open discussion to better understand the programming models and strategies that will be needed to effectively use the new generation of weather, climate, and Earth System models on such platforms. The workshop was by invitation only, and the format was designed to allow the participants to present and discuss their most recent findings in an informal and open format at an advanced technical level. The workshop's primary goals were to:

- Provide a forum to present experiences and lessons learned from porting and tuning weather and climate models on these platforms.
- Create a community of developers that can work together to develop the software standards needed for these platforms.
- Exchange information about programming techniques, code parallelization and optimization and I/O strategies on these platforms.
- Provide input to standards committees on what the community would like to see in programming models for weather/climate applications.

Organizers of this third-annual conference were: Ilene Carpenter (NREL), Mark Govett (ESRL), Chris Kerr (GFDL), Rich Loft (NCAR), Bill Putman (GSFC), and William Sawyer (CSCS).

‹ Training in geoscientific tools up Outreach activities ›

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OUTREACH ACTIVITIES

Outreach is a gateway activity: it is the conduit through which other goals are reached. Examples include integrating education and research, broadening participation, and workforce development. Enhancing these activities offers opportunities to better connect with our user community, students, and future employees at all levels. In general, the goals for enhancing our outreach programs include:

- Reach a larger and broader audience.
- Develop our message to be more impactful and compelling.
- Communicate our accomplishments and the benefits of working in CISL more effectively.

CISL's outreach program supports CISL's education imperative for outreach: to actively attract qualified candidates, particularly those from diverse backgrounds. This work fulfills CISL's strategic action item to expand outreach activities at conferences that enable CISL to effectively interact with our user community, students, and potential employees. Conference outreach also contributes to CISL's educational imperatives for workforce training and development, and for broadening participation. These efforts are supported by NSF Core funds, with supplemental funding supplied by other sources as appropriate.

‹ Support for community workshops, tutorials, and summer schools   up   NWSC visitor center exhibits ›

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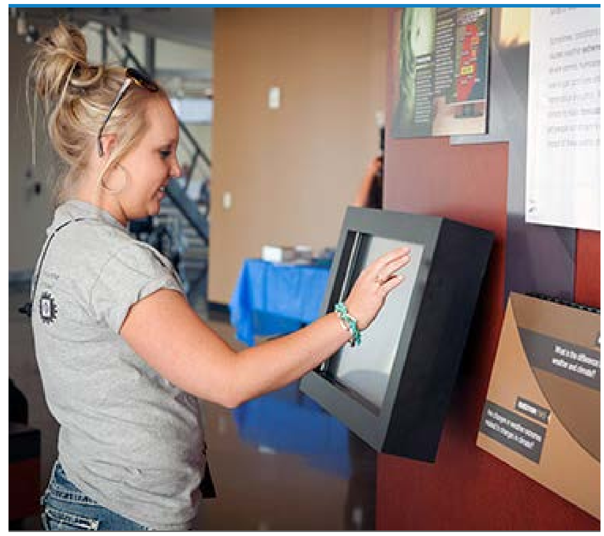
NWSC VISITOR CENTER EXHIBITS

A key goal of the NWSC facility project was to broaden its impact through an active public visitor program. The primary element of that program was a planned NWSC Visitor Exhibit to explain the science goals of NCAR and the University of Wyoming, as well as the technology employed at the NWSC to realize these goals. The NCAR-Wyoming partnership's NWSC education and outreach strategic goals are derived from an understanding of the national and regional challenges of STEM education and are designed to leverage the unique strengths of the founding NWSC partners. In October 2012, the NWSC opened its doors to the public, and inaugurated its Educational Visitor Center.



A high school student explores one of the interactive exhibits at the NWSC. The exhibits incorporate video stories, interactive games, rich imagery and general information on science and supercomputing topics, allowing visitors to explore how NCAR's mission benefits individuals and society.

CISL OSG staff, in collaboration with advisors from UCAR Spark, the University of Wyoming (UW), and the Laramie County Public Library, worked to create a visitor experience at the NWSC that would engage and educate audiences of all ages and backgrounds in NCAR's and UW's science, the facility's state-of-the-art green design, and the capabilities of the supercomputers it houses. The educational goal of the exhibit was to explain how the NWSC's research and science mission benefit people and society, while providing the visitor a fun and memorable experience.

In total, the content developed included 16 professionally produced video segments, two short animated films, two touchscreen interactive games, two kinesthetic interactive elements, multiple Q&A displays, and science and technical content and accompanying vivid "story-telling" imagery for the six focus-area themes.

The NWSC visitor center has exceeded initial estimates for community interest, total visitors, organized group tours, and school group visits. Since opening in October 2012, the visitor center has hosted nearly 3,000 visitors, roughly equivalent to 5% of the population of Cheyenne, Wyoming, where the NWSC is located. Since January 2013, when school groups first began visiting, visits have averaged 2-3 school groups per month in sizes ranging from 12 to 226. In addition, the center has received 33 non-school groups. Currently, relatively few American students pursue studies in the fields of science, technology, engineering, and mathematics (STEM), and STEM education for both students and teachers has become a national priority. The NWSC exhibit has served as the nexus for STEM events tackling this problem including:

- In July 2013, 192 Wyoming middle school and high school students invaded the NWSC to learn about science and supercomputing as part of the University of Wyoming's GEAR UP program. (Wyoming's Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) program is a federally funded program that prepares 2,000 7th–12th grade students each year to

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enter and succeed in postsecondary education.)

- Forty-two young people from the Wyoming Cowboy ChalleNGe Academy for at-risk youths, age 16-18.
- The NWSC traveling display has been used in events such as the NSF-sponsored "CHANGE THE WORLD: Science & Engineering Careers Fair" held in Virginia in September 2013.

In short, the NWSC Visitor Center has yielded rich opportunities for outreach and education about NCAR science, scientific computing, mathematics, and engineering. The STEM disciplines come to life at the NWSC, where visitors can explore interdisciplinary yet related topics like extreme weather, climate change, energy, water resources, supercomputing, facility design, energy efficient technologies, and human health.

The NWSC Visitor Center is intended for self-guided tours for individuals and groups of all ages and backgrounds, and it can also be used for presentations and special events. The visitor center consists of a theater for watching a video overview; two science displays, each with a different science focus area on each side; a young scientist display that includes a tornado simulator and an interactive computer speed demonstration; and a supercomputer display at which visitors can see inside the supercomputer and interact with an exhibit that connects the concepts of electrical power with computing power through a hand-crank "generator." A key educational goal of the visitor center was to include content that would convey elements of computational thinking. These include interactive activities that explain the concept of speedup in parallel computing and identify other kinds of parallel systems in everyday life. To engage diverse audiences, the videos in the exhibits also include Spanish language subtitles.

The NWSC Visitor Center was financed using NSF NWSC construction funds.

‹ Outreach activities up NWSC education and outreach ›

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NWSC EDUCATION AND OUTREACH

The Wyoming-NCAR partnership's NWSC education and outreach strategic goals are derived from an understanding of the national and regional challenges of STEM education and are designed to leverage the unique strengths of the founding NWSC partners. NWSC's high-level strategic EOT goals are to:

- Integrate university research with K-16 education.
- Build cyberinfrastructure and computational science capacity in Wyoming, regional EPSCoR states, and Front Range institutions.
- Train the next generation of computational scientists.
- Complement and enhance programs at community colleges to prepare students for careers in related technical fields.
- Broaden participation, by enhancing the capabilities of community colleges to train students in technical fields that better prepare them for careers in HPC-related technical fields.
- Broaden diversity by engaging minority-serving institutions, particularly regional Tribal Colleges and Historically Black Colleges and Universities.
- Build strong foundations and foster innovation to improve K-12 computational thinking, mathematics, and computational geosciences.
- Engage and inform the public about NWSC science through informal education.

A group of University of Wyoming Camp GEAR UP students listen to UCAR Spark's Marc Mueller describing elements of the NWSC and the Yellowstone supercomputer. During the summer of 2013, over 200 GEAR UP students engaged in activities relating to computing and science at the facility. GEAR UP, which stands for Gaining Early Awareness and Readiness for Undergraduate Programs, is a federally funded initiative that prepares 2,000 7th–12th grade students each year to enter and succeed in postsecondary education.

In FY2013, CISL's Outreach Services Group collaborated with the University of Wyoming and UCAR's SPARK (Education and Outreach) to materially advance each of these goals. Specifically, CISL's Outreach Services Group supported K-12 STEM enrichment by participating in the Wyoming State Science Fair for the third consecutive year. This summer also marked a first for the NCAR-Wyoming Supercomputing Center (NWSC). The center, which regularly hosts the public and local school groups to engage in self-guided tours of the Visitor Center, collaborated with SPARK staff to deliver tailor-made, hands-on, and immersive atmospheric science-related summer STEM education experiences for the *Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) Wyoming* and *Wyoming Cowboy Challenge Academy* groups.

On 9–11 July 2013, almost 200 GEAR UP students, in groups of 62 to 64 were exposed to activities and information that helped them understand interactions within complex systems as they relate to science, supercomputing, engineering, and communications. GEAR UP is a federally funded, statewide grant in Wyoming that reaches up to 2,000 students each year. Its goal is to prepare them to enter and succeed in post-secondary education through academic support and tutoring, mentoring, leadership development, career

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exploration, and educational field trips. The educational outreach program, part of the NWSC partnership, is designed to expose income-eligible students in mostly rural Wyoming areas to atmospheric and computational science, and potential career opportunities in those fields. Educational initiatives like GEAR UP are critical to training or nation's future workforce, increasing the number of eligible students who are prepared to enter and succeed in post-secondary education. Later that month, the Outreach Diversity Coordinator and NWSC staff hosted about 50 students from the Wyoming Cowboy ChalleNGe Academy (WCCA). WCCA is a National Guard-sponsored two-phase voluntary paramilitary program geared toward at-risk youth who have not graduated from high school or earned a GED. The mission of the WCCA is to provide a safe, disciplined and professional learning environment for at-risk 16–18 year-olds, graduating cadets with the values, life skills, education, and employment potential to be responsible and productive citizens.

In addition to these events, many Wyoming high school, middle school, 4H, and community college groups made valuable connections with Wyoming Community College Educators at the Wyoming Math Articulation Meeting in Rock Springs Wyoming.

‹ NWSC visitor center exhibits up Outreach at regional, national, and international levels ›

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OUTREACH AT REGIONAL, NATIONAL, AND INTERNATIONAL LEVELS

Since 1989, CISL has deployed a series of exhibit booths for a variety of scientific and technical conferences. In these booths, CISL staff demonstrates supercomputing capabilities, scientific visualization, and NCAR research in science, computational science, computing technology, and applied mathematics and statistics for the geosciences. CISL also invites NCAR scientists to present their current findings in the CISL exhibit booth. At the height of its conference outreach program, CISL staff provided demonstrations and presentations at many conferences each year, including Supercomputing, the American Meteorological Society, the American Geophysical Union, and others. In recent years, CISL has focused its energy and resources on providing NCAR outreach at the annual Supercomputing and XSEDE conferences and on local Visualization Laboratory presentations and outreach activities. CISL also hosts and provides planning and logistics support for mission-appropriate conferences and workshops.

CISL's outreach activities at SC12 in Salt Lake City, Utah included science and technology presentations in the exhibit booth. CISL invited NCAR scientists to give daily science talks in the exhibit booth.Also at SC12, CISL staffed a table at the Supercomputing Student Job Fair with computational scientists and the coordinator of SIParCS, CISL's internship program. They provided young people interested in careers in computational science and engineering with information about SIParCS and CISL's employment opportunities.

As part of its diversity program, CISL conducts outreach in mission-appropriate diversity-oriented venues. CISL staff described NCAR research careers, encouraged faculty members to nominate students for NCAR programs, and distributed printed information about internship opportunities and professional development programs including SOARS and SIParCS.

UCAR staff also distributes materials about CISL programs at diversity-oriented conferences such as the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS). CISL does outreach through site visits and presentations to universities and tribal colleges as a key strategic element of our recruiting activities. CISL also distributes information at the Supercomputing Student Job Fair and at conferences such as Supercomputing, AMS, and AGU.

CISL supported the March 2012 Wyoming State Science Fair at the University of Wyoming in Laramie. CISL and UCAR Spark supplied two volunteers as judges, presented four awards for top junior and senior computational and Earth System science projects, presented atmospheric science demonstrations, and exhibited information about the NWSC facility in Cheyenne. CISL's outreach efforts are part of the NWSC partnership with the State, University, and business community of Wyoming. CISL encourages students to embark on careers in computational science and engineering, and our efforts at this venue demonstrate our long-term commitments to outreach, workforce development, and broadening participation in the sciences.

CISL's Outreach Group developed and maintains the public visitor area at NWSC. This NWSC education exhibit informs K-12 students and the public how high performance computing supports and advances scientific research and discoveries. CISL collaborates in this effort with staff at the University of Wyoming, the Laramie County Library System, and UCAR Education and Outreach. The NWSC Education and Outreach Strategic Plan, which was written in a collaboration between directors of CISL and the University of Wyoming, calls for NWSC education efforts to support diversity and in particular to serve tribal colleges and community colleges throughout the intermountain west.

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CISL has provided mentors for UCAR's Significant Opportunities in Atmospheric Research and Science (SOARS) program for 17 years, every year since its inception. CISL's SIParCS program collaborates with SOARS in outreach activities, and has established a reciprocal arrangement for referring candidates between the programs.

CISL's outreach program supports CISL's education imperative for outreach: to actively attract qualified candidates, particularly those from diverse backgrounds. This work fulfills CISL's strategic action item to expand outreach activities at conferences that enable CISL to effectively interact with our user community, students, and potential employees. Conference outreach also contributes to CISL's educational imperatives for workforce training and development, and for broadening participation. These efforts are supported by NSF Core funds, with supplemental funding supplied by other sources as appropriate.

‹ NWSC education and outreach up Broader Impacts ›

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BROADER IMPACTS

CISL engages in a spectrum of activities designed to broaden the laboratory's impact through outreach, collaboration, and community engagement, and through capacity building at regional, national, and international scales. These activities have two main thrusts. First, CISL does outreach and provides training and education opportunities aimed at broadening participation and encouraging the development of the trained and diverse workforce necessary to continue advancing the scientific use of high performance computing resources. Second, CISL encourages collaboration and exchanges of information and expertise for developing shared cyberinfrastructure and standards that will advance high-performance computing, not only in the atmospheric and related sciences, but also in the general HPC community.

Clear examples of how CISL's education efforts broaden the laboratory's impact on the U.S. STEM workforce arise yearly from CISL's internship program SIParCS. Numerous interns have redirected their career plans in response to their positive research experiences in CISL. Students have come to IMAGe for a specific project, then returned as postdocs, taken jobs as university faculty, then sent their students here. This process keeps refreshing our workforce with new talent, it reinvigorates others at the universities, and it is a healthy model for a national center.

This work is supported by NSF Core funding.

‹ Outreach at regional, national, and international levels | up | Diversity-focused activities ›

DIVERSITY-FOCUSED ACTIVITIES

CISL Outreach Services Group participated in the 2013 Association of Computer and Information Science/Engineering Departments at Minority Institutions (ADMI) Conference in Virginia Beach, Virginia. ADMI is a national organization dedicated to exploring and providing remedies to the educational issues in computer/information science and computer engineering that confront minority institutions of higher education.

CISL supports multiple thrust areas to enhance staff diversity in the laboratory and at NCAR. The mission of CISL's Outreach Services Group (OSG) is to integrate education and research, broaden participation in Earth System sciences, and develop the future STEM workforce. OSG focuses on communication methods to connect the work of scientists and engineers with the research community, funding agencies, and the general public. This effort is sustained at local, regional, national, and international levels.

In FY2013, CISL continued developing outreach strategies to enrich computational science, mathematics, and statistics projects by aggressively building a collaborative network for expanding participation by underrepresented groups. CISL's Diversity Coordinator has been aggressively developing this network, systematically enhancing CISL's and NCAR's diversity, education, and engagement efforts. CISL continues to encourage diversity by lowering access barriers to training for students and staff from U.S. minority-serving and EPSCOR-state institutions. (EPSCoR universities are located in states that are deemed to be underserved by federal research and education funding. The goal of the Experimental Program to Stimulate Competitive Research – EPSCoR – is to balance national research and education support by strengthening it in these states.)

This is accomplished through the Research and Supercomputing Visitor Program (RSVP) which provides direct support for attendance by students and professors from Minority Serving Institutions (MSIs). This work supported 10 attendees at the Software Engineering Assembly's Annual Conference and Scalable Profiler Workshop held at NCAR in April 2013 and four attendees at the Front Range Consortium for Research Computing's Annual HPC Symposium held at Laramie, Wyoming in August 2013. Also through RSVP, CISL supported attendance by students from MSIs and EPSCoR-state institutions at the NCL Data Analysis and Visualization Workshops.

OSG staff also did face-to-face outreach and training by participating in the Association of Computer and Information Science and Engineering Departments at Minority Institutions (ADMI) symposium held at Virginia Beach, Virginia in April 2013. ADMI draws students from eight Historically Black Colleges and Universities, and it is devoted to computing issues relevant to minority students, education, and institutions.

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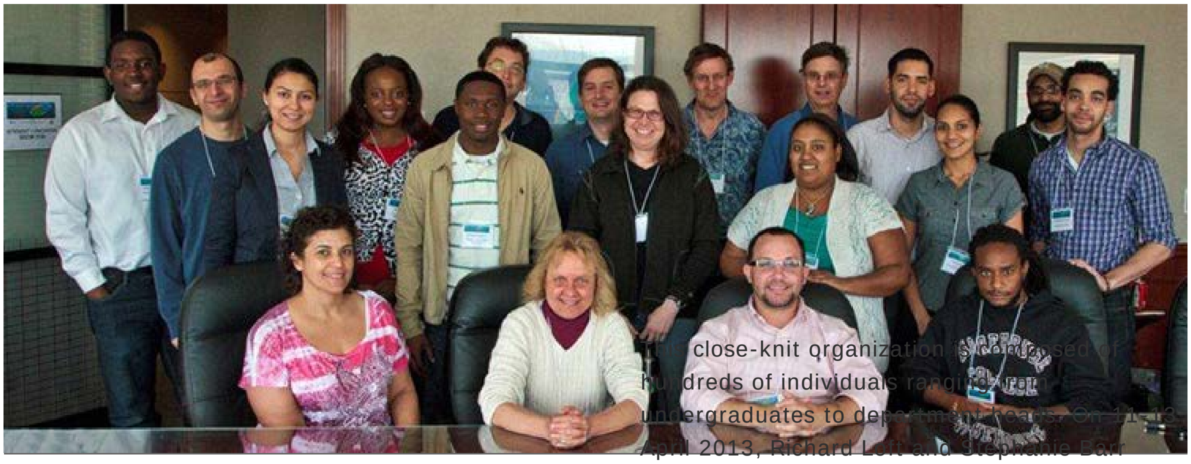


CISL sponsors with RSVP-funded students at NCAR's April 2013 Software Engineering Assembly annual technical conference.

This close-knit organization is composed of hundreds of individuals ranging from undergraduates to department heads. On 11-13 April 2013, Richard Loft and Stephanie Barr attended the ADMI Annual Symposium in Virginia Beach, Virginia as presenters, exhibitors, and student poster session judges. During this event, several key connections were made between NCAR/CISL and students, faculty and staff representing more than 10 different MSIs, including a connection between Elizabeth City State University and UCAR-member Howard University. Thanks to ADMI funding and cross-organizational ties in diversity institutional and scientific communities, CISL anticipates these connections will be leveraged and/or carefully sustained by CISL Outreach and its Diversity Coordinator to meet expected outcomes. In fact, several students with ties to ADMI's Morehouse College faculty have been offered support to UCAR and NCAR-hosted conferences and events. Additionally, some of the faculty relationships formed will be used to select committee members for our FY2013 Diversity Committee Proposal, and will serve as partners or co-sponsors for our FY2014 proposal, if it is awarded.

Students introduce themselves at a luncheon with their CISL sponsors at the SEA conference.

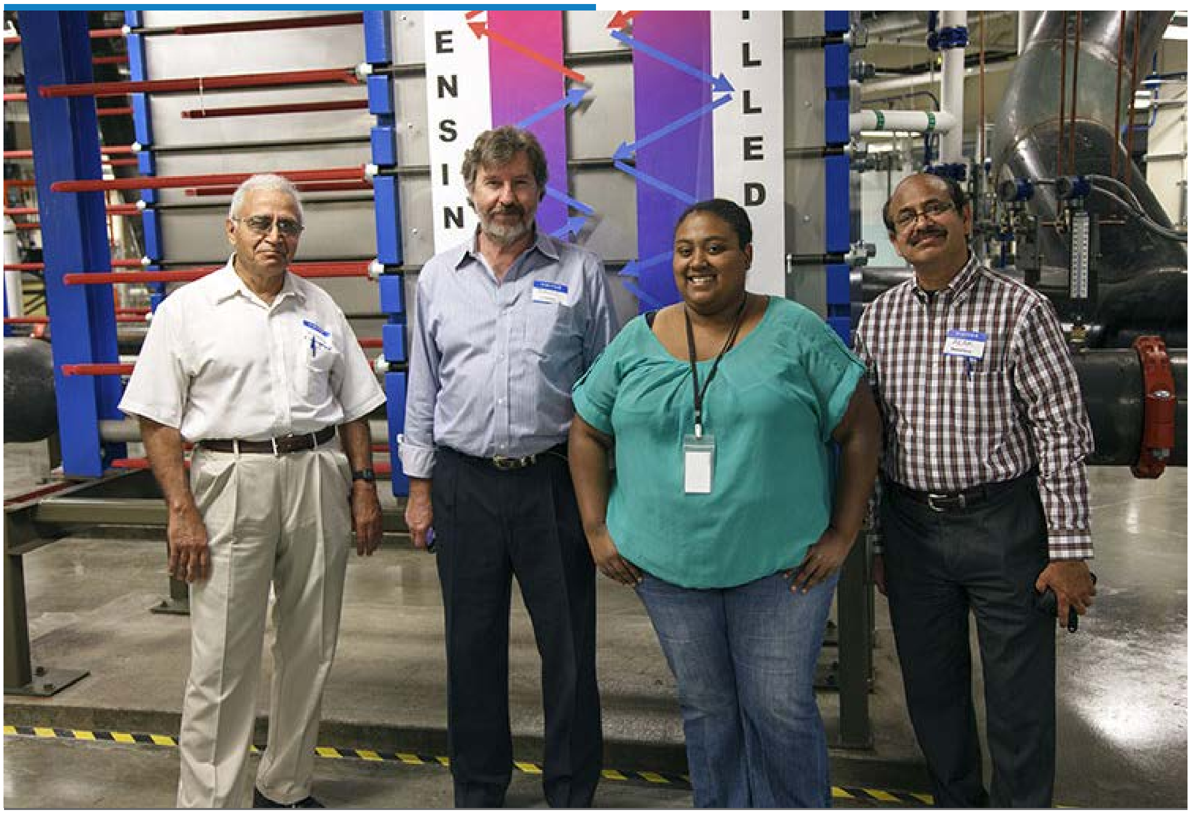
CISL's Outreach Diversity Coordinator has a key role in advertising funding opportunities through CISL's Research and Supercomputing Visitor Program (RSVP) that allow students, staff, and faculty to attend conferences and training events. The Software Engineering Assembly (SEA) conference and Scalable Profiler Workshop held 1-5 April was an annual technical conference organized by the UCAR Software Engineering Assembly (SEA) at NCAR's Center Green campus. Interested students at qualifying MSIs and EPSCoR-state universities were recruited using email, phone, social media, and word of mouth, with scholarships paying travel expenses and registration. Using new connections made in recent months, 10 students from four institutions were successfully recruited. The meeting offered hands-on computing tutorials and opportunities for students to meet and make connections with professionals in attendance. In addition, the Diversity Coordinator coordinated and co-facilitated participation by students in internship opportunities and an informal lunch with NCAR scientists and engineers.

Similar success was achieved when the Diversity Coordinator recruited four computational science faculty members from Hampton University, Salish Kootenai College, and Alabama A&M University to attend the August 2013 Front Range Consortium for Research Computing HPC

Symposium in Laramie, Wyoming. The participation of these RSVP-funded faculty served to solidify our standing and relationships with tribal colleges and MSIs, which has resulted in letters of collaboration and support from two of these universities on CISL's FY 2014 proposal.

This work is funded as specified in the following individual reports.

SEA conference participants attending the tutorial "Eclipse: a Unified Environment for the Development and Performance Tuning of Parallel Scientific Applications" presented by Jay Alameda (NCSA/University of Illinois, pointing to screen) and Wyatt Spear (University of Oregon, standing) on the NCAR campus in Boulder, Colorado.



Three of the four computational science faculty members and the CISL Diversity Coordinator attending the NWSC tour during the August 2013 Front Range Consortium for Research Computing HPC Symposium in Wyoming.

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OUTREACH

CISL conducts outreach by integrating education and research, broadening participation in Earth System sciences, and developing the future STEM workforce. (STEM stands for Science, Technology, Engineering, and Mathematics, and the National Science Foundation funds a variety of education efforts for these disciplines.) Enhancing these activities offers opportunities to better connect with our user community, students, and future employees at all levels. This year, CISL outreach goals centered on strategies to increase reach, impact, and clarity of mutually beneficial endeavors for targeted populations including, but not limited to:

Three of the four NCAR-Tapia Scholars at the 2013 Richard Tapia Celebration of Diversity in Computing Conference after lunch with CISL's Diversity Coordinator. From left to right: Tom Murphy (Contra Costa Community College), Paul Delgado (University of Texas at El Paso), Stephanie Barr (CISL), and Geri Gamble (Santa Clara University); not shown is Eduardo Sanchez (San Diego State University). CISL sponsored these four participants' attendance to both promote internships at NCAR/UCAR and to initiate or strengthen existing external partnerships that enhance the diversity of CISL's workforce.

- Higher education institutions serving large sections of minority students historically underrepresented in STEM fields.
- EPSCoR regions.
- Students in community colleges and two-year colleges.
- Non-traditional students.
- Faculty and students dedicated to pursuing research in enhancing K-12 education. (Engagement with the K-12 community is a key element of the NWSC EOT partnership and strategic plan.)
- The general public.

Engagement through Conferences, Job-Fairs, and Campus Visits

CISL continued its outreach activities at the ACM/IEEE supercomputing conference SC12 held 10-16 November 2012 in Salt Lake City, Utah. They included panel presentations in CISL's exhibit booth, disseminating information to participants, and a CISL-staffed table at the SC12 Student Job Fair to provide information about the SIParCS internship program and other employment opportunities at NCAR for young people interested in careers in computational science and engineering. CISL staff also focused on augmenting communication and interaction with fellow exhibitors who have complementary outreach, education, and diversity goals.

In early February 2013, the CISL Diversity Coordinator attended the Richard Tapia Celebration of Diversity in Computing Conference held in Washington D.C. CISL has been an active supporter, exhibitor, and attendee of this conference for many years. This trip included several inclusion, diversity, education, and engagement-related activities such as attending conference workshops, plenaries, and other sessions (birds of a feather sessions, the NCAR/UCAR opportunity exhibition, and the NCAR-Tapia Scholars Luncheon). Each of these activities served as a means to both promote internship opportunities at NCAR/UCAR and as an opportunity to initiate or strengthen existing external partnerships with students and faculty who attend the conference. This year, CISL also sponsored attendance by four participants:

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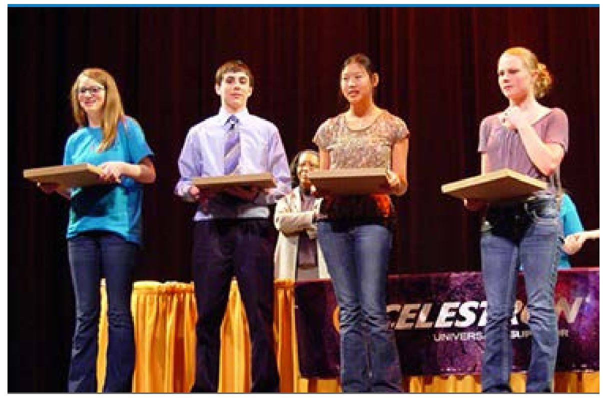
Paul Delgado (University of Texas at El Paso), Geri Gamble (Santa Clara University), Tom Murphy (Contra Costa Community College), and Eduardo Sanchez (San Diego State University). The connections made at this conference strengthened our ties to community colleges, non-traditional student communities, Navajo Technical College, the Universities of Puerto Rico at Arecibo and Turabo, and CSinParallel (Parallel Computing in the Computer Science Curriculum supported by an NSF grant for Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics.

CISL engages in numerous activities to foster education and outreach collaborations with the state of Wyoming, including at the University of Wyoming, Wyoming Community Colleges, and Wyoming EPSCoR programs. These include working with the Strategic Diversity Initiatives Committee (SDIC) to recruit and create mutually beneficial partnerships between MSIs, HBCUs, NCAR, and the University of Wyoming (UW). CISL also supports the Wyoming State Science Fair held each year at UW.



CISL partnered with the University of Wyoming (UW) to recognize outstanding young scientists at the Wyoming State Science Fair in Laramie on 4-5 March 2013. The winners of the 2013 NCAR-UW awards at the Wyoming State Science Fair are, from left, Sierra Nicole Spears, Ryan Sylvester, Jingyu Li, and Taylor Brown. CISL provided judges for the science fair and staffed an information exhibit at the reception between the fair and the awards ceremony. Each year, CISL and UW present special awards in Geoscience and in Computer Science and Mathematics.

Rationale and funding

Conference outreach also contributes to CISL's educational imperatives for workforce training and development, and for broadening participation. These efforts are supported by CISL Core funds, with supplemental funding supplied by other sources as appropriate. The Diversity Coordinator position is funded 25% by the University of Wyoming, 25% by NCAR Directorate Core funds, and 50% by CISL Core funds.

‹ Diversity-focused activities up Education ›

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EDUCATION

CISL is committed to NCAR's core education mission, offering opportunities for students and recent graduates to hone their skills in mathematical and computational science concepts. CISL also works to foster their professional development in fields that rely on advanced cyberinfrastructure. CISL maintains its ongoing dedication to attracting and retaining a diverse and talented staff that will meet supercomputing and computational science needs in the decades to come. CISL has also utilized the Diversity Coordinator position to support its transformative vision of creating a Diversity Education and Engagement Laboratory in the computational geosciences. This vision has several focal points, one of which emphasizes building a collaborative network to increase student and educator awareness and participation. Another is to support and develop educational tools centered on NCAR's traditional atmospheric science disciplines in addition to the computational sciences, mathematics, and statistics.

Fabrice Mizero gives his 2013 SIParCS presentation, "Evaluating the Impact of Infiniband Routing Algorithms on Network Performance."

2013 SIParCS Internship Highlight

On 25-26 September 2012, a little over a month after her arrival, CISL Diversity Coordinator Stephanie Barr visited Philander Smith College as part of an extended tour across three EPSCoR states: Alabama, Arkansas, and Mississippi. Over the course of 10 days, Stephanie engaged in a variety of activities focused on inclusion, diversity, education, and engagement such as presentations for local students from Minority-Serving Institutions (MSIs), meetings with potential collaborators including administrative personnel and faculty, and attending institution-hosted events. Located in Arkansas, Philander is a private four-year undergraduate liberal arts MSI affiliated with the United Methodist church and a founding member of the United Negro College Fund. The visit to Philander Smith was hosted by the school's student chapter of the National Institute of Science and served as a means of both promoting upcoming internships and an opportunity to initiate or strengthen existing external partnerships.

After Ms. Barr's visit, Fabrice Mizero, a rising junior and computer science major at Philander researched the Summer Internship in Parallel Computational Science (SIParCS) program and decided to apply. He said that he believed this opportunity would "open many doors." In May, he was accepted into the 2013 SIParCS program under the mentorship of CISL computational scientist Dr. John Dennis. Fabrice became the first Philander Smith intern to pursue a SIParCS internship, and he was the only undergraduate student in the SIParCS class of 2013. His story is one that directly embodies the spirit and desired outcomes of having a Diversity Coordinator. Fabrice originally hails from Kigali, the capital of Rwanda. One of four children, Fabrice worked to decrease the financial burden of his widowed mother. His determination and the work ethic he learned from his mother translated into a highly successful high school career. According to Fabrice, "only rich kids can afford university," which meant he would need to

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rely upon the Rwandan Presidential Scholarship (RPS) in Science and Technology for post-secondary support. Because of the high cost of equipping laboratories and recruiting qualified professors in math, computer science, physics, chemistry, and biology, it is currently impractical to educate students in Rwanda. RPS provides a merit-based approach to educate its most promising students in these specialized areas of study. Being chosen to receive the full tuition and additional support provided by RPS is no small feat. Each scholar goes through a rigorous assessment process, including national examinations in English (French is the native tongue of most Rwandans), and a qualifying interview. Fabrice excelled during his time with SIParCS. While it came at the expense of delaying his first return to his home country in two years to be with his family, he explained that the experience was well worth it. Fabrice has expressed an interest in being a champion for NCAR within the RPS community as he plans to complete his degree and pursue a Ph.D. in high perfroance computing to return to Rwanda as an asset to his country and a mentor for future students. He said, “My country is aiming to be the IT hub in Africa for 2020. It is the taxpayers’ obligation and desire to give back. I plan to utilize the knowledge from my academic experience [as one way of] contributing to this goal.”

CISL’s Diversity Education and Engagement Laboratory

Over the last year, CISL has leveraged existing and developing relationships across organizations and institutions to support and write grants that serve to enhance our diversity, education, and engagement efforts using critical and soundly designed assessment tools that will enable us to collect actionable data about our programs. These data will enhance scientific rigor in our activities, provide vital feedback that will enhance their impact and efficacy, and broaden the potential for ever-wider and more far-reaching collaborations with educators by creating within NCAR a discipline-specific laboratory for education and diversity research focused on computational geoscience. Two examples of such collaborations in FY2013 include:

- **NSF EPSCoR WyCEHG grant.** Over the past year, CISL’s Outreach Services Group worked with Anne Sylvester and Beth Cable at Wyoming’s EPSCoR office on EOT aspects of NSF’s Wyoming Center for Environmental Hydrology and Geophysics (WyCEHG) grant. This included their summer field course in hydrology and geophysics, their summer exchange program with Jackson State University, and recruitment and collaboration with other partners to increase the number of participants from underrepresented groups. A portion of this multimillion-dollar grant to the University of Wyoming will serve to develop educational resources in the form of teacher toolboxes. These toolboxes will provide standards-based computational and atmospheric science activities to the K-12 community, especially those in the Rocky Mountain and Front Range regions.

- **Innovative Technology Experiences for Students and Teachers (ITEST) grant.** CISL is currently working with Jacqueline Leonard at UW’s Science and Mathematics Teaching Center on a recently awarded NSF grant named Visualization Basics: Using Gaming to Improve Computational Thinking (UGame-ICompute). This work will assist in training and mentoring participants, and in developing age-appropriate tools, modules, and/or activities centered on computational thinking.

Rationale and funding

CISL education efforts contribute to CISL’s educational imperatives for workforce training and development, and for broadening participation. These efforts are supported by CISL Core funds, with supplemental funding supplied by other sources as appropriate. The Diversity Coordinator position is funded 25% by the University of Wyoming, 25% by NCAR Directorate Core funds, and 50% by CISL Core funds.

‹ Outreach up Training programs that broaden participation ›

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TRAINING PROGRAMS THAT BROADEN PARTICIPATION

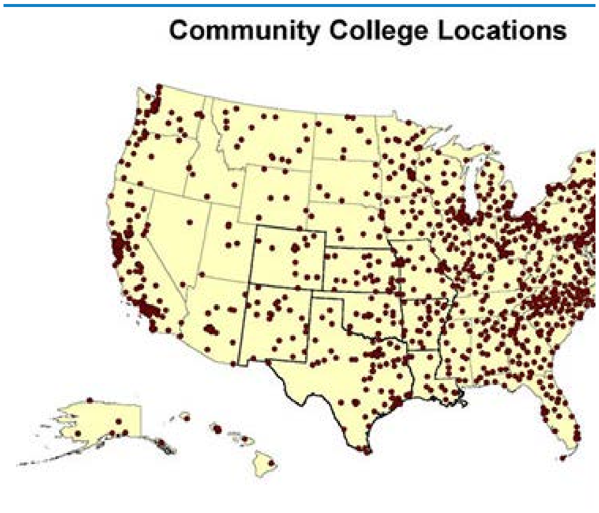
CISL is lowering access barriers to training for students and staff from U.S. minority-serving and EPSCOR-state institutions by providing travel support from its Research and Supercomputing Visitor Program (RSVP). The types of classes covered include CISL HPC training such as Fortran 90 and MPI/OpenMP, and its Data Analysis and Visualization Workshops. RSVP also encourages university visitors from diverse backgrounds to visit CISL and NCAR for extended periods.

"Data analytics for the Geosciences using R" is a new type of workshop that will multiply the efforts of statistics experts who want to make a beneficial impact on future U.S. scientists and engineers.

The focus of diversity and inclusion efforts is often placed on underrepresented groups of a specific race, ethnicity, or gender. For this reason, CISL's Diversity Coordinator has been mindful of meeting the needs of other underrepresented populations with significant barriers to access and retention, including those from nontraditional backgrounds, community/two-year college students, and people from rural areas. (The term "nontraditional student" refers to those who have one or more of the following characteristics: delayed enrollment into postsecondary education, enrolled part time, have financial independence, work full time while enrolled, have dependents, are a single parent, or didn't obtain a high school diploma.)

This section details activity dedicated to expanding diversity and inclusion-related training efforts in CISL.

Community colleges are an essential part of the postsecondary education system. The American Association of Community Colleges (AACC) reports that these institutions support 44% of all undergraduates nationwide. (The AACC is the primary advocacy organization for the nation's community colleges. It represents nearly 1,200 two-year, associate-degree–granting institutions and more than 13 million students.) While most of these institutions prepare students to enter four-year institutions, most also serve as a mechanisms for cultural, economic, and workforce development. Most community colleges provide a variety of educational options in culturally, economically, regionally, and environmentally diverse settings to a number of populations, especially those typically underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields (see table).



Locations of U.S. community colleges.

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Percentage of U.S. Undergraduates Enrolled in Community College

Subsection of Population	Total	First Generation	Black/ African American	Hispanic/ Latino	Native American	Asian/ Pacific Islander	Part-Time Students	Ages 40-65	Single Parents
% Enrolled in Community College	44%	39%	43%	52%	52%	45%	59%	57%	17%

Choosing to initiate conversations and collaborations with this population provides opportunities for CISL to re-examine and redefine its definition of diversity and to better understand the resources and needs of partner students, faculty, and communities. This effort helps CISL refine its goals for inclusion, diversity, education, and engagement. Since community colleges serve such diverse communities, the structure and programs they offer depend on the needs of the communities they serve. That is, each provides a variety of educational options in culturally, economically, regionally, and environmentally diverse settings to a number of populations, especially those typically underrepresented in STEM fields.

The R programming language is a publicly available tool that has been developed by the statistics community and is now a standard problem-solving platform for this community in industry, government, and health care.Current estimates project that there are over 2 million users of R worldwide, with thousands of contributors. In addition, R has the flexibility to support a range of users: from beginning statistics students all the way through scientists and engineers who are pursuing cutting-edge data analysis for research and commercial applications.

On June 16-19, 2013, NCAR and the University of Wyoming (UW) offered “Data Analytics for the Geosciences using R,” a short course targeted at community college and two-year college faculty who want to incorporate modern methods of data analysis into their introductory statistics courses. This course was designed to empower teachers, scientists, and engineers through the use modern methods of data analysis in a hands-on tutorial environment. It encouraged exploration of substantial environmental and Earth sciences data sets to complement a traditional introductory statistics course by developing analysis skills with larger and more complex data sets. It also encouraged appreciation for more advanced statistical methods. CISL’s Diversity Coordinator worked with Bryan Shader (UW) and Doug Nychka (IMAGe) to advertise and recruit for the workshop using professional and social media networks. Faculty at minority-serving institutions and historically black colleges and universities were also invited to participate.

The workshop was a success, with participants reporting that they planned to use the skills learned to augment their curricula and help develop students’ data analysis skills, techniques for handling larger and more complex data sets, and appreciation for the value of more advanced statistical methods. Participant feedback, in addition to community need, prompted discussions of making the workshop a continued offering, for which the Diversity Coordinator will coordinate in the Midwest region during FY2014.

CISL efforts to broaden participation in training activities such as RSVP are supported by NSF Core funding and NCAR diversity funds.

‹ Education up CISL leadership in cyberinfrastructure ›

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CISL LEADERSHIP IN CYBERINFRASTRUCTURE

CISL participates in a broad portfolio of activities intended to further the development of computing technology and the improvement of regional, national, and international cyberinfrastructure. These activities are consistent with NCAR’s leadership role as a national Federally Funded Research and Development Center (FFRDC), and are supported by NSF Core funding.

‹ Training programs that broaden participation   up   Regional CI engagement ›

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REGIONAL CI ENGAGEMENT

CISL has a strong presence in regional cyberinfrastructure (CI) development, including both the high performance computing (HPC) and networking communities. Working with regional entities broadens NCAR's impact by fostering the maturation of regional HPC CI, leverages unique regional resources and partnerships to tackle regional problems, and is a natural and mutually beneficial component of a national center's role.

CISL is a recognized leader and participant in many regional networking projects that are tightly integrated with national networks. CISL's involvement with regional networking consortia includes FRGP, UPoP, BiSON, WRN, EAGLE-Net, CHECO, BRAN, the Colorado Broadband Roundtable for the IT Economic Development and Business Planning group with the Colorado Governor's Office, CBREC, and the Quilt. These are all designed to provide NCAR/UCAR and other institutions in the region with robust wide-area data pathways. CISL designs, plans, engineers, installs, operates, maintains, develops strategy, and performs research for NCAR and UCAR state-of-the-art data networking and telecommunications facilities, providing a vital service to NCAR, UCAR, and UCP research communities by linking scientists at partner institutions throughout the western U.S. to NCAR's supercomputing resources.

On behalf of UCAR, CISL continues to lead and participate in several important metropolitan, regional, and national networking initiatives. The tangible benefits of such participation include economical, diverse, high-performance networking for UCAR and its member universities. However, the intangible benefits are at least as important: participating in these initiatives reinforces UCAR's public mission of providing services to its members while simultaneously fostering cooperative ventures, collaborations, and relationships among these institutions. As a leading participant in such community alliances, CISL's Network Engineering and Telecommunications Section (NETS) contributes to strengthening UCAR's value as an institution and helps UCAR fulfill its leadership and outreach obligations for NSF funding.

CISL is actively engaged with regional and national HPC partnerships. Perhaps the most important is the Wyoming-NCAR Alliance (WNA), which governs the joint activities of NCAR and the State and University of Wyoming related to the NWSC facility, the Yellowstone environment, and NWSC's Education, Outreach, and Training activities. CISL also continues its collaboration with the University of Colorado at Boulder and the University of Colorado at Denver on a Major Research Instrumentation (MRI) project that brought Janus, a 184-TFLOPS Intel-based Dell supercomputer to the CU Boulder campus. NCAR controls a 9.8% portion of this system and used 2.425 M CPU-hrs across 36 allocated projects. Access to Janus' computing resources were used to support a number of new startup research projects, thus serving as an important staging area for scientists preparing for the Yellowstone supercomputer.

In collaboration with the Colorado School of Mines (CSM), CISL agreed to host CSM's new IBM supercomputer named "BlueM." CISL is collaborating with CSM on a computational science research project related to this novel hybrid computing system that combines IBM's iDataPlex and Blue Gene/Q platforms. CISL has also supported several University Wyoming-focused STEM education activities and proposals including a recently funded NSF ITEST proposal related to robotics and computer gaming. These regional HPC activities allow CISL to gain hands-on experience in collaborating with campus IT staff through the processes of CI acquisition, deployment, and resource federation.

CISL also participates in the activities of the Front Range Consortium for Research Computing (FRCRC), a consortium of regional HPC organizations including Colorado State University, the University of Colorado,

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Colorado School of Mines, the University of Wyoming, NCAR, the Department of Energy's National Renewable Energy Laboratory, and NOAA's Boulder Earth System Research Laboratory. FRCRC representatives meet monthly to discuss and organize joint training, education, and outreach activities. They also consider other collaborative measures to benefit the regional development of HPC. In August 2013, FRCRC organized and hosted the third annual Front Range HPC Symposium, which attracted about 100 registered participants to a two-day series of lectures, tutorials, and affinity group discussions at the Colorado State University campus. The FRCRC also planned its booth presence at the ACM/IEEE Supercomputing 2013 trade show in Denver, Colorado, where CISL staff will provide outreach services.

These efforts advance CISL's strategic computing imperatives in hardware cyberinfrastructure, software cyberinfrastructure, and facilities. Further, this work also addresses CISL's education imperative to broaden participation. CISL's work in this area is supported by NSF Core funding, NSF MRI grant CNS-0821794, and UCAR non-federal funds.

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NATIONAL CI ENGAGEMENT

CISL has a strong presence in national CI development, including both the HPC and networking communities. Working with national entities broadens NCAR's impact by fostering the maturation of national HPC CI, leverages national resources and partnerships to tackle national problems, and is a natural and mutually beneficial component of a national center's role.

Building on its participation in the TeraGrid as a Resource Provider since 2007, CISL continues to be engaged as an active member of the Extreme Science and Engineering Discovery Environment (XSEDE) Federation and Service Provider (SP) Forum as a Level 2 Service Provider. NCAR supports XSEDE cyberinfrastructure by integrating the networking, data transfer, and science gateway services at the NCAR-Wyoming Supercomputing Center (NWSC) with XSEDE resources. Although NCAR does not plan to provide any allocable resources to XSEDE, NCAR provides a dedicated 10-Gbps networking link to XSEDEnet, with which NCAR provides high-performance access to the 10-petabyte central disk file system at NWSC to users having both NCAR and XSEDE source and destination accounts. NCAR also continues its active role in the Science Gateways area, providing user support to geoscience users through our participation in the Extended Collaborative Support Service (ECSS). This level of integration is intended to enable atmospheric scientists using XSEDE resources and resources administered by NCAR to orchestrate research campaigns across the collective cyberinfrastructure. NCAR is also active in coordinating training, education, and outreach goals with other XSEDE SPs. CISL staff contributed to paper reviews for XSEDE '13 in San Diego, and several staff attended the conference. XSEDE is funded through a five-year grant from the NSF Office of Cyberinfrastructure.

CISL is a recognized leader and participant in a number of national networking projects that are tightly integrated with regional networks. CISL's involvement with national networking consortia includes Internet2 (I2), National LambdaRail (NLR), and the Department of Energy (DOE) Energy Science Network (ESnet). These are the United States' premier networks in research and education. CISL/NETS maintains high-speed connectivity to these national networks to ensure the required connectivity between researchers that enables collaboration and access to local and remote computing, data, and other instruments.

On behalf of UCAR, CISL/NETS provides leadership and participates in these national networking initiatives. Active participation helps guide and set strategic direction for these national organizations, which helps ensure that UCAR has access to the national network connectivity and services required to carry out its mission.

Throughout FY2013, CISL and NCAR have continued to be very active in the NSF Geoscience Directorate's Earth Cube initiative. Staff have attended and contributed to all of the EarthCube Charrettes, EarthCube community groups, and smaller meetings devoted to condensing the collective outputs of the various groups into a more condensed EarthCube roadmap. CISL is also currently playing a primary role in developing a community workshop for the major NSF geoscientific data facilities.

CISL is also an active participant in the ACM SIGARCH and IEEE Computer Society Supercomputing conferences, which attract thousands of HPC experts from government, academia, and industry every year. CISL staff members serve each year on the infrastructure committee, present technical papers, and operate an NCAR exhibit booth on the conference floor. CISL is also active each year at the Supercomputing Student Job Fair, which is an opportunity to reach a broad population of students and

other job candidates. CISL also participates in the design, implementation, and operation of SCinet.

CISL staff members serve on a number of advisory panels, including Science Gateways Institute, the Petascale External Advisory Committee of the NSF Blue Waters Project, and the Technical Evaluation Panel of the Department of Defense HPC Modernization Office.

These efforts advance CISL's strategic computing imperatives in hardware cyberinfrastructure, software cyberinfrastructure, and facilities. With the exception of CISL's participation in XSEDE, CISL's national leadership activities are funded by NSF core funds.

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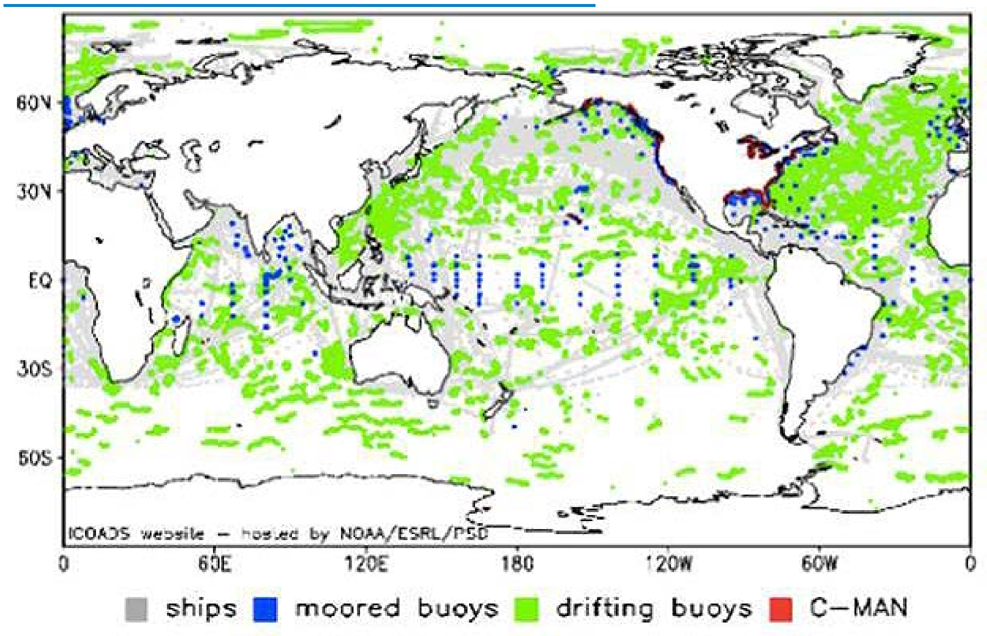
INTERNATIONAL IMPACTS

CISL is highly visible on the international front and engages with international climate and weather organizations, programs, centers, and projects. Our international impact spans data services and exchanges, analysis and visualization tools, computational support, strategic advisory functions, training, capacity building, and international conferences.



Global distribution of marine surface measurements for August 2013 in the International Comprehensive Ocean-Atmospheric Data Set (ICOADS). ICOADS collects and distributes environmental observations from merchant and research ships, moored and drifting buoys, and coastal stations. In collaboration with NOAA partners at the National Climatic Data Center and Earth Systems Research Laboratory, NCAR processes data and adds them to ICOADS on a monthly basis. The data are openly shared with the international community.

CISL contributes to developing the World Meteorological Organization (WMO) Information System (WIS). Under the auspices of the United Nations, the WMO is designing, developing, and deploying WIS as a next-generation globally federated information system for weather, climate, hydrology, oceanography, and many other disciplines. CISL plays a strong role in the management and technical direction of WIS and has contributed ideas, strategies, and services developed through our work with CDP, ESG, ACADIS, and TIGGE. CISL staff have served on several WIS committees, recently including the Expert Team on WIS Centres (ET-WISC) ,the Task Team of Data Centres (TT-DC), and the Task Team on WIS Centre Audit Certification (TT-CAC). At the request of the U.S. National Weather Service (NWS), CISL attended the WMO WIS Centre Audit for NWS. CISL data collections are now being harvested by GISC-Washington into WIS as part of production operations. In addition, CISL operates the U.S. archive and portal for the

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WMO THORPEX Interactive Grand Global Ensemble (TIGGE), an international weather forecast multimodel intercomparison collaboration with the European Centre for Medium-range Weather Forecasts (ECMWF) and the China Meteorological Administration (CMA). In tandem with this important global effort, CISL serves on the WMO GIFS-TIGGE (Global Interactive Forecast System) Working Group.

There are several noteworthy formal international data exchange agreements associated with the development of the NCAR Research Data Archive (RDA). ECMWF and JMA routinely share data under longstanding Memoranda Of Understanding with NCAR. These reanalyses and operational model outputs add to the RDA and are important because they are not available anywhere else in the U.S. CISL reciprocates by preparing observational datasets and delivering them to support future reanalysis efforts. In collaboration with NOAA, CISL participates in a biennial data-sharing activity with Russia. Meetings with personnel from the All Russian Institute for Hydrometeorology in Obninsk are very productive with new archives of upper-air soundings from the former Soviet Union being added to the RDA, and the digitization of many historical marine surface observations being added into ICOADS.

CISL's analysis and visualization tools (e.g., NCL, PyNGL, and VAPOR) are popular in centers and universities around the world. VAPOR, for example, is currently expanding ocean visualization capabilities under support from the Korea Institute of Science and Technology Information. NCL is used in 114 different countries, and CISL has conducted NCL data analysis training workshops in Australia, Turkey, Germany, Korea, and Switzerland. The RDA is an extremely valuable international scientific data resource, providing important collections to the global community and making EU collections available to U.S. scientific communities. CISL's Science Gateway Framework (SGF) federates with the global Earth System Grid Federation (ESGF), sharing catalogs and security protocols such that CCSM, CESM, WCRP/CMIP5, and other data collections are accessible via the ESGF environment. Similarly, CISL is a primary partner in the ACADIS effort. CISL provides the SGF-based ACADIS Gateway that offers data management support for NSF-sponsored Arctic research including Arctic Observing Network (AON) data for the International Polar Year (IPY). CISL also provides computing and data management support for the Antarctic Mesoscale Prediction System (AMPS), an experimental, real-time numerical weather prediction capability that supports the United States Antarctic Program, Antarctic science, and international Antarctic efforts.

CISL continues to participate in an international project to study the computer science challenges facing future exascale climate models. This G8 Exascale Climate Science (ECS) project studies various aspects of the exascale climate modeling challenge, including application scalability, node performance, and system resilience. The project uses CESM as one of the target applications. In FY2013, CISL representatives attended project meetings in Aachen, Germany and Salt Lake City, Utah. CISL's role in this effort is mainly to supply application support and feedback regarding the utility of various lines of research proposed. In addition, CISL staff have contributed to the development of the UK's National Environment Research Council (NERC) Big Data program.

CISL hosts and organizes the popular international Computing in Atmospheric Sciences (iCAS) workshop every other year in Europe, with the most recent event taking place in September 2013. iCAS is a forum where scientists, industry experts, and computing professionals from around the world can attend and discuss challenges and new approaches to advance climate and weather research. Finally, CISL staff members collaborate with many more foreign institutions and serve on various international committees and advisory panels, including the German Climate Computing Center (DKRZ) Advisory Committee.

These efforts advance CISL's strategic computing frontier in center virtualization and imperatives in software cyberinfrastructure and data curation. Further, this work also addresses CISL's science imperative for scientific excellence and CISL's imperative to broaden participation. This work is supported by NSF Core funding.

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INTERACTIONS WITH INDUSTRY

CISL maintains close contacts with High Performance Computing (HPC), networking, and related vendors as a way of providing information to vendors regarding the computational requirements of the atmospheric and related sciences and to track technology. To this end, CISL has up-to-date nondisclosure agreements with HPC-related vendors that allow CISL to keep abreast of the latest technical developments and plans in this fast-moving industrial space. CISL also routinely receives loaner equipment and new software products from vendors for evaluation and testing under these agreements. For example, in FY2013, computer scientists in CISL continued to receive and evaluate early samples of the latest generation Intel Xeon Phi many-core processors – called Knights Corner - for evaluation.

Likewise, CISL's Network Engineering and Telecommunications Section (NETS) interacts with many networking companies. NETS provides them with feedback on feature requests and keeps them informed about services that would benefit UCAR, the Front Range GigaPop consortium (FRGP), and our research and education community. In turn, NETS receives product road maps and other information about products and services we utilize in running and maintaining the networks we manage. NETS interacts with many vendors, professional associations, and consortia including ADVA Optical Networking, BICSI, Cisco Systems, EDUCAUSE, Internet2, Juniper Networks, North American Network Operators' Group (NANOG), National LambdaRail (NLR), and The Quilt coalition.

NETS staff provides input and receives product information on ADVA equipment through their Research and Education Technical Advisory Group. NETS technicians are RCDD certified through the BICSI professional association. UCAR has a non-disclosure agreement with Cisco Systems that keeps NETS appraised of product road maps, and NETS participates in special-purpose discussions with Cisco about future purchases and product requirements for UCAR and the FRGP. UCAR is a member of the higher-education information technology association EDUCAUSE and participates in training and conferences. UCAR is a participating member and represents the FRGP as a network member of the Internet2 research and education networking consortium. NETS participates in special-purpose discussions with Juniper Networks about future purchases and product requirements for UCAR and the FRGP. NETS network engineers participate in NANOG engineering meetings to improve the Internet's networking technologies and operational practices. NETS assistant manager Jeff Custard serves on the Board of Directors for the FRGP to influence the national agenda on information technology infrastructure, with particular emphasis on networking for research and education.

CISL also routinely invites vendors to attend and present at HPC-related conferences and workshops that it holds, such as the Third Programming Weather, Climate, and Earth System Models on Heterogeneous Multi-core Platforms workshop held in September 2013, which included vendor presentations from Allinea, Rogue Wave, Intel, Cray, and NVIDIA.

CISL maintains an active collaboration with Intel with regards to optimize code for both the Intel Xeon and Xeon Phi technologies. This collaboration involves regular weekly teleconferences consisting of participants form NCAR, Intel, NREL, and TACC. This working group has explored a wide range of issues associated with the Intel Phi including the efficiency of the Intel vectorization compiler, coding structures that may inhibit vectorization, OS jitter, and MPI performance.

In FY2013, CISL staff members also continued to provide advice to industry, for example through service on the IBM Deep Computing Advisory Board and the Intel HPC Round Table. As a result of the work done

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by CISL on the design and construction of the NCAR-Wyoming Supercomputing Center facility, CISL staff also served on the Uptime Institute's Oversight Board. The Uptime Institute is an unbiased, third-party data center research, education, and consulting organization focused on improving data center performance and efficiency through collaboration and innovation.

This collaborative work with industry is supported by NSF Core funds. In addition, NETS activities are supported by UCAR Communications Pool indirect funding.

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CISL PARTICIPATION IN THE HPC COMMUNITY

As part of its leadership role in the High Performance Computing (HPC) community, CISL organizes, hosts, or participates in several large-scale conferences. Through this participation, CISL fosters the interchange of ideas, technical information, best practices, and research findings. In addition to participation in relevant conferences when topics and CISL interests intersect, CISL regularly engages the HPC community via the following conferences:

- **SC conferences:** CISL is a longtime participant in the IEEE and ACM-sponsored Supercomputing (SC) conference series, the premier HPC event in the United States. CISL staff members participate on organizing and event committees, organize Birds of a Feather sessions, and routinely submit technical papers to this conference. CISL also participates in the SC Student Job Fair, a prime venue for meeting employee candidates from a variety of backgrounds who are interested in careers in HPC and related scientific fields.

- **XSEDE Annual Conference:** Formerly known as the TeraGrid Annual Conference, CISL participates in this conference by attending, presenting papers, and participating on committees where appropriate.

- **iCAS conference:** To foster international dialogue by peer centers, CISL hosts the International Computing in Atmospheric Sciences (iCAS) conference every two years under NSF sponsorship. CAS brings together international colleagues to discuss information technology advances and the transformative infrastructure that allows scientists to investigate atmospheric research as part of understanding the Earth System.

- **HPSS Users Forum:** The HPSS Users Forum is the annual gathering for the HPSS community, bringing together new and existing HPSS users from around the globe to discuss best practices, new implementations, and future directions and releases. HUF 2013 in November 2013 will be hosted by CISL at the Mesa Lab.

- **IBM SPXXL Meetings:** SPXXL is a user group for sites with large installations of IBM equipment. The SPXXL group focuses on a wide range of issues that are important to achieving petascale scientific/technical computing on scalable parallel machines.

This work is supported by NSF Core funding and augmented by registration fees and sponsor donations.

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DIRECTOR'S MESSAGE

Vanda Grubišić, EOL Director

It is my pleasure to present to you the Earth Observing Laboratory annual report for FY2013. It has been another successful year for EOL that is reflected in the high quality of service the Laboratory has provided to the atmospheric observational science community. In addition, EOL staff, postdocs, students and visitors have contributed to advancing the observational-data-based physical discovery and developments of a next generation of observational systems and data services to be placed in service of the observational science community in the years to come.

The outstanding level of the scientific and technological accomplishments of the EOL staff was recognized this year by EOL receiving two top UCAR awards. These awards exemplify dedication of EOL staff to excellence and are testament of the team efforts. William “Al” Cooper received the 2013 UCAR Distinguished Accomplishment award – the highest honor bestowed by UCAR upon an individual or a team – for his lead role in coordinating the creation and integration of fourteen externally-developed instrumentation packages, the HAIS instruments, onto HIAPER, our premier NSF/NCAR Gulfstream V jet aircraft. With HAIS instruments, HIAPER has become a complete and mature platform, affording the research community with an unprecedented set of measurements and aircraft performance capabilities that will have a profound impact on the future of atmospheric science research in years to come. This is only the seventh time in its 13-year history that the UCAR Distinguished Accomplishment Award has been given out; yet, the second time in the last two years that it has been awarded to the EOL team members. In 2011, Terry Hock and Dean Lauritsen received the UCAR Distinguished Accomplishment award for their leadership and central role in developing innovative new dropsonde technology as well as transformative delivery systems. The second UCAR award won this year by EOL staff was the UCAR Outstanding Achievement Award for Scientific and/or Technical Accomplishment that went to Britt Stephens, Pavel Romashkin, Henry Boynton, Ed Ringleman, John Cowan, Greg Bruning, Brent Kidd, Alison Rockwell, Vidal Salazar, and Janine Aquino for their contributions to the HIAPER Pole-to-Pole Observations (HIPPO) project. The multi-year, multi-phase HIPPO field campaign studied the latitudinal and vertical distribution of greenhouse gases and other atmospheric constituents across a domain stretching from the Arctic to the Antarctic, logging in process over 460 research flight hours and 150 days in the field in five 30-day missions. This extraordinary field campaign was seminal in many respects – among the first to take full advantage of the HIAPER and HAIS capabilities but also one that required new flight strategies and innovative modes of flight operations including mobility of the scientific and support crews, also posing rigorous demands on data accuracy and expectations for outreach to the public and science community. The impact of HIPPO on both the EOL operations and the scientific research has been significant and will continue to leave its mark.

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Congratulations to all the above colleagues on their success. You can read more in the following pages about the field campaigns we have supported in FY 2013 that have taken advantage of the HIAPER and its instrumentation. Also, about the advancements we have continued to pursue with some of the HAIS instruments and the development of the new Airborne Vertical Atmospheric Profiling System (AVAPS) dropsonde system for HIAPER that has seen its first use in the Mesoscale Predictability Experiment (MPEX). From the operational perspective, MPEX marks the first time we have gained permission from FAA to drop sondes from our research aircraft over land outside of the military restricted zones.

Our highest new instrumentation development priority is the Airborne Phased Array Radar (APAR), a new and unique C-band airborne radar with dual-Doppler and dual-polarimetric capabilities designed for a large fuselage aircraft such as the NSF/NCAR C-130. After the decommission of the Electra Doppler Radar (ELDORA), the scientific community has strongly voiced the need for an airborne radar for studies of clouds over open ocean or other hard-to-access parts of the Earth. APAR is our response to that need. This frontier development takes advantage of significant in-house scientific and engineering expertise and is an exceptional opportunity for EOL to make significant contributions to a next-generation radar capability in collaboration with the current and future development partners.

In parallel to the development of new observing systems, EOL has continued to invest efforts in providing unique educational opportunities to future observational atmospheric scientists and engineers as well as to training and entraining a new generation of users of the Lower Atmospheric Observing Facilities (LAOF). These activities are exemplified through our continued support of the technical and engineering internships (TIP and SUPER) and the launch of a series of Train and Entrain New Users tutorials supplemented by an exciting new web-based Digital Guide to the NSF Lower Atmospheric Observing Facilities. The Digital Guide presents the information about the LAOF and the request process for these facilities in an interactive and graphically attractive format. Its easy accessibility via the new EOL web site or through an iOS and Android apps makes it a useful resource and reference.

As in the past years, this annual report is organized around the Imperatives and Frontiers of the EOL Strategic Plan. I invite you to enter the following pages and read more about the Laboratory's remarkable activities and accomplishments in 2013.

Vanda

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NCAR UCAR Earth Observing Laboratory 2013 Annual Report

EXECUTIVE SUMMARY

For over 50 years, NCAR has been charged by the National Science Foundation with providing observing facilities and associated services for the community of university atmospheric scientists. A significant portion of this charge to NCAR now rests with the Earth Observing Laboratory (EOL), which defines its mission to be:

To develop and deploy observing facilities and provide data services needed to advance scientific understanding of the earth system.

When EOL wrote its Laboratory Strategic Plan in 2009, we framed our activities as a lab in the context of our mission statement, which is further encapsulated in our “Four Ds”: Deployment, Development, Data Services and Discovery. This annual report describes the efforts we undertook in Fiscal Year (FY) 2013 to carry out the objectives described in our Strategic Plan.

Deployment

Deployment activities in EOL are encompassed by two separate Imperatives in our Strategic Plan: Imperative I, to *“Maintain the EOL facilities that are deployed using NSF “deployment pool” funds so that they are ready for reliable and safe operation in anticipated field programs;”* and Imperative II, *“Support observing needs of research programs at a level that serves NSF, university, and NCAR program needs.”*

EOL works continuously to maintain and improve the NSF Lower Atmospheric Observing Facilities (LAOF) with which we are entrusted, and to ensure their safe and reliable operation for deployment. Several of these activities are described in Imperative I.

EOL’s deployments of the NSF LAOF in FY 2013 are described in Imperative II. Six field campaigns were conducted in FY 2013, including the Southeast Atmosphere Study (SAS), a project that combined objectives from four field campaigns and that was conducted in two sites: one in Alabama, and another in Tennessee. EOL also collaborated to support dropsonde instrumentation for the National Aeronautics and Space Administration (NASA)-led Hurricane and Severe Storm Sentinel (HS3) field campaign.

Development

Most of EOL’s Development activities are described by Imperative III of our Strategic Plan: *“Anticipate future needs resulting from changing priorities, aging equipment or emerging opportunities, and develop new technology (instrumentation, software, and infrastructure) to meet those needs.”* EOL’s FY 2013 developments included: the completion and testing of the Airborne Vertical Atmospheric Profiling System (AVAPS) Dropsonde system for the NSF/NCAR GV, known as the High-performance Instrumented Airborne Platform for Environmental Research (HIAPER); the 449 MHz wind profiler system; the Laser Air Motion Sensor (LAMS); and the successful installation and test of airborne HIAPER Cloud Radar (HCR). These developments ensure that EOL continues to be well-positioned to meet immediate and near-term community needs.

Other, longer-term and emerging EOL development efforts are contained in our Frontiers, which focus on emerging opportunities or developing needs in the atmospheric science community that EOL could address. In FY 2013 EOL addressed some of our Frontiers through continued exploratory work on the

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feasibility of developing an Airborne Phased-Array Radar (APAR), envisioned to replace the Electra Doppler Radar (ELDORA) airborne radar; work on CentNet, the multi-station, multi-sensor network; and by continuing our partnership with Montana State University (MSU) to develop a Water Vapor Differential Absorption Lidar (WV DIAL) instrument that can be used in the field.

Data Services

EOL is committed to data processing, quality control, and archival for field projects – all major aspects of the end-to-end services that EOL provides to the community – as expressed in Imperative IV: *“Provide comprehensive data services, open access, and long-term stewardship of data.”* This includes the development of Field Catalog 2.0, enhancements to operating software for instrumentation, and participation in several data services endeavors, including development of Digital Object Identifiers (DOIs) for data sets, and arranging a workshop as part of the NSF-sponsored EarthCube initiative.

Discovery

EOL strives to promote curiosity about Atmospheric and Earth sciences and to inspire development of the next generation of observational scientists and engineers. This is integral to Imperative V: *“Attract and inspire new generations of scientists, engineers and the general public to atmospheric science, conveying the excitement and intrinsic value of observational research.”* In FY 2013 EOL was active in a number of education and outreach activities, including four educational deployments, outreach as part of a major field campaign, and training and entraining new LAOF users. EOL also continued two internship programs: Summer Undergraduate Program for Engineering Research (SUPER), which focuses on undergraduate students in various fields of engineering as a complement to existing NCAR programs that primarily target students in geosciences; and our Technical Internship Program (TIP II), which establishes and increases interactions with two-year college and technical school faculty and students in order to spark interest in technical and support careers in the geosciences.

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IMPERATIVE I

Imperative I

Maintain the EOL facilities that are deployed using NSF "deployment pool" funds so that they are ready for reliable and safe operation in anticipated field programs

State of the art observations of the atmosphere and other parts of the Earth system continue to be the driver for scientific discovery and impetus for advances in geosciences. Furthermore, the robust performance and continued development of weather, climate, and chemistry models depends critically on the availability of accurate observations and measurements. Central to EOL's mission, and our first Imperative, is the maintenance of NSF-funded Lower Atmospheric Observational Facilities (LAOF) for research in atmospheric science, with emphasis on systems that are beyond the capabilities of most universities or smaller groups.

The fulfillment of Imperative I drives countless day-to-day efforts to keep operational and continuously improve the NSF LAOF in order to maintain their readiness for our vigorous deployment schedule (see Imperative II). In the run-up to each field campaign, all EOL instruments undergo exhaustive testing by our engineers and technicians to ensure optimal campaign performance. During the field phase, it often becomes necessary to make adjustments or upgrades to meet scientific objectives. And after the field phase is complete, calibrations, maintenance and repairs are performed so that the facilities can be ready to perform in their next deployments.

C-130 Inspection

During airborne research projects the performance of the scientific instruments is very important but the safe and reliable performance of the aircraft is absolutely essential. In this picture, EOL/RAF mechanics Aaron Steinbach and John Cusack are performing checks and maintenance on the C-130 engine and propeller.

Safety is the highest priority for operations of EOL facilities, and the NSF aircraft we maintain have especially stringent maintenance and inspection requirements. The maintenance program for the NSF/NCAR C-130 requires a quadrennial inspection of approximately one-third of the airplane and sub-systems, and in FY 2013, such an inspection was undertaken at Cascade Aerospace in Abbotsford, British Columbia, Canada. Major areas involved in the inspection included wing flaps and flap wells, landing gear, tail empennage, instrument and antenna attach points as well as the engine burner cans and compressor vanes. Only minor corrosion problems were detected in the airframe and these were corrected. Three of the four engines had minor cracking in the burner cans and damaged vanes in the first stage of the turbine. All of the damaged parts were replaced.

This inspection was similar to the first one, conducted in 2000/2001. The cost of that inspection was driven by deferred U.S. Navy maintenance and the impacts of the plane having been in storage for a

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number of years. Since that first inspection the plane has been maintained in accordance with its Lockheed-Martin maintenance program. As a result, the cost of the inspection has fallen every 4 years to a new low in 2013. Based on the excellent condition of the plane and its operational usage, EOL expects it to be of use to the research community for years to come.

High Spectral Resolution Lidar (HSRL)

HSRL operating in its downward-pointing configuration onboard HIAPER during TORERO in FY 2012.

The High Spectral Resolution Lidar (HSRL) is a HAIS instrument (named from the HIAPER Aircraft Instrumentation Solicitation). It was deployed for the first time in the Tropical Ocean Troposphere Exchange of Reactive halogen species and Oxygenated VOC (TORERO) project in January 2012, where it provided important operational information, gave quantitative information on aerosol scattering and differentiation of ice from aerosol layers from the depolarization measurements, and was used to identify the top of the troposphere and sub-visual cirrus, and measure the stratospheric aerosol layer.

In FY 2013 we significantly improved the performance and reliability of HSRL by moving its hardware and software to a new computer and upgrading to the Scientific Linux operating system, including installing several proprietary drivers. EOL engineers also added polarization support to HSRL real-time software and the HSRL processing software. Furthermore, a failed seed laser unit was replaced with a fiber-based seed laser in order to restore the normal operation mode during operations to measure oriented scattering from clouds.

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IMPERATIVE II

Support observing needs of research programs at a level that serves NSF, university and NCAR program needs

Field program planning and implementation is a critical community service, and EOL's efforts here are part of NCAR's Strategic Imperative to provide observational facilities that meet the science community's needs. EOL employs and trains project staff, assists PIs with project planning and preparation, supports observing programs by operating facilities and instruments, and preserves quality of collected data for decades in support of research and field programs worldwide. In FY 2013, EOL provided field program planning and implementation for six NSF-supported research missions:

1. Instrument Development and Education in Airborne Science Phase 4 (IDEAS IV);
2. Shallow Cold Pool (SCP);
3. Southern Andes-ANtarctic GRavity wave InitiAtive (SAANGRIA) -Test;
4. SPRITE SPECTRA-II;
5. the Mesoscale Predictability Experiment (MPEX); and
6. the Southern Oxidant and Aerosol Study (SOAS) and Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks (NOMADSS), under the umbrella of the Southeast Atmosphere Study (SAS).

We also supported the Hurricane and Severe Storm Sentinel (HS3), a NASA-led campaign on which EOL collaborated for the dropsonde system on the NASA Global Hawk.

Shallow Cold Pool (SCP)

EOL technician Chris Golubieski works with TIP intern Jesse Stillwell on tower set up for SCP.

In early FY 2013, the Shallow Cold Pool (SCP) experiment used EOL's Integrated Surface Flux System (ISFS) sensors on 23 towers (one 20 m tower, one 5 m tower, and 21 smaller towers) in a shallow gully within the Pawnee Grasslands in northern Colorado to examine the formation and maintenance of common shallow cold pools. The PIs for SCP – Larry Mahrt (NorthWest Research Associates), Christoph Thomas (Oregon State University), Tom Horst (NCAR/EOL) and Danijel Belušić (Monash University) – proposed to observe these cold pools because they had not been previously examined with turbulence measurements and almost nothing is known about their dynamics and interaction with gravity waves and other submesoscale motions. With weak large-scale flow and clear nocturnal skies, all but the flattest terrain leads to shallow cold pool formation that may be embedded within deeper, larger-scale cold pools. Shallow cold pool formation may lead to high concentrations of contaminants, cold surface temperatures and occasional dense fog formation. SCP was successfully conducted as planned and included two PI-supported students as well as an EOL Technical Internship Program (TIP) participant. This success was in spite of a devastating lightning strike suffered by the site during the set-up period for the campaign. This strike severely and negatively affected a

number of the instruments, including some supplied by the PIs. However, EOL staff spent considerable time repairing both the EOL and PI systems and were able to minimize the impact to the science schedule. The EOL staff's extraordinary efforts were acknowledged by Brad Smull, the NSF Program Officer responsible for SCP, who said, *"...it is clear that NCAR/EOL staff provided exemplary assistance in recovering from this setback and minimizing impacts on the science being pursued."*

SCP research and the analysis of collected data have provided new insight into the role of sub-mesoscale air motions, wind shear, turbulence, and intermittent cloud cover.

SAANGRIA-Test

The Southern Andes-ANtarctic GRavity wave InitiAtive (SAANGRIA) Test flights were conducted in February 2013 using HIAPER – the NSF/NCAR GV aircraft – and carried out from the Rocky Mountain Metropolitan Airport (RMMA) in Broomfield, CO. During these flights, the instruments critical to the NSF-approved 2014 DEEPWAVE-NZ experiment were operated and tested. The test flights were designed to test the performance of the user supplied lidars and camera system for measuring temperature, airglow and gravity waves, and the sodium layer well above the aircraft in the stratosphere and mesosphere. The HCR and new AVAPS were also tested and flown for the first time on HIAPER during SAANGRIA-Test, as were the optical windows needed for SPRITE SPECTRA-II. The PIs for SAANGRIA Test were Dave Fritts (GATS Inc.), Ron Smith (Yale University), Jim Doyle and Steve Eckerman (Naval Research Laboratory).

Mesoscale Predictability Experiment (MPEX)

EOL successfully conducted the Mesoscale Predictability Experiment (MPEX), led by PIs Morris Weisman (NCAR Earth System Laboratory (NESL), Mesoscale and Microscale Meteorology (MMM) Division) and Jeff Trapp (Purdue University), in the U.S. intermountain region and high plains during the late spring/early summer of 2013. This campaign included the use of HIAPER, along with the new GV AVAPS ((Airborne Vertical Atmospheric Profiling System), the Microwave Temperature Profiler (MTP), and several university-provided ground-based mobile upsonde systems. 17 students participated in MPEX, mostly as part of the ground-based operations.

Airborne research flights (blue track) are conducted in the same airspace as many other commercial flights (white labels). During the MPEX project the NSF/NCAR HIAPER aircraft operated alongside hundreds of commercial airplanes safely, dropped sondes over land, and helped the scientists collect measurements in a very busy airspace.

MPEX was motivated by the basic question of whether experimental, sub-synoptic observations could extend convective-scale predictability and otherwise enhance skill in regional numerical weather prediction over a roughly 6 to 24 hour time span. Operationally, MPEX was the first campaign to use the new GV AVAPS, which provided critical data for the campaign, and was also the first campaign in which EOL dropped sondes over land. These drops and the new AVAPS contributed greatly to the collection of a robust dataset for the campaign. MPEX data will be used to improve model forecasting of major storm systems over the central U.S.

Southeast Atmosphere Study (SAS)

The Southeast Atmosphere Study (SAS) brought together resources and facilities from NSF, the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency

During SAS, EOL operated the NSF/NCAR C-130 aircraft with over 25 scientific instruments onboard to study mercury and other air pollutants over the southern eastern United States. In this picture, the C-130 is taking off from the Smyrna, TN airport on a humid day, and one can see the propeller tip contrails, also known as ectoplasm effect, caused by miniature "clouds" forming in the area of rapidly changing pressure at the tips of the propellers.

(EPA), and the Electric Power Research Institute (EPRI) and was conducted in June/July 2013 from two sites: Smyrna, TN for the NSF/NCAR C-130, and rural Alabama for the EOL Integrated Surface Flux System (ISFS) and other ground-based instrumentation. EOL also provided project management for SAS, which was the "umbrella" for the Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks (NOMADSS) project and the Southern Oxidant and Aerosol Study (SOAS). NOMADSS also included the North American Airborne Mercury Experiment (NAAMEX), and the TROPospheric HONO (TROPHONO) campaign. The NOAA-sponsored Southeast Nexus (SENEX) campaign was also co-located with the SAS complex. SAS' main purpose was to ensure that the objectives of the individual projects were coordinated. The SOAS objectives include the direct quantification of volatile organic carbon (VOC), ozone and NOx surface fluxes to HOx/NOx/ozone/organics/aerosol distributions, sources and sinks.

NAAMEX's primary goals were to constrain emissions of mercury from major source regions in the United States, and to quantify the distribution and chemical transformations of speciated mercury in the troposphere. The objectives for TROPHONO were to establish nitrous acid (HONO) distribution and budget in various air masses in the troposphere, to collect bulk aerosol samples for laboratory photochemical experiments, and to quantify daytime and nighttime HONO sources and sinks. Finally, SENEX's goals were to use the NOAA P-3 aircraft to sample air masses that contain a different mixture of emissions (urban, power plant, forest) and to follow these air masses as they are transported and chemically transformed in the atmosphere.

During SAS, much time was spent ensuring the instruments on the NSF/NCAR C-130 operated well and delivered high quality data. In this picture EOL/RAF technician John Munnerlyn and student Dan Stechman are performing checks on the instrument that measures the concentrations of carbon dioxide, methane and water vapor in the air.

SAS was logistically challenging because of the number and experience level of funding agencies involved, a complex group and large number of PIs (48 for SOAS, led by Anne Marie Carlton (Rutgers University) and 30 for NOMADSS, led by Dan Jaffe (University of Washington)), and the larger than originally anticipated scope of the project. However, EOL was able to coordinate all of the various players and objectives and successfully support the conduct of this campaign. SAS also provided participation opportunities for 95 students, mostly at the graduate level. SAS will provide significant enhancements to photochemical data in the Southeast U.S. both from the airborne and ground-based platforms. This information is crucial in evaluating causes of regional pollution, which is important for policy makers.

SPRITE SPECTRA-II

Sprites are optical phenomena triggered by the discharges of positive lightning between an underlying thundercloud and the ground. Sprites typically start 70-80 km above thunderstorms and move downwards over a 50 km altitude range. In summer 2013, SPRITE SPECTRA-II used HIAPER and its instrumentation to determine the physical processes involved in sprites, and in particular the ionization of molecules in the blue part of the light spectrum. The blue light cannot be adequately observed from

ground-based measurements, or by viewing through the normal NSF/NCAR GV windows as was done in the 2009 SPRITE SPECTRA flights.

Sprites photographed from the NSF/NCAR HIAPER aircraft during SPRITE SPECTRA-II.

During SPRITE SPECTRA-II, HIAPER flew as high as allowed for safe operations at about 200 km distance from thunderstorms. The SPRITE SPECTRA-II research flights targeted Mesoscale Convective Systems (MCS) due to their high number of lightning strikes. This project used high-speed imagers to record sprites with high temporal and spatial resolution. They used slit-less spectroscopy to obtain sprite spectra with ~500 m altitude, 0.1 ms temporal and 10 nm spectral (400-800 nm) resolution. For high spatial resolution they used a telescope with 3 m spatial and <100 ms temporal resolution.

The PIs – Hans Stenbaek-Nielsen from the University of Alaska, Fairbanks and Matthew McHarg from the U.S. Air Force Academy – provided an instrument package of two high-speed cameras mounted with the same viewing axis. One (the imager) was mounted inside a normal HIAPER window, while the other (the spectral instrument) was mounted to look through a new side-looking fused silica optical window panes, thus extending the transmissivity down to about 275 nm. The fused silica window panes have almost 100% transmissivity, well below the atmospheric limit of 360-370 nm for severe absorption; this new modification allowed UV photography of the sprites.

SPRITE SPECTRA-II was accomplished on schedule and produced an excellent data set. It also included 2 graduate students from the University of Alaska and 1 undergraduate student from U.S. Air Force Academy. Successful modifications to the equipment and sampling strategy based on lessons learned from the first SPRITE SPECTRA campaign in FY 2009 allowed collection of more photographs and unique documentation of the vertical propagation of sprites.

Instrument Development and Education in Airborne Science Phase 4 (IDEAS IV)

The fourth installment of the EOL-led Instrument Development and Education in Airborne Science (IDEAS IV) program provided testing opportunities on HIAPER for airborne instrumentation created for geosciences research. Operated from RMMA in September-October 2013, with PIs Jeff Stith (NCAR/EOL) and Al Rodi (University of Wyoming), the campaign was designed to strengthen the ties between NCAR and the university instrument development community by providing test flight opportunities for new or modified instruments and a unique opportunity to train students in observational science. The flights were also important for EOL to test and improve several of our airborne instruments: the new three-dimensional Laser Air Motion System (LAMS), the HIAPER Cloud Radar (HCR), and the Holographic Detector for Clouds 2 (HOLODEC II), the last of which was a joint development between NCAR and Michigan Technological University (MTU). Data from IDEAS IV is being used by two Ph.D. students in their theses: Robert Jackson (University of Illinois at Urbana-Champaign) and Christina McCluskey (Colorado State University).

Christina McCluskey, a graduate student at CSU, works on the Counterflow Virtual Impactor (CVI) instrument, which was part of the IDEAS IV flights. (Photo credit: Joachim Jansen of the Institute of Marine and Atmospheric Sciences, Utrecht University, The Netherlands)

The IDEAS IV flights were used to test LAMS' filtering methods in various conditions, and for calibration maneuvers, allowing for the first creation of three dimensional wind measurements from the new system.

We also tested HCR control systems and conducted a set of tests in various cloud conditions. Coordinated HCR scanning with CHILL scans in precipitating cloud provided for in-cloud comparison data from the two radar systems (W-band HCR and S-band CHILL). HOLODEC II was flown in high cloud conditions with comparison data that the Small Ice Detector, Version 2 (SID-II) and Cloud Particle Imager (3V-CPI) HAIS instruments collected. Inlet sampling for contamination due to cabin air was also performed in a variety of aircraft configurations and altitudes. Comparisons between the total water content from the Counterflow Virtual Impactor (CVI) and the University of Colorado at Boulder Closed Path Laser Hygrometer, Version 2 (CLH-2) were made and will be used to assess the data quality from the CLH-2 instrument.

Hurricane and Severe Storm Sentinel (HS3)

The NASA Global Hawk unmanned aerial vehicle.

The Hurricane and Severe Storm Sentinel (HS3) is a five-year NASA-sponsored mission designed to investigate the processes that lead to hurricane formation and intensity change in the Atlantic Ocean basin. EOL deployed the dropsonde system on the Global Hawk (GH) during this campaign in August-September 2013, during which we released 439 sondes from 7 HS3 flights over ocean. This includes one flight during which 88 sondes were successfully released – this is the maximum number of sondes the GH AVAPS system can carry. The data during the campaign was relayed through the Global Telecommunications System (GTS) after Quality Control (QC) processing and was incorporated into the National Hurricane Center forecasting. The dropsonde measurements played a critical role in allowing HS3 to meet its primary goals.

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IMPERATIVE III

Anticipate future needs resulting from changing priorities, aging equipment or emerging opportunities, and develop new technology (instrumentation, software, and infrastructure) to meet those needs.

The NSF LAOF maintained and deployed by EOL are of vital importance to the community's scientific interests, and these systems continue to be in high demand. However, there is also a constant, ongoing process of acquiring new capabilities, and retiring and replacing those that become outdated. Changing community priorities and technological opportunities call for ongoing development to ensure that EOL's observing systems and support matches evolving community needs. In addition to such evolutions, it is necessary to plan for the replacement or end-of-life of systems that become obsolete or too costly to maintain. Thus, Imperative III calls upon EOL's scientific and engineering leadership and expertise for a healthy development effort, and for the retention and training of staff who can conduct that research and development. It also requires the development of life-cycle and end-of-life plans for major facilities, instruments and software (see Imperative IV for more information on data services and software developments).

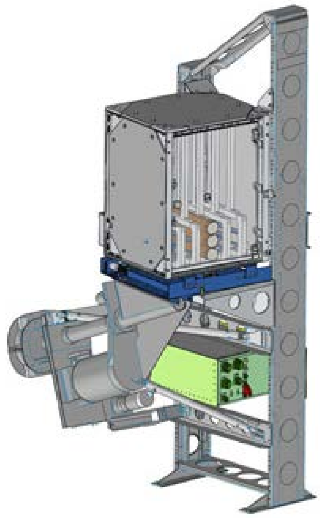
Climate process studies are of particular emerging importance and it will be important for EOL to expand service in this area. In FY 2013, we examined recommendations of the EOL-organized 2012 LAOF Workshop on Meeting the Challenges of Climate System Science for possible future instrument developments to address the needs of the climate community. The shift toward an emphasis on studies that contribute to the support of climate process study research, on both local and global scales, can be well served by new or developing EOL facilities, such as the now fully operational HIAPER aircraft, the planned CentNet sensor array, and FRONT. The attendant shift in the use of observing facilities features increased aircraft use in collection of global-scale observations, longer-term deployment of observing systems and sensors, repeated observations to cover seasons and broader areas, networks that provide a larger number of measuring stations, and development of reliable, easily deployable sensors. EOL also used the input from the community obtained at the November 2012 NSF Workshop on Radar Technologies to inform FY 2013 discussions on future radar directions. We also strengthened and expanded our partnership with DLR, the German Aerospace center, by holding a joint workshop in FY 2013, to foster future joint developments of critical-need new instruments that could fly on both the HALO (German DLR-operated G550) HIAPER (NSF/NCAR GV) aircraft.

Our development efforts in FY 2013 included continued work on the new Airborne Vertical Atmospheric Profiling System (AVAPS) for HIAPER; the HIAPER Cloud Radar (HCR); the Front Range Observational Network Testbed (FRONT); the Laser Air Motion Sensor (LAMS); and the 449 MHz wind profiler. Plans for other, emerging developments are discussed in our Frontiers.

HIAPER Airborne Vertical Atmospheric Profiling System (AVAPS)

An improved Airborne Vertical Atmospheric Profiling System (AVAPS, also known as the dropsonde system) for HIAPER has been a high priority instrument in order to meet the scientific community's needs for dropsonde operations from our high altitude aircraft. The previous manually-operated AVAPS, located in the aircraft baggage compartment in the rear of the aircraft, required that the dropsonde be manually

loaded into the launcher. This placed limitations on the number of drops because of safety procedures, and suspended operations during turbulence since crew could not move around the cabin.



A schematic of the new HIAPER AVAPS design.

In FY 2013, EOL completed construction and testing of the new AVAPS for HIAPER. The new system's design was leveraged from the development of the fully automated dropsonde system for the NASA/NOAA Global Hawk (GH), which was successfully deployed in January 2011 during the Winter Storms and Pacific Atmospheric Rivers (WISPAR) campaign, and in August 2012 and August 2013 during the HS3 campaigns (see Imperative II). Building on this work, the system for HIAPER is automated and has a capacity of 50 mini-sondes and can be reloaded with additional sondes during flight, allowing for an unlimited number of sondes to be dropped during a mission. Another feature of the new system is that it allows eight sondes to be airborne at any given time, compared to four for the current system. The resultant increased safety of operation and doubling of the number of sondes that can be in the air simultaneously are major improvements over the previous system.

The AVAPS system for HIAPER under construction in EOL's Design and Fabrication Services (DFS) Facility.

The HIAPER automated dropsonde system was tested for the first time in February 2013 during the Southern Andes-ANtarctic GRavity wave InitiAtive (SAANGRIA)-Test flights, and was used for research for the first time during the Mesoscale Predictability Experiment (MPEX) field campaign in late spring/early summer of 2013 (see Imperative II for further discussion of these campaigns). The system performed well, and while there were some intermittent issues with fast falls that we are investigating, we anticipate successful resolution of these issues in FY 2014. This new capability will allow finer scale evaluation of rapidly evolving mesoscale systems.

HIAPER Cloud Radar (HCR)

HCR undergoes integration on to HIAPER.

In its airborne configuration, HCR is mounted in a wing-pod on HIAPER, and is designed to provide high-resolution, research-quality data on cloud structures from our high-altitude aircraft. In early FY 2013, EOL successfully completed the electrical and mechanical integration of HCR with HIAPER. HCR was then test flown for the first time in February 2013, as a single-frequency (W band), downward-pointing system with polarimetric capability. In addition to this success, EOL engineers and technicians identified and successfully addressed a few issues with pressurization and temperature stability of the instrument.

We were also successful in developing and verifying an aircraft motion correction algorithm in FY 2013, which enabled scanning capability and real-time attitude correction to be added to HCR. The instrument

participated in the IDEAS IV deployment to verify all changes and modification, and it performed well.

S-Pol Radar and FRONT

The S-band Dual Polarization Doppler (S-Pol) radar is unique because of its flexible design. Through this design, it can support different operating modes and advanced waveforms that are selectable by the user. This dual-polarimetric, 10-cm weather radar is transportable and can be deployed to remote locations around the world in eight standard-sized sea containers; previous deployment locations include Brazil, Italy, Barbuda, Taiwan, and most recently the Republic of Maldives in the Indian Ocean. S-Pol provides measurements of cloud and precipitation microphysics and dynamics, ultimately leading to improved forecasting of cloud and precipitation formation and severe weather events.

S-Pol being set up at the FRONT Firestone site.

In FY 2013 S-Pol was reconditioned after its FY 2012 deployment to the Republic of Maldives for the Dynamics of the Madden-Julian Oscillation (DYNAMO) field campaign. This reconditioning prepared S-Pol for its move to the Front Range Observational Network Testbed (FRONT) site, which began in late summer 2013. Wireless communications with the site were completed and became functional in fall 2013, and the radar has successfully collected some test data. Next steps will be to complete remote operation capability and calibrations. FRONT has already been requested for use by the community in experiments in 2014.

Laser Air Motion Sensor (LAMS)

Air motion relative to an aircraft is at present measured on our aircraft with a 5-hole gust probe, which employs pressure sensors. Although robust, the method is not highly accurate, in part because the motion of the aircraft modifies the airflow field in its vicinity. Ideally, air motion should be measured some distance from the aircraft, where the airflow has not been modified by deformation around the fuselage. To address this issue, EOL engineers developed the Laser Air Motion Sensor (LAMS), which focuses a continuous-wave coherent laser beam about 20 m ahead of the aircraft. Therefore, LAMS is able to make accurate wind velocity measurements in undisturbed air and measure the aircraft's true air speed. The current LAMS sensor measures the air speed towards the aircraft with an accuracy of about 10 cm s^{-1}; this is almost a factor of 10 more accurate than what can be obtained using in-flight aircraft calibration maneuvers. The 3-Dimensional (3-D) LAMS, reconfigured to enable retrieval of all three components of wind vector, was completed in FY 2013 and tested in IDEAS IV on HIAPER.   3-D LAMS will provide high quality wind measurements for use in a variety of scientific studies, including those involving dynamics and chemistry in the upper troposphere-lower stratosphere (UTLS) region in mid and high latitudes from the NSF/NCAR GV, and lower tropospheric studies using the NSF/NCAR C-130.

449 MHz wind profiler

EOL is developing an innovative modular 449 MHz wind profiler network to update our boundary-layer wind profiling capability. As a basic boundary-layer wind profiler, the new system will provide an improved height coverage and temporal frequency of wind and temperature measurement compared to the 915 MHz system. The new system design is modular and can be configured to match a given experiment's needs – either as a large network of boundary-layer profilers or a smaller number of profilers that can probe higher into the atmosphere. Advanced signal processing techniques are an

integral part of the new profiler and are critical to its combination of high sensitivity, high vertical resolution, and ground-clutter cancellation. In FY 2013, EOL refined, improved and tested the 7-antenna prototype that is capable of probing up to mid-tropospheric altitudes, in preparation for the second Meteor Crater Experiment (METCRAX II) deployment in early FY 2014. This included improving the range-imaging (RIM) resolution to 30 m (rather than the previous 150 m), which was accomplished in collaboration with Dr. Philip Chilson, an ASP Faculty Fellow in EOL from the University of Oklahoma, and with Dr. Hubert Luce, a visitor to EOL from South-Toulon Var Université, La Garde, France. Other developments for the 499 MHz system included adding temperature profiling to the RASS, and testing the system's 8 kW amplifier. Those tests revealed a need for upgrade to its transistors; this upgrade is underway in preparation for DEEPWAVE-NZ in summer 2014. That campaign will be the first deployment of the 7-module mid-troposphere version of the 449 MHz system.

The 7-module 449 MHz profiling system set up for testing in Boulder, CO.

DLR Collaboration

DLR, the German Aerospace center, is Germany's national research center for aeronautics and space. Its extensive research and development work in aeronautics, space, transportation, energy, defense and security research is integrated into national and international cooperative ventures. One of the cooperative ventures is working with EOL on a variety of complementary topics associated with aircraft and airborne instrumentation. DLR operates HALO, the High Altitude and Long Range Research Aircraft, which is a Gulfstream G-550 that is similar to NSF/NCAR HIAPER, a Gulfstream V aircraft.

DLR and the German scientists they support have a long history of airborne research and collaboration with U.S. scientists in NSF-sponsored research. For example, during the Deep Convective Clouds and Chemistry Experiment (DC3) in summer 2012, DLR provided its instrumented Falcon aircraft to fly in coordinated fashion with HIAPER in support of more detailed chemical measurements of storms. With the arrival of HALO, the opportunities for such contributions are even more significant, due to the greater payload and performance of the G-550 as compared to the Falcon. Furthermore, projects such as the HIAPER Pole-to-Pole Experiment (HIPPO) have demonstrated the importance of long-range high-performance aircraft in obtaining global-scale measurements of atmospheric constituents relevant to climate (Wofsy, 2011). Future experiments of this type would benefit greatly from the participation of two highly capable aircraft such as HALO and HIAPER. Similarly, NCAR's capabilities in airborne radar and DLR's in airborne lidar are complimentary, and EOL's extensive experience in instrument flight certification will also be helpful to this collaboration.

An example of this type of collaboration is EOL's work with DLR on the dual canister wing stores project. These wing stores (pods that hang below the wing of the aircraft) will provide the DLR HALO aircraft with

additional capacity to install atmospheric research equipment, as the wing stores on the NSF/NCAR HIAPER do. In FY 2013 EOL/DFS fabricated six sets of wing stores for DLR and supported the documentation audit by Gulfstream to ensure the hardware met Federal Aviation Administration requirements.

Furthermore, in FY 2013 EOL arranged and participated in a joint HIAPER-HALO workshop, to foster international cooperation in airborne global scale geosciences and plan for joint HALO and HIAPER research. The goal of the workshop was to establish collaboration by gathering a small group of representative scientists from the U.S. and Germany to learn about recent and upcoming HALO (for the U.S. participants) and HIAPER (for the German participants) programs; to describe and discuss how field projects are developed and supported for HALO and HIAPER; and to describe how scientists from each country might be able to participate.

Participants from DLR and NCAR at the HALO-HIAPER Workshop in April 2013.

Beyond field campaigns, the workshop also strived to identify common research instrumentation on the two platforms and discuss opportunities for developing common formats, calibration procedures, mission/flight planning tools and data management procedures for common data products; to identify unique research instrumentation on the two platforms and discuss opportunities for developing and sharing instrumentation across the two platforms to provide investigators in each country additional measurement capabilities; and to discuss unmet research needs that might benefit from joint campaigns using HALO and HIAPER.

Leveraging expertise from both EOL and DLR would reduce the time and cost associated with developing new, critical-need instruments, and would allow EOL and DLR to pursue joint development of such instruments that could fly on both HALO and HIAPER. This workshop was a promising step on that path.

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IMPERATIVE IV

Provide comprehensive data services, open access, and long-term stewardship of data

NSF policy requires data set preservation and availability to users pursuing research questions apart from those that justified the original project. Since 2011, NSF requires that grant proposals include comprehensive data management plans. Additionally, one of NSF's core expectations in the NSF - UCAR Cooperative Agreement focuses on data issues, specifically calling for NCAR to "serve as stewards of high quality scientific data on behalf of the community through maintenance, enhancement and curation." For EOL, this charge falls on the Computing, Data and Software Facility (CDS). CDS is responsible for developing and maintaining EOL's computing infrastructure, data and metadata services, collaborative tools, and software engineering, all of which are integral to EOL Imperative IV. CDS serves as the umbrella for all data management activities in EOL, and takes a proactive approach in working with PIs on data management needs.

Data sets collected and preserved by EOL have value that extends far beyond immediate project-team use. Modern data-access mechanisms increase the importance and utility of data set preservation, and improve data access by the scientific community. Leveraging these mechanisms, EOL has enlarged the scope of its data services to include service provision from mission planning stages, to data collection and quality control and long-term archives. EOL also provides stewardship for a select set of data not collected by its observational facilities. These efforts directly feed into NCAR's Strategic Plan Imperative to develop and provide state-of-the-art data services that meet the needs of NSF, NCAR, and the science community.

In FY 2013, the EOL suite of data tools and services provided end-to-end support of field experiments, from initial planning, through data acquisition and field coordination to final processing, archival and distribution.

CDS deployed its state-of-the-art data acquisition systems for several projects in FY 2013. The NCAR In-situ Data Acquisition System (NIDAS) system was a central front-end component of SCP (ISFS), IDEAS IV (HIAPER), SAS (ISFS, ISS and C-130), SPRITE SPECTRA II (HIAPER) and MPEX (HIAPER). Our remote instrument control systems were deployed during HS3 (GlobalHawk) and MPEX (HIAPER) and the Field Catalog was used in SAS, SAANGRIA-Test and MPEX. These tools ensured that data collection was conducted reliably and that quality issues were identified and addressed early in the field program in order to provide a dataset of the highest quality. The Field Catalog assisted researchers in collecting data from a wide variety of sources beyond NSF's LAOF, helped tremendously in the coordination of missions, and served as the initial documentation tool for logs, quality reports and mission summaries that will be used during the scientific analysis phase.

Once the field phase ended, the final quality control processing began. Quality control revisions that occurred during the processing of datasets collected from EOL field experiments were meticulously tracked by our Dataset Tracking System (DTS) during final processing. Quality assurance, composite generation and format conversions were performed to ensure that the scientific analysis phase could be completed efficiently and that the utility of the data is maximized. When the final datasets were complete, they were ingested into the EOL Metadata Database and Cyberinfrastrcture (EMDAC) system

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for final archiving and distribution. CDS will remain involved with these data and the subsequent analysis for years to come as part of our commitment to long-term stewardship.

In addition to providing data services to researchers involved in FY2013 field campaigns and those supported in previous years, we have also engaged in a number of developments in the data service area, as described below.

Field Catalog 2.0

The Field Catalog is a tool in high demand by the research community. In FY 2013, EOL successfully finished development of Field Catalog 2.0, condensing field catalog software to a single code base that is more efficient, modern, reliable and expandable so that EOL can provide new capabilities as investigator requirements change over the coming years. The first deployment of the Field Catalog 2.0 was the Mesoscale Predictability Experiment (MPEX), and in that campaign, OpenStreetMaps and OpenLayers were implemented, as was playback mode and inclusion of airborne cameras along with interactive dropsonde and other Field Catalog product layers. The Field Catalog 2.0 design has allowed EOL to propagate improvements to prior catalog versions and provide a foundation for expansion of new capabilities in the future. Furthermore, the facilitation of mobile access to Field Catalog mapping products has allowed EOL to capitalize on the use of devices such as smart phones and tablets, which are becoming more prevalent in the community. The architecture changes included in the Field Catalog refactoring will allow for more efficient maintenance using state-of-the-art web development frameworks, and includes the addition of new features requested by the community.

Lidar Radar Open Software Environment (LROSE)

Atmospheric researchers make extensive use of scanning and profiling remote sensors, including microwave radars, wind profilers, lidars and sodars. However, extracting the full value from measurements made with these sophisticated instruments depends on having good software tools, and on shared analysis among the community of users. Therefore, capitalizing on NCAR's history of software development for scanning radars, the goal of LROSE is to provide open source tools to the community for data exchange, quality control, analyzing and visualizing Radar and LIDAR data.

The LROSE approach would to also facilitate wind profiler and other remote sensor research. For instance, converters for common commercial wind profiler formats could greatly broaden the use of non-LAOF wind profiler datasets. The LROSE model will allow flexibility in addressing, and timely response to, changing needs in today's world of quickly evolving software and instrument development.

In FY 2013, EOL enhanced legacy software to make it more useful and maintainable. We also solicited input from the community at the November 2012 NSF Radar Workshop, where the LROSE proposal was very well received, and we met with representatives of the Department of Energy Atmospheric Radiation Measurement project to discuss potential collaborations and a software system they are developing that would complement LROSE. There is potential for collaboration with various other organizations as well, including NOAA, NASA and BALTRAD (Baltic Radar Network). The LROSE framework is designed to foster community participation in future radar and lidar software development.

Data Citations and Digital Object Identifiers (DOIs)

Federal agencies, professional societies, and research organizations in the geosciences are moving towards requiring researchers to formally cite data (or digital resources) that lead to a given research result. However, before digital resources can be cited, they must be designated as citable objects with unique identities. The most common type of unique identifier used within current global scholarly communication systems is Digital Object Identifiers (DOIs). DOIs provide unique identifiers/locators for web-based objects (they are now most commonly assigned to journal articles), and are an integral

component of data citations. They are designed to overcome the inherent unreliability of URLs by providing persistent locators for internet-based resources.

In FY 2013, working closely with the NCAR Library and other NCAR/UCAR Labs and entities, EOL developed a plan for implementing Data Citation and Digital Object Identifiers (DOIs) for its portfolio of observational datasets. We modified our metadata database to include fields necessary for implementation of DOIs and to make sure information needed for citation of our data is accurate and complete. The DOI implementation project will more closely link scholarly publication with the datasets actually used.

EarthCube workshop

Participants in the June 2013 Real-time data EarthCube workshop.

The goal of the NSF-sponsored EarthCube initiative is to transform the conduct of research by supporting the development of community-guided cyberinfrastructure to integrate data and information for knowledge management across the Geosciences. In FY 2013, EOL organized the EarthCube Domain End-User Workshop: Integrating Real-time Data into the EarthCube Framework, which focused on both finite time period events, such as field campaigns, as well as longer-term monitoring networks.   This workshop engaged a broad group of cyberinfrastructure experts and disciplinary scientists from the geosciences to aid in development and articulation of a community-based vision for a real-time data and knowledge management system to serve the needs of researchers in various geosciences fields, by optimizing resources and maximizing the scope and impact of science in the future. The executive summary of the workshop is viewable here.

Advances in Observing System Software

EOL made software enhancements for core instrumentation in FY 2013. This included prototyping the down-converter frequency tuning capability for the Software-Defined Digital Down Converter (SD3C), and adding the Range-Imaging-Method (RIM), which provides for sub-gate resolution for remote sensing instrumentation. EOL collaborated with the Center for Severe Weather Research (CSWR) to deploy the SD3C to a Doppler on Wheels (DOW) radar, which resulted in significant improvements in the DOW's performance.

We decided to postpone the seven panel (multi-receiver card) capability for the 449 MHz profiler in favor of the RIM development mentioned for SD3C. However, we extensively refactored the profiler host software for increased reliability, maintainability and RIM support, and we also developed a new control interface. The profiler was operated in Boulder with these enhancements, and will be deployed for the early FY 2014 METCRAX II field program.

EOL implemented the Laser Air Motion Sensor (LAMS) data ingest into NCAR In-Situ Data Acquisition Software (NIDAS), and created recording and decoding routines for both LAMS and the Small Ice Detector, Version 2 (SID-II). We have also added functionality for five new sensor types to NIDAS. Major software refactoring improved the data system performance and reliability, and the addition of integrated calibrations simplified aircraft sensor processing.

We were able to significantly improve the performance and reliability of the High Spectral Resolution Lidar (HSRL) by upgrading its software to the Scientific Linux operating system. We also added polarization support to the HSRL real-time software and the HSRL processing software.

Nagios use in EOL was expanded to include the monitoring of Field Catalog data streams and the HIAPER

Cloud Radar (HCR). By raising the Nagios error threshold for S-Pol, its configuration was tuned to send only the most critical errors to the technicians and thus the reporting frequency was reduced. Nagios use on the Field Catalog has allowed developers and catalog administrators to focus less of their time on monitoring products and more of their time addressing needs that occur during the field campaign, thus increasing efficiency.

EOL made progress in software enhancements for other instrumentation as well. We developed a plan for the migration of the ~1M lines of unsupported Visual Basic code to a current software environment for the Microwave Temperature Profiler (MTP); made algorithm improvements and added new instrument processing to Nimbus, and significant (user-requested) enhancements to Aspen; developed the Remote Instrument Control (RIC) system, which was then successfully deployed for the Southern Andes-ANtarctic GRavity wave InitiAtive (SAANGRIA)-Test field campaign, allowing soundings to be securely initiated and managed via the Internet; and completed of the first phase of HCR software development, which led to successful operation of this radar during the SANGRIA-Test and Instrument Development and Education in Airborne Science Phase 4 (IDEAS IV) programs.

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IMPERATIVE V

Attract and inspire new generations of scientists, engineers and the general public to atmospheric science

EOL's commitment to both continuing and expanding the Laboratory's portfolio of education and outreach (E&O) contributions is reflected in EOL's Strategic Plan Imperative V. This Imperative aligns with NCAR's goal to attract a diverse group of university students and early career scientists and engineers, and to provide exciting educational and professional opportunities. With the suite of NSF Lower Atmospheric Observing Facilities (LAOF) that EOL manages, we are in a unique position to provide exceptional education and training to new observational atmospheric scientists and engineers, and to inform and excite the public with the impact of observational research.

The promotion of atmospheric science is crucial to inspire the development of the next generation of observational scientists and engineers, and is an institutional charge that is important to EOL.

Students pursuing education in science, technology, engineering and mathematics (STEM) can be motivated to seek careers in observational meteorology through exposure to NSF LAOF, and EOL outreach activities. EOL can also help the public understand better the value of observational atmospheric science by demonstrating direct measurements of the atmosphere and explaining what scientists learn from these observations. The mechanisms EOL provides to support and inspire undergraduates and graduates, high school students, teachers, and faculty will ensure the field of atmospheric science remains vibrant well into the future.

In FY 2013 EOL conducted education and outreach activities for several field campaigns; participated in an educational field deployment; conducted the 13th year of EOL's Summer Undergraduate Program for Engineering Research (SUPER) internship; and completed the second year of the Technical Internship Program (TIP) for science support students.

Education and Outreach Activities During Field Campaigns

When requested, EOL staff work closely with the PIs of funded research projects on dedicated education and outreach efforts during field campaigns to increase the understanding of and public appreciation for observational research in the atmospheric sciences and its relevance to society. In FY 2013, EOL staff planned and conducted an extensive education and outreach effort for the Southern Atmosphere Study (SAS; see Imperative II). The PIs, the EOL Director, and NSF Program Officers attended one of these activities and the scope and outcomes of the activity were well-received by all of the participants.

EOL is working to entrain the next generation of users of its facilities. EOL, in conjunction with other LAOF partner organizations, developed and delivered a Train and Entrain New Users workshop at the American Geophysical Union (AGU) 2012 Fall Meeting. The workshop was well attended and received positive comments from the NSF/AGS Division Director and the NSF Program Manager for the LAOF. We offered a shortened version of the workshop at the 2013 American Meteorological Society (AMS) Annual Meeting and during the 36th Conference on Radar Meteorology.

EOL also developed a Digital Guide to the LAOF, which can be accessed either via EOL's website or through an iOS or Android app. The guide contains information about the LAOF and how to request these facilities, both presented in an interactive and accessible manner.

Educational Deployments

Each year, NSF makes a subset of LAOF available for educational purposes to colleges and universities across the continental U.S. This effort is managed by EOL and exposes undergraduate and graduate students in science and engineering to observational meteorology, without requiring faculty to design and propose a full-scale scientific field

campaign.

NSF funded 4 educational projects in FY 2013, all using the Doppler on Wheels (DOW) radar.

1. Doppler Radar for Education and Mesoscale Studies (DREAMS) at Stony Brook University, New York, June 17 - July 8, 2013.

2. Geoscience Education and Outreach of Weather in New York using the DOW at Hobard & William Smith Colleges (GEO-WIND-HWS), Geneva, New York, February 13 – March 1, 2013.

3. University of Nebraska DOW Education and Outreach Project – 3 (UNDEO-3), Lincoln, Nebraska, March 24 – April 7, 2013.

4. Western Illinois University DOW Radar Observations (WIUDOW), Macomb, Illinois, September 16 - October 4, 2013.

Internship Programs

EOL's Summer Undergraduate Program for Engineering Research (SUPER) hosted four interns in FY 2013. SUPER is designed to provide students hands-on experience working with atmospheric observing systems by teaming with lead engineers on engineering problems directed at scientific advancement. This program focuses EOL's outreach efforts on the engineering community in a manner analogous to what other programs in UCAR/NCAR currently do for young scientists. EOL typically receives resumes from mechanical, electrical and computer, aerospace, optical, environmental, chemical, and industrial engineering students. The FY 2013 interns worked on projects to make improvements to ozone sensors and data acquisition systems; design and implement of control systems for airborne operations; development of real-time, interactive data displays; and automated dropsonde deployment systems. The scholarly disciplines represented by the interns were electrical and computer engineering, mechanical engineering, and computer science. Furthermore, the follow on proposal to add a data system to the ozone photometer, the instrument that was subject of two SUPER interns projects in FY 2013, was one of three selected as a two-semester capstone project at the Embry-Riddle Aeronautical University (ERAU) from a pool of twelve competing proposals. The project team at ERAU consists of two electrical engineering students and two computer sciences students led by a professor, and the final delivery of the data system is expected in spring of FY 2014.

The EOL Technical Internship Program (TIP) also continued in FY 2013. This program provides internship opportunities for students focused on science support from 2-year colleges and vocational/technical institutions in the Boulder/Denver area. The objective is to establish connections with students and faculty, spark interest in technical careers in the geosciences, and create EOL/student mentoring relationships that will foster students' academic advancement and careers.

EOL sponsored three interns in FY 2013 for TIP. The 2013 interns were assigned to the positions of instrument designer/maker, project management assistant, and scientific data assistant, and were students from Front Range Community College and Arapahoe Community College.

As part of the *"Diversity in Engineering Pipelines and Partnerships"* project, for which EOL was awarded NCAR Diversity Funds, an EOL scientist and engineer visited the North Carolina State University (NCSU) College of Engineering in Raleigh, NC in May 2013 to give a two-part seminar to a group of students. The seminar and visit furthered the goal of the project, which is to increase knowledge of engineering careers in atmospheric science particularly (but not exclusively) among under-represented groups at select universities. This is expected to lead to fruitful sensor or instrument development collaborations and will enable EOL to access pools of under-represented applicants for engineering openings at NCAR.

The education and outreach activities EOL provided as part of the SAS field campaign and the NCAR Diversity Program provided support and inspiration to high school students and teachers, undergraduate and graduate students and faculty, with a goal of ensuring the field of atmospheric science becomes even more diverse and vibrant well into the future.

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FRONTIER I

Improve observing capabilities for weather and climate phenomena with high socio-economic impact

EOL has provided prominent support for studies of hurricanes, tornadoes, and other severe storms. Airborne studies of convective systems require nowcasting and displays of the rapidly changing meteorological environment. EOL's Field Catalog 2.0 development, which was completed in FY 2013, worked to make the Catalog more efficient, modern, reliable and expandable so that EOL is able to provide new capabilities as investigator requirements change over the coming years. The first deployment of Field Catalog 2.0 was the Mesoscale Predictability Experiment (MPEX; see Imperative IV) and this development is now part of our Imperatives.

Observational aspects of hurricane studies are centered on measurements from dropsondes. EOL developed the Airborne Vertical Atmospheric Profiling System (AVAPS), or dropsonde system (including the launch mechanisms, sondes, and software for launch operations, real time sonde data displays, and post processing) that are currently used for operational and research purposes on aircraft, balloon, and Unmanned Aerial System (UAS) platforms in the U.S. and internationally. A unique partnership among EOL, NOAA and NASA led to development of an autonomous, remotely operated dropsonde system for the NASA Global Hawk UAS, and in FY 2013 EOL completed the redesign of the dropsonde system on HIAPER. The new system, now part of our Imperatives, uses the smaller sondes as used on the Global Hawk, allows for 8 sondes in the air simultaneously instead of the previous 4, and has remote operations capability. It was successfully flow during Southern Andes-ANtarctic GRavity wave InitiAtive (SAANGRIA)-Test and MPEX, and is further discussed in Imperatives II and III.

A potential new and unique EOL system for studies of severe weather is Airborne PhasedArray Radar (APAR). The scientific community has strongly voiced the need for an airborne radar, in particular for studies over open ocean or complex terrain. This is especially important now that the platform for the Electra Doppler Radar (ELDORA), the Naval Research Laboratory (NRL) P3, has been decommissioned. EOL is in a unique position to play a leading role in airborne phased array radar (APAR) technology, specifically with respect to the airborne antenna. The availability of and direct access to the NSF/NCAR C-130, combined with in-house scientific and engineering expertise, create an exceptional opportunity for EOL to make significant contributions to such a next-generation radar capability.

The NSF/NCAR C-130 with a model (styrofoam panels) of the Line Replaceable Units (rectangular elements) and the full sized aperture (the four by four matrix) for APAR.

As a result, the development of APAR with dual-Doppler and dual-polarimetric capabilities to replace ELDORA has been identified as a long term goal for EOL. At X-band, ELDORA experienced severe attenuation in heavy rain situations, and its lack of dual polarization capability severely restricted its scientific usefulness in advancing quantitative precipitation estimates and water cycle research in those regions not covered by ground-based operational radars. APAR is being designed to address these issues. While implementing dual-polarization on APAR will be technologically difficult, the polarimetric capability of APAR will enable unprecedented microphysical studies from an airborne radar. Phased-array technology applications will help advance science in several areas related to clouds, in particular dynamics and physics of clouds over open oceans and difficult to access regions of the Earth such as the polar areas. Furthermore, higher temporal and spatial resolution measurements are needed to investigate detailed mesoscale storm structures and evolution.

APAR will be flown on the NSF/NCAR C-130, where it can be combined with other remote sensors available in EOL and with the many other measuring capabilities that this platform provides. APAR antenna system would consist of four distinct apertures strategically located about the fuselage. This APAR design could also be adapted to other agencies' C-130s, including the U.S. Air Force hurricane reconnaissance fleet. The potential to improve hurricane track and intensity forecasts by continuously assimilating APAR data from those reconnaissance missions into operational numerical models may provide even greater societal impacts for the general public beyond the benefits to be gained by the scientific research community.

Development of APAR requires substantial effort and resources. As such, EOL has taken a phased approach to APAR development and is partnering with MIT/Lincoln Laboratory and V. Chandrasekar (EOL Affiliate Scientist from Colorado State University) on this effort. After successfully developing a small, low cost, dual-pol phased array antenna prototype in FY 2012, EOL completed the next phase in FY 2013: design, construction, and testing of an APAR prototype subpanel. The sub-panel design is unique and has led to further discussions with other groups interested in airborne phased array radars.

The APAR development is a multi-disciplinary effort, requiring the skills of scientists, technicians, instrument makers, and mechanical, electrical, antenna, RF and software engineers. Input from the community is a critical part of APAR development and in FY 2013 EOL finalized an APAR white paper to outline the full project. EOL will seek collaborative partners for APAR and has already generated significant interest based on the APAR subpanel results.

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FRONTIER II

Provide new or significantly strengthened capabilities to support observational research in key areas where support needs are growing in importance

A significant portion of EOL support throughout its history has been devoted to support of climate research, as EOL has much to offer in this area. However, the nature of the needs and opportunities is changing, and so there is reason to change the nature of our support. HIAPER opens new opportunities for global-scale observations, and potential of such observations was illustrated by the HIPPO missions. The NSF/NCAR C-130 will continue to play a role in climate process studies. FRONT and CentNet have the potential to provide longer-term observations covering an area similar to a grid box in a climate model. FRONT can also provide a setting for incorporating testbed measurements while longer-term observations provide context for the testing of new instruments. The history and experience of EOL in process studies will continue to serve the needs of the climate community for such observations.

EOL's collaboration with Kevin Repasky (EOL Affiliate Scientist) of Montana State University (MSU) on the Water Vapor Differential Absorption Lidar (WV DIAL) is an example of a development that will support observational research in a number of key areas. The weather forecasting and climate research communities have a clear need to obtain improved measurements of water vapor. Accurate, high-resolution, continuous measurements of water vapor are a key observational gap. Engineers from MSU have developed a lab-based, low-cost, eye-safe, diode-based WV DIAL system for remote sensing of water vapor in the atmosphere. The WV DIAL will provide measurements of water vapor from the surface to 6 km and of aerosols to 12 km. A unique aspect of this instrument is the low cost due to the use of commercial off-the-shelf components. EOL is partnering with MSU to enhance the system for operating in the field and for long periods of time that would be required for use in a field campaign. The resultant instrument will fill a national long-term observing facility gap and greatly benefit studies of micro- and meso-scale meteorology, water cycle, carbon cycle and, generally, biosphere-hydrosphere-atmosphere interaction research at weather and climate variability time scales.

In early FY 2013, a test prototype of the WV DIAL was fielded at the National Weather Service office in Dallas/Ft. Worth, TX for two weeks. During this last-of-four field test, the instrument was evaluated to determine if the technology was well suited to make long-term continuous measurements of water vapor. Data from the test was evaluated, deficiencies identified and engineering solutions proposed, and an evaluation meeting of the performance was presented to a group, including input from NCAR, MSU, NASA, and NOAA. Following that, EOL developed a preliminary design to make the system eye-safe and opto-mechanically stable via a shared telescope, and the EOL- MSU team developed a rigorous method of lidar model and designed a two channel instrument to allow measurements closer to the surface. This team also worked to construct a two channel DIAL prototype.

EOL also built upon the input received during the 2012 LAOF Workshop: Meeting the Challenges of Climate System Science, holding an internal development summit in FY 2013 to examine current EOL developments in light of the measurement capability needs expressed during that workshop. We will continue to inform our development directions with input from the climate community.

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FRONTIER III

Develop new capabilities that focus on processes at interfaces in the atmosphere

The air-sea interface, the air-land interface, and the tropopause have diverse observational needs: ships, buoys, and aircraft for the first; facilities such as ISFS for the second; and high-altitude aircraft and balloons for the third. There are many possible measurement tools and observational opportunities for these interfaces: controlled towed vehicles to extend the reach of research aircraft closer to the surface; ocean sensors like Airborne eXpendable BathyThermographs (AXBTs) for studies of the upper layer of the ocean; measurements of fluxes of trace gases to or from the lower surface (land or sea); new sensors on dropsondes for characterizing the chemistry of the tropopause region; the development of remote sensors that measure profiles of trace gases and for measurement of fluxes (e.g., via combining a DIAL with a Doppler lidar); and development of large arrays of sensors to increase coverage and resolution of measurements. Other areas with potential include using Unmanned Autonomous Systems (UASs) for boundary-layer studies, the remote measurement of 3-D wind, tethersonde capability to increase the altitude range of boundary layer measurements, and higher-response measurements from research aircraft to measure fluxes and probe the fine-scale structure of turbulence. Understanding processes at interfaces continues to grow in importance and is prominent in many assessments of needs for the future. To address some of these needs, EOL is developing CentNet and FRONT for greater boundary layer coverage through longer timeframes, broader areas, and complex terrain. Sensor simplification and miniaturization are leading to new opportunities in this area and FRONT will be an excellent testbed for these sensors (see Frontier IV).

A CentNet tower undergoing testing at NCAR/EOL in Boulder, CO.

There is now broad recognition within the geosciences that the multi-scaled features characterizing landscapes present unique challenges that hinder progress in multiple fields connected to climate, air quality, atmospheric composition, surface hydrology, and ecology. To make scientific progress on these challenges requires measuring and modeling spatial gradients in state variables and their concomitant fluxes at unprecedented spatial scales.

A large network of ground-based sensors would help address these challenges and would facilitate research in the biogeosciences, hydrology, and urban meteorology, in addition to the mesoscale meteorological research traditionally supported by tower networks. EOL therefore is designing and prototyping CentNet, a network of up to 100 stations that can be deployed on spatial scales from 1 m to 100 km in support of surface exchange research and a wide variety of bio-geophysical field studies. CentNet would allow direct research-quality measurements of all components of the surface energy and water budgets, complemented by measurements of key elements of the carbon budget. The CentNet system could also be used for both weather and climate process studies. This development builds on EOL's current Integrated Surface Flux System (ISFS), expanding it to include an array of semi-autonomous sensor stations that can be deployed in a variety of spatial patterns and for a wide range of time periods.

CentNet is designed to minimize set up and maintenance time. As part of this, Radio Frequency (RF) communications will be used as much as possible to reduce cabling, and each station will have two-way communication via the Internet for real-time data display and control. The system also has the ability to cycle power on any sensor, e.g. one that is not reporting.

In FY 2013, EOL successfully incorporated smart sensor and communication technologies into CentNet for the SCP campaign (see Imperative II), allowing for improvement to operational efficiency. SCP provided the opportunity to explore wireless communication technology for CentNet. Using the latest in long range Bluetooth technology, high rate data from all stations was transmitted consistently to a central location, and stations were able to operate off the power. The experience gained with the Bluetooth technology provided the opportunity to do preliminary testing of wireless communication from standard sensors.

Also in FY 2013, CentNet sensors for the measurement of net radiation and 10m wind speed and direction were selected

after extensive laboratory and field testing of candidate sensors. Two-component sonic anemometers were chosen to measure wind speed and direction because of the linearity and robustness of the measurement technique. For net radiation, we tested and evaluated two 4-component net radiometers through a field intercomparison to four secondary-standard radiometers. The tested net radiometers had very similar performance after field calibration with respect to our secondary-standard radiometers. The final selected net radiometer sensor was chosen for use in CentNet because its modular design incorporates 4 individual second class radiometers, each of which can be simply replaced if it fails. It will be used for solar radiation measurements.

Work continued in FY 2013 on the evaluation of the telescoping tower, focusing on how to mount instruments on the tower. ISF and DFS cooperated to build a mount design; part of the design is the ability to swing sensors out of the way of other sensors when the tower sections are lowered. Testing of the mount was successful and we plan to explore improvements in FY 2014.

A development that has become part of our Imperatives is the innovative, modular 449 MHz wind profiler network, which will probe higher and be simpler to deploy than our 915 MHz profiling system. The 449 MHz profiler's unique hexagonal-antenna and its modular design will provide for assembly in a variety of configurations to meet the diverse range of experiments that EOL supports. More information on the 449 MHz wind profiler may be found in Imperative III.

Similarly, the Laser Air Motion Sensor (LAMS), which provides high-resolution wind measurements from aircraft, has moved into our Imperatives. EOL engineers developed the LAMS for deployment on HIAPER and C-130, and by focusing a continuous-wave coherent laser beam about 20 m ahead of the aircraft, the instrument is able to make accurate wind velocity measurements in undisturbed air and measure the aircraft's true air speed. The 3-Dimensional LAMS will provide high quality wind measurements for use in a variety of scientific studies, including those involving dynamics and chemistry in the upper troposphere-lower stratosphere (UTLS) region in mid and high latitudes from HIAPER, and lower tropospheric studies using the NSF/NCAR C-130. See Imperative III for further information on LAMS.

HSRL will also be especially useful in studies of the UTLS region in all areas of the globe when it's included in the HIAPER payload because of its ability to measure particle backscatter and depolarization 10km above the aircraft flight level. For more information on HSRL measurements see Imperative I and Imperative II.

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FRONTIER IV

Develop new calibration and testing facilities, including testbed capabilities, for the community, either in collaboration with other agencies or specifically for NSF-supported research

The most prominent test-bed development area in EOL is the Front Range Observational Network Testbed (FRONT), and in FY 2013 the S-Pol radar began its move to the FRONT site. FRONT has substantial potential to serve community needs, as it integrates Colorado State University's (CSU) CHILL and EOL's S-Pol radar systems to streamline engineering development and operations for expanded science, research and education opportunities. FRONT will provide the scientific community with opportunities to conduct target-of-opportunity scientific field experiments; maintain a long-term mesoscale test bed for assessing instruments, data quality procedures, sensor integration, numerical models, networking capabilities and derived products; provide a framework for local field campaigns; and provide hands-on education.

FRONT's technical goals are to establish common system software, data formats and data processing environment; share common receiver and system control hardware; and remote-control both radars for unattended operations. With S-Pol's move to a new home-base east of U.S. Interstate 25, FRONT has begun its development into a world class dual-Doppler, dual dual-polarization radar network, with fully available S-Pol functionalities. FRONT is discussed further in Imperative III.

Beyond the testbed capabilities of FRONT, there are also needs for calibration facilities for water vapor sensors; an environmental chamber with precise pressure and temperature control for testing instruments over a wide range of these parameters; and a wind tunnel test facility for aircraft inlets to which EOL would have access, perhaps operated by EOL. Associated with these needs, is the need for more attention to measurement science: calibration, uncertainty characterization, and documentation of instrument characteristics.

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DIRECTOR'S MESSAGE

It is a privilege to introduce this report, which highlights some of the great work undertaken by my colleagues at the High Altitude Observatory (HAO) in the past year. HAO's mission is to understand the behavior of the Sun and its impact on the Earth; to support, enhance, and extend the capabilities of the university community and the broader scientific community, nationally and internationally; and to foster the transfer of knowledge and technology. All aspects of this mission are illustrated in the report that follows.

A number of HAO staff were recognized with awards during the past 12 months. In December 2012, Matthias Rempel won the University Corporation for Atmospheric Research (UCAR) Distinguished Achievement Award. I believe that Matthias is the youngest ever recipient of this, UCAR's most prestigious, award. It is only the sixth time that the award has been made, and it is the third time that an HAO colleague has been so honored: Tim Brown was the first ever recipient, and two years ago Bruce Lites was the second HAO colleague to be so honored. Tim, Bruce, and Matthias make a distinguished trio indeed.

Dr. Michael Thompson, HAO Director

In January 2013 the Observatory made its annual awards. The John W. Firor Publication Award for 2012 went to Stan Solomon, Liying Qian, and their co-authors for their 2010 paper, "Anomalously low solar extreme-ultraviolet irradiance and thermospheric density during solar minimum." The Walter O. Roberts Scientific and Technical Advancement Award for 2012 went to Matthias Rempel for his groundbreaking numerical simulations work to advance understanding of the structure of sunspots. The HAO Director's Award for outstanding contributions to HAO in the furtherance of the Observatory's mission and goals went to Joan Burkepile, Becca Hathaway (UCAR Community Programs), Don Kolinski, and Mark Miesch for their leading roles in the design and production of the Sun-Earth Connections exhibit at the National Center for Atmospheric Research (NCAR) Mesa Lab.

Some HAO colleagues also received promotions during the year. Mark Miesch was promoted to Scientist III. Joe McInerny was reclassified to Associate Scientist III, Rebecca Centeno-Elliott, Alfred deWijn, Astrid Maute, and Liying Qian were all reclassified to Project Scientist II. Ron Lull was reclassified to Systems Administrator II, and Kim Nesnadny has been promoted to team lead for the Computer Systems Management Team (CSMT) group.

Congratulations to them all!

I shall not go through all the highlights reported here, they are well described in the report that follows. However, I should like to mention just one significant achievement this year: the successful completion and deployment to the Mauna Loa Solar Observatory (MLSO) of the COSMO K-Coronagraph. The K-Coronagraph is the first element in the Coronal Solar Magnetism Observatory (COSMO). The other elements are COSMO ChroMag, for which a prototype was completed this year and which will undergo further testing on our Mesa Lab spar in Boulder in spring of 2014 before deployment to MLSO, and the COSMO Large Coronagraph, which is on track to undergo its Preliminary Design Review in March 2014. The K-Coronagraph, under the leadership of Joan Burkepile, was completed on time and within budget. It replaces the old MLSO K-Coronameter (MK4) and will produce images with ten times better signal-to-noise and twelve times faster image cadence than its predecessor. At time of writing, the new instrument is in calibration testing phase. The K-Coronagraph data will all be made available on a daily basis to the community via our web site, from which all of the MK3/MK4 observations since 1980 are also available.

My work as HAO Director would be impossible without the support of many colleagues, particularly my executive team of Gang Lu, Steve Tomczyk, and Joanne Graham; my executive assistant Bev Johnson; and section heads Sarah Gibson, Scott McIntosh, and Art Richmond. As of October 2013, Art stepped down as a section head after long service, and Mike Wiltberger stepped up to replace him. I would also like to take the opportunity to acknowledge three other colleagues whose leadership is crucial to the success of HAO: Instrumentation Group manager Scott Sewell, MLSO manager Joan

Burkepile, and Computer CSMT lead Kim Nesnadny. Thanks to them all.

Finally, kudos for the production of this report goes to Joanne Graham. Thank you to her and to all colleagues who provided inputs.

‹ 2013 HAO Annual Report up Scientific Discovery & Innovation ›

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SCIENTIFIC DISCOVERY & INNOVATION

HAO conducts a comprehensive program of solar-terrestrial physics, encompassing solar physics, physics of the heliosphere, study of geospace and space weather, and the physical processes of Earth's magnetosphere and upper atmosphere. The main research areas include: investigations of long-term solar variability using state-of-the-art numerical models, theoretical and observational studies of transient solar phenomena, and research into terrestrial upper atmosphere's response to variable solar output and its coupling to the lower atmosphere.

Following are some of our scientific highlights from fiscal year 2013.

‹ Director's Message up Simulations of Cannibalistic CMEs ›

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SIMULATIONS OF CANNIBALISTIC CMES

The majority of Earth-directed Coronal Mass Ejections (CMEs) reach us within 24 to 72 hours after being launched from the Sun. However, there is a certain class of CMEs that arrive at Earth much faster than models have predicted, with an impact larger than what the current generation of forecasts infers. These fast CMEs pose a significant problem for those dependent on accurate space weather forecasts to protect satellites in low-Earth orbit and power grids on the ground.

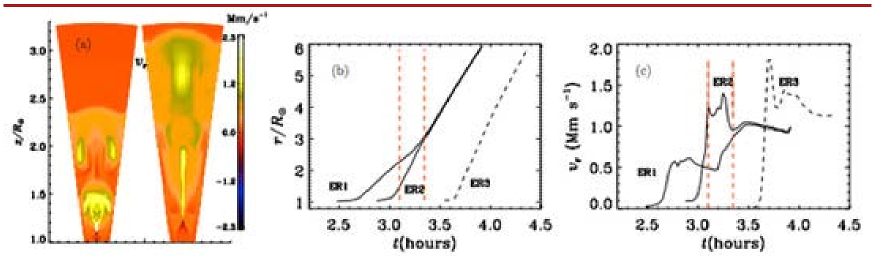

Figure 1: The first magnetohydrodynamic (MHD) simulations of a repeating (or “homologous”) sequence of three distinct CMEs from the same source region.

Magnetohydrodynamic (MHD) simulations have been carried out to investigate the generation mechanism of the fast CMEs [*Chatterjee and Fan*, 2013]. Figure 1 illustrates a repeating (or “homologous”) sequence of three distinct CMEs from the same source region on the Sun. These CMEs originate from the repeated formation and (partial) eruption of magnetic loops that are driven by the continuous emergence of a twisted magnetic “rope” through the simulated photospheric boundary and into a pre-existing coronal loop structure. This situation mimics many contemporary observations. The formation of these CMEs, and the impact that each of them has on the local environment of the ejecting region, leads to what is being dubbed “cannibalistic” behavior. The simulation shows that a CME erupting into the open magnetic field created by a preceding CME has a higher speed, while the slower leading CME clears out the upstream environment for the following CME. The second of the three successive CMEs is cannibalistic as it catches up rapidly with the preceding CME, and the two then merge into a single fast CME before exiting the computational domain. The collision of the two CMEs also results in a significant shock and a burst of radio emission. All of the CMEs triggered in the simulation, including the leading merged CME, attain speeds in excess of 1000 km/s as they exit the domain so that they all meet the fast CME criteria. Another interesting finding from the simulation is the repeated formation of features called sigmoids, which are S-shaped current systems that typically occur in solar active regions prior to eruption or after each CME as the corona recovers.

Knowledge of such homologous eruptive systems, and the fast CMEs resulting from them, will ultimately improve our ability to forecast the arrival time of a CME, its strength, and its magnetic field orientation at Earth. These are critical parameters needed by operational space weather forecasters to provide timely accurate warnings of the impending storm conditions that allow the relevant parties to minimize capital and collateral losses. These results mark the first of a series of novel experiments to study the interaction of large-scale magnetic flux systems in the Sun’s interior, their evolution and propagation to the Sun’s outer atmosphere, and ultimately their impact on the near-Earth environment.

This work was supported by the National Science Foundation (NSF), #M0856145.

‹ Scientific Discovery & Innovation   up   Origins of the Sunspot Cycle ›

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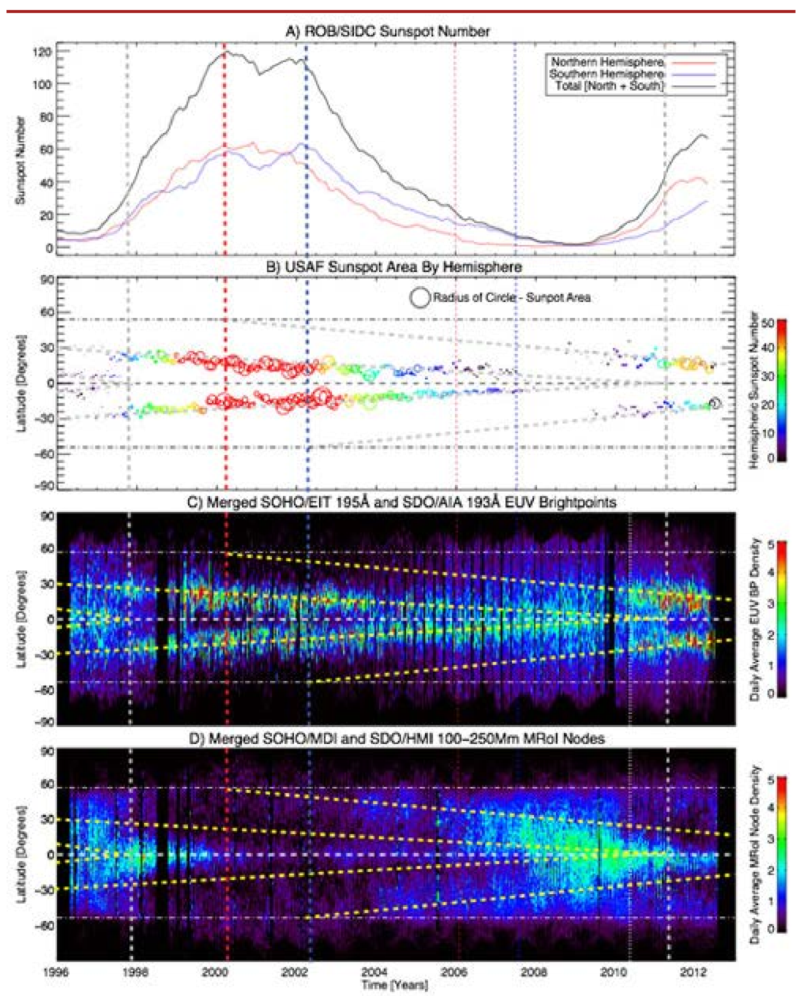
ORIGINS OF THE SUNSPOT CYCLE

Sunspots are the canonical marker of the Sun's internal magnetic field. Since the early twentieth century we have observed the magnetic field associated with sunspots flipping polarity approximately every 22 years. A considerably longer record of measurements has demonstrated that the number of sunspots waxes and wanes over a period that is approximately eleven years, although that “sunspot cycle” length can vary from as short as 8 to as long as 14 years. As yet there is no complete physical explanation for the observed activity cycles or how they are related.

Variations in sunspot numbers are closely related to the evolution of the Sun’s global magnetic fields which, in turn, drive the radiative, particulate, and eruptive outputs that bathe the Earth and the solar system. Fortunately, the Earth’s own magnetic field acts as a form of shield, protecting us from most of the harmful solar energetic particles and cosmic rays. The ever-increasing reliance of humanity on space-based technology has reached the point where understanding the origins and impacts of magnetic activity of our star, the Sun, becomes imperative.



Recently, Scott McIntosh and colleagues conducted detailed analysis of small ubiquitous features on the Sun based on a 17 year-long record of coronal images and photospheric magnetograms from the Solar and Heliospheric Observatory (SOHO) and Solar Dynamics Observatory (SDO) spacecraft. Their analysis indicates that the landmarks of 11-year sunspot variability are strongly tied to the spatial and temporal overlap of the activity bands, which in fact possess a 22-year magnetic activity cycle. They demonstrated that the sunspot cycle can be conceptually explained in the context of an “interference pattern” involving the interaction of oppositely polarized magnetic activity bands that exist in the deep solar interior. Figure 2 depicts times when the oppositely signed activity bands of the previous solar cycle appear to cancel at the equator (thick gray dashed vertical lines). These cancellation points mark the start of a new sunspot cycle as the internal cancellation at low latitudes permits sunspots to form in abundance with the existing higher-latitude bands in both hemispheres. The figure also shows that the hemispheric sunspot number (hSSN) maxima (thick red and blue dashed vertical lines) coincide with the initial migration of a new (oppositely signed) activity band at high latitudes (~55°) in each hemisphere. The appearance of this new activity band results in a downturn in net magnetic flux available to form sunspots in each hemisphere and thus defines the sunspot maxima for that hemisphere. Note the nearly two-year offset between the

hemispheric sunspot maxima. Interestingly, as shown in this figure, the solar minimum is a time when a great deal of magnetic flux can be present under the solar surface but concurrent strong mutual cancellation or interference between four activity bands takes place at low latitudes (bracketed by the thin dashed lines and the next termination point).

Figure 2: Oppositely signed activity bands of the previous solar cycle appear to cancel at the equator (thick gray dashed vertical lines). These cancellation points mark the start of a new sunspot cycle.

This work provides observational insight into a long-standing problem in solar (and astro-) physics. Based on this analysis an observationally determined forecast for the onset of the next solar cycle (25) among other things can be developed and continuously adjusted. Furthermore, aspects of this research indicate that the observed overlap of the activity belts and their interference increases the occurrence of space weather events and their severity.

This work is supported by the NSF, #M0856145 and NASA/Lockheed Martin Award #8100003006

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THE DECLINE IN SOLAR ACTIVITY IN RECENT YEARS

The solar energy output is not constant but varies over many time scales. The Sun can produce large and fast eruptions at any time, but generally, the frequency and intensity of these events follows the 11-year solar cycle and peaks at solar maximum, when the Sun is peppered with regions of intense magnetic fields that take the form of dark sunspots and bright regions called faculae. One of the great challenges in solar physics is to understand, and ultimately predict, solar magnetic activity and how the appearance of sunspots and faculae modulate the Sun's radiative output.

Not all solar cycles are the same, and some can be much stronger or weaker than others, as illustrated by the historical sunspot record shown in Figure 3. For most of the space age, we have witnessed a period of high solar activity, but the current solar cycle, cycle 24, has been unusually quiet and was preceded by a long solar minimum that lasted for over three years. In spite of the fact that in 2012–2013 we were at the peak of cycle 24, activity remained at moderate level, making cycle 24 one of the lowest cycles in the past 100 years. This long stretch of low solar activity has brought some to wonder if sunspots were changing and the Sun was about to enter a new Maunder Minimum.

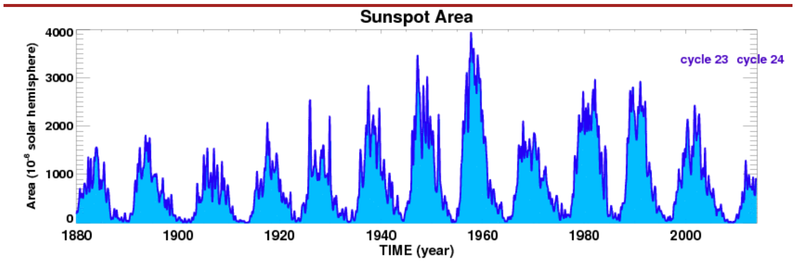

Figure 3: Total area on the visible disk of the Sun covered by sunspots, measured in millionth of solar hemisphere, and averaged over 81 days, the time corresponding to three solar rotations. Solar magnetic activity waxes and wanes with a period of about 11 years.

To address these questions, in collaboration with researchers at California State University, Northridge (CSUN), we have analyzed sunspot and faculae observations taken at the San Fernando Observatory (SFO) operated by CSUN. This is the longest record of photometric observations of the Sun. At SFO, they measure not only the number of sunspots, but the area and intensity of each individual sunspot using an automatic detection program that runs on carefully calibrated solar images that have an accuracy of better than 1%. Our goals were: 1) to quantify the changes in sunspots and faculae during the recent solar cycles and 2) to determine their effect on solar irradiance.

We found that magnetic activity started to change in cycle 23. While still an above-average cycle, cycle 23 at its peak showed a decrease of about 27% in total sunspot area compared to the previous cycle. This change was almost entirely due to the decrease in number of very large sunspots during cycle 23. The trend continued in cycle 24, when sunspots of all sizes have been scarce, and in particular the larger ones. A similar change was found in faculae.

A controversial study based on the analysis of data taken at Kitt Peak Solar Observatory concluded that sunspots were becoming less dark at a worrisome rate of about 2% per year since the early '90s. If this trend were to continue, the Sun would experience a new Maunder Minimum by the year 2022. However, questions were raised about the reality of such trend because this data set suffered from serious selection

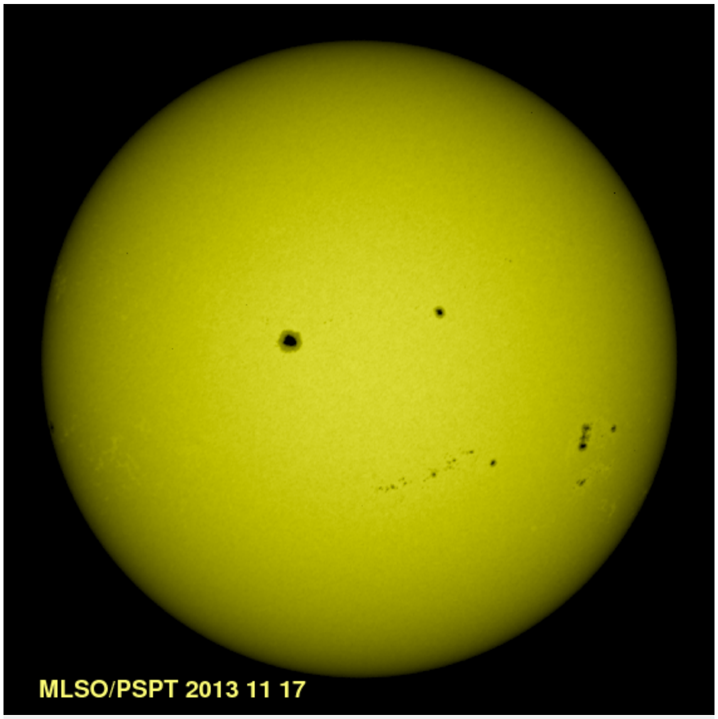

Figure 4: Image of the Sun taken in visible light with the Precision Solar Photometric Telescope (PSPT) at Mauna Loa Solar Observatory on November 17, 2013, during the maximum of solar cycle 24. Large sunspots are usually darker than the smaller ones.

effects, with only a very small number of observations taken in the early years, when most of the decline in sunspot darkness took place.

To check if the change in sunspot darkness were real, we used the longer and very homogeneous data set collected at SFO, which includes over 20,000 sunspot measures. The SFO data showed that sunspots are not becoming less dark over time. There are fewer sunspots on the Sun during the recent years, but the physical properties of sunspots have not changed. There is a well-known relationship between the size and darkness of a sunspot. On average, the largest sunspots are also the darkest (Figure 4) and harbor the strongest magnetic fields. This relationship has not changed. Moreover, when we examined the intensity of sunspots as a function of time, we found that the average intensity has been remarkably stable over time, as shown by the first order fit to the data shown by the dashed blue line in Figure 5. There are a lot of variations on a given day because sunspots of various size and intensity can be present on the Sun, but no significant trend is noticeable in the average intensity.

Thus, we did not find evidence that sunspots have changed. There are fewer sunspots on the Sun, which is normal for weak cycles, but the scarcity of large sunspots should not be interpreted as a sign of an incoming Maunder Minimum. We know from the drawings of the Sun made by Hevelius in 1644, just one year before the Maunder Minimum started, that there were large sunspots on the Sun before the Maunder Minimum. We still do not know what caused the decline in solar activity in recent years. A series of similarly weak cycles was observed at the beginning of the 1900, which suggests this may be related to a 100-year modulation in solar activity, known as Gleissberg cycle.

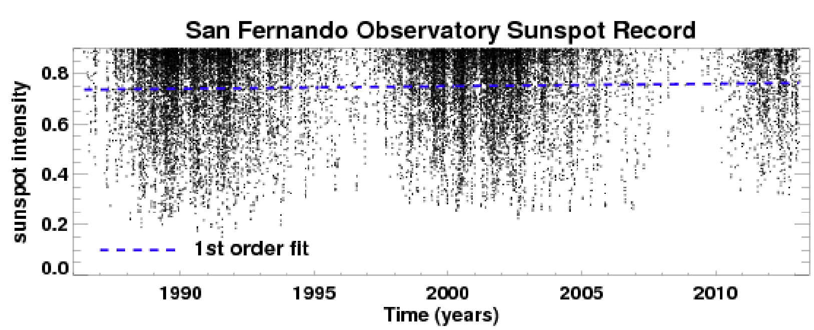

Figure 5: Sunspot intensity as a function of time as recorded at San Fernando Observatory. The linear fit shows less than 3% change in sunspot average intensity over the 27 years of observations.

This work was supported by the NSF, #M0856145.

Our findings were published in the AstroPhysical Journal and AstroPhysical Journal Letters in 2013.

References:

de Toma G., Chapman G.A., Preminger D.G., & Cookson A.M., ApJ, A770, 89, 2013.

de Toma G., Chapman G.A., Cookson A.M. & Preminger D.G. ApJ Lett., 771, L22, 2013b.

‹ Origins of the Sunspot Cycle up Response of the Ionosphere to Thunderstorms ›

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RESPONSE OF THE IONOSPHERE TO THUNDERSTORMS

A key tool in our investigation of the coupled Sun-Earth system is computer simulations or numerical models. Typically these models cover an altitude ranging from the Earth surface to several hundred kilometers. This range includes the troposphere, where everyday (or terrestrial) weather occurs, middle atmosphere with ozone heating in the stratosphere and cooling in the mesosphere, and the upper atmosphere where the temperature profile increases with altitude, also known as the thermosphere and ionosphere.

A recent study carried out by HAO scientist Hanli Liu, in collaboration with S. Vadas from Northwest Research Associates, Inc. (NWRA), showcases how terrestrial weather phenomena such as thunderstorms can drive large-scale disturbances in the ionosphere and thermosphere. The coupling between the lower atmosphere and the thermosphere-ionosphere takes place through gravity waves. Gravity waves are naturally occurring phenomena that happen in fluids in the presence of gravity. A common form of gravity waves is the waves seen on the ocean driven by the wind. Tidal variations are another form of gravity waves and they are seen both in bodies of water and throughout the atmosphere. Gravity wave perturbations can also be created by the collection of large thunderstorm activity, referred to by meteorologists as deep convection. In the tropical regions, deep convection is more than a typical afternoon thunderstorm and can extend over vast regions.

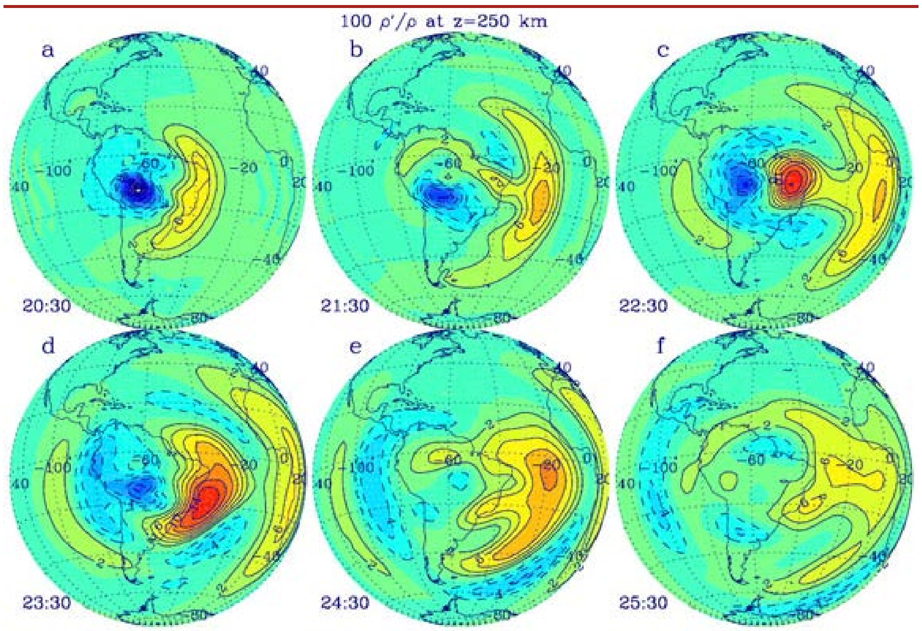

Figure 6: Relative changes in the neutral density at the bottom of the F region of the ionosphere during a 6-hour peroid of strong thunderstorms that occurred over Brazil on the evening of October 1, 2005.

Adapted from [*Vadas and Liu*, 2013], Figure 6 shows the TIME-GCM simulations driven by reconstructions of the lower atmosphere during a deep convection event that happened on the evening of October 1, 2005. A few hours after the thunderstorm, a decrease of the thermospheric density at 250 km is seen over western Brazil. There is a corresponding increase in density over eastern Brazil and the Atlantic Ocean. Even after the deep convection had ended, the enhancements continued to move eastward. By analyzing the simulation results, the scientists were able to determine that the forces resulting from the dissipation of the gravity waves propagating up from the troposphere were responsible for the large-scale changes in thermospheric and ionospheric density as observed. In addition to these large-scale density enhancements, a series of secondary gravity waves was seen in the thermosphere. The effects of these secondary waves on the large-scale ionosphere structures are studied in a companion paper [*Liu and Vadas*, 2013] in which they found that these waves change the wind dynamo and transport in the ionosphere. Such ionospheric perturbations can affect radio wave propagation, satellite communications, and acquisition of Global Positioning System (GPS) signals.

This work was supported by funding from the NSF #M0856145 and award number NWRA-10-S-135.

Reference:

Liu, H.-L., and S. L. Vadas (2013), Large-scale ionospheric disturbances due to the dissipation of convectively-generated gravity waves over Brazil, *J. Geophys. Res.*, *118*(5), 2419–2427, doi:10.1002/jgra.50244.

Vadas, S. L., and H.-L. Liu (2013), Numerical modeling of the large-scale neutral and plasma responses to the body forces created by the dissipation of gravity waves from 6 h of deep convection in Brazil, *J. Geophys. Res.*, *118*(5), 2593–2617, doi:10.1002/jgra.50249.

‹ The Decline in Solar Activity in Recent Years | up | Capabilities for Prediction in Solar Outputs and their Impacts ›

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CAPABILITIES FOR PREDICTION IN SOLAR OUTPUTS AND THEIR IMPACTS

Prediction of solar variations and understanding their impacts is an HAO imperative. More accurate prediction and attribution are important for understanding impacts on the Earth, from short-term space weather to long-term solar modulation.

Observations from the HAO-developed Coronal Multi-channel Polarimeter (CoMP), deployed at our Mauna Loa, Hawaii, facility, have been used to better understand the magnetic and thermodynamic state of the corona.

Magnetism defines the complex and dynamic solar corona. Twists and tangles in coronal magnetic fields build up energy and ultimately erupt, hurling plasma into interplanetary space. These CMEs are transient riders on the ever-outflowing solar wind, which itself possesses a three-dimensional morphology shaped by the global coronal magnetic field. Coronal magnetic fields are thus at the heart of any understanding and predictive capability of the solar origins of space weather.

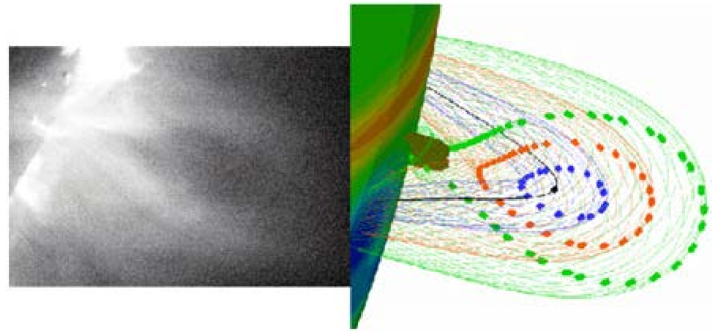

Figure 7: Depiction of topological changes associated with the formation of a current sheet beneath a magnetic flux rope.

We have historically been limited by the difficulty of directly measuring the magnetic fields of the corona and have turned to observations of coronal plasma to trace out magnetic structure. Recent work by an HAO student *(Forland et al., 2013)* has illustrated the power of this approach: a survey of coronal cavities, dark regions in which intense and twisted magnetism dwells, has demonstrated that a teardrop shape is a strong indicator of impending eruption. Such a shape is consistent with topological changes associated with the formation of a current sheet beneath a magnetic flux rope *(Figure 7)*. This acts as a slow-burning fuse, pushing the flux rope ever higher until ultimately it crosses a threshold height for a magnetic instability, and the cavity erupts as a coronal mass ejection.

Our ultimate goal is to predict all types of solar eruptions. To do that, we will need to measure the coronal magnetic field itself. Unprecedented measurements now being obtained by the Coronal Multichannel Polarimeter (CoMP) have demonstrated the presence of twisted magnetic fields within cavities. A full determination of the three-dimensional coronal magnetic fields will require more and bigger telescopes: as such it represents an exciting frontier in the science underlying space weather prediction.

This work funded by NSF #M0856145

‹ Response of the Ionosphere to Thunderstorms   up   Community Model Development ›

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COMMUNITY MODEL DEVELOPMENT

One of the cornerstones of HAO's activities is the development and support for a series of numerical models that are available for the broad research community to use freely. Among the models supported are the Thermosphere-Ionosphere-Electrodynamic General Circulation Model (TIEGCM), the Coupled Magnetosphere Ionosphere Thermosphere Model (CMIT), and the Extended Whole Atmosphere Community Climate Model (WACCM-X). The TIEGCM and its sister model TIMEGCM are general circulation models that are widely used by the upper atmosphere research community to study the dynamics of and the interactions between the mesosphere, ionosphere, and thermosphere. CMIT combines the Lyon-Fedder-Mobbary (LFM) global model of the Earth's magnetosphere with the TIEGCM via a customized electrodynamic coupling module. WACCM-X completes the family of community models supported by HAO and includes the physics of both the lower atmosphere and ionosphere. The scientific and software engineering staff of the observatory supports each of these models, allowing the community to collaborate on research projects, participate in model development, or use the models for independent research.

Over the course of the past year, significant efforts have been made to improve the capabilities of the TIEGCM. Version 1.95 of the model was released under an open source license that lets members of the scientific community freely use the model for their research. This version includes numerous performance enhancements as well as advances in the fundamental physics of the model. It also includes support for users to easily execute the model on the NWSC Yellowstone high-performance computing (HPC) system. Significant progress was also made toward the release version 2.0 of the TIEGCM. Among the key features of this new version are increased spatial resolution, parallelization of the electrodynamic solver, and additional physics modules for eddy diffusion and helium ions. The development of the helium module is a collaborative effort with scientists outside of HAO.

With the end of the Center for Integrated Space Weather Modeling (CISM) project, the primary responsibility for developing the CMIT model and supporting its use by the community was transitioned to HAO. On the support side, HAO now manages the documentation website and version control repository, and helps with the email system. The code distribution consists of a user-friendly system that is easy to use, build, run, and analyze the model. Work on the model included moving to the latest version of the TIEGCM in the modeling framework. The vast majority of effort on the model development this year focused on improving the LFM magnetospheric component. A rewritten computational core was used to increase the resolution in each dimension. Figure 8 shows an image from one of these high-resolution simulations. Bursts of strong flows push around the magnetic field in the inner magnetosphere and lead to the development of strong currents. Only at this high resolution are we able to closely examine the evolution of flow bursts as they propagate from the distant magnetotail to close to geosynchronous orbit. These new data structures support the additional physics of having multiple ion species present in the magnetosphere. The multi-fluid extensions are essential for allowing mass coupling between the magnetosphere and ionosphere.

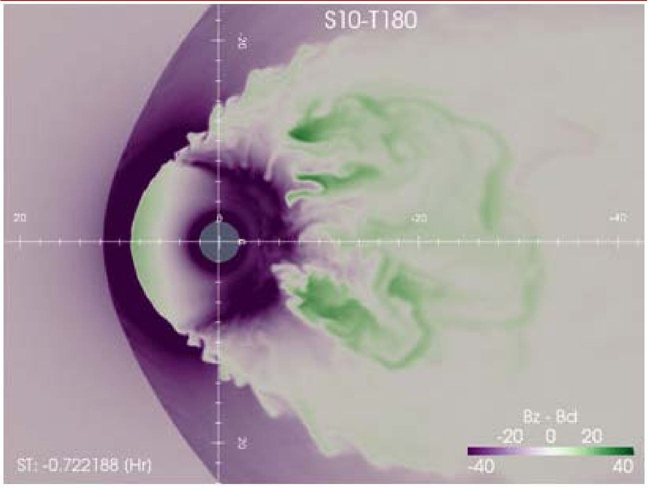

Figure 8: Results from a very high resolution CMIT calculation of the magnetosphere. Clearly evident in the central portion of the magnetosphere are multiple flow bursts that have pushed magnetic fields in front of them. As they propogate earthward the size of the structures becomes gradually smaller.

The WACCM model is part of the NCAR CESM and as such, a working group is formed to guide the scientific and computational development of the model. Scientists at HAO have been actively involved in developing the model, especially the upward extension of the model to include the thermosphere and ionosphere. In collaboration with a visiting scientist from China, we have begun testing options for ionosphere-plasmasphere extension to the model. Members of the HAO WACCM team, in collaboration with scientists from NCAR's IMAGe program, have begun doing runs with

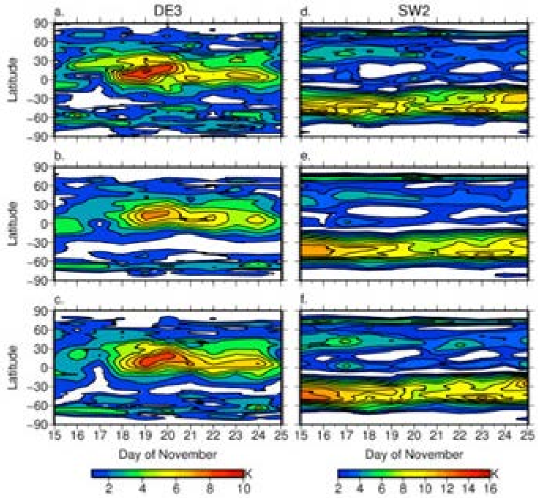

Figure 9: Influence of assimilating data from the lower atmosphere observations alone (b and e), and assimilating both lower and upper atmosphere observations (c and f), as compared to the true states (a and d) of two dominating atmospheric waves in the lower thermosphere and ionospheric E region (115 km) using WACCM and DART.

the Data Assimilation Research Testbed (DART) to assimilate weather data from radiosondes, aircraft, and satellites as well as temperature observations by middle/upper atmosphere satellites in order to improve the model's accuracy. Figure 9 illustrates the impact of adding lower atmosphere weather data alone and adding both lower and upper atmosphere observations on the simulation and prediction of the upper atmosphere using WACCM and DART.

Another important partnership for providing the community with access to our models is the collaboration between HAO and the National Aeronautics and Space Administration's (NASA's) Community Coordinated Modeling Center (CCMC). HAO provides CCMC with the latest releases of the TIEGCM and CMIT models and ensures their proper operation on HPC resources available to CCMC, while CCMC provides a web-based application for submitting requests to run these models and provide model outputs to users. Since the installment on the CCMC site, over 275 runs have been conducted using these models.

The work described above was funded by NSF #M0856145 as well as numerous NASA-funded awards.

‹ Capabilities for Prediction in Solar Outputs and their Impacts | up | Observational Facilities and Data Service ›

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OBSERVATIONAL FACILITIES AND DATA SERVICE

Observational research and provision of observational facilities are central to HAO's vision and mission. To fulfill this imperative, HAO will maintain its observing facilities and seek opportunities to develop and upgrade existing observational technology and instruments. Major efforts include completing the transition of CoMP to routine operations in its synoptic mode, constructing the K-Coronagraph as a component of the COSMO project, and enhancing HAO's data service capability for the community.

‹ Community Model Development up Coronal Solar Magnetism Observatory (COSMO) ›

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CORONAL SOLAR MAGNETISM OBSERVATORY (COSMO)

Driven by society's need to understand the origins of space weather, HAO scientists, along with colleagues at the University of Hawaii, the University of Michigan, and George Mason University, plan to build COSMO. The facility will take continuous synoptic measurements of the entire corona in order to understand solar eruptive events that drive space weather and to investigate long-term and solar-cycle phenomena. The primary instrument will consist of a 1.5-m coronagraph with two detector systems: a narrow-band filter polarimeter and a spectropolarimeter. Supporting instruments are a white-light coronagraph to record the evolution of the electron scattered corona (K-corona) and a chromosphere and prominence magnetometer called ChroMag. This new facility will supersede the current NCAR MLSO, which has been collecting synoptic coronal data for over 40 years in support of the solar and heliospheric community.

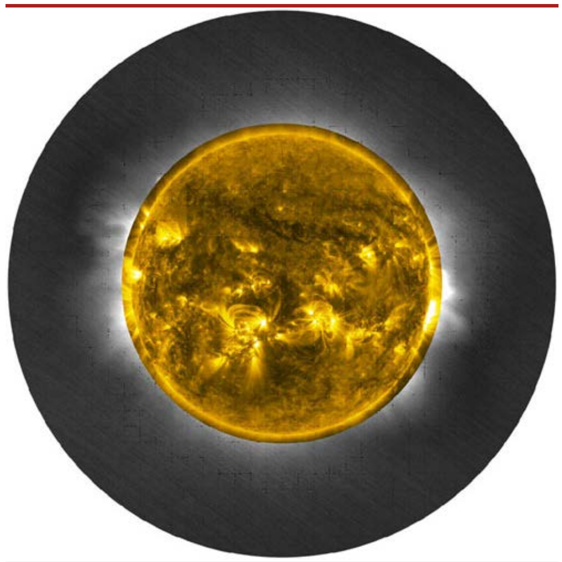

Figure 10: Image from the recently deployed K-coronagraph superimposed on a disk image from SDO/Atmospheric Imaging Assembly (AIA).

2013 has seen significant progress on all aspects of the COSMO program. First, we have completed the construction of the new K-Coronagraph instrument and deployed it to MLSO. It is operational and the instrument is undergoing a period of calibration. Data from the instrument will be made available to the community in early 2014. An image from the new K-Coronagraph is shown in Figure 10, superimposed on a disk image from AIA.

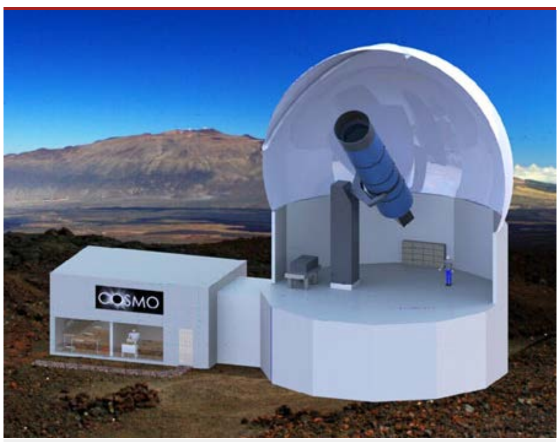

Figure 11: Cutaway view of the rendering of the COSMO Large Coronagraph.

Secondly, we have completed a prototype tunable filter for the ChroMag instrument. It has been deployed to the solar-pointed spar in Boulder at the NCAR Mesa Lab and has started obtaining data. In the next six months, we plan to demonstrate the feasibility of a narrow-band tunable filter and polarimeter for observations of chromospheric magnetism.

In addition, with financial support from the NSF, we have been moving forward with the engineering development of the COSMO Large Coronagraph (LC). A conceptual design of the COSMO facility is drawn in Figure 11. Colleagues from China have joined in the development of COSMO, and engineers from the Nanjing Institute of Astronomical Optics and Technology have made significant contributions to the optical and mechanical designs of the COSMO LC. We plan to hold a Preliminary Design Review (PDR) for the COSMO LC in the spring of 2014. Following the PDR, the next step will be to seek funding to construct COSMO.

‹ Observational Facilities and Data Service | up | COSMO K-Coronagraph ›

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COSMO K-CORONAGRAPH

The new K-Coronagraph replaces the MK4 K-Coronameter, which was the longest running white light coronal instrument in history, operating from 1980 to 2013. The K-Coronagraph is the first white light coronagraph to routinely view the very low corona (down to 1.05 solar radii) outside of a total solar eclipse. It is used to observe CMEs from the Sun. CMEs are explosive events that can eject a billion tons of magnetized plasma into interplanetary space. These events are a major driver of space weather which poses hazards to astronauts, satellites, and power grids, and interfere with communication and GPS systems. It will also be used to study changes in the solar atmosphere that occur over long time scales such as the 11-year sunspot cycle. The K-Coronagraph is the first of a suite of three COSMO instruments to be deployed. Data from this instrument will be freely available to the community and can be accessed through our website at http://mlso.hao.ucar.edu

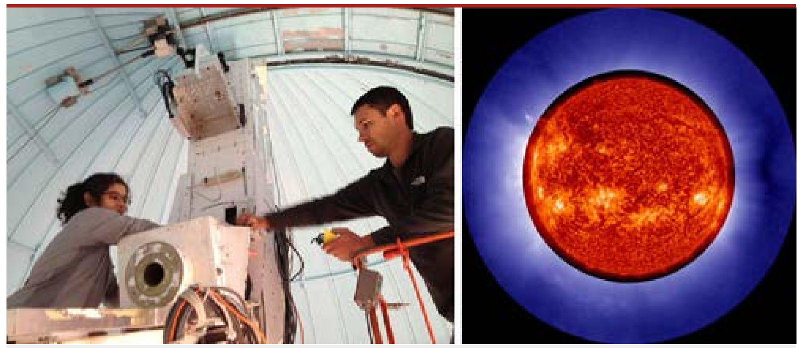

Figure 12: (Left) Lisa Waters and Brandon Larson installing the K-coronagraph at MLSO and (Right) a composite image of the Sun acquired on Dec 9, 2013. The solar disk image (in orange) was taken in an ionized line of helium by the AIA instrument onboard NASA's SDO satellite. The outer image (blue/white) of the solar corona was acquired by the COSMO K-Coronagraph at the Mauna Loa Solar Observatory. The COSMO K-Coronagraph is the first white light coronagraph to routinely view the very low corona where most solar activity originates.

This development was funded in full by NSF #M0856145.

‹ Coronal Solar Magnetism Observatory (COSMO) up Sunrise II ›

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SUNRISE II

The Sunrise high-altitude balloon mission to study the Sun's magneto-convective processes at very high resolution was conducted in partnership with international partner institutions and the NASA Columbia Scientific Balloon Facility. The objective of the HAO effort was three fold: 1) develop a gondola observing platform for the balloon that was strong enough to protect the very fragile Sunrise primary mirror and post-focus scientific instrumentation while 2) being agile and intelligent enough to maintain solar pointing accuracy to within one tenth of an arc second for prolonged periods of time in the harsh wind shears of the Earth's stratosphere, and 3) to bring the mirror, instruments, and their valuable data safely to the ground again. In June of 2013, the second flight of the Sunrise observatory launched from Esrange near Kiruna, Sweden. In preparation for the flight, HAO scientists and engineers redesigned and refurbished the Sunrise gondola's pointing system from the first Sunrise flight in only nine months. After launch, the balloon remained airborne for nearly six days, floating high aloft the North Atlantic observing the Sun continuously. It made its final decent in northern Canada and was safely recovered with the mirror and instrument intact (again). The engineering goals were comprehensively met.

Figure 13: The Sunrise II Gondala just prior to launch, Kiruna, Sweden.

Figure 14: The Sunrise II landed intact on June 17, 2013, after being aloft for about five days.

The science goals of the Sunrise mission were to study the solar magnetic field, to investigate photospheric and chromospheric phenomena, to resolve time-dependent characteristics of magneto-convective patterns, to analyze small scale interaction of convective flows and the magnetic field, and to test the predictions of magneto-hydrodynamic models. Studying these effects helps answer the following questions: 1) How is the magnetic field brought to and removed from the solar surface? 2) How does the magnetic field transport energy and momentum to the outer atmosphere? 3) What are the origin and the properties of the intermittent magnetic structure in the photosphere? 4) What is the underlying physics of the solar UV irradiance variability? 5) What is the physical nature of the solar chromosphere, and how is it heated?

The data from the second flight are currently under analysis, but the instruments performed beautifully. The telescope was able to perform the highest resolution images of the Sun's transition region ever taken—these images look directly at the energy release of the Sun's crucial interface to the heliosphere. The Sunrise project also provided a number of opportunities for students and early-career scientists to be involved in the mission at all stages, including analyzing engineering data from the first science flight, flight preparation, and flight operations during the second flight.

This effort was funded by NASA #X13AE20T and Max Plank #1076996.

‹ COSMO K-Coronagraph | up | Research to Application ›

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RESEARCH TO APPLICATION

HAO's mission includes efforts to support the fostering and transferring of knowledge and technology from its origins in fundamental research for the benefit of society. In partnership with NASA's CCMC and the Space Weather Prediction Center (SWPC) at the National Oceanic and Atmospheric Administration (NOAA), HAO will continue to develop, test, and transfer our numerical models for space weather applications.

‹ Sunrise II up Model Transition Activities ›

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MODEL TRANSITION ACTIVITIES

HAO's mission includes supporting the transition of technology from research to applications. One of our key partners in this effort is SWPC, which is operated by NOAA to be the nation's definitive source for forecasts of space weather events that can impact our technology. Traditional weather forecasts benefit from several numerical weather models, many of which have their roots in the research community. Whilst SWPC has an advanced numerical simulation for modeling the arrival time for CMEs emitted from the Sun, it does not have any numerical models for determining duration and intensity of the geomagnetic storms driven by these CMEs. During this past year SWPC conducted a competition among the major geospace numerical models in order to select the initial model for transition into operations. HAO staff participated in this process by contributing runs, assisting the calculation of model comparison metrics with the CMIT geospace model. Figure 15, adapted from [*Pulkkinen et al.*, 2013], shows the rankings of various models for computing the magnitude of storm-driven response on the ground via a skill score. This metric was selected by SWPC since accurate prediction of the perturbation strength is essential for making accurate forecasts of impacts on power grid during major geomagnetic storms. In addition to these metric efforts, HAO staff spent time talking with SWPC staff about the computational requirements and concept of operations for the geospace weather prediction model.

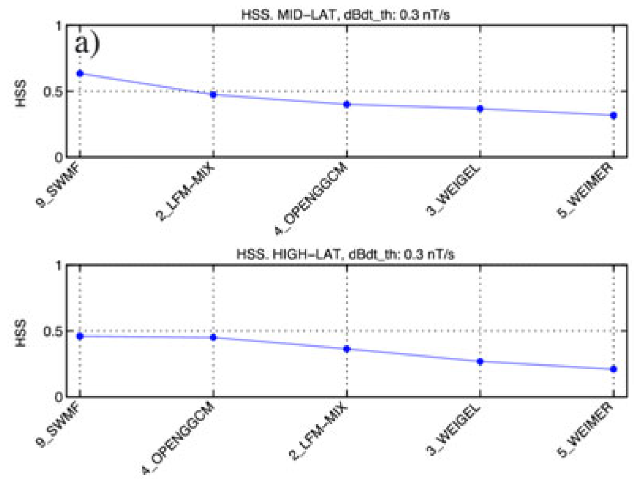

Figure 15: Performance skill scores of various models participated in the SWPC geospace model selection process for predicting the ground magnetic field response during a CME-driven magnetic storm. Correct prediction of the ground magnetic field response is essential for developing forecast tools to protect the power grid from geomagnetic storms.

Reference:

Pulkkinen, A. et al. (2013), Community-wide validation of geospace model ground magnetic field perturbation predictions to support model transition to operations, *Space Weather*, *11*(6), 369–385, doi:10.1002/swe.20056.

‹ Research to Application | up | Education and Outreach ›

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EDUCATION AND OUTREACH

HAO Scientists Spend Time in the Classroom

NCAR, UCAR, and HAO are very supportive of staff outreach and collaboration with Universities. The HAO staff is committed to attracting and training a new generation of students to solar and space sciences by teaching courses and workshops at universities around the world. Dr. Mausumi Dikpati's University Visits in Scientific Interaction and Teaching (UVISIT) was funded by UCAR, HAO, and Lyndon State College. Dr. Phillip Judge's teaching sabbatical was funded by the Advanced Studies Program (ASP) Faculty Fellowship Program, HAO, and Montana State University (MSU).

‹ Model Transition Activities up HAO Scientist Dr. Mausumi Dikpati teaches at Lyndon State College ›

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HAO SCIENTIST DR. MAUSUMI DIKPATI TEACHES AT LYNDON STATE COLLEGE

In fall 2013, Dr. Mausumi Dikpati visited the Atmospheric Sciences Department of Lyndon State College in Lyndonville, Vermont, for two weeks as part of the UVISIT program of UCAR. She was hosted by Professor Bruce Berryman, chair of the Atmospheric Science Department.

Dr. Dikpati taught a full-credit course in space weather and climate to upper level undergraduates. She also introduced the topic to college freshmen and sophomores. This is a topic not ordinarily taught at Lyndon State. In addition to teaching a for-credit course, Dr. Dikpati gave ten lectures to varied audiences on space weather and climate. These were well attended by students and community members alike.

As part of her visit, Dr. Dikpati created extensive web-based materials that will be used by Lydon State faculty as they offer this course beginning spring 2014.

Figures 16: Mausumi Dikpati teaching space weather and climate at Lyndon State.

‹ Education and Outreach up HAO Scientist Phillip Judge teaches at Montana State University ›

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HAO SCIENTIST PHILLIP JUDGE TEACHES AT MONTANA STATE UNIVERSITY

Figure 17: (Left) Dr. Philip Judge teaching at MSU, and (right) Dr. Judge receiving the "OGLI" award from MSU graduate students. (Photographs courtesy of Bozeman Daily Chronicle/Adrian Sanchez-Gonzalez.)

Dr. Phillip Judge, a senior scientist in the NCAR/HAO, spent nearly a full year at MSU in Bozeman, MT, on a teaching sabbatical. Phil had decided to take a sabbatical several months prior to heading to Montana. He chose MSU because it has a strong solar physics department where researchers also develop instruments. Being at MSU also gave him close access to collaborators on a new Interface Region Imaging Spectrograph (IRIS) mission with which Dr. Judge is involved.

Dr. Judge taught graduate-level classes in solar physics at the university. He found this to be a challenging, fulfilling, and rewarding experience. Outside of the classroom, Dr. Judge worked with students at all levels. He also developed problem sets and lecture notes on plasma physics and atomic and plasma spectroscopy for graduate students. Once completed, they will be available more broadly. Dr. Judge enjoyed his teaching experience. Knowing that he has influenced a group of a dozen or more students who are seriously embarking on or considering astrophysics, space physics, or solar physics as a career made this experience especially fulfilling.

HAO is proud of Dr. Judge's contributions and happy to say that he was awarded a student-choice awarded called "OGLI" for the Outstanding Graduate Level Instructor for physics in 2013.

‹ HAO Scientist Dr. Mausumi Dikpati teaches at Lyndon State College   up   The Eclipse Megamovie Project (EMP) ›

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THE ECLIPSE MEGAMOVIE PROJECT (EMP)

In the afternoon and early evening of August 21, 2017, a total solar eclipse will cross the continental United States from Oregon to South Carolina via many of the country's beautiful national parks. Scientists from HAO have teamed with science education experts at UCAR/SPARK and the Center for Science Education at the UC Berkeley Space Sciences Laboratory to undertake an ambitious project. This project will communicate the Sun-Earth connection with members of the general public using the total solar eclipse as a conduit. This project, dubbed the "Eclipse Megamovie Project," or EMP, will use the theater of the total eclipse to showcase solar-terrestrial science with the general public and, if weather permits, have them contribute to a movie of the Sun's evolution during the 95-minute transcontinental passage.

Images taken by EMP contributors will be calibrated and stitched together into a movie by the project team. As well as being a wonderful vehicle for public outreach and education, the movie will offer potential scientific opportunities. Citizen and professional scientists alike will be able to view and explore the evolution of the Sun's chromosphere and corona over the course of the eclipse with incredible time resolution. In addition to direct observation of the eclipse, the star field visible during this eclipse will offer a fantastic opportunity to repeat the famous experiment of 1919 that verified Einstein's Theory of General Relativity.

Figure 18: Images taken by EMP contributors during the November 14, 2012, total solar eclipse in North Queensland, Australia.

In the winter of 2012, a prototype of the 2017 EMP was undertaken in tropical North Queensland. The total solar eclipse on November 14, 2012 fell across a relatively small piece of Australia's northeast coast and permitted the EMP team an invaluable first airing for their educational materials in addition to providing a controlled environment to test image capture and analysis strategies for the uploaded images. Also, the EMP team learned a lot from engaging the crowds of international and local visitors with whom they shared the beach. A user-friendly website was developed (www.eclipsemegamovie.org) to facilitate the transfer of information to the public, including a smartphone application that captures images of the eclipse and supplies the necessary metadata to the team (exact time, location, etc.). Some examples of the magnificent 2012 EMP images are shown in Figure 18. The team is currently building the proto-movie based on their Australian experience and are anticipating with great excitement the massive challenge that the 2017 EMP will present in a little less than four years.

This work funded by NSF #AGS-1247226.

‹ HAO Scientist Phillip Judge teaches at Montana State University up Visitors ›

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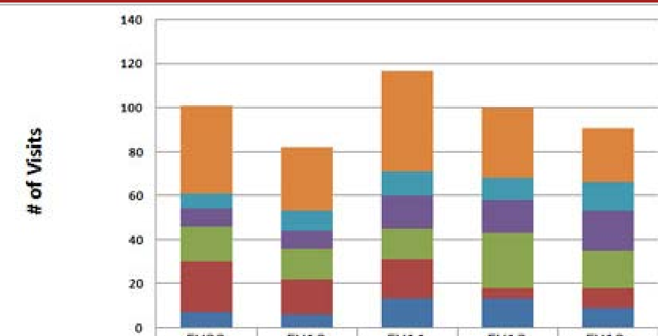
VISITORS

HAO is committed to a vibrant visitor program, allocating sizable base funds to the program despite the current very tight budgets. HAO supported 10 postdocs and 4 graduate research assistants (GRAs) to carry out their research under the supervision of HAO scientific staff during the past year. HAO staff mentored six Research Experiences for Undergraduates (REU) students and one Significant Opportunities in Atmospheric Research and Science (SOARS) students during last summer, and hired three undergraduate student interns who have worked at HAO since summer 2012 under the newly established HAO Engineering Internship. HAO also hosted six affiliate scientists and 95 other visiting scientists (of which 23 were student visitors).

Visitors to HAO are supported by a variety of funding sources. The primary funds come from NSF #M0856145.



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1-7 Days	40	29	46	32	25
8-14 Days	7	9	11	10	13
15-30 Days	8	8	15	15	18
1-2 Months	16	14	14	25	17
3-6 Months	23	16	18	5	9
6 Months - 1 Year	7	6	13	13	9

Figure 19: Visitor profiles for the past five fiscal years.

‹ The Eclipse Megamovie Project (EMP) up

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NESL DIRECTOR'S MESSAGE

The Annual Report documents the considerable accomplishments of NESL staff over the past year. This work furthers our mission to advance understanding of

weather, climate, atmospheric composition and processes, to provide facility support for such advancements to the wider community, and to produce research results that can be applied to the benefit of society. The highlighted research from each of NESL's three scientific research divisions: the Atmospheric Chemistry Division (ACD), the Mesoscale and Microscale Meteorology (MMM) Division, and the Climate and Global Dynamics (CGD) Division, is not exhaustive but presents a flavor of the scientific achievements and improvements to our community modeling and observing facilities. More detailed descriptions of smaller projects and activities can be found on the individual divisional websites.

A primary mandate for NESL is to serve the atmospheric science programs at UCAR member institutions and, in so doing, the broader research community. NESL has a proven record of leadership and achievement in advancing knowledge and in providing and supporting community-based resources. These include advanced observing facilities and support for field programs, valuable research data sets, and widely used state-of-the science community weather, chemistry and climate models. NESL thus enjoys both a strong reputation and a close relationship with the national and international scientific communities with which it works in order to address today's highly multidisciplinary environmental challenges. This high level of collaboration is best indicated by the large and increasing number of joint proposals and papers coauthored by NESL and university scientists, while a measure of success is the number of citations of published work. NESL also has a strong visitor program and an exceptional track record in mentoring and advising graduate and post-graduate students.

Over the next five years, NESL will be guided by a new Strategic Plan, which aligns closely with NSF and NCAR strategic goals. This provides a roadmap for achieving the NESL vision of being an internationally leading research laboratory in the atmospheric and related Earth system sciences. Building on the new divisional Strategic Plans, the NESL Strategic Plan is arranged around six top-level themes: three Scientific Challenges and three opportunities aimed at Enabling World Class Community Science. The new NESL Strategic Plan will be published early in 2014, and this NESL Annual Report takes the opportunity of organizing around the Strategic Plan's six themes, which are as follows:

- ***Interdisciplinary Science Challenge 1:*** Identify and model the processes responsible for hazards related to weather and air pollution, and project the influences of climate change.
- ***Interdisciplinary Science Challenge 2:*** Determine the inherent predictability of the Earth system with respect to weather, climate and air quality.
- ***Interdisciplinary Science Challenge 3:*** Identify and model the processes and interactions that govern climate variability on timescales long enough for forcing to dominate over initial conditions.
- ***Enabling World Class Community Science 1:*** Continued development and support of NCAR community models.
- ***Enabling World Class Community Science 2:*** A more unified strategy toward model and data assimilation system development for weather-chemistry-climate prediction.
- ***Enabling World Class Community Science 3:*** Expand community access and use of instruments, models and data sets.

Addressing these six collaborative thrusts and fulfilling the NESL mission requires a cutting-edge scientific program of discovery-oriented research balanced and integrated among theory, observation, and modeling. It also requires NESL scientists to work in a close, synergistic relationship with the academic community, and an organizational commitment to develop and retain a world-class staff of scientists and engineers.

In the year ahead, NESL will continue to work closely with the other NCAR laboratories, UCAR, and our external stakeholders to ensure that our research and facility support is optimally positioned to meet the needs of the wider community. As we look forward to exciting new discoveries in Earth system science, NESL will also lead in communicating the significance of this work to our sponsors, professional organizations, policy makers and the general public. This will have the dual benefits of promoting informed discussion and decisions, while at the same time, emphasizing the importance of investment in our research and major facility development.

‹ 2013 NESL Annual Report up 7.1. Interdisciplinary Science Challenges ›

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7.1. INTERDISCIPLINARY SCIENCE CHALLENGES

While core disciplines necessarily remain an emphasis, NESL programs have become increasingly interdisciplinary to address the challenges of studying the atmosphere and the Earth as a system.

‹ NESL Director's Message up 7.1.a. Identify and model the processes responsible for hazards related to weather and air pollution, and project the influences of climate change ›

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7.1.A. IDENTIFY AND MODEL THE PROCESSES RESPONSIBLE FOR HAZARDS RELATED TO WEATHER AND AIR POLLUTION, AND PROJECT THE INFLUENCES OF CLIMATE CHANGE

NESL scientists, in collaboration with university colleagues and international research organizations are conducting research aimed at understanding the causes of such hazards and how they change over time. An overarching goal is to improve our capabilities to predict them.

‹ 7.1. Interdisciplinary Science Challenges up 7.1.a.1. Improve understanding of climate change contributions to extreme events, associated environmental and societal impacts ›

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7.1.A.1. IMPROVE UNDERSTANDING OF CLIMATE CHANGE CONTRIBUTIONS TO EXTREME EVENTS, ASSOCIATED ENVIRONMENTAL AND SOCIETAL IMPACTS

To explore the simulation of hurricanes and extreme events, a high resolution version of CAM5 at 12.5 km coupled to a 10 km ocean has been configured and run in short tests. Complementary to these experiments has been ongoing analysis of the decadal climate prediction experiments performed for CMIP5 with two initialization schemes using CCSM4. We have analyzed and quantified the role of aerosols, particularly the indirect effect, in the response of the climate system to increasing greenhouse gases. We also completed analyses of decadal climate prediction experiments with two initialization methods, including the DART coupled initialization, providing a better understanding of past decadal climate variability and an improved quantification of the future time evolution of the statistics of regional climate. Analyses of higher resolution coupled and time slice experiments have begun to address possible future regional changes of extremes and hurricanes.

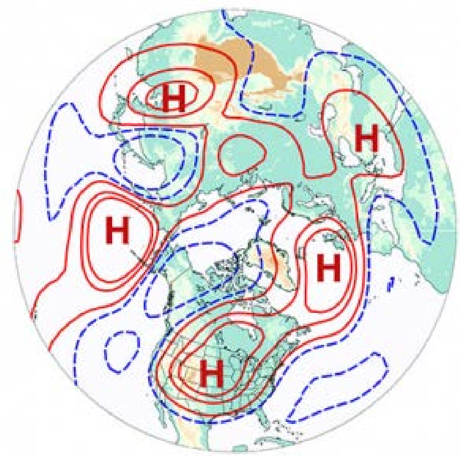

Figure: *Foreshadowing the emergence of summertime heat waves. This map of air flow a few miles above ground level in the Northern Hemisphere shows the type of wavenumber-5 pattern associated with U.S. drought. This pattern includes alternating troughs (blue contours) and ridges (red contours), with an "H" symbol (for high pressure) shown at the center of each of the five ridges. High pressure tends to cause sinking air and suppress precipitation, which can allow a heat wave to develop and intensify over land areas. (Image courtesy Haiyan Teng.)*

‹ 7.1.a. Identify and model the processes responsible for hazards related to weather and air pollution, and project the influences of climate change   up   7.1.a.2. Hurricane Prediction ›

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7.1.A.2. HURRICANE PREDICTION

Working with DOE and the Offshore Energy Industry, NESL scientists are assessing changing impacts of hurricanes on offshore facilities arising from climate variability and change. In FY2013, new capability was implemented in WRF to two-way couple to regional ocean and wave models (see Figure). This allows scientists to study future hurricanes in a fully coupled modeling framework. New collaboration with Applied Research Associates, Inc. is combining information on future changes in hurricane activity from NESL dynamical model simulations with stochastic track models to produce robust results on future impacts to industry. Further, complementary statistical downscaling approaches have been developed to hone in on future hurricane activity in vulnerable regions. (colors and height of the surface) and bottom panel shows cool wakes in the ocean surface temperature trailing behind the storms.

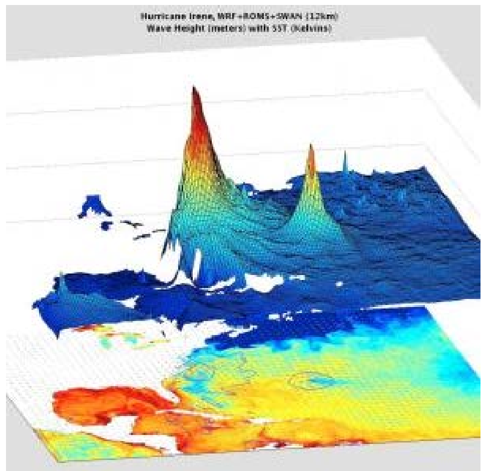
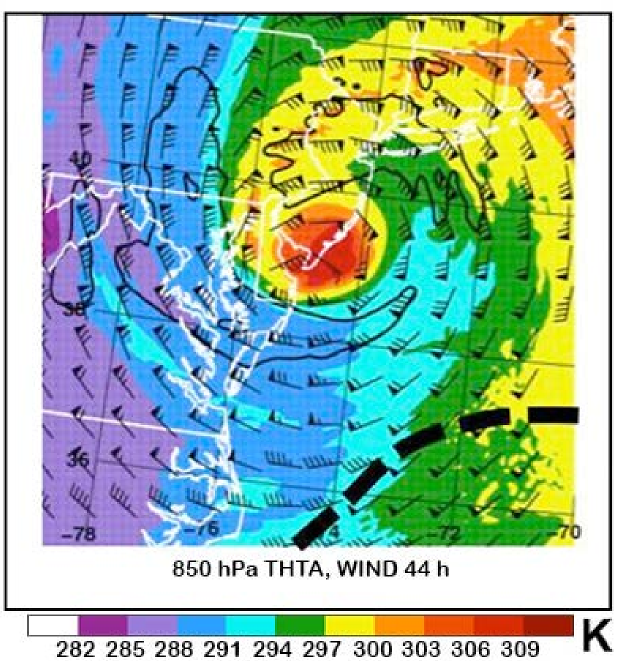


Figure: Snapshot of a simulation of hurricane Irene and tropical storm Jose using the WRF model fully coupled to a regional ocean model and wave model. Top panel shows wave height (colors and height of the surface) and bottom panel shows cool wakes in the ocean surface temperature trailing behind the storms.

Hurricane Forecast Improvement Project (HFIP)



NESL scientists are contributors to the Hurricane Forecast Improvement Project (HFIP), a NOAA-led initiative to improve hurricane forecast skill, with an emphasis on hurricane intensity and structure. HFIP involves a combination of operational and research efforts, including NCAR, universities, NOAA, and the Naval Research Laboratory. Program goals are to conduct resolution tests to determine if higher resolution models systematically improve intensity forecasts, and implement new models into a quasi-operational framework, in addition to models run operationally at NCEP. The retrospective effort is coordinated through RAL's Developmental Testbed Center.

The work in FY2013 featured two main threads. The first was collaborating with Ryan Torn of the University at Albany (SUNY) to conduct retrospective tests with upgrades to the Advanced Hurricane WRF (AHW). The primary changes in the model were in the cumulus parameterization, the drag formulation and the sea-surface temperature initialization. After completing these tests, it was decided to use the 2012 version of the cumulus scheme and keep all other updates. The resulting configuration has been running in the Atlantic this season.

Other HFIP-related tasks completed were an analysis of the intensification of Hurricane Sandy prior to landfall in New Jersey. This paper is now in press in Monthly Weather Review. The paper examines how the temperature contrast provided by the Gulf Stream and cooler surface temperatures over land helped intensify the low-level winds. It was an

unconventional process that intensified the storm and resulted in the spatial pattern of temperature shown in the Figure. Heavy rainfall initiated near the Gulf Stream and formed an intense rain band. Contraction of this front resulted on a low-level jet that ultimately contributed to the symmetric circulation of the storm while leaving the central warm core largely intact.

Galarneau, T. J., Jr., C. A. Davis and M. A. Shapiro, 2013: Intensification of Hurricane Sandy through warm core extratropical seclusion. Mon. Wea. Rev., http://dx.doi.org/10.1175/MWR-D-13-00181.1.

‹ 7.1.a.1. Improve understanding of climate change contributions to extreme events, associated environmental and societal impacts | up | 7.1.a.3. Communicating Weather- and Climate-Related Risk for Use in Decisions ›

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7.1.A.3. COMMUNICATING WEATHER- AND CLIMATE-RELATED RISK FOR USE IN DECISIONS

Using social science and interdisciplinary concepts and methods, NESL scientists conduct research to understand and enhance the use and value of weather forecasts and warnings and information about weather in the context of climate variability and change. This includes investigating how weather-related risk messages are generated, communicated, interpreted, and used in decisions. It also includes building understanding of people's perceptions of weather risk and the underlying vulnerabilities and other contextual factors that influence weather-related decision making.

In FY2013, NESL scientists completed mental models analysis examining how members of three expert groups in Boulder, Colorado (NWS forecasters, public officials, and broadcast media) conceptualize flash flood risks and associated uncertainty and make warning decisions. The analysis identifies important features of flash flood warning systems, and it suggests several areas for improvements in risk communication, including development of warning content, coordination across domains of expertise, and management of uncertainty across the system (Morss, R. E., J. Demuth, A. Bostrom, J. Lazo, and H. Lazrus, 2013: Experts' mental models of flash flood risks and warning decisions: A study of Boulder, Colorado. Submitted to *Risk Analysis*). Analysis of data from mental models interviews with members of the Boulder public is ongoing.

Other work included using data from a public survey in the Miami area to complete analysis of how different members of the public perceive and respond to different types of hurricane forecast messages. Scientists also began analysis of the Miami survey data using theoretical risk communication frameworks to investigate why people respond to hurricane risk messages differently.

NESL scientists also conducted and analyzed interviews with stakeholders in south-central Oklahoma to understand how stakeholders with diverse cultural beliefs perceive drought risks across weather and climate scales, and on how these perceptions and other factors influence water management decisions in the face of uncertainties in future precipitation and drought. In FY2013 scientists completed the stakeholder interviews, conducted initial quantitative analysis following the Cultural Theory of Risk, and compared results with hydrological and climatological data on drought in the region. These initial results indicate that there is a strong cultural signal in how people perceive the importance of water and water resources, yet despite cultural differences, all interviewees consider drought to be a significant risk in the region. In addition, perspectives on drought and water derived from interviews were integrated into a GIS tool that will be made available to the public.

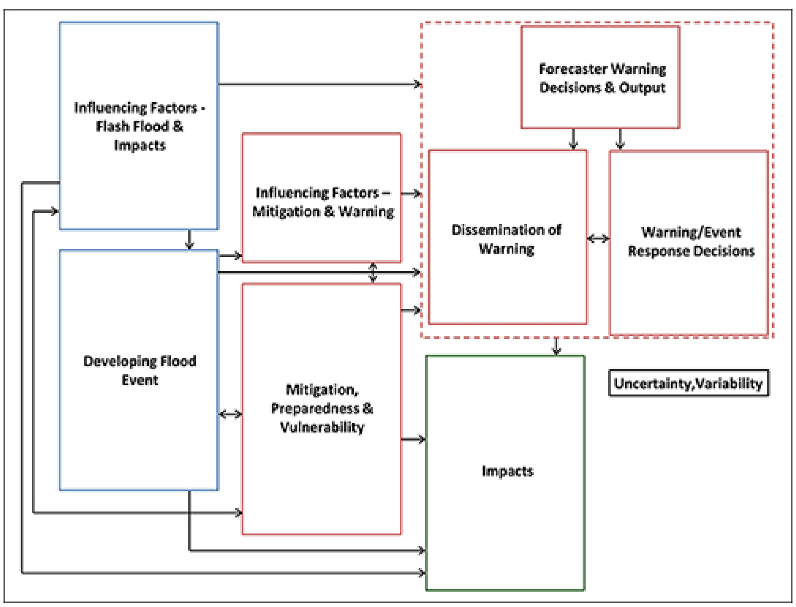

Figure. Overview of the model of the flash flood warning system, combining data gathered from NWS forecasters, local public officials, and media personnel.

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7.1.A.4. CLOUDS AND PRECIPITATION

To address the fact that microphysical fall-speed estimates in earlier studies are significantly in error for smaller particles found in the upper troposphere, NESL scientists are conducting a comprehensive study of how these new results affect weather and climate model simulations. As a first-order test of the fallspeed algorithms used in CAM, scientists compared the temperature dependence of the ice water content (IWC) as derived for convective and convective-outflow ice clouds and stratiform-type clouds from CAM to those from in-situ observations (Heymsfield et al., 2013), both having relatively large samples. With a given amount of condensate as determined by temperature, the storage of the IWC is dependent on the ice particle fallspeed. The convectively-generated cloud for the CAM output has about the same IWCs as in-situ observations at the lower temperatures but seemingly underestimates the IWC at the warmer temperatures (see Figure). For the stratiform clouds, CAM IWCs are systematically lower. These results suggest that the CAM fallspeeds are overestimated.

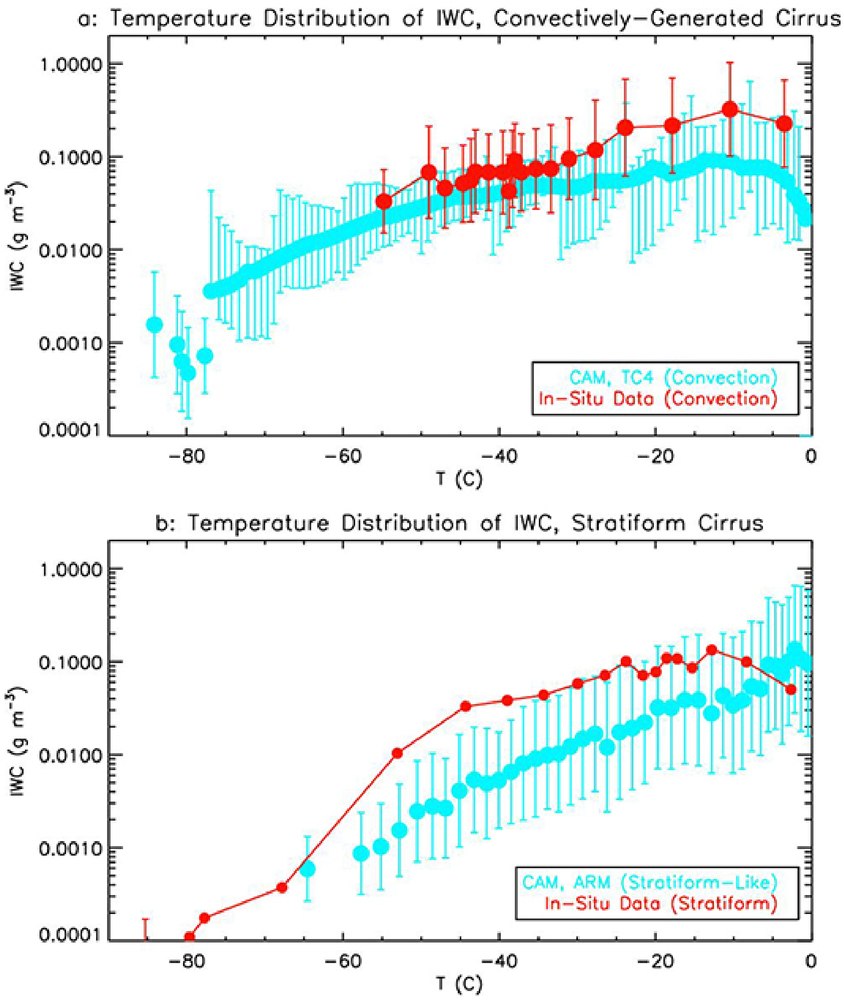

Figure: Comparison of ice water contents from CAM to those from our in-situ observations for (a) convectively-generated ice cloud and ice particle outflow regions and (b) stratiform cloud.

‹ 7.1.a.3. Communicating Weather- and Climate-Related Risk for Use in Decisions | up | 7.1.a.5. Boundary-Layer Turbulence and Surface Exchange ›

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7.1.A.5. BOUNDARY-LAYER TURBULENCE AND SURFACE EXCHANGE

The importance and potential impact of wind energy research has been growing in recent years, yet hub-height winds remain among the most difficult weather variables to forecast. To address this, NESL scientists, in close collaboration with RAL, are conducting basic research underlying wind energy.

NESL scientists are undertaking advanced simulations of atmospheric turbulence to explore problems ranging from large scale (i.e., where should wind turbines be placed?) to very small scales (i.e., characterizing the wind field within which a turbine's blades operate). In FY2013 they used MMM turbulence and wave-resolving large-eddy simulation code to make significant progress in producing and analyzing simulations investigating the impacts of swell propagation directions relative to the driving pressure gradient on winds and turbulence levels across the plane of current offshore wind turbines.

Work was also carried out in collaboration with NCAR scientists and community researchers to simulate extreme wind, wind shear, and turbulence events that stress turbines, with the goal of improved turbine design.Canopy-resolving turbulence simulations investigating atmospheric stability influences on canopy-induced turbulence have been performed and are being analyzed toward improved predictive skill of turbulence levels across the rotor plane.

In collaboration with Northwest Research Associates, RAL and Vestas (one of the world's leading wind turbine manufacturers), NESL scientists used aircraft and off-shore platform data to ascertain atmospheric stability's influence on winds and turbulence across a turbine's rotor plane (see Figure). WRF's single-column model has been configured to mimic these observations and will be used to test/improve WRF's representation of stratification and (in combination with the above-mentioned wavy simulations) swell influences in offshore environments.

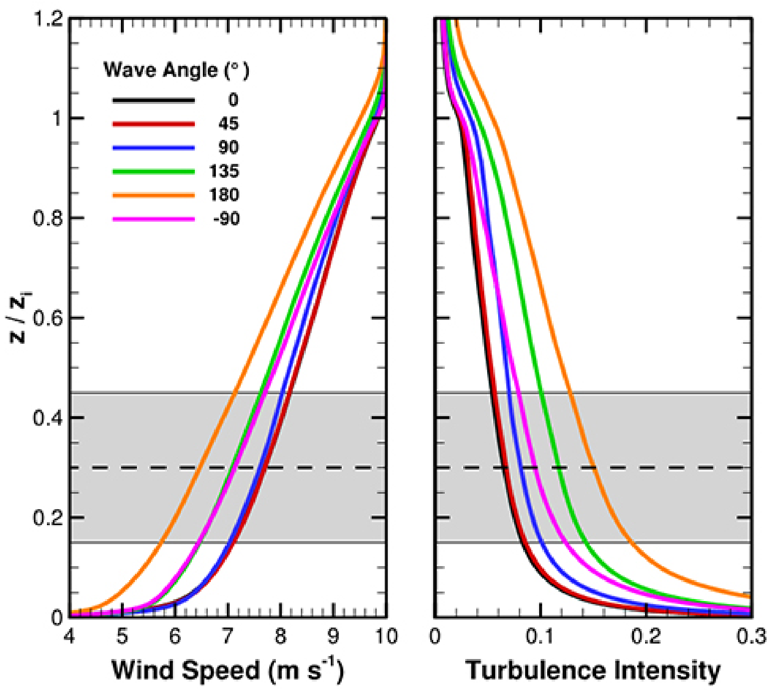

Figure 1: Vertical profiles of mean wind speed (left panel) and turbulence intensity (right panel) relative to the boundary layer depth (z_i) responding to an imposed geostrophic wind (U_g, V_g) of (10, 0) ms^{-1} and a wavy underlying surface. The wavy surface is generated such that the waves are in equilibrium with a 15 ms^{-1} wind speed at 10 m.   Therefore in the simulation the underlying waves are larger than the imposed geostrophic winds can support, i.e. the wind and waves are in disequilibrium. The results depict the atmospheric response to rotating the wave-propagation direction relative to the imposed geostrophic wind, where a wave angle of: 0° implies that the waves are traveling in the same direction as the imposed geostrophic wind, (90°, -90°) implies that the waves are propagating in a direction 90° to the (left, right) of the geostrophic wind, and at 180° the waves are propagating against the geostrophic wind. The dashed-line represents the typical hub height of a wind turbine (~ 100 m), and the gray shading depicts the vertical span of a typical turbine's rotor plane. The wave-induced pressure drag increases with increasing wave angle, resulting in approximately a 15% wind speed reduction at hub-height for the most extreme case (180°). This increased wave-induced drag also generates

increased vertical shear of the horizontal wind across the rotor plane resulting in almost a factor of two increase in turbulence intensity at hub-height. Understanding and predicting the wind/turbulence response to waves will serve to improve offshore wind deployment strategies and reduce the overall cost of energy.

Turbulence

In FY2013, NESL/MMM scientists conducted fine-resolution large-eddy simulations (LES) that couple stratified atmospheric turbulence in high-wind marine boundary layers with a spectrum of phase-resolved moving surface waves. A set of eight large-eddy simulations of marine atmospheric boundary layers with a resolved spectrum of time varying surface waves were carried out using fine spatial resolution (1024x1024x512 gridpoints) on the peta-scale machine Yellowstone.

Analysis of the results illustrates coupling across scales as wave impacted surface layer turbulence transitions into convective rolls with increasing distance from the water surface. Also, scientists found that in a swell dominated regime wave-induced vertical velocity and pressure signals are readily observed well above the standard reference height, z = 10 m. However, as the winds increase these wave-induced signals become increasingly buried in high levels of turbulence and the wave-induced motions are detectable mainly in the lower levels of the surface layer. At the boundary-layer top, the simulations reveal large engulfment events and highlight the dramatic changes in boundary-layer entrainment as the large-scale winds increase from 5 to 25 m/s under weak surface heating.

‹ 7.1.a.4. Clouds and Precipitation up 7.1.a.6. Dynamics of Mesoscale Weather Systems ›

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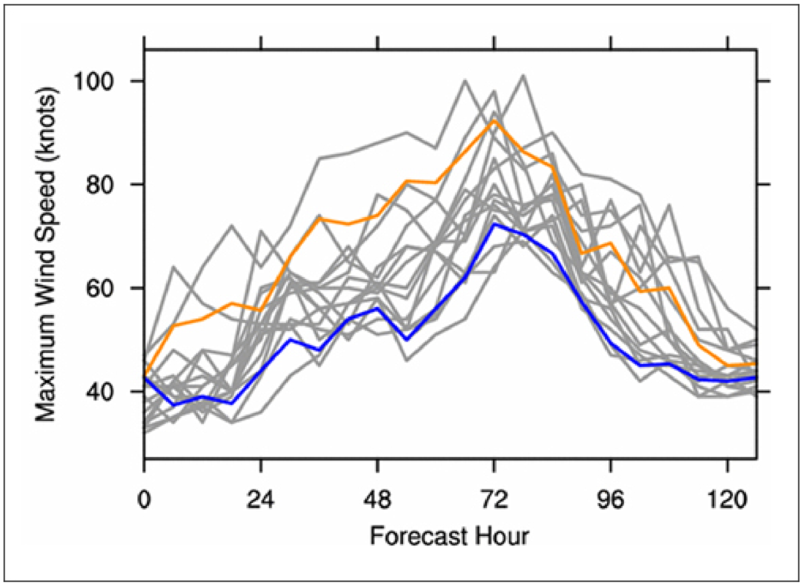
7.1.A.6. DYNAMICS OF MESOSCALE WEATHER SYSTEMS

In FY2013, extensive retrospective hurricane simulations were conducted and analyzed to identify and reduce systematic errors in hurricane track and intensity forecasts over the Atlantic and eastern Pacific Basins. NESL/MMM scientists collaborated with Ryan Torn of the University at Albany (SUNY) to conduct retrospective tests with upgrades to the Advanced Hurricane WRF (AHW). These tests resulted in a new configuration of the model that has been running as an 20-member ensemble for the Atlantic hurricane season. An example for the intensification of hurricane Humberto appears in the Figure. The forecast shown was initialized at 12 GMT on 9 September. Humberto reached an intensity of 75 knots at 21 GMT on 11 September (black dot in figure), and it quickly weakened after about 78 hours, similar to what was predicted in the ensemble.



‹ 7.1.a.5. Boundary-Layer Turbulence and Surface Exchange   up   7.1.a.7. Asian Air Quality Studies / Gases and Aerosols in Megacity-Biosphere-Atmosphere Interactions (GAMBAI) ›

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7.1.A.7. ASIAN AIR QUALITY STUDIES / GASES AND AEROSOLS IN MEGACITY-BIOSPHERE-ATMOSPHERE INTERACTIONS (GAMBAI)

GAMBAI – GASES AND AEROSOLS IN MEGACITY-BIOSPHERE-ATMOSPHERE INTERACTIONS

GAMBAI is an international collaboration focusing on air quality and the transport of pollutants in East Asia. The scientific goal of GAMBAI is to improve understanding of the chemical evolution of air influenced by anthropogenic and natural emissions over South Korea, Japan and Taiwan on local and regional scales. Chemical transformations, including the formation of ozone and secondary organic aerosols, are of particular interest, in conjunction with quantifying emissions from the various East Asian sources. GAMBAI is building on measurement and modeling efforts already taking place in China, South Korea and Japan, and facilitates collaboration and coordination of these activities. NESL/ACD scientists are sharing their expertise in measurements of VOC emission fluxes and global and regional chemistry modeling with Asian scientists and students. This year the first results of these collaborations were published.

A new tower and measurement site have been established in the Taehwa Research Forest, 35 km southeast of Seoul, with a large suite of trace gas measurements. The site is regularly influenced by pollution from Seoul, but is also in the center of a large pine plantation and mixed forest. The measurements of CO, NO_x and SO_2 indicate large urban influence on the atmospheric composition. The installation of a PTR-MS and the collection of cartridge samples at the tower site, under the guidance of ACD scientists, provided measurements of a large suite of volatile organic compounds (VOCs), of anthropogenic (benzene, toluene) and natural (isoprene, monoterpenes) origin (see Figure 1). These measurements showed very high levels of isoprene and monoterpenes at the site, in addition to the anthropogenic VOCs, helping to explain the high ozone levels observed (frequently over 80 ppb). Model simulations with WRF-Chem, including the MEGAN biogenic emissions model, show generally good agreement with observations, and support the correlation of high ozone with biogenic emissions. These new observations have identified some limitations in the model, which will be improved in future work, including biogenic emissions and urban precursors.

Measurements at other ground sites in Korea, using other techniques, had not observed the high levels of biogenic compounds seen at Taehwa. Thus, this study has shown the great importance natural emissions can have on the chemical evolution of urban pollution outflow, and highlights the need for further work in regions of megacities surrounded by forests.

This project is the start of a major research initiative within ACD. Scientists at NCAR, PNNL and U.S. universities will continue collaborations with scientists in Korea on the improvement, analysis and interpretation of the ground-based observations along with comparisons to regional and global model simulations. Plans are being developed for an intensive field experiment in 2016 with the NCAR GV, along with aircraft from NASA, DOE and Korea, which will provide detailed information on the chemical composition through the troposphere and evolution of pollution outflow from East Asia and its impact on Korea and the region.

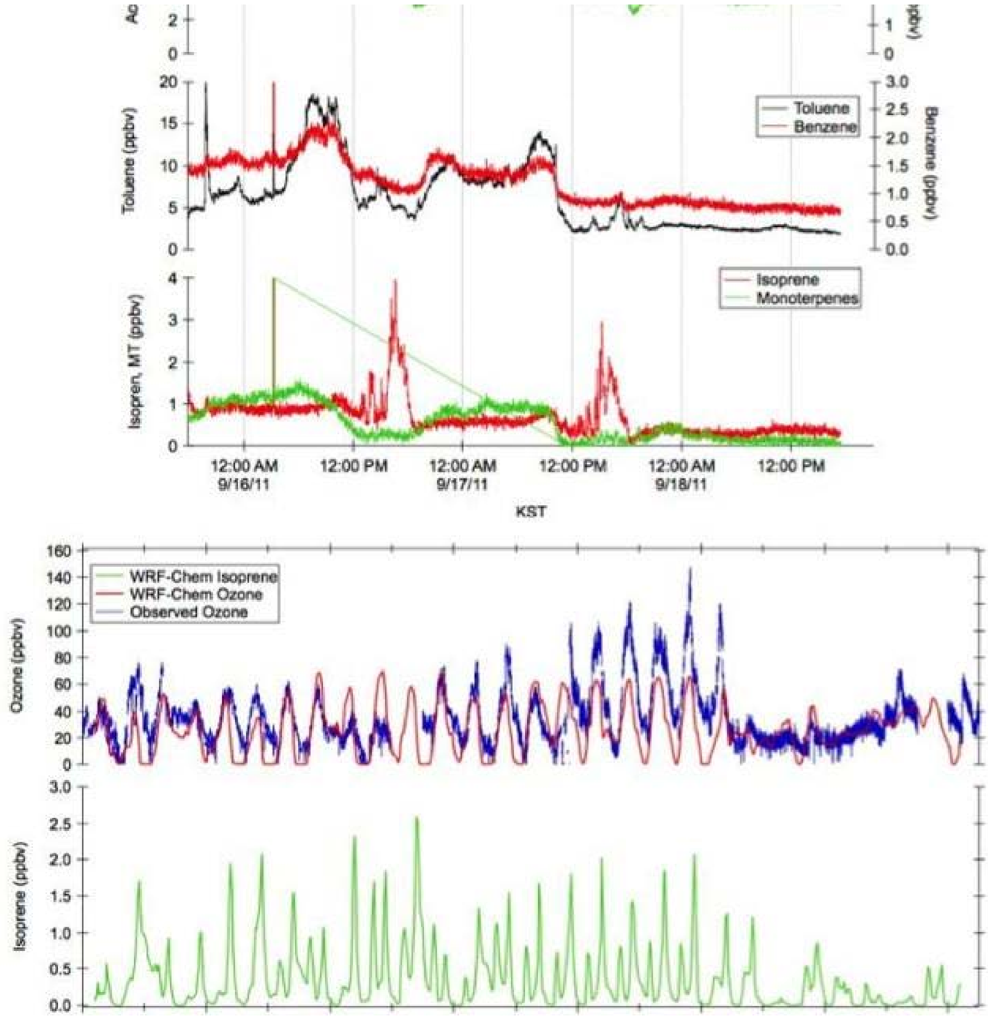

Figure 1: Top - Temporal distributions of VOCs (oxygenated, aromatic, and biogenic) observed at Taehwa Research Forest near Seoul by PTR-MS. Bottom - The WRF-Chem model simulated ozone and isoprene temporal variations, along with the observed ozone. [Figures 5 and 7 from Kim et al., 2013] (Click for larger image.)

Reference: Kim, So-Young, Xiaoyan Jiang, Meehye Lee, Andrew Turnipseed, Alex Guenther, Jong-Choon Kim, Suk-Jo Lee, Saewung Kim, Impact of biogenic volatile organic compounds on ozone production at the Taehwa Research Forest near Seoul, South Korea, *Atmos. Environ., 70*, 447, 2013.

‹ 7.1.a.6. Dynamics of Mesoscale Weather Systems | up | 7.1.a.8. Risks Associated with Air Quality and Climate in Asia: An International Workshop ›

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7.1.A.8. RISKS ASSOCIATED WITH AIR QUALITY AND CLIMATE IN ASIA: AN INTERNATIONAL WORKSHOP

An international workshop on “Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia” was held at NCAR, 9-12 July 2013. About 55 scientists (photo below) from Asia, Europe, and the United States participated in the workshop to foster collaborations between the atmospheric chemistry, climate, health, agriculture, hydrology, and social sciences communities and to develop ideas and plans for future studies in the Asian region. The participants agreed it was important to use a holistic approach for a 2030 climate scenario, meaning to include both the physical and social sciences, such as connecting urbanization to rural regions, agriculture, and health, or adding water nutrients and pollutants with economic policies. A summary article is planned to describe tools from different communities that can be used together for future projects focused on Asia. This workshop is a component of an NSF Earth System Modeling Project on Chemistry and Climate in Asia (PIs: M. Barth, NCAR and G. Carmichael, U.Iowa), which is developing a community and research tools focusing on the climate and air quality of Asia and their impact on humans.

(Click for larger image.)

‹ 7.1.a.7. Asian Air Quality Studies / Gases and Aerosols in Megacity-Biosphere-Atmosphere Interactions (GAMBAI) | up | 7.1.a.9. REACCTING - Research of the Emissions, Air Quality, Climate and Cooking Technologies In Northern Ghana ›

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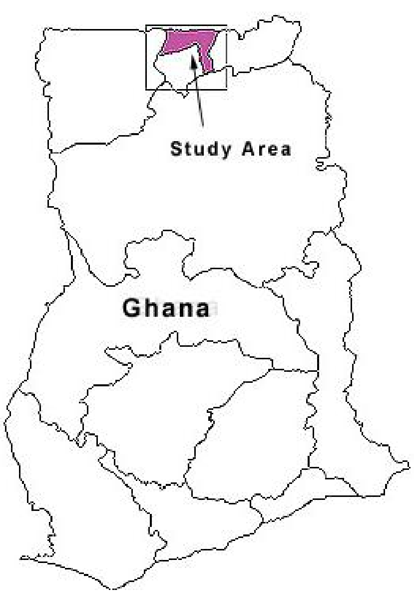
7.1.A.9. REACCTING - RESEARCH OF THE EMISSIONS, AIR QUALITY, CLIMATE AND COOKING TECHNOLOGIES IN NORTHERN GHANA

According to recent reports, nearly **three billion people** in the developing world cook food and heat their homes with open fires or cookstoves that are fueled by solid biofuels. The smoke exposure from these activities is estimated to lead to approximately four million premature deaths each year. The emissions from these processes also add significantly to global emissions of greenhouse gases, short-lived climate forcers, and air pollutants. However, emission estimates from these processes, and their atmospheric impacts, are still highly uncertain. Furthermore, stove technologies exist that enable reductions in the amount of fuel used for cooking, and in emissions. Yet, the extent to which these technologies will be utilized, change emissions, and impact health and atmospheric composition is unclear.

Many studies are being performed worldwide to try to understand the use of various stove technologies, their emissions, and their impacts. One such study is being led by NESL/ACD scientist Christine Wiedinmyer (pictured here) and has begun in the northern region of Ghana (See inset below). This region, impacted by strong dry and wet seasons, is one in which biomass is a dominant source of cooking fuel. Two different stoves, one low-emitting gasifier stove and one locally made “efficient” stove, will be tested through a randomized intervention in rural communities of the Kassena-Nakana District of the Upper East Region. The value that households place on these technologies and their various characteristics will be evaluated; the emissions, resulting personal exposure to smoke, and health outcomes will be measured. A component of this multi-disciplinary project includes the design and application of sensors that will be used to monitor emissions, ambient air quality, and personal exposures. Stove use and emissions will be scaled up through emissions and chemistry-climate models, including WRF-Chem, to investigate the impact of cooking and other sources on air quality and regional climate.



Instrumentation has been tested in the lab and in the field throughout 2013, and the first air measurement station was established in Navrongo in Sept. 2013. Data are currently being collected for ambient trace gases, including ozone, nitrogen oxides, carbon monoxide; these are the first measurements of their kind in this region of the world. The stove distribution and the first round of surveys will begin in Nov. 2013.

This project includes a multi-disciplinary team from many institutions, including NCAR ACD and RAL, the Mechanical Engineering and Mathematics Departments of the University of Colorado-Boulder, and the Navrongo Health Research Center in Ghana. The research includes the intersection of air quality and health, climate, economics, and engineering. The work is funded by NSF Award #1211668 and a second grant has been approved for funding by the U.S. EPA.

‹ 7.1.a.8. Risks Associated with Air Quality and Climate in Asia: An International Workshop | up | 7.1.a.10. The Upcoming Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ) ›

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7.1.A.10. THE UPCOMING FRONT RANGE AIR POLLUTION AND PHOTOCHEMISTRY EXPERIMENT (FRAPPÉ)

The Front Range Air Pollution and Photochemistry Experiment –FRAPPÉ– aims to characterize and understand summertime air quality (AQ) in the Northern Front Range Metropolitan Area (NFRMA). Despite efforts to limit emissions, the NFRMA is still experiencing AQ problems and is exceeding the National Ambient Air Quality Standard (NAAQS) for ozone on a regular basis in summer. The complex meteorology and the mix of diverse pollution sources present challenges with respect to characterizing, modeling and forecasting the transport and photochemical processes contributing to local AQ. In addition, long-range transport of pollution into the area and its impact on surface AQ is poorly characterized, as is the effect of NFRMA outflow on its surroundings.

The FRAPPÉ campaign will take place in summer 2014, and is aimed at answering the following question: *What are the factors controlling NFRMA surface ozone and are current emission controls sufficient to reduce ozone levels below the NAAQS?* Funding for the campaign, which involves deployment of the NCAR C-130 in coordination with ground-based measurements, has been secured from NSF Lower Atmospheric Observing Facilities for C-130 operation and $2M has been contributed by the State of Colorado to fund measurements and instrumentation contributed by our University partners. Proposal selection is ongoing and the C-130 payload as well as plans for instrumentation at the ground sites will be finalized by the end of 2013. NASA will conduct the fourth intensive of DISCOVER-AQ concurrently with FRAPPÉ, bringing two additional instrumented aircraft as well as ground remote sensing and in-situ equipment to the area. Base of operations will be the Research Aviation Facility at Rocky Mountain Metropolitan Airport. Sampling strategy using the C-130 is illustrated in Figure 1.

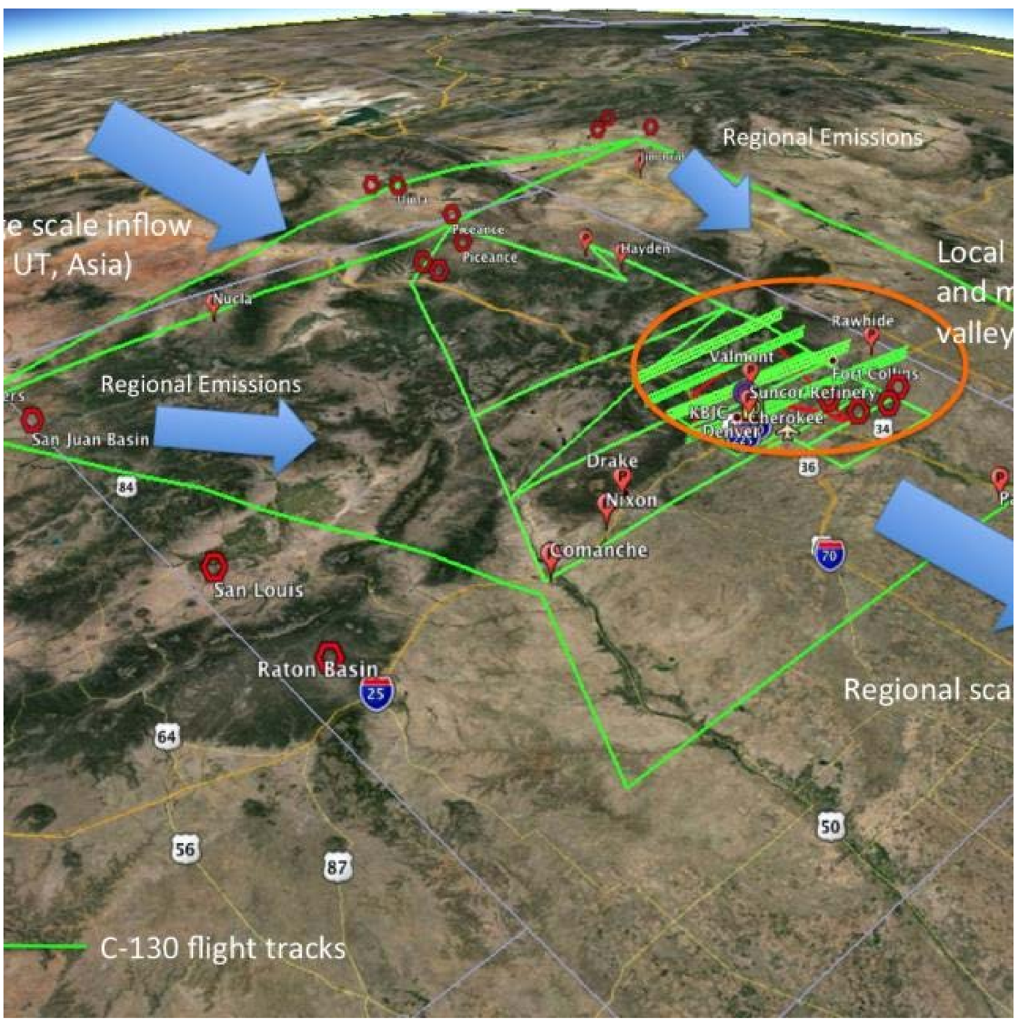

Figure 1: Planned flight activities of the NCAR/NSF C-130 aircraft during FRAPPÉ. Major regional point and area sources are shown as hexagons (large areas of oil and gas development) and place marks (Electricity Generation Units). The C-130 will focus both on the photochemistry and emissions in and surrounding the urban area, on the larger regional background as well as inflow and outflow from the NFRMA. (Click for larger image.)

‹ 7.1.a.9. REACCTING - Research of the Emissions, Air Quality, Climate and Cooking Technologies In Northern Ghana
up
7.1.b. Determine the inherent predictability of the Earth system with respect to weather, climate and air quality ›

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7.1.B. DETERMINE THE INHERENT PREDICTABILITY OF THE EARTH SYSTEM WITH RESPECT TO WEATHER, CLIMATE AND AIR QUALITY

Society continues to desire better predictions related to weather, air quality, and regional and global climate change. Further gains in prediction skill can only be assessed with the knowledge of the inherent predictability (the time beyond which the marginal benefit of forecast-error reduction relative to the cost of forecast-system improvement is negligible) of the Earth system with respect to specific predictions.

‹ 7.1.a.10. The Upcoming Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ) up 7.1.b.1. Identify and model the physical, chemical, biological, and human components that govern the climate system ›

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7.1.B.1. IDENTIFY AND MODEL THE PHYSICAL, CHEMICAL, BIOLOGICAL, AND HUMAN COMPONENTS THAT GOVERN THE CLIMATE SYSTEM

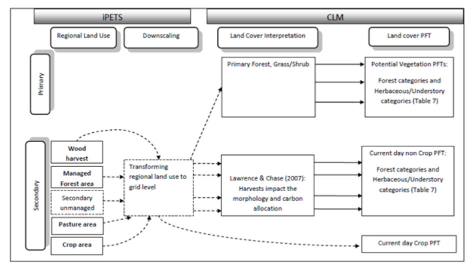

Figure: *Land Use Linkage Scheme of iPets to CLM.*

The Integrated Assessment Modeling (IAM) team worked on integrating a spatial land use model into iPETS, allowing linkages to land surface models such as NCAR's CLM and the Integrated Science Assessment Model (ISAM) developed at the University of Illinois in order to investigate interactions between future changes in the demand for land, resulting emissions, and climate change (and its feedback on land use decisions).

IAM has revised and refined the initial methodology developed for generating spatial land use projections and expanded the initial application from the U.S. to a global model. IAM has tested its performance globally over a historical period, and a manuscript for submission to a journal is in its final stages. This work was carried out with collaborators Mike Dalton at NOAA and Prasanth Meiyappan and Atul Jain at the University of Illinois. The work was presented and discussed at a number of professional meetings, including at the CESM Societal Dimensions Working Group meeting in February, an annual meeting of the integrated assessment community at Snowmass in July, and a meeting of the global land modeling community in Amsterdam in September.

‹ 7.1.b. Determine the inherent predictability of the Earth system with respect to weather, climate and air quality | up | 7.1.b.2. Understand and model how human systems influence, and are influenced by, the physical climate system ›

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7.1.B.2. UNDERSTAND AND MODEL HOW HUMAN SYSTEMS INFLUENCE, AND ARE INFLUENCED BY, THE PHYSICAL CLIMATE SYSTEM

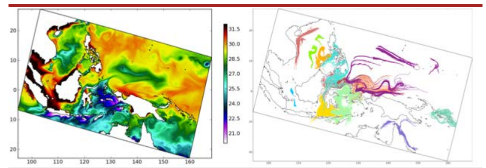

Figure: *ROMS simulations for the Coral Triangle region, showing sea surface temperature for August 2003 (left), and 30-day larval dispersal trajectories from reefs within different "eco-regions" (right). Note that the regions of greatest mixing of larvae (e.g., center of figure) coincide with regions of highest biodiversity (figures from Dr. Frederic Castruccio, NCAR).*

The IAM team has participated in the initial round of modeling for the Latin America Modeling Project (LAMP). IAM group members are co-leading task groups within LAMP on base year data and on building energy use in energy scenarios for Latin America. They are also key participants in a task group on agricultural modeling. Initial scenarios generated with the iPETS model with and without climate policy, and including land use for agriculture with associated climate change impacts, have been submitted to the project for presentation at an October 2013 meeting of the project. Further progress will be made and reported at the next LAMP meeting, likely in late spring/early summer 2014.

A set of global spatial population projections for use in emissions and impact studies was completed; the model developed to produce these projections will form one component of a Community Demographic Model (CDM) currently under development. A paper documenting the methodology and applying it to projections for the U.S. is in press at the journal Environmental Research Letters. Expansion of this method to a global projection is well under way with a fast-track version anticipated by December 2013 and a more refined version expected by the summer of 2014. This work has been presented at seminars at NSF, the Aspen Global Change Institute, and at a workshop on global population projections at Hunter College in NY.

Much work has also been completed in the study of the Coral Triangle (CT), a region of maximum marine biodiversity that includes more than 75 percent of the world's coral species, and more than 3000 species of fish. With 150 million people living in the CT's coastal regions, humans rely heavily on fishing and other marine resources so it is a priority to understand how 21st century climate change will impact this region The CT-ROMS modeling effort will provide valuable information in regional marine conservation planning, particularly for coral reef ecosystems that support the livelihoods of many resident communities. The continued development of carbon-system parameterizations in CESM will improve our ability to address marine productivity and impacts of ocean acidification at both global and regional scales.

‹ 7.1.b.1. Identify and model the physical, chemical, biological, and human components that govern the climate system   up   7.1.b.3. Regional Climate Research ›

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7.1.B.3. REGIONAL CLIMATE RESEARCH

Society is becoming increasingly vulnerable to weather and climate events, especially those at the severe and high-impact end of the spectrum. Yet uncertainty over potential climatic changes in these high-impact events severely hampers capacity to plan for, adjust to, and mitigate impacts. The Prediction Across Scales Initiative is developing advanced numerical and statistical predictive techniques that will improve society's capacity to mitigate, respond, and adapt to effects of high-impact weather and climate on scales from hours to decades. This effort provides special focus on advancing community modeling facilities, and ties to several NCAR imperatives. The importance of this work is demonstrated by the considerable industry interest in, and support for the initiative.

This major initiative involves a wide range of scientists and disciplines within and outside of NCAR. They include CCSM/CESM, WRF and its components (CESM, NRCM, WACCM, WRF-Chem, WRF-Fire, and Advanced Hurricane WRF (AHW)), MPAS development, and the Regional Climate Prediction Program. These tools have been used to test new physical and dynamical core approaches, development of new components including chemistry and air quality, coupled atmosphere-ocean processes, discovering remote impacts of local processes (upscaling), and providing assessments of regional climate changes to societal groups. In parallel with the modeling, considerable effort has ensured societal applicability including development of decision support tools and methods of communicating information with input from societal partners as the research and development proceeded.

In an effort to assess uncertainty in simulated regional climate and extreme events, an ensemble of current climate simulations using different model physics and initial conditions has been generated to estimate regional climate simulation uncertainty. An ensemble of both current and future regional climate simulations over North America and the North Atlantic is currently in progress. A one-year simulation using NRCM over the U.S. and North Atlantic at 4-km grid spacing highlighted the importance of "convection permitting" resolution for regional climate simulation.

Future changes in precipitation extremes have also been analyzed using NRCM simulation data for each climate regime across the U.S. Results have been published. Societal impacts have been assessed using the Ogallala aquifer in Southern Oklahoma as a focus study region to explore the role of drought perceptions in decision making for water resource management in a changing climate.

In an effort to assess the impact of full two-way interaction between the atmosphere and ocean on the regional climate of the United States and extreme events, hurricane case studies have been simulated using the NRCM coupled to the Regional Ocean Modeling System and the SWAN wave model.

A new Cyclone Damage Potential index has been developed that is flexibly adaptable to a range of specific impact assessments. This has been used in commercial applications by Willis Re. Ecological impact studies completed and published include climate change impacts on fish and birdlife management.

NRCM simulations have been downscaled using NRCM-Chem (a fully coupled chemistry transport model) to assess future changes in air quality and climate over the summertime US (example shown in Figure below). The work has been submitted for publication and illustrates the need for high resolution to address regional and local air quality or establish links to human health and society.

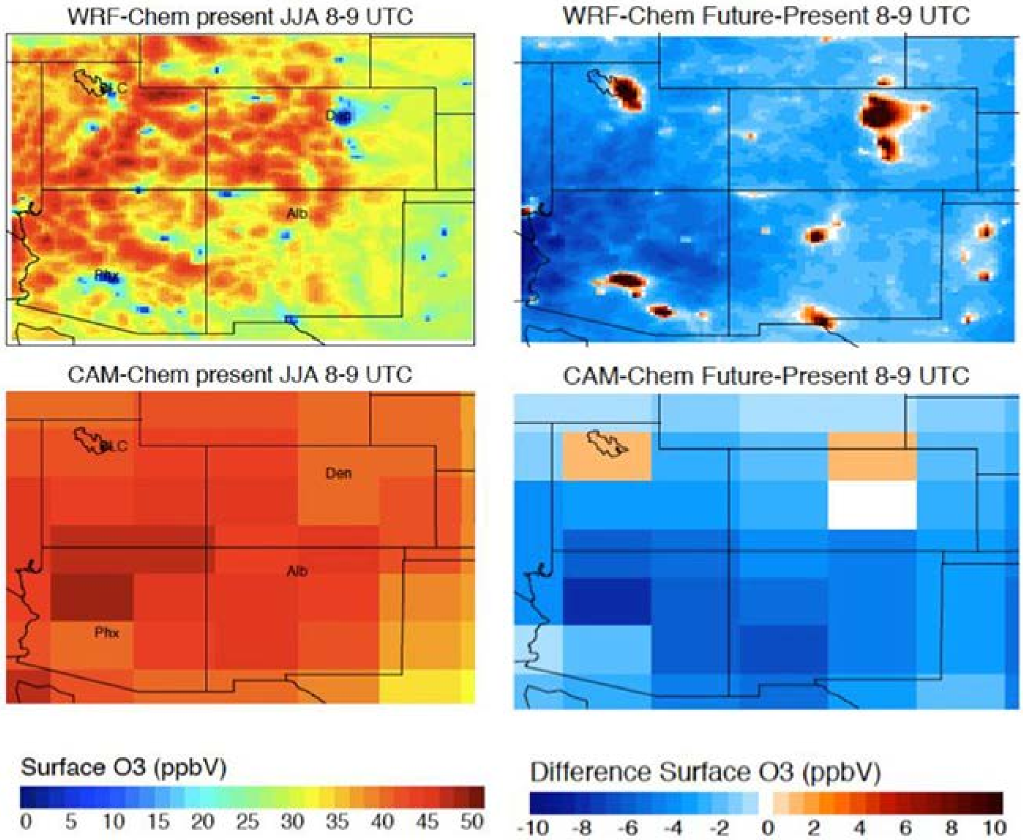

Figure: Spatial distribution of the average nighttime (8-9 UTC) surface ozone mixing ratios from NRCM-Chem (top) and a global model simulation (bottom) for present time (left) and the difference between future and present time ozone (right) for the Four-Corner States. The cities (Den-Denver, SLC – Salt Lake City, Phx – Phoenix, Alb - Albuquerque) are indicated in the maps. High resolution is necessary to capture the details of urban centers. Source: Pfister et al. submitted.

NRCM is moving to very-high resolution simulations to test the optimal resolution for regional climate simulations of a range of severe weather and to provide a basis for the further development of advanced statistical techniques. Simulations of hurricane activity have been conducted at 36km, 12km and 4km grid spacing. The benefits of 12km over 36km are negligible since the missing information at 36km can be readily reconstructed using statistical modeling. The 4km simulation, on the other hand, provides additional useful information that is currently being explored statistically. This work is being utilized by several offshore energy groups in their planning and design process.

NRCM has been utilized in a wide range of simulations (example shown in Figure) and studies aimed at providing regional climate assessments for weather extremes and atmospheric chemistry over the U.S. and East Asia. A number of sophisticated statistical downscaling methods have been developed. Test regional climate simulations have been completed with the MPAS and the planned transfer to this platform is on track. All of this work has been done in close collaboration with academia and industry users and is being published in a series of publications.

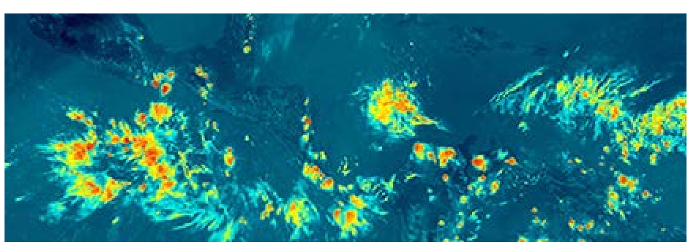

Figure: Snapshot from a 4-km climate simulation using the NRCM showing active tropical convection and resolved thunderstorm clusters over Central America.

NESL scientists also conducted fully coupled CESM simulations of global hurricane activity. Specifically,50+ year fully-coupled simulations using a 25km atmosphere (CAM-SE) coupled to a 0.1o ocean were conducted. The runs have realistic tropical cyclone (TC) climatologies in the western Pacific (North and South) and Indian Ocean, but seriously underpredict activity in the northeastern Pacific and Atlantic. This is probably related to significant cold biases in SSTs in these basins.

In FY2013 efforts were made to further develop combined statistical-dynamical downscaling techniques to augment NRCM results, including exploration of the potential for sub-basin scale assessments such as the Gulf of Mexico for the case of tropical cyclones.New empirical downscaling methods have been developed for all tropical cyclone basins and some sub-regions including the Gulf of Mexico (example shown in Figure below). Results have been published. In addition improved statistical modeling approaches to assess future changes in tropical cyclone intensity have been developed.

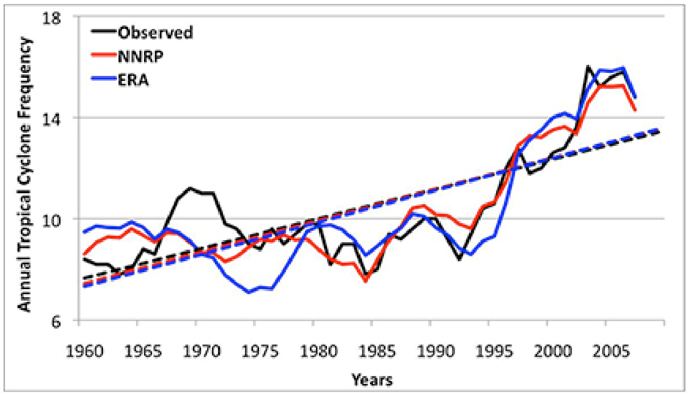

Figure: A 5-yr running mean of observed North Atlantic tropical cyclone storm frequency (black), and that estimated from the Cyclone Genesis Index applied to two different reanalysis datasets (red and blue) with dashed linear trend lines superimposed. Source: Bruyere et al. (2012).

To better address future regional climate change, a fully coupled 50-km resolution version of CCSM4 has been run for a long control run, as well as 20th and 21st century simulations. Additionally, a quarter-degree (roughly 25 km) version of CAM5 has been configured and run in AMIP-style experiments contrasting present and future climate, as well as in fully coupled mode with both a 1 degree and 1/10 degree ocean. In parallel, societal impacts are being studied using a1km regionally refined land model of the U.S. mid-Atlantic, relating future energy demands to projected daily summer temperatures.

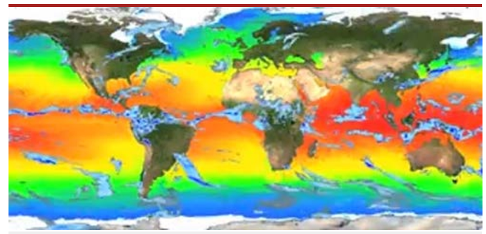

Figure: *Weather fronts and storms in a global model.*

EaSM

NESL has partnered with NCAR/CISL, NSF, DOE, the U.S. Department of Agriculture and academia on a series of accelerated Earth System Modeling (EaSM) climate research initiatives (CRI) aimed at broadening interdisciplinary research and support. Regional climate initiatives in the community using WRF and NRCM have continued to expand rapidly over the past year with first users now experimenting with the Model for Prediction Across Scales (MPAS) for regional climate studies. NESL is responding by providing tutorials and special sessions at WRF workshops in these areas and a dedicated user support desk. In addition, regional climate data have been made accessible via web download at rda.ucar.edu/datasets/ds601.0/ and a quick-look plot browser is available at http://www.mmm.ucar.edu/prod2/nrcm/RCPP/RCPP.html (see Figure below) for users to rapidly select periods of interest. Support from NSF EaSM funds has accelerated the development and use of the MPAS modeling system for regional climate studies.

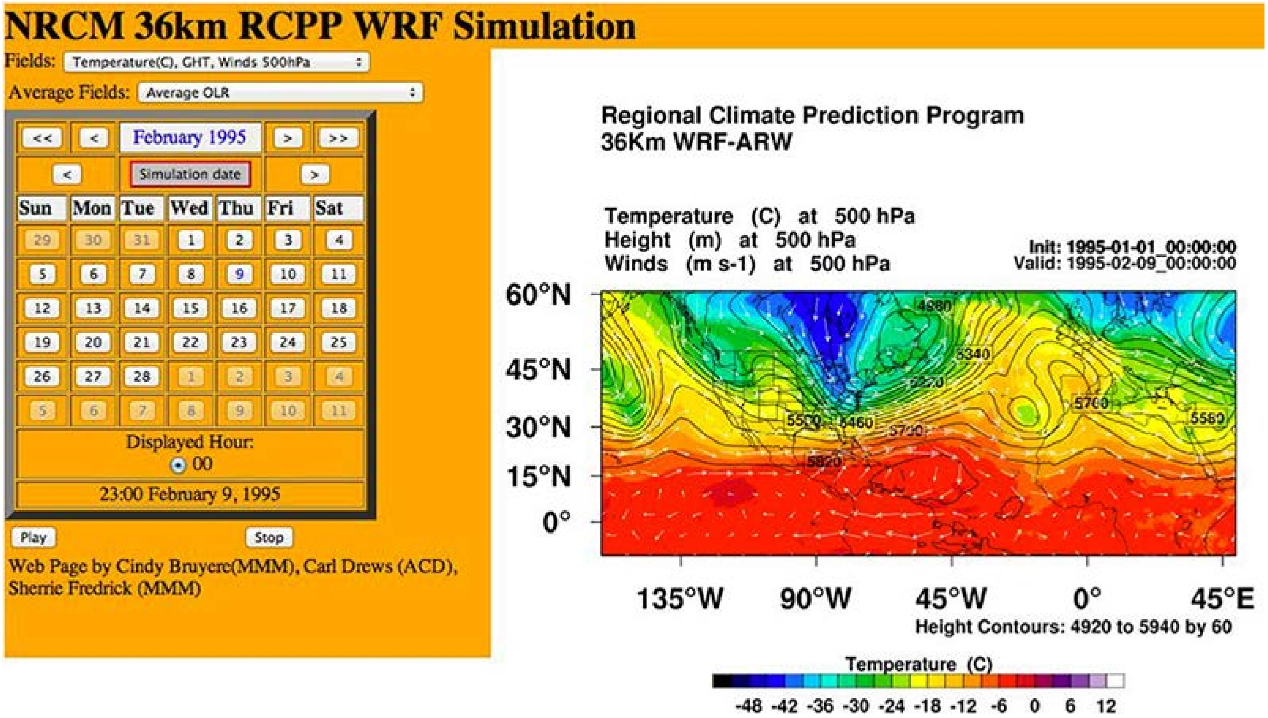

Figure: Screenshot from the online plot browser.

The WRF modeling system continues to be updated and version 3.5 was released in the spring of 2013. Online documentation was provided for portability of codes and guidance for regional climate studies has been updated. The MPAS code was released to the community in June 2013. The MPAS release contains all the climate modules from the WRF-NRCM code.

Additional support has been added for users running WRF-NRCM. This includes help with special climate pre-processing of data, running the model in climate mode as well as help with post-processing and visualization. In the last year alone NESL/MMM staff has already responded to over 100 emails. Pre-processing code has been made available to facilitate importing Global Climate Model data into WRF. WRF-NRCM data from model runs performed at NCAR have been post-processed and are now available on NCAR's RDA web site. This will be an ongoing effort in the coming years.

NESL scientists commenced trials of MPAS as a next-generation regional climate EaSM for community release.Successful simulations of the highly active 2005 North Atlantic hurricane season have been conducted using both a single resolution global mesh and a global mesh with refinement over the Atlantic basin (see Figure).

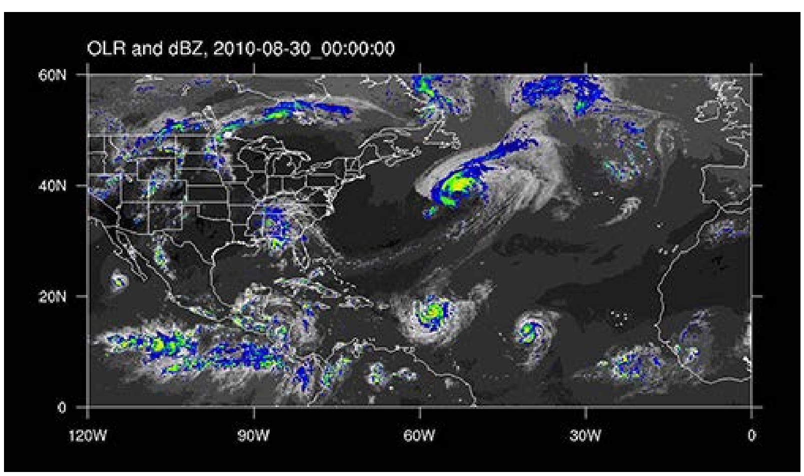

Figure: Hurricane development in a MPAS global simulation of the 2005 hurricane season.

‹ 7.1.b.2. Understand and model how human systems influence, and are influenced by, the physical climate system up 7.1.b.4. Surprising Growth of Organic Aerosols ›

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- 7.1.b.9. Expansion of the tropics studied using satellite measurements of tropical cirrus
- 7.1.b.10. Upper Mesospheric Ozone from Satellites
- 7.1.b.11. Evaluating model simulations of global hydrocarbons using satellite measurements
- 7.1.b.12. Dynamics and transport of monsoonal circulations based on potential vorticity
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7.1.B.4. SURPRISING GROWTH OF ORGANIC AEROSOLS

Organic aerosols (OA) are major drivers of climate change, but their sources, properties, and removal mechanisms are poorly known, and therefore they remain the cause of the largest uncertainties in the radiative forcing of climate (IPCC-SPM, 2013). The chemistry producing OA from atmospheric hydrocarbons is very complex, and only one model, developed here in NESL/ACD, is capable of including sequences of hundreds of thousands reactions that control and modify particle mass, composition, thermodynamics, and optical properties. This model, the Generator for Explicit Chemistry and Kinetics of Organics in the Atmosphere (GECKO-A, developed in collaboration with U. Paris and with partial support from DOE/ASR) is being used to examine the evolution of aerosol-laden plumes downwind of source regions, e.g. from urban or forest precursor hydrocarbons.

A remarkable result from the GECKO-A simulations is the prediction that OA mass continues to grow for several days downwind, with multi-day OA mass becoming several times larger than in the source region during the first day. Figure 1 (updated from Lee-Taylor et al., 2011) illustrates the OA growth downwind of Mexico City. When the urban plume moves outward, it is diluted with cleaner background air and so the particle concentrations (mass per unit volume, red curve) decrease as expected, and any health effects related to their inhalation would similarly decrease. However, the total mass (plume-integrated, black curves) is seen to increase by a factor of ~4 over several days, and it is this total mass that determines the radiative impact of the OA.

Because of this paramount importance to climate science, we tested the robustness of our predicted OA growth *via* a number of sensitivity studies. These included changes in the calculations of thermodynamic properties (e.g. vapor pressures, which determine gas/particle partitioning), various ways of estimating chemical fragmentation *vs*. functionalization (determining the chemical aging of the gas-particle mixtures), environmental conditions such as temperature and dilution rates, contributions from background (seed) aerosols, the role of dry and wet deposition of both gases and particles, as well as tests of numerical robustness of our model. Some of these sensitivity studies are shown in the figure, and continue to indicate strong OA growth downwind of sources. This multi-day regional scale growth is not currently considered in climate models, but if confirmed by observation, it suggests that climate models may be seriously underestimating the impact of urban aerosols on regional scales, and thus may be getting the right climate for the wrong radiative forcing.

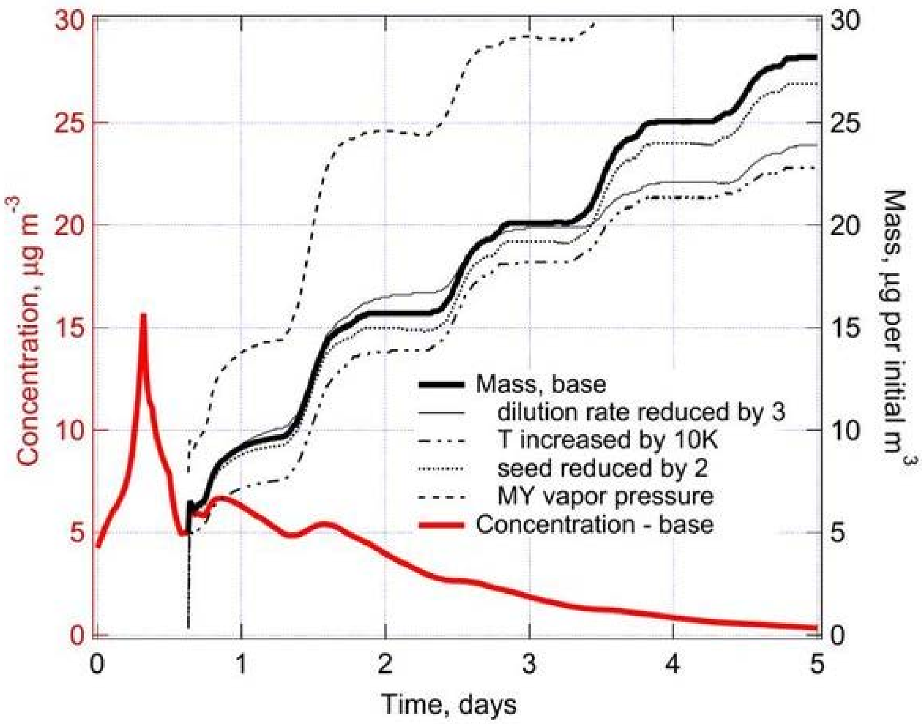

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Figure 1: Growth of organic particles downwind of Mexico City. The plume is released from the city at 3pm on the first day. Particle concentrations in the plume (mass per unit volume, red, left scale) decrease because of dilution with cleaner background air. However, plume-integrated particle mass (black, right scale) increases several-fold during the outflow. Sensitivity studies, in which the dilution rate with background air was decreased by a factor of 2, air temperature was increased by 10K, seed aerosol concentrations were reduced, and vapor pressures of organics were calculated by a different method (MY), indicate that total organic particle mass continues to grow strongly in all cases tested.

‹ 7.1.b.3. Regional Climate Research | up | 7.1.b.5. NESL participation in the Study of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) campaign ›

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7.1.B.5. NESL PARTICIPATION IN THE STUDY OF EMISSIONS AND ATMOSPHERIC COMPOSITION, CLOUDS AND CLIMATE COUPLING BY REGIONAL SURVEYS (SEAC4RS) CAMPAIGN

NESL scientists participated in the NASA Study of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys ($SEAC^4RS$) campaign, operated from Houston TX, over August and September 2013. This is a revised $SEAC^4RS$ campaign from the original science plan based on Thailand in 2012. The campaign targeted the impact of wildfires on air quality and chemical composition, natural and anthropogenic emission in the Southeast US coupled to convective pumping, and convective transport during the North American monsoon season and its impact on UTLS composition, especially on water vapor transport into the stratosphere. NESL scientists contributed to the scientific planning and the flight planning for the campaign.

The North American monsoon (NAM) circulation has been studied extensively for its impact on western and central US precipitation. The $SEAC^4RS$ campaign represents the first intensive airborne investigation of the role of NAM in pumping surface emissions to the upper troposphere and lower stratosphere. The campaign devoted about one-fourth of the flights to mapping the vertical and horizontal gradient associated with the anticyclonic monsoonal flow and the associated deep convection. In situ observations from both the DC-8 and the ER-2 research aircraft obtained significant new data for the role of NAM in chemical transport in the UTLS. The ER-2 observations further demonstrate that deep convection and the NAM flow play a significant role in water vapor transport into the stratosphere. Figure 1 shows selected ER-2 and DC-8 flight tracks indicating extensive campaign coverage over North America. The campaign data analysis in the following years is expected to provide insight into the transport process, to connect the in situ observations with the long-term satellite data and to improve convective transport modeling.

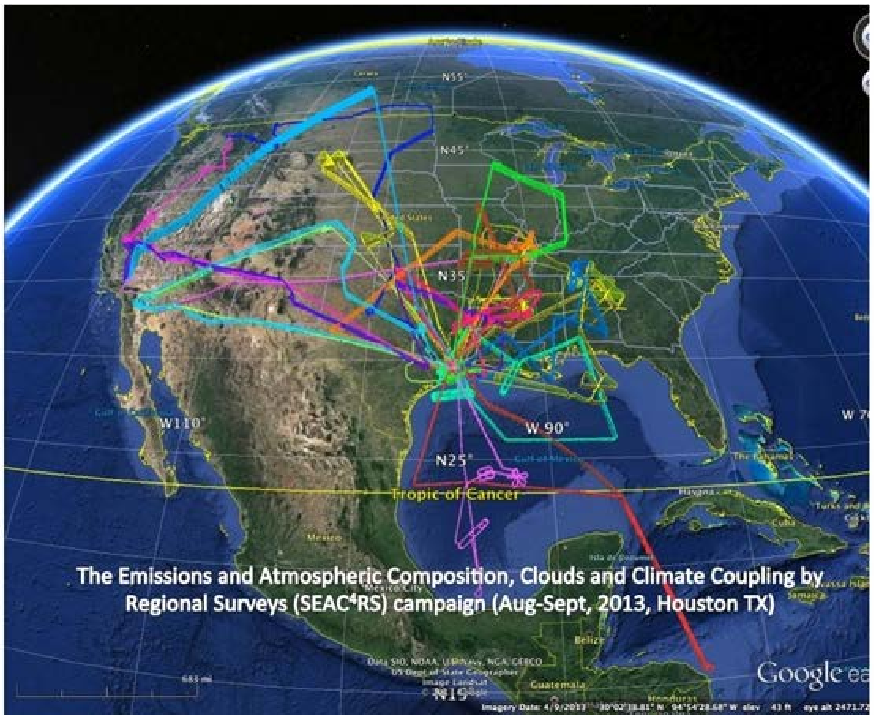

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Figure 1: SEAC[4]RS campaign selected flight tracks indicating extensive coverage of North America. The DC-8 and ER-2 aircraft combined vertical range covers from the surface to the lower stratosphere. The combined payload measures a large suite of chemical compounds and aerosol-cloud information.

One specific focus of NESL/ACD scientist during SEAC4RS was on determination of spectrally resolved actinic flux and calculation of atmospherically important photolysis frequencies, using the Charged-coupled device Actinic Flux Spectroradiometer (CAFS) instrument on board the NASA DC-8 aircraft. The measurement is sensitive to cloud, aerosol, albedo and composition dynamics and is critical to understanding the evolution of ozone, greenhouse gases, and natural and anthropogenic emissions. One goal is to examine convection of boundary layer species to the UT/LS region where volatile organic compounds (VOCs) and radical species are exposed to complex radiative environments associated with storm clouds. The resulting oxidative chemistry is strongly tied to photodissociation of atmospheric species at altitudes where ozone greenhouse forcing is strongest.

Figure 2 shows two NASA DC-8 aircraft profiles in cloud-free conditions that illustrate the impact of aerosols on photolysis. The colors represent the ratio of NO_2 photolysis calculated from the CAFS measurement to clear sky values from the NCAR Tropospheric Ultraviolet and Visible (TUV) radiative transfer model. The measurement and model agree very well on the left under low aerosol optical depth (AOD) conditions with only minor impact near the surface due to boundary layer aerosols. On the right, photolysis is strongly impacted under significant aerosol loading from an aged smoke plume. The data analysis is in the early stages and will continue to be expanded and refined.

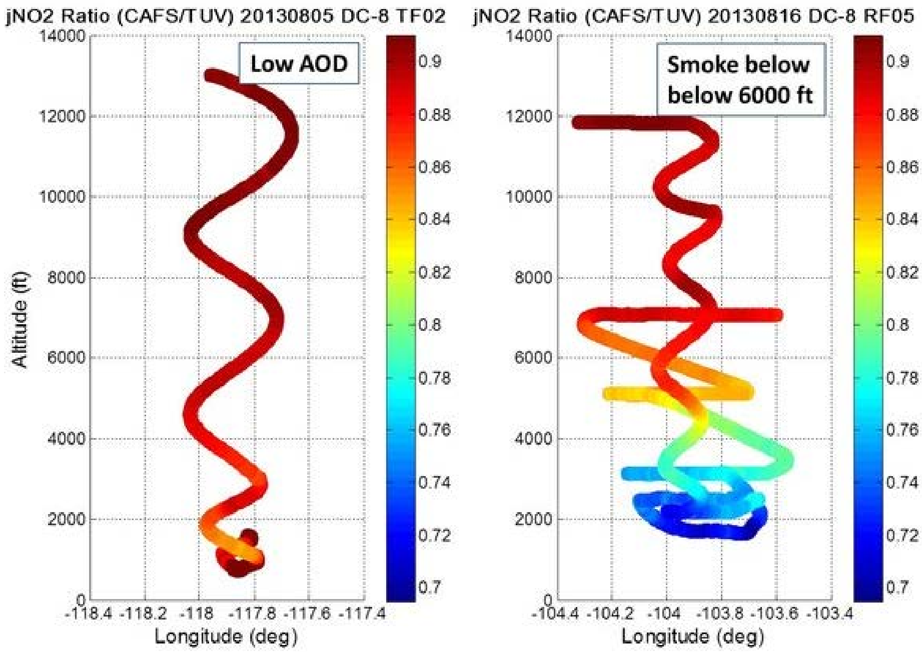

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Figure 2: Ratio of measured (CAFS) to modeled (TUV) J-NO_2 values for two aircraft profiles. Left panel: Data obtained under conditions of low aerosol loading. Right panel: Data obtained under high aerosol loading from an aged smoke plume.

‹ 7.1.b.4. Surprising Growth of Organic Aerosols up 7.1.b.6. Preliminary Highlights from the Deep Convective Clouds and Chemistry (DC3) Field Campaign ›

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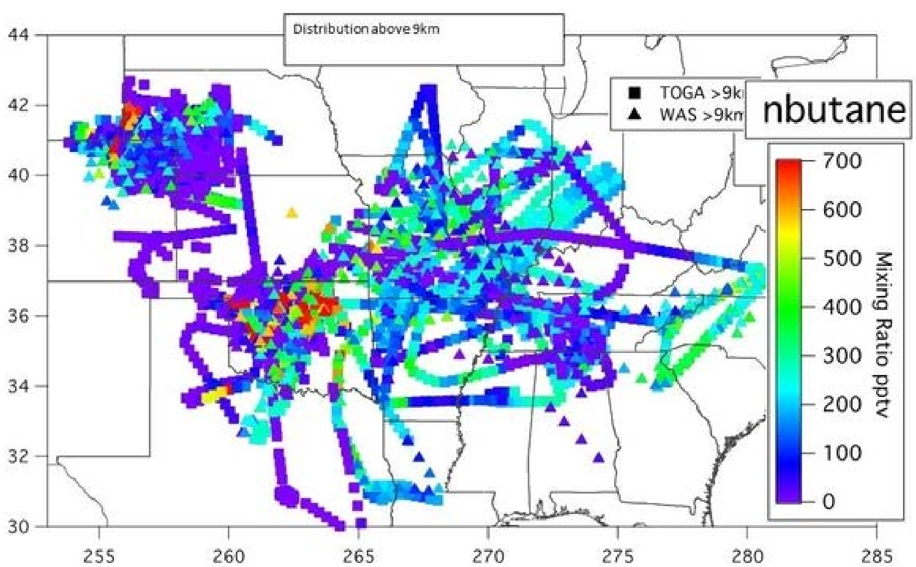
7.1.B.6. PRELIMINARY HIGHLIGHTS FROM THE DEEP CONVECTIVE CLOUDS AND CHEMISTRY (DC3) FIELD CAMPAIGN

The DC3 field campaign, co-led by investigators from NCAR, Penn State University and Colorado State University, took place is spring/summer 2012. The campaign, involving both instrumented aircraft flights and ground-based measurements, investigated the impact of deep, mid-latitude continental convective clouds on upper tropospheric (UT) composition and chemistry. A primary motivation of DC3 is in determining the role of these convective events on the concentration of ozone in the UT, where ozone acts as a greenhouse gas. The aircraft (NSF/NCAR G-V, NASA DC8 and DLR Falcon) were based in Salina, Kansas, while a network of ground-based instrumentation was deployed in Colorado, Oklahoma and Alabama in support of the project. NCAR hosted a DC3 data workshop in February, 2013, and numerous topics and events were identified for detailed analysis and eventual publication. While campaign data analysis is ongoing, some preliminary research highlights are outlined below.

One of the goals of DC3 is to characterize the processing of chemical constituents by thunderstorms. Short-lived compounds can only reach the UT via fast transport through deep convection. For example, n-butane (a tracer of oil and gas activity) is used here to show how patterns in storm outflow correspond to near-surface distributions. By measuring a wide variety of compounds across a range of solubility and reactivity, the convective transport, or conversely the scavenging, of chemical species, can be quantified. These findings are relevant to understanding ozone chemistry in the UT. Figure 1 shows measurements of n-butane below 3 km and above 9 km, showing areas of high concentration at low altitudes in Oklahoma/Texas and Colorado, and corresponding high values in the upper troposphere. In Figure 2, n-butane concentrations are plotted as a function of altitude, again providing evidence for its convective transport from near the surface to 10-12 km altitudes.



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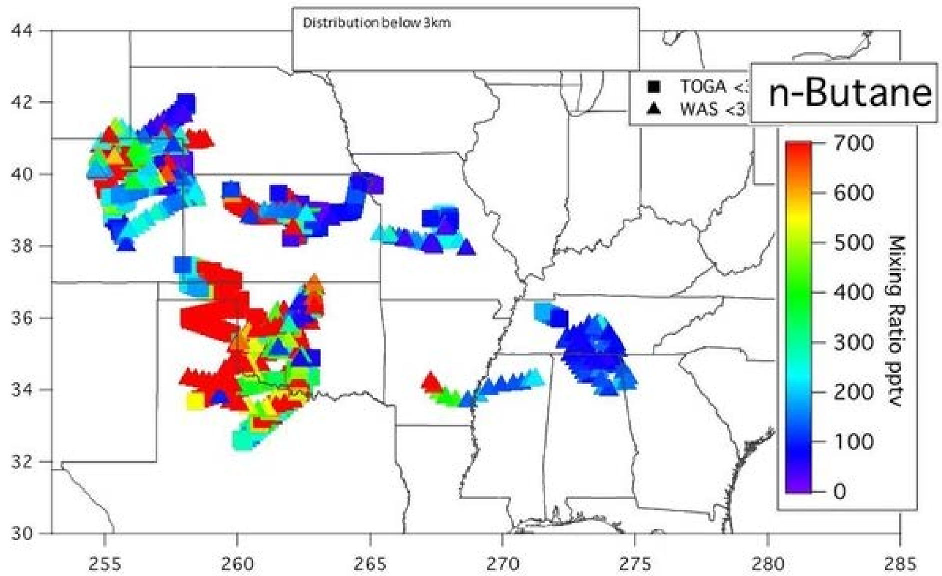

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Figure 1: Top plot is an n-butane concentration map for altitudes above 9 km, showing its transport to the UT. Bottom plot is an n-butane concentration map for the boundary layer (z < 3 km) showing regions of high concentrations in western Oklahoma and Texas and in Colorado. Data provided by E. Apel (NCAR) and D. Blake (U. California – Irvine).

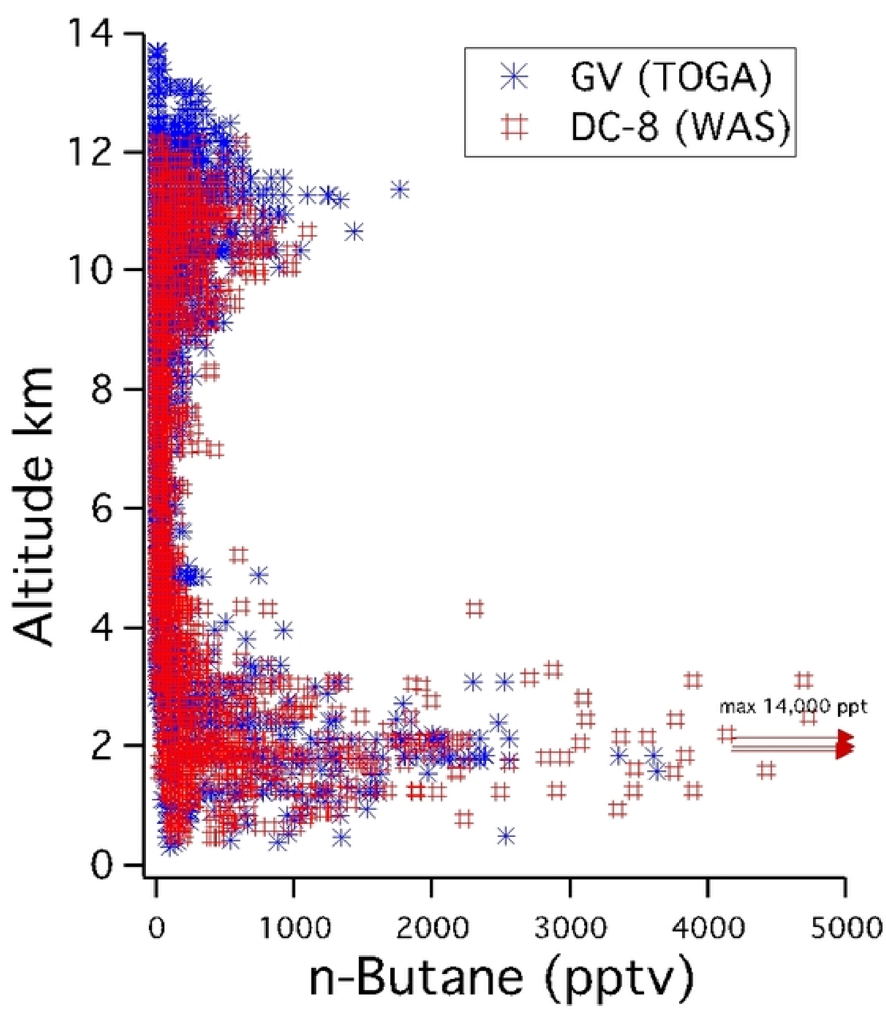

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Figure 2: Vertical profile of n-butane showing its convective transport from near the surface to the 10-12 km altitude region. Data provided by E. Apel (NCAR) and D. Blake (U. California – Irvine).

During DC3, an exceptional opportunity arose to study the outflow from a mesoscale convective system (MCS) over a large area of the Midwest. The MCS had developed during the night of June 20-21. Figure 3 (left panel) shows a radar image of the reflectivity, demonstrating the extent of this large scale system. The DC8 interrogated the outflow starting early in the morning on the 21st and the GV continued mapping the outflow from midday until the evening of the 21st. The flight tracks of the DC8 (pink) and GV (green) are shown in Figure 3 (right panel).

(Click for larger image.)

Figure 3: (left panel) A radar image of reflectivity, showing the extent of the MCS observed on June 20-21, 2012. (right panel) Flight tracks for the DC8 (pink) and GV (green) on June 21, 2012.

In Figure 4, the chemical evolution of a number of chemical species (toluene, formaldehyde and ozone) is shown in the outflow of the MCS in the UT (> 10 km). To test our understanding of the expected chemical evolution, the detailed NCAR master mechanism (MM) was used to model the event. The model was initialized with conditions pertaining to 12:45 UTC (shown by the rectangle in Figure 4), and then was allowed to run over the course of the day. Results from the MM are shown as continuous lines and are drawn in the same color as the corresponding measurements of the trace species. It is clear that photochemistry produces ozone in the outflow and the model is able to reproduce the trend but underpredicts the amount of ozone. (The spikes in the ozone are believed to be from stratospheric air mixed in). The MM agrees well with measurements for formaldehyde and toluene.

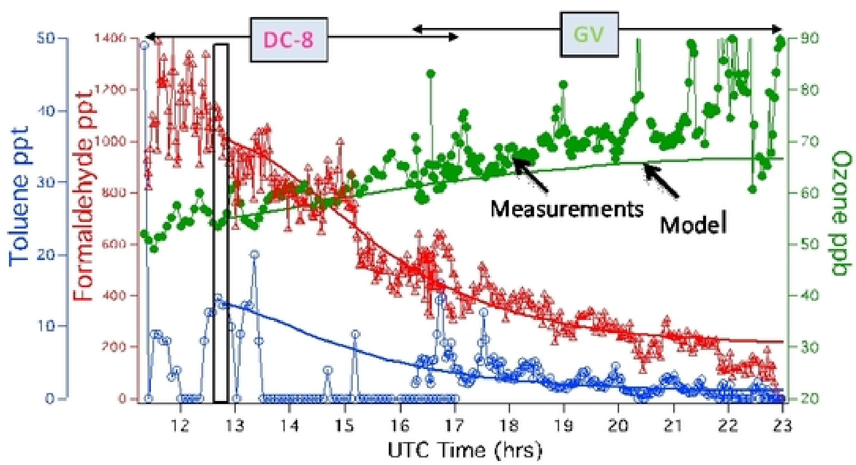

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Figure 4: Evolution of concentrations of formaldehyde (red), toluene (blue) and ozone (green) above 10 km in the outflow of a mesoscale convective system observed in the Midwest ion June 21st, 2012. Symbols – measured data; Solid lines -

Another DC3-related study being conducted by NESL ACD scientists involves an investigation of the regional enhancement of NOx in the upper troposphere over the eastern US compared to the western US owing to lightning production from storms originating over the Rocky Mountains and the high plains. Data from DC3 and a previous campaign (START-08) were used to calculate average NOx loadings for the UT, revealing a significant enhancement of NOx over the eastern half of the US. Global models such as MOZART currently underestimate this enhancement by about a factor of 2. Total lightning NOx production and distribution/transport as well as chemistry are being explored as potential reasons for this. A presentation of these findings will be given at the 2013 AGU Fall meeting.

‹ 7.1.b.5. NESL participation in the Study of Emissions and Atmospheric Composition, Clouds
up
7.1.b.7. Overview of NESL/ACD Participation in the 2013 Southeast Atmosphere Study (SAS) ›

and Climate Coupling by Regional Surveys (SEAC4RS) campaign

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7.1.B.7. OVERVIEW OF NESL/ACD PARTICIPATION IN THE 2013 SOUTHEAST ATMOSPHERE STUDY (SAS)

NESL/ACD scientists led ground-based and airborne components of the Southeast Atmosphere Study (SAS, http://www.eol.ucar.edu/projects/sas/) during June-July 2013. The Southern Oxidant & Aerosol Study (SOAS) was the ground-based component in Centreville, AL, where ACD scientists made measurements of emissions fluxes and ambient concentrations of biogenic VOCs, NOx, and particles. The Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks (NOMADSS) project consisted of 19 flights of the NCAR C-130, based near Nashville, TN. ACD scientists on the aircraft measured a large suite of VOCs using TOGA and a PTRMS, as well as NO, NO_2, aerosols, CO, CH_4 and actinic flux. ACD scientists also provided chemical tracer forecasts from MOZART-4 and Flexpart for flight planning.

A major NESL/ACD focus for the campaign will be on the emissions of the biogenic VOC, isoprene, and the impacts of its chemistry. Figure 1 shows all of the isoprene measurements made from the C-130 with the Trace Organic Gas Analyzer (TOGA) when the aircraft was below 1 km. Highest levels were seen over forests when conditions were warm and sunny. Concentrations were relatively low over Alabama due to cloudy and cool weather. VOC measurements with high time resolution by PTR-MS allowed determination of eddy covariance fluxes in the mixed layer, as shown in Figure 2. These measured fluxes will be used to evaluate and improve the biogenic emissions model MEGAN. Data reduction, finalization and analysis is currently in progress, and more detailed scientific results will be presented in future reports.

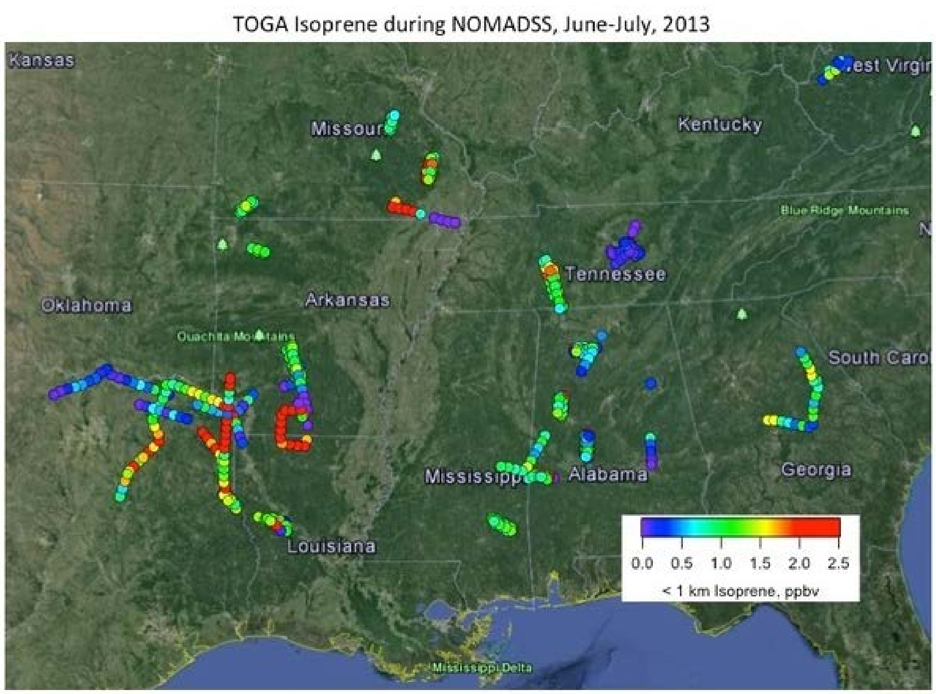

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Figure 1. Isoprene mixing ratios measured by TOGA during NOMADSS from the C-130 when below 1 km altitude.

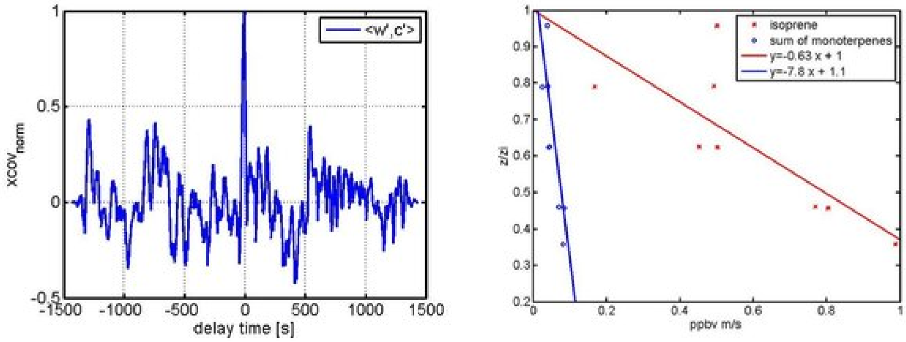

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Figure 2: Left: Normalized covariance between vertical wind speed (w’) and isoprene concentration (c’). Right: Isoprene and monoterpene fluxes at different heights within the boundary layer measured during a racetrack flown over the Alabama ground site.

‹ 7.1.b.6. Preliminary Highlights from the Deep Convective Clouds and Chemistry (DC3) Field Campaign

up

7.1.b.8. Overview of the 2013 Tropical Ocean tRoposphere Exchange of Reactive halogen species and Oxygenated VOC (TORERO) Field Campaign ›

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7.1.B.8. OVERVIEW OF THE 2013 TROPICAL OCEAN TROPOSPHERE EXCHANGE OF REACTIVE HALOGEN SPECIES AND OXYGENATED VOC (TORERO) FIELD CAMPAIGN

The Tropical Ocean tRoposphere Exchange of Reactive halogen species and Oxygenated VOC (TORERO; http://www.eol.ucar.edu/projects/torero/) field study took place in January-February of 2012 over the eastern tropical Pacific, led by Prof. Rainer Volkamer (CU Boulder). The project involved several ACD research groups on board the NCAR GV aircraft, and coordinated intercomparisons with two research vessels, including the NOAA Ka'imimoana. Analysis of the chemical data collected during the project is ongoing. This includes comparisons of the organohalogen measurements from the aircraft to CAM-chem model results and to data collected on the ship, as presented at the 2012 Fall AGU meeting.

Figure 1 shows the TOGA measurements of some of the observed halogenated VOCs in the marine boundary layer against University of York measurements on board the NOAA Ka'imimoana. Overall, very good agreement was observed for the organohalogens CH_2Br_2, $CHBr_3$ and CHClI. As shown in Figure 2, the overall distribution of bromoform in the free troposphere is well-represented by the CAM-chem model, although the model fails to simulate elevated halogenated VOCs in the free troposphere due to convection events, e.g. the latter half of Flight 12 in which elevated bromoform was observed between 5 and 10 km. Convection of ocean-source bromine compounds is an important mechanism for transporting reactive bromine to the stratosphere.

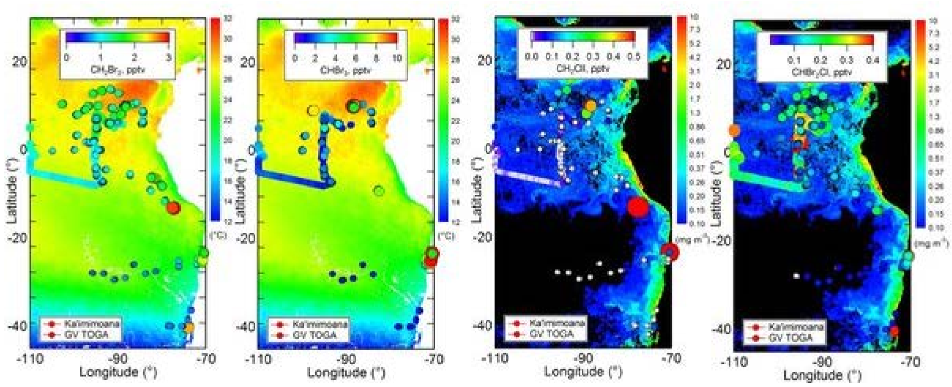

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Figure 1. GV TOGA observations below 0.5 km and University of York data from the Ka'imimoana overlayed on maps of the MODIS sea surface temperature (SST) and Chlorophyll-a (Chl-a).

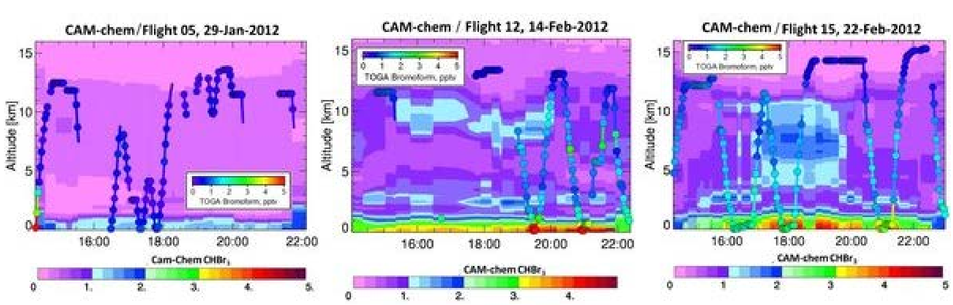

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Figure 2. Time series of TOGA bromoform ($CHBr_3$) data from three TORERO flights against a CAM-chem model simulation.

‹ 7.1.b.7. Overview of NESL/ACD Participation in the 2013 Southeast Atmosphere Study (SAS) up 7.1.b.9. Expansion of the tropics studied using satellite measurements of tropical cirrus ›

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7.1.B.9. EXPANSION OF THE TROPICS STUDIED USING SATELLITE MEASUREMENTS OF TROPICAL CIRRUS

Recent observations have highlighted possible widening of the tropics over the past several decades (based on thermal structure, winds, tropopause height and ozone), and current research is aimed at understanding these changes and links to other aspects of the climate system. New work by ACD scientists focused on evaluating possible changes in cirrus clouds near the tropical tropopause, using satellite measurements from multiple satellites. These data include HIRDLS satellite measurements in conjunction with other NASA experiments (CLOUDSAT, SAGE, HALOE, and CLAES), spanning the time period from 1985 to the present. The geographical distributions of cirrus in the Tropical Tropopause Layer (TTL) averaged over a number of years for each of the satellite experiments is shown in Figure 1. Analysis using these data (Massie et al., 2013) determined that the cloud distributions do not show evidence of statistically significant widening trends during 1985-2012. This statistically insignificant trend is similar to recent results for tropical tropopause height and tropopause latitudinal gradients near 100hPa derived from reanalysis data sets.

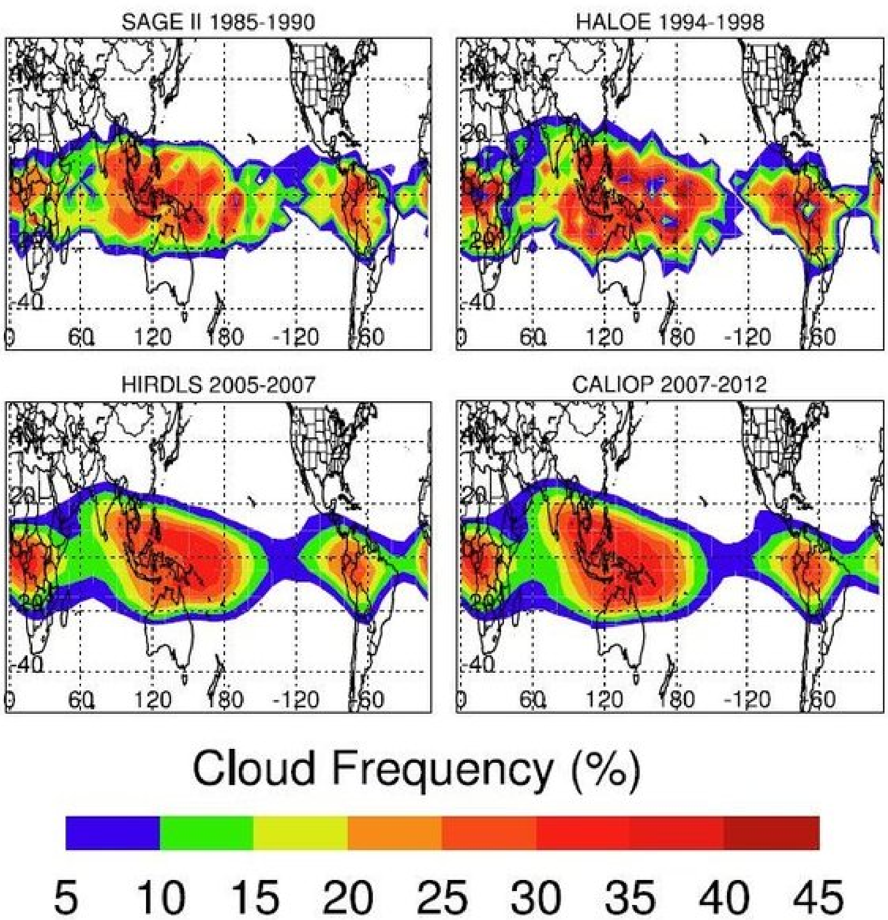

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Figure 1: Frequency of occurrence for cirrus clouds near 100hPa (~16 km) based upon SAGE, HALOE, and HIRDLS extinction data at vertical resolutions near 1km, and CALIOP cloud layer data for the 16.2-17.2km altitude range. The years of the averaging are indicated in each panel.

Massie, S. T., R. Khosravi, and J. C. Gille (2013), A multidecadal study of cirrus in the tropical tropopause layer, J. Geophys. Res. Atmos., 118, 7938–7947, doi:10.1002/jgrd.50596.

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7.1.B.10. UPPER MESOSPHERIC OZONE FROM SATELLITES

Ozone plays a key role in the energy budget throughout the depth of the middle atmosphere; it is therefore important to know what the distribution of ozone is and how it varies with season. Over the past decade there have a number of satellite instruments that made measurements of ozone in the upper mesosphere. These are: Sounding of the Atmosphere using Broadband Emission Radiometry (SABER), Halogen Occultation Experiment, High Resolution Doppler Imager, Michelson Interferometer for Passive Atmospheric Sounding, Global Ozone Monitoring by Occultation of Stars, Atmospheric Chemistry Experiment—Fourier Transform Spectrometer, Solar Occultation For Ice Experiment, Optical Spectrograph and InfraRed Imaging System, and Superconducting Submillimeter-Wave Limb-Emission Sounder. Comparisons of each ozone data set with SABER using coincident profiles indicate agreement in the basic vertical profile of ozone but also some systematic differences in daytime ozone. Ozone from the SABER 9.6 micron channel is higher than the other measurements over the altitude range 60–80 km by 20–50% (see Figure 1). Nighttime comparisons indicate better relative agreement (<10% difference). Taking all the data, not limited to coincidences, shows the global and seasonal distributions of ozone in the upper mesosphere from each instrument. The average maximum in ozone mixing ratio is around 90–92 km during daytime and 95 km at night. There is a maximum in ozone density at night (90 km) and during some hours of the day. The latitude structure of ozone has appreciable variations with season, particularly in the tropical upper mesosphere. The basic latitude-altitude structure of ozone depends on local time, even when the analysis is restricted to day-only observations.

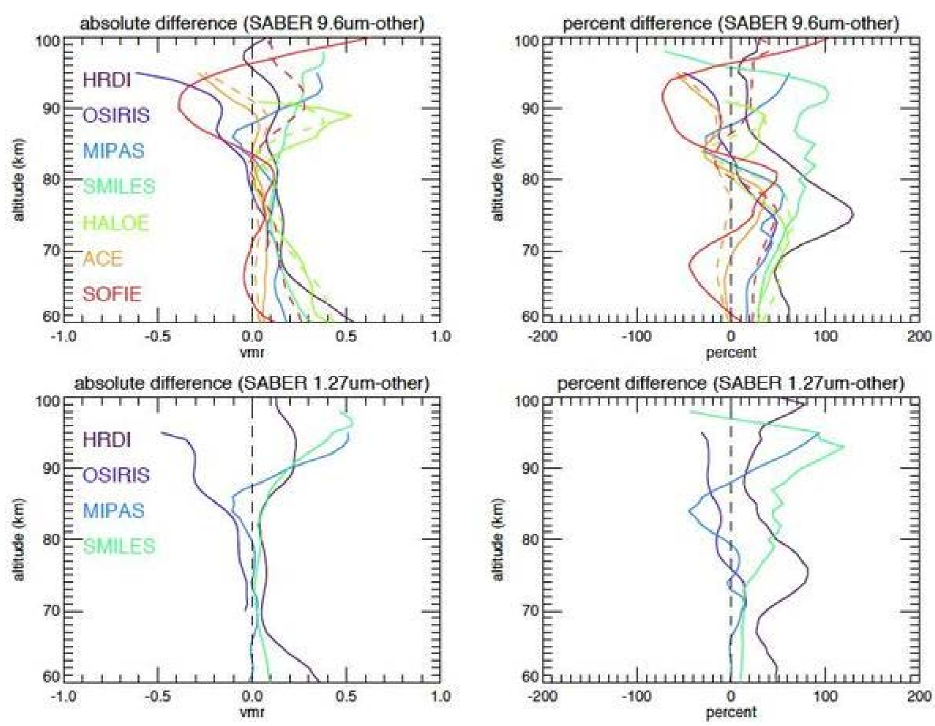

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Figure 1: Top shows profiles of the absolute (left, units ppmv) and percentage (right) differences (SABER ozone from the 9.6 micron channel minus the other instrument) for SABER and seven other instruments from coincident measurements.

For the solar occultation instruments (HALOE, ACE-FTS, and SOFIE), solid lines are for sunrise and dashed lines are for sunset. Bottom shows profiles of the absolute (left) and percentage (right) differences between SABER ozone from the 1.27 micron channel and four other instruments from coincident measurements.

‹ 7.1.b.9. Expansion of the tropics studied using satellite measurements of tropical cirrus | up | 7.1.b.11. Evaluating model simulations of global hydrocarbons using satellite measurements ›

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7.1.B.11. EVALUATING MODEL SIMULATIONS OF GLOBAL HYDROCARBONS USING SATELLITE MEASUREMENTS

Satellite measurements from the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) have been used to evaluate the global, seasonal variations of several hydrocarbons, including carbon monoxide (CO), ethane (C_2H_6), acetylene (C_2H_2) and hydrogen cyanide (HCN). These data were used to evaluate the behavior of hydrocarbons in chemistry climate model simulations using WACCM (incorporating tropospheric photochemistry, time-varying hydrocarbon emissions and meteorological fields nudged from reanalysis). The comparisons demonstrate that WACCM is able to simulate much of the observed behavior from the middle troposphere to the stratosphere (Figure 1), suggesting a reasonable simulation of sources and large-scale transport. Variability for CO, C_2H_6 and C_2H_2, is dominated by a semiannual cycle in the tropical upper troposphere, related to seasonally-varying sources and deep tropical convection. There is also a maximum during Northern Hemisphere summer tied to the Asian monsoon anticyclone. These species also reveal a strong annual cycle above the tropical tropopause, tied to annual variations in the upward branch of Brewer-Dobson circulation. HCN shows important differences from the other species, due to a longer photochemical lifetime and a chemical sink associated with ocean surface contact, which produces a minimum in the tropical upper troposphere. For HCN, transport to the stratosphere occurs primarily through the Asian summer monsoon anticyclone. The modeled hydrocarbon levels are too low in the Southern Hemisphere during Austral spring, indicating an underestimate of biomass burning emissions and/or insufficient vertical transport in the model.

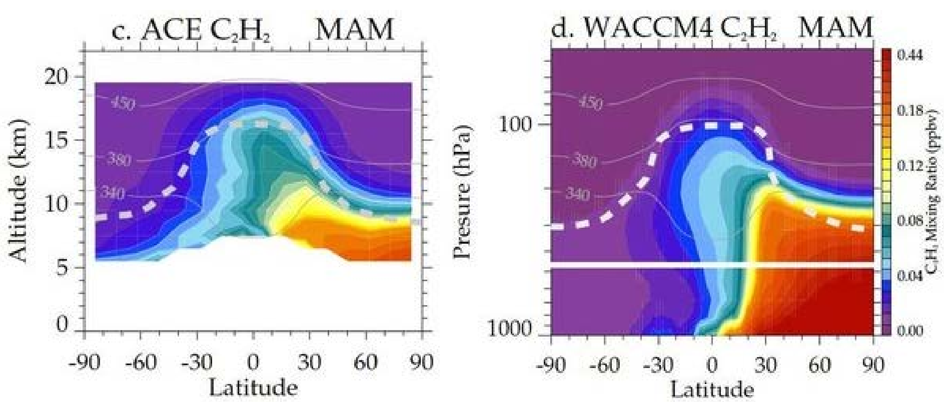

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Figure 1: Latitude-height sections of acetylene (C_2H_2) mixing ratio during March-April-May (MAM) derived from ACE-FTS measurements (left) and WACCM simulation (right). Acetylene has a relatively short photochemical lifetime (~ 2 weeks), and is a sensitive measure of large-scale circulation and transport. The dashed line denotes the tropopause.

‹ 7.1.b.10. Upper Mesospheric Ozone from Satellites　　up　　7.1.b.12. Dynamics and transport of monsoonal circulations based on potential vorticity ›

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7.1.B.12. DYNAMICS AND TRANSPORT OF MONSOONAL CIRCULATIONS BASED ON POTENTIAL VORTICITY

The circulation of the Asian monsoon strongly influences UTLS chemical behavior, including transport between the tropics and extratropics and from the troposphere to the stratosphere. The monsoon circulation in the UTLS consists of a strong anticyclone that is highly dynamically variable, and a key aspect of current research is aimed at understanding the links between dynamical and chemical variability within the monsoon. New work has explored the use of potential vorticity (PV) as a dynamical tracer for the anticyclonic circulation, and quantified the forcing of PV from deep convection in the monsoon region. PV variability of the anticyclone includes characteristic 'eddy shedding' events, wherein low PV air separates from the main anticyclone region, often moving towards the west (an example is shown in Fig. 1a), but also occasionally to the east. This work has also quantified relationships between PV and trace constituents, and MLS satellite measurements of carbon monoxide (CO, a tropospheric pollution tracer) are especially valuable for quantifying daily synoptic-scale variability. CO shows strong correlations with PV fields (Fig. 1b), and eddy shedding events are often mirrored in CO transport. These studies are enhancing understanding of the inherent large-scale dynamical and chemical variability for the UTLS monsoon regions, and providing a useful perspective to measurements from operational aircraft (e.g. IAGOS, CARIBIC) and for future research aircraft measurements within these regions.

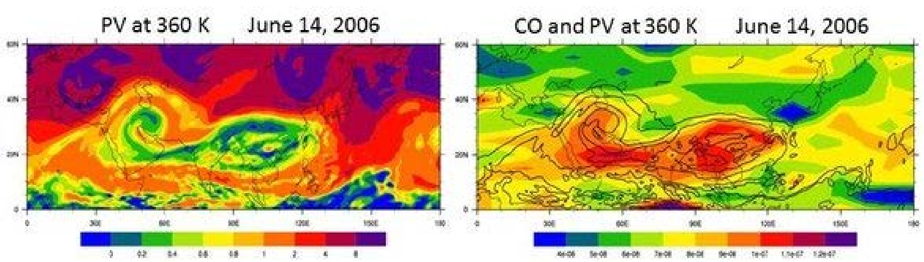

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Figure 1. Left panel shows potential vorticity (PV) structure of the Asian monsoon anticyclone at the 360 K isentropic level (near 12 km) on June 14, 2006. Yellow to blue colors denote low PV, associated with the anticyclonic circulation. Right panel shows corresponding map of MLS CO for this day (colors), with PV overlaid in black contours.

Garney, H. and W.J. Randel, 2013: Dynamic variability of the Asian monsoon anticyclone observed in potential vorticity and correlations with tracer distributions. *J. Geophys. Res.*, submitted.

‹ 7.1.b.11. Evaluating model simulations of global hydrocarbons using satellite measurements | up | 7.1.c. Identify and model the processes and interactions that govern climate variability on timescales long enough for forcing to dominate over initial conditions ›

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7.1.C. IDENTIFY AND MODEL THE PROCESSES AND INTERACTIONS THAT GOVERN CLIMATE VARIABILITY ON TIMESCALES LONG ENOUGH FOR FORCING TO DOMINATE OVER INITIAL CONDITIONS

The long term evolution of climate is influenced both by the response of the climate system to anthropogenic forcing and also by a wide range of Earth system feedbacks involving, for instance, interactions between the marine and terrestrial biosphere and the changing atmospheric composition. NESL scientists are working to reduce uncertainties by improving the simulation of the response of the climate system to altered radiative forcing by greenhouse gases and aerosols.

‹ 7.1.b.12. Dynamics and transport of monsoonal circulations based on potential vorticity | up | 7.1.c.1. Predict the time-evolution of global and regional climate... ›

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7.1.C.1. PREDICT THE TIME-EVOLUTION OF GLOBAL AND REGIONAL CLIMATE...

PREDICT THE TIME-EVOLUTION OF GLOBAL AND REGIONAL CLIMATE BY CONSIDERING MORE CLIMATE SYSTEM COMPONENTS THAN JUST THE ATMOSPHERE

We have been working towards a greater understanding of factors that contribute to the poor representation of the intrinsic modes of variability at decadal time scales in climate models. Efforts quantify the uncertainty in climate projections resulting from chaotic behavior and natural variability, and provide a community forum for expert-user guidance on existing climate datasets, which enhances projection utility in observational and model evaluation studies. There is a quantitative evaluation of refined grids based on rigorous observational comparisons over North America, which enables confident determination of the statistics of regional events under climate change to be passed to water resource decision makers.

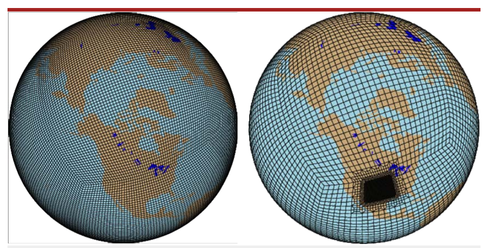

Figure: *Community Atmosphere Model (CAM) grid specifications using the spectral element dynamical core on a cubed sphere. A globally unified 100-km resolution grid is shown along side a similar grid with 25-km regional refinement over the United States.*

‹ 7.1.c. Identify and model the processes and interactions that govern climate variability on timescales long enough for forcing to dominate over initial conditions

up

7.1.c.2. Data Assimilation ›

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7.1.C.2. DATA ASSIMILATION

In FY2013, NESL scientists began conducting data-assimilation experiments using conventional observations with MPAS and an ensemble Kalman filter. The intent is to identify and reduce systematic errors in MPAS. Performing cycling data assimilation with a model is a sensitive test for systematic error and bias in the model. In cycling data assimilation, the model's short-term forecast is used along with observations to produce an analysis from which the next short-term forecast begins, and the process is repeated for extended periods. NESL scientists have implemented an ensemble Kalman filter (EnKF) for MPAS that assimilates most observations except satellite-observed radiances. The system cycles stably in experiments of a month or more. The experiments revealed bias relative to radiosondes in the mid-troposphere and the stratosphere. As shown in the Figure below, changing the convective parameterization from Kain-Fritsch to Tiedtke and the radiation scheme from RRTMG to CAM reduces both biases substantially, though undesirably large bias remains in the stratosphere.

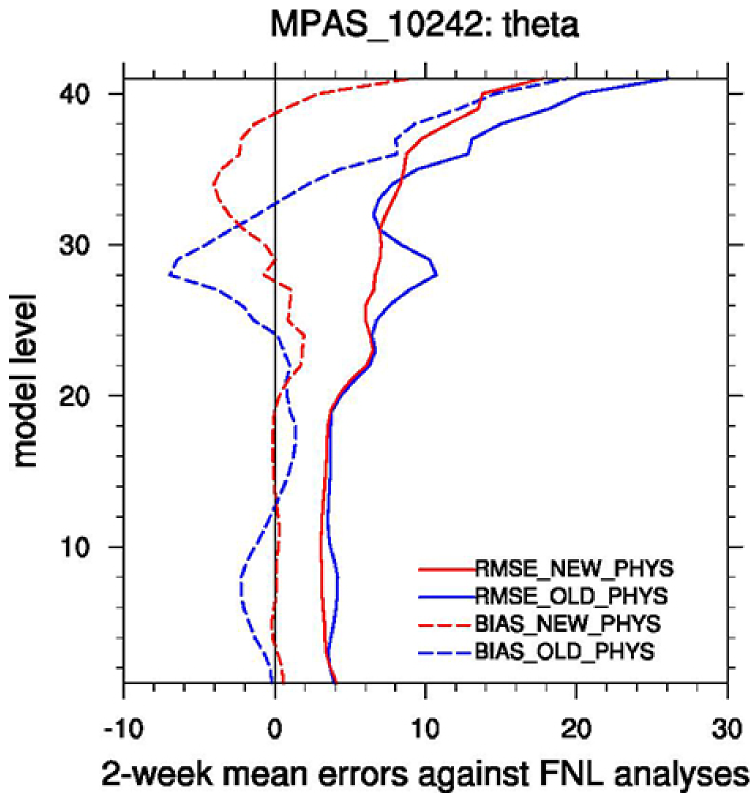

Figure: Bias (dashed) and rms (solid) of differences of 5-d MPAS forecasts relative to NCEP analyses. Results are shown for the model configured with Kain-Fritsch convective parameterization and RRTMG radiation (blue) and with Tiedtke convective parameterization and CAM radiation (red).

‹ 7.1.c.1. Predict the time-evolution of global and regional climate... up 7.1.c.3. Convective Weather Prediction ›

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7.1.C.3. CONVECTIVE WEATHER PREDICTION

In Spring 2013, MMM ran WRF on a 3-km grid in real-time in support of a community scientific campaign: MPEX— the Mesoscale Predictability Experiment. This was done in lieu of contributing WRF runs for the NOAA Storm Prediction Center's Spring Forecast Experiment (SFE), as in years prior. The goals of MPEX are to improve convection-permitting forecasts by reducing initial condition uncertainty through targeted sub-synoptic observations upstream of convective events and to sample the storm environment to better understand how developing convection impacts predictability. The MMM MPEX real-time runs were initialized with analyses produced by an ensemble data assimilation system from NCAR's Data Assimilation Research Testbed (DART). The DART setup featured a 50-member ensemble to generate 15-km analyses. For the first time for MMM's Spring forecasts, WRF was run in ensemble mode at convection-permitting (3-km) grid scales for the forecasts themselves. It was found that ensemble WRF did provide useful guidance of significant severe weather hazards for the first 24 hrs, although there was evidence of model drift in cycled runs. The Figure below presents an example of the WRF forecasts, showing predicted reflectivities of >45 dBZ from each member for the El Reno, OK tornado event of 31 May 2013. For this 12-h forecast, the observed areas of this reflectivity are also shown (black). The arrow notes the location of El Reno, which the ensemble members have largely covered. In other areas, the red and green circles note zones of model overprediction (green) and underprediction (red) for this time.

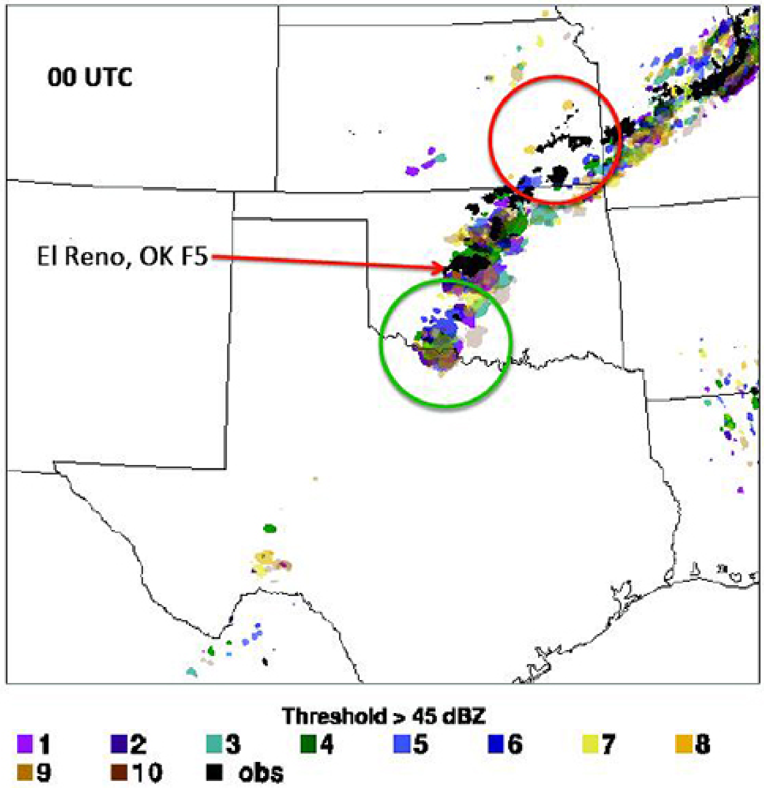

Figure: Forecasts of >45 dBZ reflectivity from real-time WRF runs for the MPEX campaign. 12-h forecasts valid 0000 UTC 1 June 2013 (1200 UTC 31 May initialization). Ensemble runs shaded, key at bottom. Black regions mark observed areas of >45 dBZ.

‹ 7.1.c.2. Data Assimilation up 7.1.c.4 Investigation of Stratospheric Sulfate Aerosol Trends using the Whole Atmosphere Community Climate Model (WACCM) ›

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7.1.C.4 INVESTIGATION OF STRATOSPHERIC SULFATE AEROSOL TRENDS USING THE WHOLE ATMOSPHERE COMMUNITY CLIMATE MODEL (WACCM)

The NCAR Community Earth System Model (CESM) system is facilitating the investigation of the interactions among different components of the earth-atmospheric system. One of the available atmospheric models is WACCM (Whole Atmosphere Community Climate Model), which was specifically developed to simulate interactions between chemistry and climate across all levels of the atmosphere. WACCM is particularly well suited to studies of the evolution and climate impacts of the stratospheric sulfate aerosol layer, which observations show increased by 4-10% per year between 2000 and 2010. This increase in aerosol, which scatters sunlight back to space, has been suggested as a factor in the reduced rate of global warming observed during the same period. Using WACCM with a new prognostic representation of stratospheric aerosol based on emissions, we showed that moderate volcanic eruptions known to have occurred during this period are the primary source of this increase, while anthropogenic sulfur pollution increased at one-tenth of the magnitude needed to account for the stratospheric trend. We have recently applied this new capability in WACCM to the 2011 eruption of the Nabro volcano in Eritrea, showing how it input the largest increase in stratospheric aerosol in 20 years in part via a previously unknown entry mechanism involving the Asian monsoon. We continue to develop these capabilities to study the impacts on climate, chemistry, and dynamics of historical and future volcanic eruptions, changes in sulfur pollution, and potential future attempts to geoengineer the climate via deliberate enhancement of stratospheric sulfate.

REFERENCE:

Neely, R.R., III, O.B. Toon, S. Solomon, J.-P. Vernier, C. Alvarez, J.M. English, K.H. Rosenlof, M.J. Mills, C.G. Bardeen, J.S. Daniel, and J.P. Thayer, Recent anthropogenic increases in SO2 from Asia have minimal impact on stratospheric aerosol, J. Geophys. Res., 40, 999-1004, doi:10.1002/grl.50263, 2013.

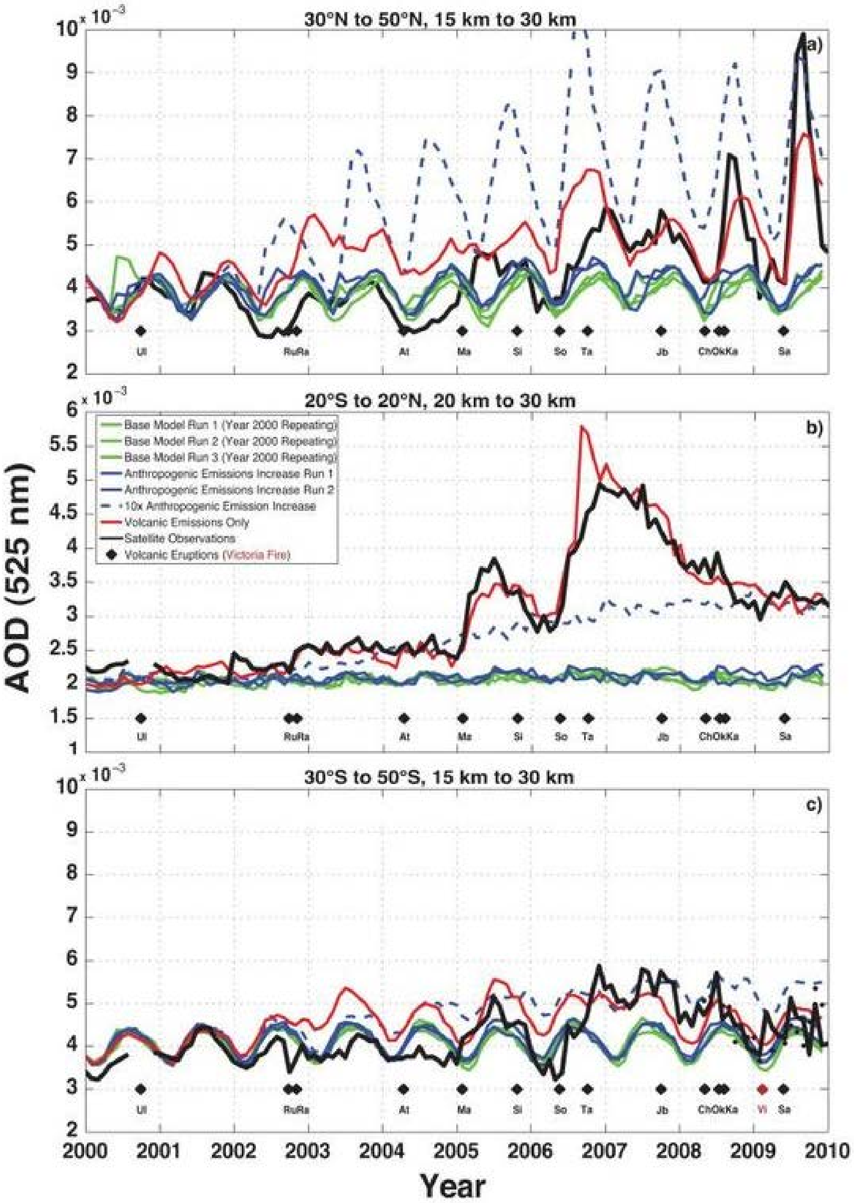

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Figure1: Observed and modeled time series of stratospheric AOD from three latitude bands. a) Monthly averaged AOD at 525 nm from 30°N to 50°N integrated from 15 km to 30 km, b) 20°S to 20°N integrated from 20 km to 30 km, c) 30°S to 50°S integrated from 15 km to 30 km from satellite observations (black line) from SAGE II (2000 to August 2005), GOMOS (March 2002 onward) and CALIOP (April 2006 onward) and the simulation results. Baseline model runs are in green. Model runs with the increase in anthropogenic emissions from China and India are in blue. The dashed blue line depicts a model run with 10x the actual increase in anthropogenic emissions. The model run with volcanic emissions is in red. The black diamonds and initials along the bottom of the plot represent the volcanic eruptions that were included in the model run. Figure 1c also denotes the Victoria Fire in red.

‹ 7.1.c.3. Convective Weather Prediction | up | 7.1.c.5 Using the Whole Atmosphere Community Climate Model (WACCM) to investigate the “World Avoided” by the adoption of the Montreal Protocol ›

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7.1.C.5 USING THE WHOLE ATMOSPHERE COMMUNITY CLIMATE MODEL (WACCM) TO INVESTIGATE THE “WORLD AVOIDED” BY THE ADOPTION OF THE MONTREAL PROTOCOL

The Whole Atmosphere Community Climate Model (WACCM), coupled to a deep ocean model, was used to calculate the impact of continued growth of halogenated ozone depleting substances (ODS) in the absence of the Montreal Protocol. The top panel of the figure below shows that, under the Montreal Protocol, the ozone column recovers to 1980 values after about 2055. On the other hand, in the “world-avoided” scenario, with continuous growth of ODS at 3% per year, a a global collapse of the ozone layer is observed in mid-century, with column amounts falling to 100 DU or less at all latitudes. The growth of ODS, which are also greenhouse gases, also produces a radiative forcing of 4 W m^{-2} by 2070, nearly equal that of the non-ODS greenhouse gases CO_2, CH_4, and N_2O in the RCP4.5 scenario of IPCC. This leads to surface warming of over 2 K in the tropics, 6 K in the Arctic, and close to 4 K in Antarctica in 2070 compared to the beginning of the century.

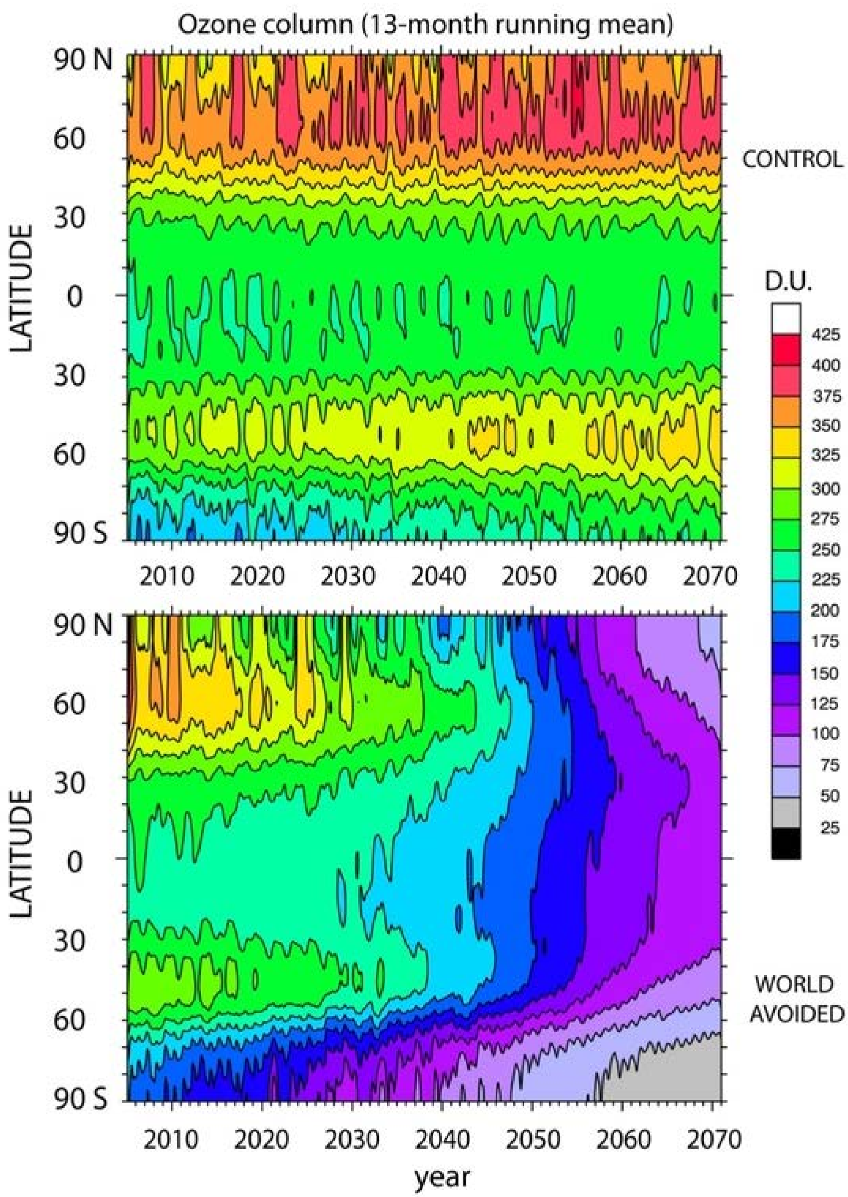

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Figure 1: Evolution of the total ozone column (DU) in the (top) control and (bottom) world avoided simulations between 2005 and 2070. The time series have been smoothed with a 13-month running mean to suppress the annual cycle and emphasize long-term.

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7.2. ENABLING WORLD CLASS COMMUNITY SCIENCE

Through an easy-to-use infrastructure NESL provides researchers our modeling facilities such as the Community Earth System Model (CESM) and the Weather Research and Forecasting (WRF) model, their various components (including WACCM in CESM), and specialized modules, along with model and observational datasets. NESL also provides an advanced chemical measurement capability, ranging from satellite observations to in-situ measurements. In particular, NESL is a leader in the development and use of chemistry instrumentation in support of the scientific needs of the broader academic community, as exemplified through support for large field campaigns.

‹ 7.1.c.5 Using the Whole Atmosphere Community Climate Model (WACCM) to investigate the “World Avoided” by the adoption of the Montreal Protocol | up | 7.2.a. Continued development and support of NCAR community models ›

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7.2.A. CONTINUED DEVELOPMENT AND SUPPORT OF NCAR COMMUNITY MODELS

Computer models are powerful tools for meeting the intellectual challenge of understanding the Earth system, and they are the only scientific tool capable of integrating the myriad physical, chemical and biological processes that determine the evolution of the atmosphere as well as past and future climates. Models are essential for testing and confirming understanding, and for making predictions of use to society and policy makers. The international-scientific and user community is widely utilizing NESL community models at a level far in excess of any comparable activities, with more than 20,000 registered users of the Weather Research and Forecasting (WRF) model and the Community Earth System Model (CESM) worldwide.

‹ 7.2. Enabling World Class Community Science   up   7.2.a.1. Community Earth System Model ›

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7.2.A.1. COMMUNITY EARTH SYSTEM MODEL

We have made significant progress over the last year in simplifying the portability of the CESM system, extending the capability to permit the community to create new model resolutions, creating a new CESM validation capability (a work in progress), and considerably improved the flexibility to create new model configurations.

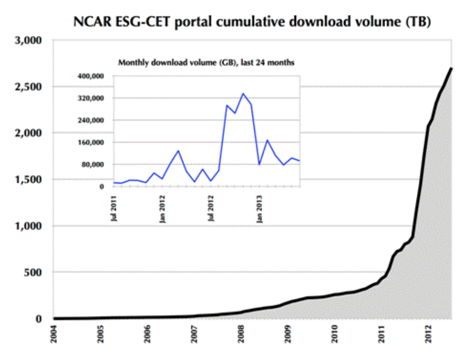

Figure: *CESM data downloads from the NCAR data portal.*

Over the past year we released CESM 1.2.0 and CESM 1.1.1 and CESM 1.0.5. This was accompanied by a new flexible scripting and testing infrastructure and new easier-to-browse web documentation. We created a new bulletin board for CESM that is widely used by the community. It enables the community to interact more easily with each other and enables CESM Software Engineering Group to respond to requests in a timely manner. We have also folded MPAS-Ocean into the CESM coupling infrastructure (CPL7) and are ready to commence core forcing experiments.

Development activities have resulted in new CESM capabilities and improved versions that have been thoroughly tested, and control simulations have been performed. All significant model updates, along with control data sets, have been made available to the community. The research community continues to have free and open access to a comprehensive set of CESM production simulations. For example, results from the CMIP5 simulations are thoroughly and openly documented in a total of 60 papers in two special collections in the *Journal of Climate* and software engineering advancements are featured in a special issue of the *International Journal of High Performance Computing Applications*.

CESM continues to contribute to numerous intercomparison projects. For example, several CESM simulations have been contributed to GeoMIP, and the impacts on the hydrological cycle have been documented (Tilmes et al., JGR, accepted, 2013); analysis on nitrogen and sulfur depositions (Lamarque et al., ACP, 2013) has been performed based on the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) simulations; new simulations on the chemical effect of volcanic emissions from the Permian-Triassic Siberian traps (Black et al., Geology, accepted, 2013) have been performed; and CESM CORE experiment simulations have been made available for analysis and have been documented in recent publications (e.g. Danabasoglu et al., Ocean Modeling, 2013).

‹ 7.2.a. Continued development and support of NCAR community models | up | 7.2.a.2. The WRF Modeling System ›

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7.2.A.2. THE WRF MODELING SYSTEM

MMM continued with its community support of WRF through FY2013. The number of registered users of WRF continued to grow and is currently over 24,000. About 69% of these are foreign, and 153 countries are represented. These user figures reflect registrations made through the WRF download site (see Figures below). It also charts the increase in the number of WRF registered users since its initial release. The number of subscribers on the WRF e-mail list is about 7,658. E-mail inquiries to *wrfhelp* (the WRF user assistance service) average about 350/month, and the servicing of these over the year has been a significant effort.

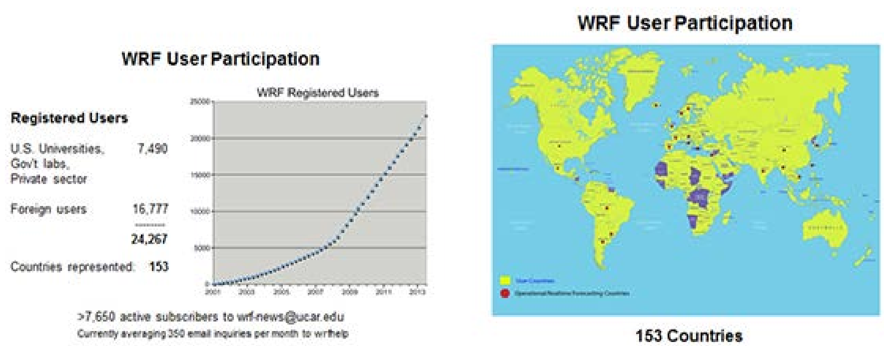

Figure: WRF registered users by user group (left) and plot of number of registered users by year above, countries (right).

MMM issued a major WRF release Version 3.5 in April 2013. This included WRFDA 3.5 and WRF-Chem 3.5. WRF V3.5 offers many new features and improvements that reflect contributions from throughout the WRF community, and they speak to WRF's position as a community model. Some of these are as follows:

- Community Land Model Version 4 (CLM4) from CAM
- WRF-Hydro hydrological model
- New microphysics schemes: CAM 5.1 2-moment scheme, NSSL 1-moment schemes
- New cumulus schemes: Grell-Freitas ensemble scheme, Global/Regional Integrated Modeling System (GRIMS) shallow

cumulus scheme
- New PBL scheme: Grenier-Bretherton-McCaa scheme
- Polar modifications: Variable sea ice depth, variable snow depth on sea ice
- PWP 3D ocean model
- NetCDF4 outputting

In September 2013 MMM made public WRF minor release V3.5.1. This contained bugfixes as well as some further parameterization upgrades.

Regarding WRF-Chem, one aim was to continue development with foci on organic chemistry, biogenic emissions, and cloud effects on chemistry. Recent contributions to the WRF-Chem model include a chemical option (called MOZART-MOSAIC) based on the MOZART chemical mechanism, but describing in more detail the gas-phase production of secondary organic aerosols. This new option works with the sectional approach MOSAIC aerosol module, which is becoming one of the most sophisticated chemical options in WRF-Chem. The parameterization of lightning flash rate was updated for WRF, while the NO_x production from lightning was updated in WRF-Chem, giving more flexibility to analyze lightning and its production of NO_x. To facilitate the creation of the WRF-Chem emission files from global emissions inventories, a new preprocessing tool was developed and released to the community.

For field project support and analysis, there were a number of WRF-Chem simulation efforts. High-resolution (3 km) WRF-tracer simulations were conducted for the SEAC4RS experiment to forecast locations of boundary layer and stratospheric air. WRF-Chem simulations were done for analyses for the ARCTAS/CARB, CalNex, DC3 and BEACHON field campaigns. Chemistry-climate simulations using NRCM-Chem for North America and Southeast China were conducted to examine air quality in future climate scenarios. Lastly, simulations of aerosol-cloud-precipitation interactions for Asia and the Indo-Gangetic Plain were run, as well as simulations for the evaluation and analysis of a dust storm over India.

‹ 7.2.a.1. Community Earth System Model up 7.2.a.3. The Antarctic Mesoscale Prediction System (AMPS) ›

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7.2.A.3. THE ANTARCTIC MESOSCALE PREDICTION SYSTEM (AMPS)

The Antarctic Mesoscale Prediction System (AMPS) is a real-time, experimental WRF system run at high resolution over Antarctica in support of the U.S. Antarctic Program (USAP) and funded primarily by NSF's Division of Polar Programs. These efforts have supported the NSF-funded Antarctic Program and various Antarctic scientific campaigns, improved high-latitude WRF capabilities for the worldwide users community, improved the forecasting products for the USAP, and advanced model evaluation and model-based research over Antarctica. The work is vital to USAP activities, as the weather forecasters depend on a well-maintained, robust, tailored, and upgraded forecast system. AMPS also offers support to international scientific activities across Antarctica.

AMPS provided NWP guidance to the USAP forecasters through the 2012–2013 field season. This was delivered through the AMPS web page (http://mmm.ucar/edu/rt/amps) as well as the Antarctic IDD (internet data distribution) service. In FY2013, a back-up AMPS web page capability was created, supported by NCAR's Computational and Informational Systems Lab (CISL). This provides a needed redundancy for forecast delivery in the event that the main AMPS server in MMM goes down.

During the season high-resolution forecasts were produced for the GIMBLE (Geophysical Investigations of Marie Byrd Land Lithospheric Evolution) campaign and for the Pine Island Glacier field work. For these science programs, two new 5-km forecast grids were set up for the regions and products for them were provided. AMPS also continued to support the NSF research vessels *R/V Nathaniel B. Palmer* and *R/V Laurence M. Gould* in their southern Ocean and Antarctic missions in the 2012–2013 season. AMPS provided ship-following model plot windows to give WRF forecast information to the vessels daily.

In FY2012–2013, the AMPS team worked with CISL on the setup and testing of a new computer for AMPS. This machine, Erebus, was installed at the NWCS and tested in this period. AMPS was ported to the new platform and significant grid enhancements were made. The resolutions were improved from 45 km, 15 km, 5 km and 1.67 km to 30 km, 10 km, 3.3 km, and 1.1 km. The entire continent is now covered by a 10-km grid, the highest real-time Antarctic continental model forecast domain in operation. The Figure offers an example of the 1.1-km grid that now better resolves the critical McMurdo region. Seen are katabatic outflow from Byrd Glacier, a lee vortex north of Ross Island, and katabatic flow into Terra Nova Bay.

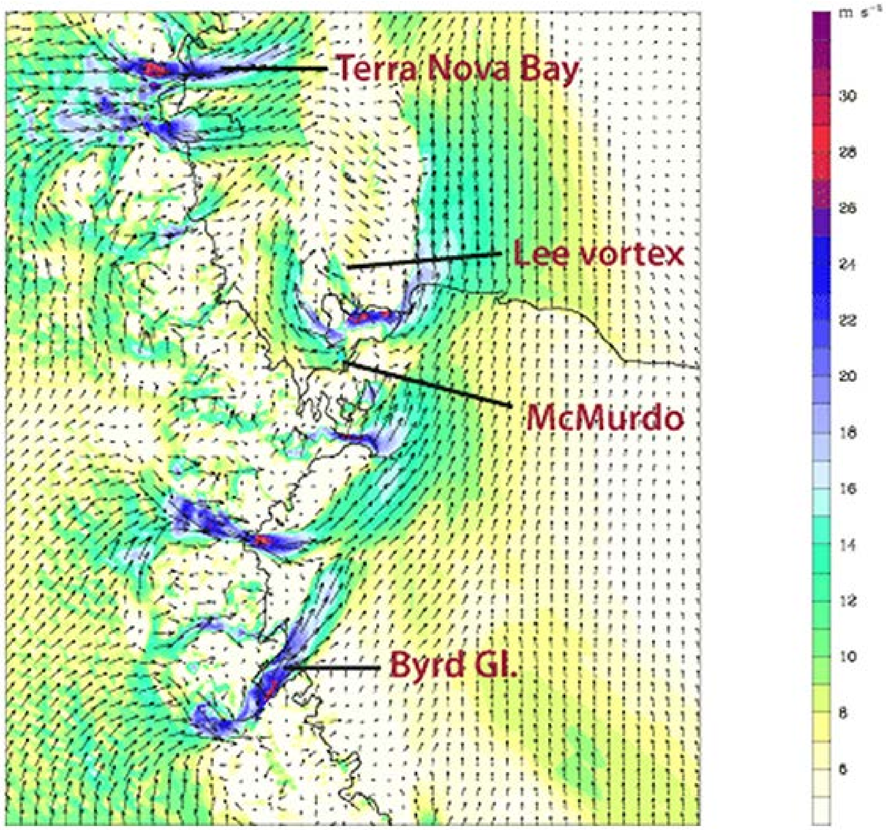

Figure: New 1.1-km AMPS domain for the Ross Island area showing forecasts of surface winds. 12-hr forecast valid at 1200 UTC 17 June 2013 shown. 10-m winds (ms^{-1}) shaded, scale to right. Surface wind vectors shown.

Over the past year, new polar modifications for WRF were implemented. This was done under special funding from the NSF Office of Cyberinfrastructure and in collaboration with AMPS partner The Ohio State University. The polar modifications better capture conditions unique to the high latitudes, such as sea ice and glacial ice. Examples of the new modifications are incorporation of variable snow depth on sea ice and variable sea ice albedo. The polar modifications were features in the WRF V3.5 major release (April 2013).

‹ 7.2.a.2. The WRF Modeling System up 7.2.a.4. Fire INventory from NCAR (FINN): A daily fire emissions product for atmospheric chemistry models ›

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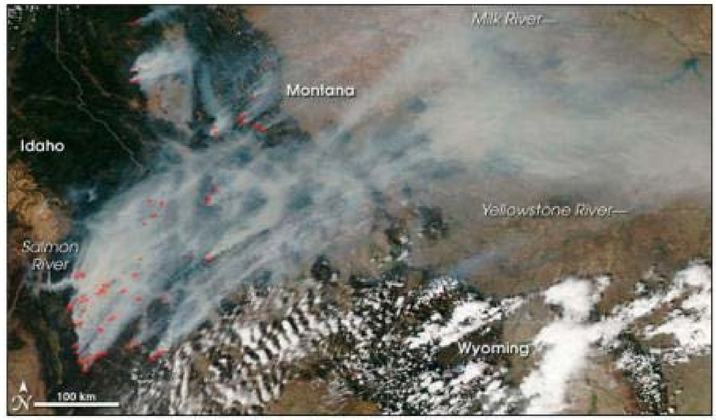
7.2.A.4. FIRE INVENTORY FROM NCAR (FINN): A DAILY FIRE EMISSIONS PRODUCT FOR ATMOSPHERIC CHEMISTRY MODELS

Open biomass burning makes up an important part of the total global emissions of greenhouse gases, reactive trace gases, and particulate matter. Although episodic in nature and highly variable, open biomass burning emissions can contribute to local, regional, and global air quality problems and climate forcings. The Fire INventory from NCAR (FINN) model provides high resolution, global emission estimates from open burning; these emissions have been developed specifically to provide input needed for modeling atmospheric chemistry and air quality in a consistent framework at scales from local to global. The inventory framework produces daily emission estimates at a horizontal resolution of ~1 km^2. The product differs from other inventories because it provides a unique combination of high temporal and spatial resolution, global coverage, and estimates for a large number of chemical species.

FINN emission estimates are based on the framework described by Wiedinmyer et al. [2006; 2011]. FINN uses satellite observations of active fires and land cover, together with emission factors and estimated fuel loadings to provide daily, highly-resolved (1 km) open burning emissions estimates for use in regional and global chemical transport models. Daily fire emissions for 01 January 2002 through 31 July 2013 have been estimated using the first version of the FINN model framework and are available for download and use at http://bai.acd.ucar.edu/Data/fire/. A processor to include FINNv1 emission estimates and apply a plume rise to the emissions within the WRF-chem online chemical and transport model is also available for download at http://bai.acd.ucar.edu/Data/fire/. FINN fire emissions are calculated in real time and are processed as inputs to the MOZART real time forecasts (available via http://www.acd.ucar.edu/acresp/forecast/).

In recent years, FINN emissions have been used in many modeling studies that simulate the chemical and climate impacts from fires. By using FINN emissions within the WRF-Chem model, Jiang et al. (2012) explored the impacts of fire plumes on ozone chemistry during a wildfire event in Idaho and Montana during August 2007. WRF-chem simulated the immediate addition fire emissions combined with the changes in photolysis rates, boundary



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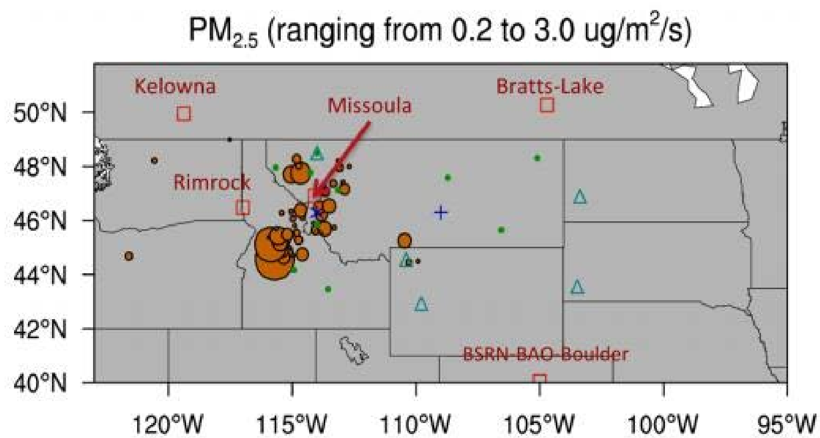

(b)

layer height, and biogenic emissions. The results highlighted the importance of including the radiative impacts of fire plumes. val Martin et al. (2013) used FINN emissions in conjunction with satellite observations to explore the importance of fire smoke or air quality and regional climate in Colorado. This work is being continued in an effort led by NESL/ACD to investigate the health impacts of the fire smoke and degraded air quality from the 2012 fires in Colorado.

More recent efforts associated with the FINN model include the development of version 2.0 of the model and a global emissions inventory from open burning of waste and trash.

REFERENCES

Jiang, X., C. Wiedinmyer, A.G. Carlton. Aerosols from fires: an examination of the effects on ozone photochemistry in the Western United States. *Environmental Science & Technology,* 46(21), 442-460, doi:10.1021/es301541k .

Val Martin, M., Heald, C. L., Ford, B., Prenni, A. J., and Wiedinmyer, C.: A decadal satellite analysis of the origins and impacts of smoke in Colorado, Atmos. Chem. Phys., 13, 7429-7439, doi:10.5194/acp-13-7429-2013, 2013.

‹ 7.2.a.3. The Antarctic Mesoscale Prediction System (AMPS)   up   7.2.a.5. Studies of Chemistry and Climate: The ACCMIP and GeoMIP Projects ›

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7.2.A.5. STUDIES OF CHEMISTRY AND CLIMATE: THE ACCMIP AND GEOMIP PROJECTS

Simulations under the Atmospheric Chemistry and Climate Model Intercomparison Project (www.giss.nasa.gov/projects/accmip), co-led by NASA-GISS and NESL scientists, have generated a variety of fields needed for the understanding and quantification of the impact of changes in emissions from pre-industrial conditions to 2100. Because of its importance in the regulation of CO_2 uptake by plants, but also its potential detrimental effect above a certain threshold, it is important to document the past and future changes in nitrogen deposition. We have also combined this analysis with sulfate deposition as this is an important component to acid rain. In the analysis (Lamarque et al., 2013), we have made extensive use of new observations to assess the quality of the present-day distribution of nitrogen deposition (Figure 1), but also its change from 1980-2000 and 1850-2000, the latter using an array of ice-core measurements.

We have shown that, except for an underestimate of ammonia deposition over Southeast Asia, the models are very capable of reproducing the present-day distribution of deposition (nitrate, ammonium and sulfate). However, the analysis of the *change* in deposition has highlighted significant shortcomings, most likely from the underlying emissions. This was particularly significant for the NH_3 emissions over the United States. Over all, this study has shown the potential from long-term measurements (ice-core and surface) to bring constraints on emission changes.

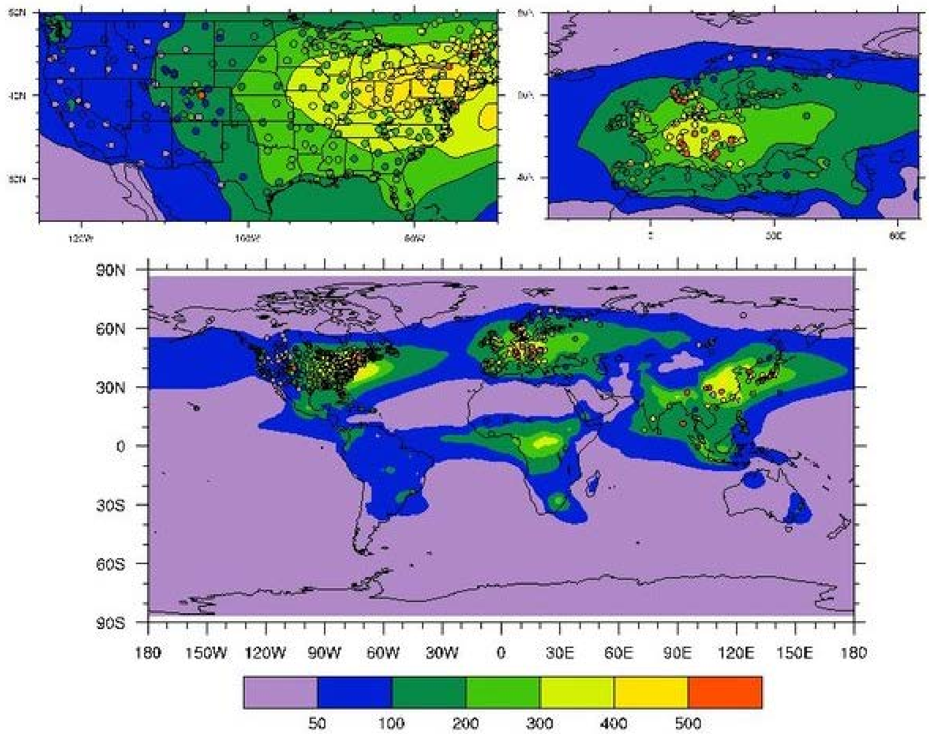

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Figure 1. Nitrate wet deposition (mg(N)m^{-2} yr^{-1}) for 2000. Contours are for the multi-model mean, filled circles are for the wet deposition network observations.

Several scientists from NESL/ACD have significantly contributed to the Geo-engineering Model Intercomparison Project (GeoMIP, http://climate.envsci.rutgers.edu/GeoMIP/). In addition to performing and submitting results from GeoMIP simulations, they have led the analysis (Tilmes et al., 2013) of the potential precipitation changes under a solar reduction management (SRM) scenario aimed at canceling out the idealized climate forcing from an instantaneous quadrupling of CO_2 ($4xCO_2$) above pre-industrial (1850) levels. By focusing on the global scale, but also on the regional monsoonal regions, they were able to identify a reduced global evaporation (of 10%) and precipitation reduction compared to the control (i.e. 1850 conditions with no CO_2 increase and no counter-balancing SRM, Figure 2) over East Asia (6%), South Africa (5%), North America (7%) and South America (6%). These changes in precipitation in both total amount and frequency of extremes, point to a considerable weakening of the hydrological cycle in a geo-engineered world.

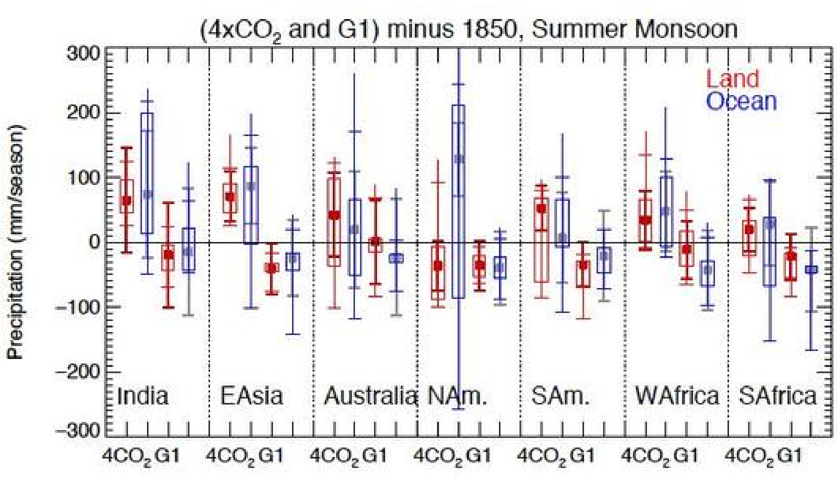

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Figure 2. Annually-averaged absolute change of precipitation from the 1850 control for the 4xCO2 and geo-engineered simulations (G1). All available ensemble members and all years are considered, except for the first 10 years of the $4xCO_2$ experiment. The multi-model range is shown by the vertical line, the 25^{th} and 75^{th} percentiles of the multi-model results

are illustrated by the color box, and the 5th and 95th percentiles are illustrated by the horizontal bars. The multi-model mean is shown as a solid square.

‹ 7.2.a.4. Fire INventory from NCAR (FINN): A daily fire emissions product for atmospheric chemistry models | up | 7.2.b. A more unified strategy toward model and data assimilation system development for weather-chemistry-climate prediction ›

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7.2.B. A MORE UNIFIED STRATEGY TOWARD MODEL AND DATA ASSIMILATION SYSTEM DEVELOPMENT FOR WEATHER-CHEMISTRY-CLIMATE PREDICTION

The Earth system contains features and processes that operate on a wide range of time and space scales, from detailed cloud and chemical processes to meso- and synoptic-scale weather systems, basin-scale ocean circulations, and continental-scale ice sheets. Climate and weather share many of the same underlying physical processes, so more unified approaches to model development and application could have many advantages. NESL scientists will engage with the broader community in development efforts focused on high- and variable-resolution models, the development of across scale parameterizations, new approaches to model testing and evaluation utilizing data assimilation, and new modeling initialization strategies.

‹ 7.2.a.5. Studies of Chemistry and Climate: The ACCMIP and GeoMIP Projects | up | 7.2.b.1. Ensure that all CESM components use scale-adaptive techniques... ›

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7.2.B.1. ENSURE THAT ALL CESM COMPONENTS USE SCALE-ADAPTIVE TECHNIQUES...

ENSURE THAT ALL CESM COMPONENTS USE SCALE-ADAPTIVE TECHNIQUES SO THAT REGIONAL AND GLOBAL CLIMATE CAN BE SIMULATED CONCURRENTLY

Progress on the explicit and consistent representation of small-scale variability necessary for scale-aware parameterizations has come from the co-development of versions of CAM-SE at resolutions of 100km and 25km. Similarly, the POP ocean model has been further developed at 100km and eddy-resolving 10km resolutions. An order century simulation of 25km CAM coupled to 10km POP has reduced long-standing biases, such as the double ITCZ, and eastern boundary current SSTs. Work has commenced to discover the scale issues that have produced an the overly vigorous hydrological cycle. In addition, increased vertical resolution in CAM and parameterizations of convectively driven gravity waves have combined to produce the first recognizable Quasi-biennial Oscillation in the model. The net result is a commitment by CESM to continue development of 25km CAM for general release, and coupling for CMIP 6. The successful parameterizations will become the key guide for the high resolution limit of scale-aware parameterizations. The understanding of forced versus natural variability has advanced to the point of finding that order 5 years is the time scale when initial conditions dictate predictability, and that after about 10 years the forcing becomes the dominant player. Some climate impacts and feedbacks of meso-scale ocean eddies, dynamic land-ice and vegetation, land-use change, atmospheric composition, ecosystems, and human dimensions have been quantified.

Assessment tools have been developed for the diagnosis of atmospheric modes of variability in model simulations. Simulations from the Large Ensemble project are enabling an unprecedented ability to assess climate variability within the CESM context. Analysis of CESM decadal prediction (DP) ensemble forecasts initialized with two different historical ocean and sea ice conditions has continued. A focus has been on the assessment of the retrospective DP skill of sea surface temperature (SST) variability. Results indicate predictive skill in SST variations in the subpolar gyre region of the North Atlantic. Representations of cloud processes designed to enable scale-aware capability have been developed, tested and made available to the model development community.

‹ 7.2.b. A more unified strategy toward model and data assimilation system development for weather-chemistry-climate prediction | up | 7.2.b.2. The Model for Prediction Across Scales (MPAS) ›

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7.2.B.2. THE MODEL FOR PREDICTION ACROSS SCALES (MPAS)

The Model for Prediction Across Scales (MPAS) is a next-generation modeling system being developed for weather, regional climate, climate, and Earth system research and prediction. It is designed to simulate the interactions of small-scale phenomena (e.g., clouds, small hydrologic basins, and small estuaries) with large-scale phenomena (e.g., planetary atmospheric waves and Earth-ocean circulations). A critically important aspect of this project is to develop MPAS components (atmosphere, ocean, land surface models, etc.) that scale well on new computer architectures and can simulate all necessary scales for NCAR and community research and production applications.

In FY2013, NESL scientists achieved a number of accomplishments including:

- As of June 2013, MPAS is freely available to the community in a joint release with DOE.
- MPAS-Atmosphere (MPAS-A) is now running as a atmospheric component in CAM/CESM using PIO. Initial testing (aquaplanet (APE) and AMIP testing) is just beginning.
- The CESM/CAM radiation package has been implemented; the GFS physics port is still in progress.
- MPAS-A has been used in real-time NWP testing for the 2013 hurricane season where daily 10-day forecasts were produced on a uniform 15 km global mesh and a variable-resolution 60-15 km mesh where the high-resolution region was centered over the Atlantic hurricane basin. While the Atlantic hurricane season has been quiet, forecasts from both MPAS configurations captured many of the observed tropical storms. The strong typhoons in the western Pacific have been well forecast by the uniform resolution 15 km MPAS configuration. Yearlong regional climate simulations have also been produced using MPAS-A and a data ocean; these results are currently being analyzed.
- MPAS-A has been run using uniform global meshes of 30, 15, 7.5 and 3 km as part of an NCAR/ASD allocation on Yellowstone. The initial scaling results have met expectations with regard to the solver performance and have demonstrated MPAS ability to perform capability computations on Yellowstone. The results also have uncovered problems associated with the scaling of the Parallel IO package in MPAS.
- MPAS-A is now fully coupled to the ensemble Kalman filter in the Data Assimilation Research Testbed (DART). Preliminary results with uniform meshes found no significant problems with MPAS-A, and variable-resolution mesh testing is underway.
- The variable-resolution testing of MPAS has been undertaken within the tropical cyclone forecast experiment. The development of scale-aware physics is focused on the deep convection parameterization, and several efforts are being led by investigators in other labs (EPA, NOAA, DOE) in collaboration with MPAS developers.
- Under the NCAR/ASD allocation, hydrostatic- and nonhydrostatic-scale tests have been performed that verify the accuracy of the MPAS-A global solver at these scales. Most important, convective-scale structures are well simulated at the nonhydrostatic scales, and are comparable to those produced with state-of-the-art could models (e.g. WRF). An example of these convective structures is given in the Figure below.

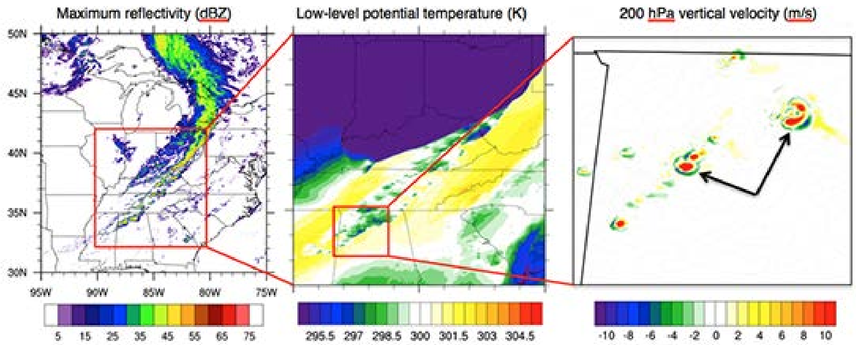

Figure: Supercell thunderstorms simulated in global MPAS using a 3 km mesh in a 4 day 3 hour forecast valid 3 UTC 27 October 2010. The left panel depicts the column-maximum radar reflectivity that shows the isolated severe convective cells ahead of the cold front. The middle panel shows the cold pools associated with the convection in the warm sector ahead of the cold front. The right panel shows the classic splitting supercell structure in the upper level vertical velocity field.

‹ 7.2.b.1. Ensure that all CESM components use scale-adaptive techniques... up 7.2.b.3. Prediction of Future Summertime Ozone over the U.S. ›

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7.2.B.3. PREDICTION OF FUTURE SUMMERTIME OZONE OVER THE U.S.

As modern society, commerce, and industry become increasingly complex, their vulnerability to changes in weather, air quality, and climate also increase, emphasizing the need for reliable projections of future climate and air quality on regional to local scales. This requires models with high spatial resolution with at the same time multiple year-long simulations to quantify the interannual variability and provide statistically significant projections. With support of an NSF EaSM and NCAR Accelerated Scientific Discovery grant, a set of regional chemistry climate simulations was conducted to study future changes in air quality and climate over the summertime U.S. and analyze chemistry-climate feedbacks. The simulations were run at 12 km grid spacing using a fully coupled regional chemistry-transport model (NRCM-Chem) based on the regional Weather and Forecasting model with Chemistry. The simulations are for a most extreme climate scenario with ~8 $W\ m^{-2}$ radiative forcing by 2100 but large reductions in short-lived pollutant emissions in the developed world.

These simulations supplement the global simulations performed for IPCC AR5 and, in particular, quantify the ability of global models at moderate horizontal resolution to capture regional air quality characteristics. They will also contrast the chemical importance of specific events (e.g., heat waves) between present time and future. To assess the impacts of changes in emissions versus changes in climate on air quality, sensitivity simulations for the 2050s were run with anthropogenic emissions held at present-time levels. Simulations without chemistry allow quantifying changes in weather patterns and climate associated with atmospheric composition.

Results indicate that a warming climate will aggravate ozone pollution over the U.S. by 2050 increasing the 95^{th} percentile of daily 8-hour maximum surface ozone from 79 ppbV to 87 ppbV. However, if emissions of pollutants continue to decline, U.S. ozone levels should improve even as temperatures rise. A comparison of NRCM-Chem ozone to global CAM-Chem projections (2°x2°) shows that even though the global model is biased high in surface ozone compared to NRCM-Chem and compared to observations, both models predict similar changes between present time and future ozone (Figure 1). However, on more local scales the regional model is providing important information on the different response of urban versus rural environments that are not resolved by the global model or in parts can be opposite in sign. The study demonstrates the need for considering degradation of air quality with future climate change in policy-making and illustrates the need for high-resolution models to study future air quality.

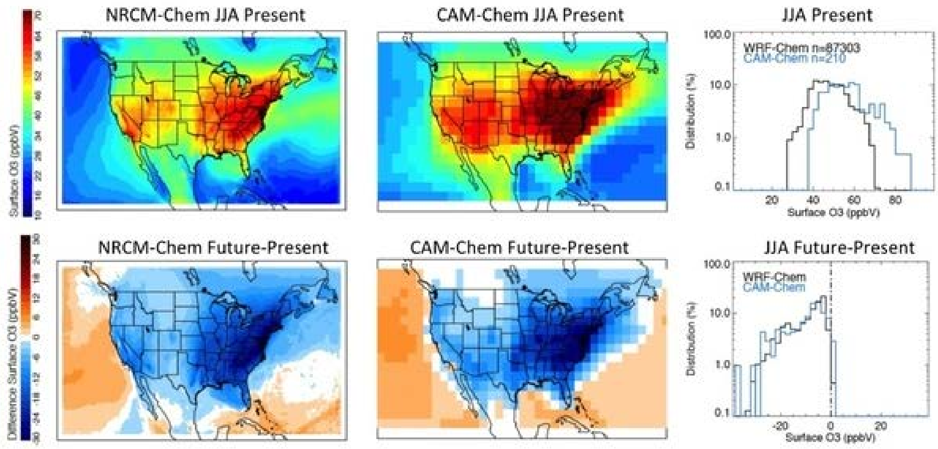

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Figure 1: Average daytime surface ozone mixing ratios (16-22 UTC) from NRCM-Chem (left) and CAM-Chem (right) for present time (top) and the difference between future and present time ozone (bottom). According frequency distributions for CAM-Chem (blue) and NRCM-Chem (black) over the contiguous U.S. (land; 28-50N) are shown next to the maps.

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7.2.C. EXPAND THE COMMUNITY USE OF AND ACCESS TO INSTRUMENTS, MODELS AND DATA SET

A central feature of NESL's mission is to provide to the broader community data, models and instruments and related expertise. Within the community, datasets encompass output from climate model experiments, post-processed model data, observations from satellites, field programs and laboratory experiments, and value-added observationally based datasets. Community model codes, as well as information on model configurations, experimental designs, and on-line diagnostics are made available through frequently updated web pages. NESL conducts tutorials to train university students and other community scientists in the development and application of NESL community model. NESL has started a major activity to foster the development of a strong and linked atmospheric chemistry observational community; to provide an intellectual meeting ground for the discussion and prioritization of scientific problems and for the development of community-wide observational capabilities to address these problems; and to provide a vehicle for community guidance into the prioritization of the observational facilities maintained and developed within NESL in collaboration with the NCAR Earth Observing Laboratory (EOL).

‹ 7.2.b.3. Prediction of Future Summertime Ozone over the U.S. | up | 7.2.c.1. Deployment of the Time-of-Flight Thermal Desorption Chemical Ionization Mass Spectrometer (TOF-TDCIMS) at Mace Head, Ireland ›

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7.2.C.1. DEPLOYMENT OF THE TIME-OF-FLIGHT THERMAL DESORPTION CHEMICAL IONIZATION MASS SPECTROMETER (TOF-TDCIMS) AT MACE HEAD, IRELAND

ACD/NESL scientists, in collaboration with Univ. of Eastern Finland, study the composition of recently formed atmospheric aerosol in order to understand the processes by which newly formed particles grow to become potential cloud condensation nuclei (CCN), and thereby impact climate. For this work, they have developed and deployed the Time-of-Flight Thermal Desorption Chemical Ionization Mass Spectrometer, or TOF-TDCIMS, an instrument that measures the composition of small (10-30 nm in diameter) particles in the atmosphere. In May 2011 the instrument was deployed at Mace Head, Ireland, a remote coastal station. While sea salt and dust are thought to be the main components of larger particles in clean marine air, the composition of nanometer-sized particles is still an open question. Some evidence has shown that sea salt can be directly emitted from the ocean surface at these small sizes. Other evidence suggests that there is a large component of mixed sulfate-organic aerosol in this size range, implying that the particles were nucleated and grown from gas phase sulfuric acid and organic compounds. TDCIMS observations, published this year in Atmospheric Chemistry and Physics Discussions, points to the latter as the source of marine nanoparticles. These results emphasize the importance of understanding nucleation and growth by sulfur- and organic-containing compounds, and suggest that ocean biota may be the determining factor in the formation of potential CCN in this clean marine environment.

Mace Head, Ireland

‹ 7.2.c. Expand the community use of and access to instruments, models and data set | up | 7.2.c.2. Continued Development of a Scanning Mobility Particle Sizer (SMPS) ›

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7.2.C.2. CONTINUED DEVELOPMENT OF A SCANNING MOBILITY PARTICLE SIZER (SMPS)

During the past year, NESL/ACD scientists continued to improve and characterize a Scanning Mobility Particle Sizer (SMPS), an instrument for airborne measurements of ambient aerosol size distributions (see Figure 1). The SMPS was developed in 2012 for the NSF GV aircraft, which can fly at altitudes above 45,000 ft. (~13,700 m), in the upper troposphere/lower stratosphere. This placed strict requirements on the control of gas flows within the instrument, at pressures ranging from ~15 kPa to atmospheric pressure. During summer 2013, the SMPS was successfully adapted to fly on board the NSF C130 for the NOMADSS (Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks) field study. Following this, comprehensive measurements of the detection efficiency was determined for particles as a function of ambient pressure and particle diameter. The SMPS provides size distribution measurements down to sizes of 8 nm; when combined with existing aerosol instruments on both aircraft, this new suite of instruments is able to obtain both total aerosol number concentration and a complete size distribution from 8 nm to several microns.

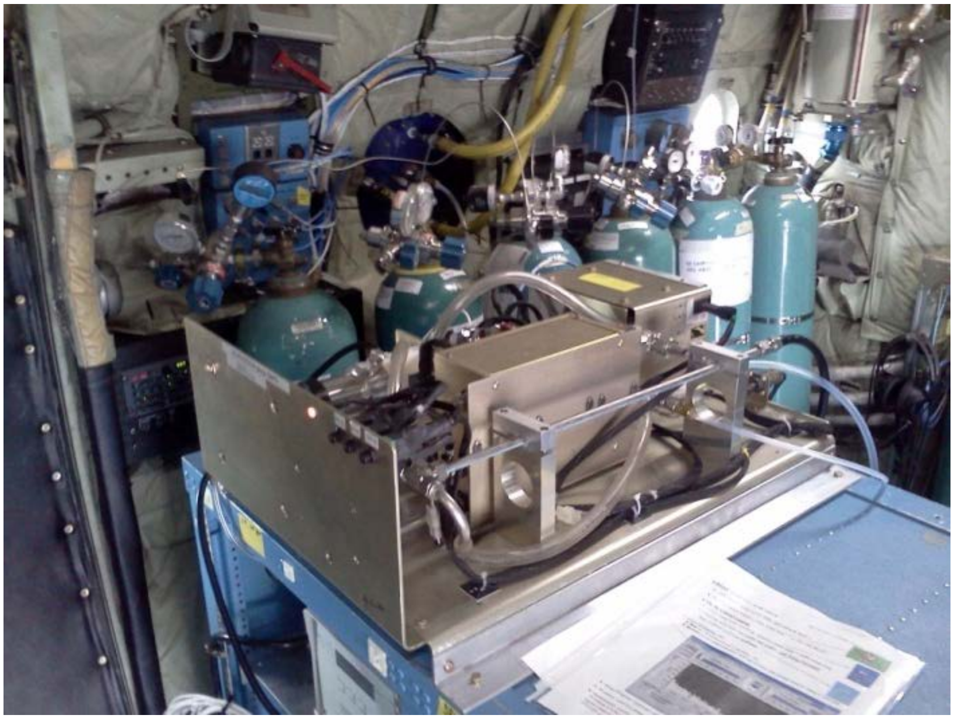

Figure 1: The SMPS mounted atop an instrument rack in the C130 during NOMADSS.

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7.2.C.3. MOPITT VERSION 6 PRODUCT RELEASE

The NCAR/MOPITT team in NESL/ACD recently released the MOPITT Version 6 (V6) product for carbon monoxide (CO). Major enhancements offered in the V6 product include (1) refined geolocation (latitude and longitude) data, (2) use of the NASA MERRA ('Modern-Era Retrospective Analysis For Research And Applications') reanalysis product for meteorological fields and a priori surface skin temperatures, (3) updated a priori CO concentrations and (4) distribution of Level 2 and Level 3 products in HDF5 format. Corrected geolocation data will benefit studies of CO emissions on fine spatial scales, including urban sources. The use of MERRA meteorological fields in MOPITT data processing reduces MOPITT retrieval errors and will benefit climate applications. Finally, new CO a priori based on CAM-Chem simulations for 2000-2009 should generally improve background CO concentrations for the period of the MOPITT mission. The figure below demonstrates the value of MOPITT V6 products for analyzing the production and transport of CO from fires in the Yosemite region during August, 2013.

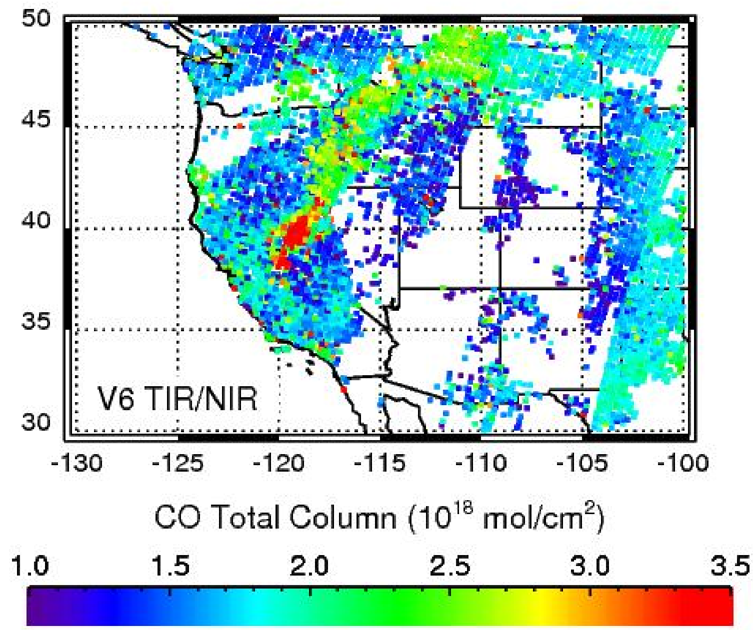

Figure 1. Five-day composite (Aug. 21-25, 2013) of MOPITT CO total column retrievals showing intense pollution from fires in Yosemite region of California and associated plume traveling to the northeast. Plot was generated with MOPITT Version 6 Level 2 'multispectral' retrieval product.

‹ 7.2.c.2. Continued Development of a Scanning Mobility Particle Sizer (SMPS) up 7.2.c.4. HIgh Resolution Dynamics Limb Sounder (HIRDLS) Data Retrievals ›

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7.2.C.4. HIGH RESOLUTION DYNAMICS LIMB SOUNDER (HIRDLS) DATA RETRIEVALS

During the launch of the High Resolution Dynamics Limb Sounder (HIRDLS) instrument on NASA's Aura satellite, it was damaged in such a way that an obstruction was introduced into the optical train, obscuring 80-95% of the instrument's view of the atmosphere. Since that time, August 2004, the HIRDLS team has worked to understand the nature of this blockage, and develop ways to correct for it. Previous efforts led to data versions 3-6, retrieving increasing numbers of the originally expected quantities, temperature, 10 trace gases, and aerosol extinction, resulting in Version 7 (V7) retrieved profile (Level 2) data, as described last year.

In the final 9 months of the HIRDLS program, which ended on June 30, 2013, the team did extensive documentation of the data, and validation of these profiles, resulting in the Data Description and Quality document, available on the HIRDLS web site. More interestingly, they gridded the data, using the Kalman filter mapping approach originally suggested by Clive Rodgers (Retired from Oxford University), first applied to satellite data by William Kohri in an NCAR Cooperative Thesis in 1981, and subsequently used by several others. The maps at each of HIRDLS pressure levels contain 5600 vertical profiles of each species, from 63°S to 80°N every day, spanning the period from late January 2005 to mid-March 2008. Three maps of all species have been created and archived, based on all data, and on the ascending (day) and descending (night) segments of the orbit. For the diurnally varying species (NO_2, N_2O_5, $ClONO_2$) only the day and night maps are provided.

Examples are shown in Figure 1, where polar stereographic maps of HIRDLS temperatures on the 10 and 82 hPa surfaces are compared with maps of temperatures from the GEOS5 data assimilation for December 21, 2006. The excellent agreement suggests that HIRDLS data can be relied on at higher levels, where GEOS5 is not assimilating any

measurements. V7 is likely the final version of HIRDLS data, since funding for continued development has ended.

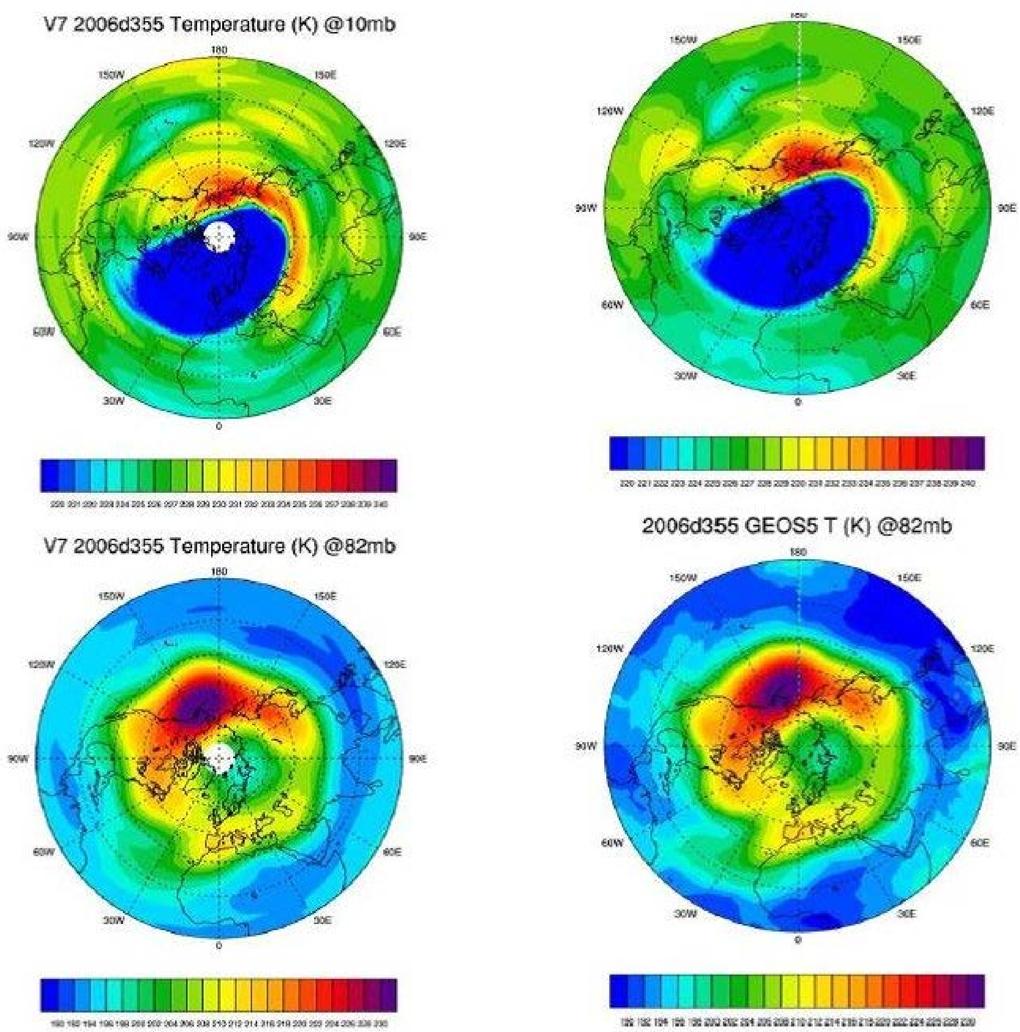

Figure 1. Comparison of HIRDLS V7 gridded temperature data with GEOS5 temperatures on the 10 and 82 hPa surfaces for December 21, 2006.

‹ 7.2.c.3. MOPITT Version 6 Product Release up 7.2.c.5. Laboratory Studies of the Atmospheric Oxidation Pathways of Butanols ›

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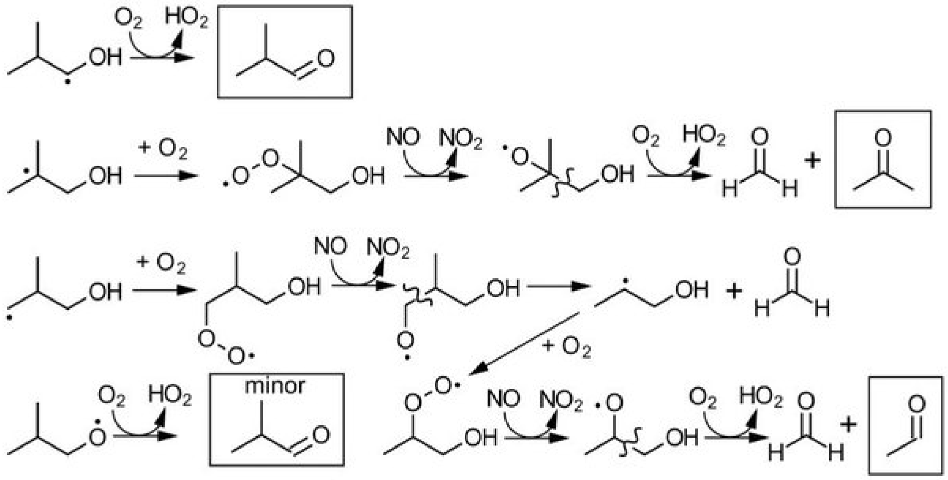
7.2.C.5. LABORATORY STUDIES OF THE ATMOSPHERIC OXIDATION PATHWAYS OF BUTANOLS

Butanols have been proposed as a biofuel alternative to conventional fossil fuel gasoline formulations. As with all such formulations, emission to the atmosphere is a consequence of their widespread usage. Knowledge of the oxidation products is thus fundamental to understanding the effects of butanol emissions upon the atmosphere. To help constrain these effects, a team of scientists from NOAA, the Pontificial Catholic University of Rio de Janeiro and NESL/ACD conducted detailed product studies in the NESL/ACD laboratory chamber for the reactions of *i*- and *s*-butanol with OH in the presence of NO_x.

One previous product study was available for the reaction of *i*-butanol with OH, while two studies were available for *s*-butanol. It is important to note that the reported carbon mass balance in the earlier studies did not exceed 75%. Hence, they are not able to provide a sound quantitative basis for ascribing site-specific reactivity of these two alcohols.

A multi-analytical approach was developed for these experiments coupling GC-FID with FTIR. This approach enabled both major and minor products to be quantified. So far, a carbon mass balance of ~102% for i-butanol has been determined, which includes a minor contribution from the (minor) gamma reaction site, allowing us to construct a full reaction mechanism for i-butanol oxidation in the presence of NO_x:



(Click for larger image.)

Further modeling is being conducted for the *s*-butanol experiments, which are expected to exhibit close to unit carbon mass balance also.

These data will be useful for determining site-specific reactivity for these specific compounds (see McGillen et al., J. Phys. Chem. A, 2013), but could also be useful for augmenting structure-reactivity relationships (e.g. Bethel et al., Int. J. Chem. Kinet., 2001), which would enable us to better estimate the atmospheric behavior of alcohols that have not been subjected to product studies. A quantitative understanding of the product yields also gives some information on the relative importance of various decomposition pathways of the relevant hydroxyl-substituted alkoxy radicals.

‹ 7.2.c.4. HIgh Resolution Dynamics Limb Sounder (HIRDLS) Data Retrievals   up   7.2.c.6. Community Datasets ›

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7.2.C.6. COMMUNITY DATASETS

Community datasets encompass output from climate model experiments, post-processed model data, observations from satellites, field programs and laboratory experiments, and value-added observationally based datasets. NESL scientists evaluated data sets and examined their suitability for model evaluation and other studies, and transformed data sets into user-friendly formats. NESL also provided expertise and instrumentation needed to conduct community field experiments. A major accomplishment has been the Climate Data Guide (climatedataguide.ucar.edu) where the suitability of various data sets are gathered and critically evaluated for use in diagnostic studies and model validation.

‹ 7.2.c.5. Laboratory Studies of the Atmospheric Oxidation Pathways of Butanols | up | 7.2.c.7. NESL Community Tutorials and Workshops ›

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7.2.C.7. NESL COMMUNITY TUTORIALS AND WORKSHOPS

Rising Voices

The challenges of understanding and responding to a changing climate and extreme weather necessitate broad engagement with diverse communities. As climate science has matured, it has moved toward a more inclusive dialogue where scientists and policy makers work together with seasoned indigenous communities to define and carry out research programs that advance science and address community priorities. In FY2013, NCAR hosted a workshop on the growing engagement of Native American, Alaska Native, and Pacific Island communities in climate and weather science, research, policy, and community response conversations. The workshop, held on July 1-2, addressed the question: *What are the elements of successful co-production of science and policy in the fields of extreme weather and climate change?*

The workshop was conducted in collaboration with the Indigenous Peoples Climate Change Working Group (formerly the American Indian/Alaska Native Climate Change Working Group) and the Smithsonian National Museum of the American Indian. Participants were actively involved in cross-cultural scientific engagement with Native American, Alaska Native, and Pacific Island communities from academic institutions, including tribal colleges and universities, as well as government agencies and non-governmental organizations. Travel support was provided for a limited number of the 53 registered participants. The workshop goals were to:

- Identify lessons learned for, or barriers to, achieving successful co-production of science and policy by appraising the first-hand experiences of those involved in cross-cultural efforts to integrate indigenous knowledge and diverse understandings in climate and weather modeling and assessments;

- Foster and support collaborations between experts on cross-cultural engagement and NCAR scientists; and
- Promote student opportunities to work with NCAR scientists.

Rethinking Failure – Engineering for Climate Extremes

Engineering systems for water resource management have been developed empirically from observed extremes. In recent years, increases in population in vulnerable locations in combination with anthropogenic changes to the built and natural environment have all increased the risks posed to water infrastructure (storage and flood prevention) and to the reliability of the systems. NCAR hosted a workshop on August 8-9, 2013 to explore alternative approaches to determine the risks from extreme weather, and to use these in new ways to rethink engineering solutions to catastrophic climate events. The workshop addressed the question: What knowledge is required by engineering designers and risk managers to address the risks from high impact weather events, and how can this be best supported by science?

The 29 registered participants were actively involved in assessing and responding to high impact weather events such as floods and droughts, and were from engineering consultancies, academic institutions, government agencies and non-governmental organizations. The workshop goals were to:

- Identify lessons learned for, or barriers to, achieving successful co-production of science and policy by appraising the first-hand experiences of those involved in cross-cultural efforts to integrate indigenous knowledge and diverse understandings in climate and weather modeling and assessments;
- Develop approaches that help in designing the built water systems in a more reliable, resilient and sustainable manner;
- Develop and synthesize ideas for a larger research proposal;
- Foster and support collaborations between experts on water resource management and NCAR scientists; and
- Promote early career opportunities to work with NCAR scientists.

CESM Workshop Tutorial

The 18th Annual CESM Workshop in June, 2013 was highly successful, with a total of 396 participants. Our annual CESM tutorial, targeted at graduate students and early career scientists, was held in August. Despite travel restrictions placed on many agencies, we had a very successful tutorial with 72 participants. In March, 2013, we held a CESM tutorial in Taiwan for the first time. This was a practical session to teach the participants how to run CESM efficiently and effectively. Independent of the CESM tutorials, we held 3 sessions that trained scientists in the use of the interpreted NCAR Command Language (NCL) so that they have the programming tools they need to easily and effectively analyze model and observationally based data sets in a variety of formats.

Figure: *2013 CESM Tutorial.*

WRF Workshop & Tutorials

The 14th WRF Users' Workshop held in Boulder on June 24–28 attracted approximately 220 participants. The first day presented a continuation of the model fundamentals lecture series, with the topic being "Atmospheric Radiation and the Effect of Clouds and Aerosols." The core of the workshop featured talks covering a range of WRF topic areas (new development, physics, data assimilation, chemistry, regional climate modeling), while the final day offered instructional talks.

The two annual WRF tutorials held in Boulder, were highly successful with participation maxing out at capacity. The first session held the last week of January 2013 and the first few days of February 2013 included a basic WRF tutorial and a WRF Met tutorial. The second session held during a two week period in July 2013 included a basic WRF tutorial, a WRF DA tutorial, a WRF Chem tutorial, and a WRF Regional Climate tutorial. In collaboration with the UK's National Centre for Atmospheric Science, NESL scientists conducted a WRF tutorial in York, UK.

In addition, three WRF tutorials focusing on best practices using the Nested Regional Climate Model (NRCM) were held outside the United States. The first was held in Vietnam in collaboration with the Norwegian Bjerknes Center for Climate Research. The second and third tutorials were held in India. The tutorial locations were the Energy and Resources Institute and The Energy and Resources Institute (TERI). These tutorials were attended by international university researchers and industry. An article regarding the Vietnam event was published in the AGU:

newsletter: http://www.agu.org/sections/atmos/pdf/Newsletters/ASnewsletterVol6No4.pdf.

‹ 7.2.c.6. Community Datasets up

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DIRECTOR'S MESSAGE

Welcome to the Research Applications Laboratory's Annual Report for FY2013. Our goal is to conduct directed research that contributes to the depth of fundamental understanding of the atmosphere and its interaction with society, and to develop and transfer knowledge and technology that expands the reach of atmospheric science and contributes to the betterment of life on Earth. We are, at present, an organization with annual expenditures of approximately $30M and a staff comprised of nearly 200 scientists, software engineers, and management/administration personnel.

Brant Foote - RAL Director

I hope you will enjoy reading this year's Annual Report. As in the past, it follows the outline of our current strategic plan, providing details on our many accomplishments over the past year and our plans for the future. Below, I highlight several significant accomplishments of the past year:

Hydrometeorology

For more than a decade, RAL scientists have made major contributions to Water System research at NCAR, particularly with regard to the impact of changing climate on the Colorado Headwaters. In 2013, this base-funded work was augmented by complementary programs funded by the Bureau of Reclamation and the Army Corps of Engineers, as well as by private and non-governmental organizations in the U.S. and Europe. To meet a growing need for probabilistic forecasts at variable temporal scales, RAL has also initiated efforts to develop a new "Minutes to Seasons" hydrometeorological forecasting capability

I am particularly pleased with advances that have been made in developing WRF-Hydro and making it available to the community. WRF-Hydro provides a framework within which the WRF model is combined with a flexible, extensible distributed hydrological modeling system using a unified computational architecture. Model code and documentation for WRF-Hydro were released to the community in April 2013. A user manual, code documentation and test cases, as well as domain pre-processing tools, are freely available through the WRF-Hydro website located at: http://www.ral.ucar.edu/projects/wrf_hydro/. With a growing network of model users and increasing record of improved model skill, it is becoming clear that WRF-Hydro is an essential community resource for hydrometeorological and hydroclimatological prediction.

Climate Downscaling

A combination of downscaling techniques has been tested for the first time as a way to drastically reduce the computational cost of dynamical downscaling over a 3-dimensional grid. This combination utilizes the strengths of the Analog Ensemble (AnEn) wind downscaling tool, the Simple Weather Model—an intermediate complexity weather model—and RAL's Dynamic Integrated Forecast System (DICast). Preliminary tests indicate the ability of this approach of reducing the cost of dynamical downscaling by a factor between 5-10 for short duration forecasts, and approximately a factor of 100 for climate time scales, depending on the location and the required accuracy. Tests are ongoing to assess in depth the accuracy and reliability of this approach, as well as the ability of AnEn to preserve the 3-dimensional physical structure of the atmospheric flow.

Weather, Climate and Health

As part of an NSF-funded program studying the spread of mosquitoes carrying the dengue virus in Mexico, RAL scientists have developed a new model to better track the mosquito. "WHATCH'EM" is a physically-based energy balance model of water height and temperature in containers that may serve as incubation sites for mosquitoes. WHATCH'EM simulates the highly non-linear manner in which atmospheric conditions and container characteristics determine water temperature and height, leading to results that are not always intuitive and likely not simulated by simpler empirical models. Simulations are expected to aid in understanding the limiting climatic and container-related factors for proliferation of mosquitoes carrying the dengue virus. This model is also being employed in a newly funded project by the Defense Threat Reduction Agency aimed at developing an early warning system for dengue risk.

Renewable Energy

In 2013, RAL embarked on a major DOE-funded effort to advance the state-of-the science of solar power forecasting. In partnership with national laboratories, utilities, independent service operators, and universities, scientific advances are being made in solar radiation measurement and cloud observation and tracking techniques, as well as in their use for short-range prediction. We are also working with NOAA and CSU to advance the use of satellite data in models and to develop a new technology to fully assimilate multiple sources of cloud data into a rapid update version of WRF. Our ultimate goal is to deploy a prototype solar forecasting system and test it in collaboration with utilities and service operators in geographically diverse areas, including Long Island, NY, Colorado, coastal California, and Hawaii.

Surface Transportation

RAL scientists created the Pikalert Enhanced Maintenance and Decision Support System (EMDSS) in 2013, incorporating innovative Connected Vehicle technology into the MDSS we developed for the Federal Highway Administration. Pikalert features a Motorist Advisory and Warning system which provides hyper-local and rapid-update road weather warnings to the travelling public, as well as 24-hour forecasts of road weather conditions. Pikalert also enables maintenance providers to better monitor and react to changing road conditions, improving their ability to make spot treatments on roads and thus improve safety and mobility, as well as minimize environmental impacts from the use of de-icing chemicals.

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NEXT GENERATION AIR TRANSPORTATION

Play a leadership role within the atmospheric research community to provide the necessary scientific underpinning and technology to support the weather and climate–related needs of the Next Generation Air Transportation System (NextGen).

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- Turbulence
- Ceiling and Visibility Research and Development
- Integration of Weather Information into Air Traffic Management Decisions for Reduced Weather Impact
- Dissemination of Aviation Weather Information
- Oceanic Weather

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INFLIGHT, GROUND AND ENGINE ICING

FAA-SPONSORED ACTIVITIES

For the past two decades RAL scientists have worked to improve diagnoses and forecasts of icing conditions that impact aviation. Our largest program is the FAA's Aviation Weather Research Program, which is focused on providing operationally-available, automated in-flight icing forecasts over the CONUS and Alaska. At this time, the Current and Forecast Icing Products (CIP and FIP), developed at RAL, are running at the National Weather Service's Aviation Weather Center (AWC) and are approved for unrestricted supplementary use. The outputs include expected icing severity, probability of encounter, and potential for supercooled large drop (SLD, those drops with diameters exceeding 50 microns) at 20-km resolution over the CONUS for 0-12 h. A new version with 13-km resolution has been delivered and is being tested at AWC.

In 2013 RAL continued work on these projects within the FAA program: 1) MICRO (Model for Icing Conditions in Real-time Operations), which will incorporate a high-resolution NWP model and improved use of sensor data to output the full drop size distribution (DSD) for icing prediction and severity calculations, 2) IPA (Icing Product-Alaska) which will revise CIP and FIP for the Alaska weather and data environments, and 3) evaluations of improvements to icing diagnosis using NEXRAD dual-polarization data.

Preliminary studies of the Icing Hazard Level Algorithm (developed in 2012) applied to NEXRAD dual-polarization data show very favorable results. Versions of the IHLA with and without the dual-pol data were compared with pilot reports of inflight icing conditions.

This image shows from left to right: 0.5o reflectivity from KCLE (Cleveland, OH NEXRAD); corresponding IHLA product with dual-polarization; IHLA with a new supercooled liquid water module; and without the module. For algorithm output, red and brown indicate likely icing, green is possible, and blue is no icing. The pink cross is a pilot report of mixed icing near the radar image altitude; the dual-polarized version of the algorithm correctly diagnosed icing conditions while the non-polarized versions did not. NCAR has also been working with NSSL on a winter hydrometeor classification algorithm pertinent to aviation hazards; the new output fields should be included in test versions of NSSL's Multi-Radar-Multi-Sensor mosaic in early CY2014.

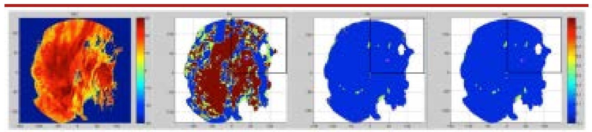

Figure 1. From left to right: 0.5o reflectivity from KCLE (Cleveland, OH NEXRAD); corresponding IHLA product with dual-polarization; IHLA with a new supercooled liquid water module; and without the module.

A draft Concept of Operations was completed for MICRO, describing the planned outputs and their intended use by pilots, dispatchers and meteorologists. This was written in conjunction with FAA and their support staff, and input from the FAA's Icing Steering Committee was particularly helpful in defining the end use of the products and how they fit into current and future regulations. Additionally, NCAR staff worked with FAA, NASA, NOAA, and private industry representatives on an InFlight Icing Research Evolution Plan to define a pathway from basic research to implementation and use of icing products.

The High Ice Water Content (HIWC) project conducted a Real Time Nowcasting Experiment (RTNE) in Darwin, Australia in spring 2013. Staff travelled to Darwin to install their ALPHA (Algorithm for Prediction of High Ice Water Content (HIWC) Areas) workstation and collaborate with Australian Bureau of Meteorology staff to forecast HIWC conditions in the area. The RTNE was a "dress rehearsal" for a larger experiment, with a research aircraft, scheduled for spring 2014. ALPHA will be part of the flight planning process to guide the aircraft into HIWC regions to sample their microphysical characteristics and effect on engine performance. During the RTNE, internet connections were thoroughly tested, data set availability was determined, and a good collaboration with BOM meteorologists was established, all which will increase the chances of success of the 2014 field campaign. The ALPHA concept uses NWP output combined with satellite and radar data to diagnose cold cloud tops, warm atmosphere (compared to a standard sounding), high radar reflectivity below typical flight cruise altitudes, and other factors to determine regions conducive to the HIWC hazard.

The Terminal-Area Icing Weather Information System (TAIWIS) focused on defining user requirements for icing information in the airport terminal area. This somewhat arduous task was needed to insure that research and development activities truly addressed the needs of the community. Two reports were generated: one described current capabilities in icing detection, diagnosis and forecasting applicable for the terminal area; the other presented a high-level description of a TAIWIS incorporating elements from WSDDM (Weather Support for Deicing Decision Making), NIRSS (NASA Icing Remote Sensing System) and MICRO (Model for icing Conditions in Real-time Operations).

NASA-SPONSORED ACTIVITIES

The NASA Icing Remote Sensing System (NIRSS) is being converted from a upward-looking system to a scanning system, providing potential support for an airport terminal area. Preliminary data processing was accomplished to determine how to apply the vertically pointing-based algorithms to different elevation angles, and how best to display the data. NIRSS has also been incorporated into the dual-polarization studies to help developers better understand the icing environment and include new features in the icing detection algorithm.

PLANS FOR 2014

In 2014 we will continue to upgrade our automated icing algorithms to use higher resolution numerical weather prediction model and observational data, and to better interpret those data in terms of their effect on the diagnosed and predicted icing environment.

TAIWIS will conduct a small experiment at Denver International Airport to assess the variability of snowfall rate across the airfield. Five shielded snowgauges will be deployed and data will be collected at 1-min intervals. Deicing "holdover times" are usually determined by a single measurement at the airfield; if this varies considerably safety could be compromised as higher snowfall rates cause deicing fluids to fail more quickly. Variability in surface winds and in radar reflectivity aloft will also be analyzed to evaluate whether these could be used as predictors for snowfall rate variability at the surface.

Modules to use dual-polarization NEXRAD to detect high Zdr bands within precipitation and to detect negative Zdr in graupel will be tested and implemented in the upcoming year to augment our radar-based icing detection algorithm. There is also the possibility of a research flight campaign in 2014-2015 in the Great Lakes Region to further test the ground based remote sensing algorithms discussed within.

Our work on a Global Forecast Icing Severity (GFIS) algorithm will resume in FY2014 in collaboration with NCEP's Meteorological Development Laboratory. The GFIS is scheduled for implementation and testing at NCEP in early CY2014.

‹ Next Generation Air Transportation up Prediction of Storm Hazards for Aviation ›

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STRATEGIC PLANS

RAL Strategic Plan

NCAR Strategic Plan

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PREDICTION OF STORM HAZARDS FOR AVIATION

BACKGROUND

The Next Generation Air Transportation System (NextGen) is a national priority designed to meet the air transportation needs of the United States in the 21st century—in particular, a significant growth in demand for air traffic services, possibly on the order of two to three times today's demand levels. Since weather conditions can seriously restrict aircraft operations and levels of service available to system users, the manner by which weather is observed, forecast, disseminated, and used in decision-making is of critical importance.

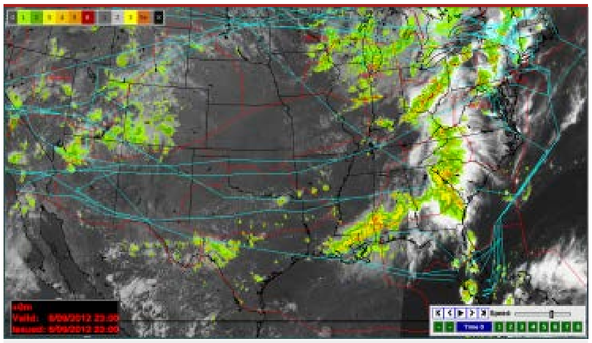

Figure 1. Analysis and forecast products made available to aviation planners via a web-based display.

For the past several years, the NCAR Research Applications Laboratory has been engaged in multiple FAA-funded research and development efforts geared toward improved convective weather support for air traffic management en route and in/out of terminals (i.e., CoSPA), and more recently for airport operations safety for outdoor workers (i.e., lightning hazard). In addition, efforts have continued in terms of enhancing our understanding of numerical weather prediction model performance, which enables effective harvesting of model predictions for convective storm initiation and probabilistic forecasting.

FY2013 ACCOMPLISHMENTS

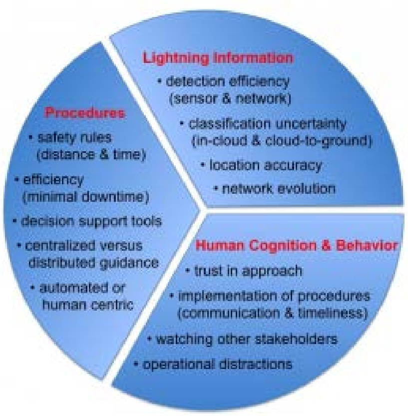

Figure 2. Uncertainties associated with the ramp closure decision-making process.

The 0 – 8 hour CoSPA forecasts, jointly developed and maintained by MIT Lincoln Laboratory, NOAA Earth System Research Laboratory, and NCAR RAL, continue to be made available to aviation planners (i.e., select FAA and airline industry partners) via a web-based display from April through October (i.e., convective season). The display allows users to overlay airports and associated arrival and departure fixes, route structures, and sectors on current and forecast weather facilitating the product's utility (Figure 1). This past summer, like the previous year, only a reduced operational evaluation was conducted by the FAA that primarily relied on surveys and interviews with select groups of users. The analyses convey sustained interest and usage of the CoSPA forecast products by the aviation planners. An initial version of CoSPA is currently undergoing acquisition by the FAA's NextGen Weather Processor.

Another major research effort has been focused on the safety risks of

personnel working outdoors at airports (e.g., baggage handlers, food and fuel suppliers) and the impact on operational efficiency when thunderstorms are in the vicinity that may generate cloud-to-ground lightning strikes. In collaboration with airport stakeholders, we have been evaluating procedures in place and weather data sources used in the decision making. This task includes observations on-site with airport and airline stakeholders, and development of enhanced monitoring and nowcasting capabilities of lightning at airports. Findings so far from observations at a major airport suggest that there is substantial uncertainty associated with the decision-making process for ramp closures (i.e., pulling people inside for safety reasons) due to thunderstorms and lightning in close proximity of concourses/gates. This uncertainty is caused by the various sources of lightning information, differences in procedures applied by the various stakeholders, human cognition and behavior, and the way information is communicated (Figure 2).

Lightning-induced ramp closures, especially for prolonged duration or if multiple closures happen in succession, can exert notable impacts on traffic in/out of an airport (Figure 3) and potentially cause ripple effects through the national airspace system.

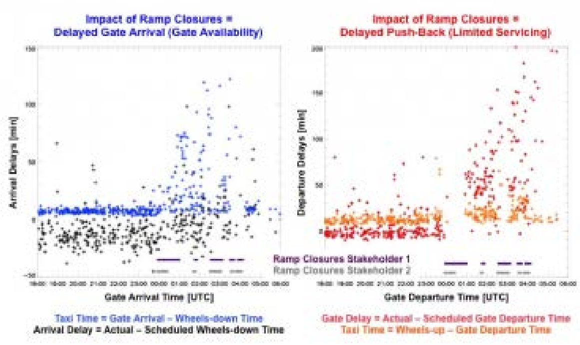

Figure 3. Observed impacts of ramp closures on air traffic arrivals (left) and departures (right).

Unexpected initiation of large-scale convective storms can have substantial impacts on air traffic. Using data mining approaches and ensemble forecasts, our research this past year has been geared toward early identification of areas prone to develop large-scale storms, including assessment of how well numerical weather prediction models capturie those storm initiation areas. Unfortunately, numerical weather prediction models continue to experience difficulty in grasping whether a storm should be initiated or not in a particular area and to how it will evolve, given the timing of initiation and whether the storm system remains organized long enough. We observed notable regional differences in model skill.

This substantial prediction uncertainty is reason for developing probabilistic convective storm guidance products using ensemble forecasts. Two probabilistic prediction efforts are underway, one focused on developing a probabilistic storm impacts product based on ensemble forecasts for the United States, while the other aims at mounting a probabilistic convection guidance product based on global ensemble forecasts for strategic transoceanic air traffic planning. Both these tasks include a close collaboration with the NWS Aviation Weather Center (AWC).

FY2014 PLANS

Research and development may continue toward improving the CoSPA forecast system, particularly focused on the calibration of model storm intensity, correction of model storm position errors and treatment of storm initiation in the blending algorithm. CoSPA forecasts will be provided again to aviation planners during the next convective summer season.

It is expected that new capabilities and products will be periodically demonstrated to users as technologies mature. An enhanced lightning nowcasting capability will be evaluated during the next year and field observations will be conducted at another major airport in a different climatic setting. Development of ensemble-based probabilistic storm impact predictions will continue for both domestic and international flight domains.

‹ InFlight, Ground and Engine Icing   up   Turbulence ›

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TURBULENCE

BACKGROUND

Turbulence encounters by general and commercial aviation pose significant safety and flight efficiency concerns. Almost anyone who has flown commercially has had an unpleasant experience with turbulence and has a tale to tell about it. In fact, turbulence encounters account for well over 75% of all weather-related injuries on commercial aircraft and amount to at least $200M annually in costs according to some estimates. Consequently, there is an urgent need to provide better turbulence information to pilots and route planners so that the number of encounters can be minimized, or at least provide adequate warnings so that passengers and crew can prepare for an expected encounter.

For more than fifteen years, a group of scientists and engineers at the National Center for Atmospheric Research's Research Application Laboratory (NCAR/RAL) has led efforts to address these needs. Working under the sponsorship of the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), theNational Oceanic and Atmospheric Administration (NOAA), and the Taiwan Civil Aeronautics Administration (CAA) and in collaboration withseveral universities and private companies, the team has conducted research aimed at improving our fundamental understanding of the nature and causes of turbulence and has developed new techniques for better observing and forecasting turbulence.

Efforts have been focused in four areas: (1) Development and implementation of new techniques for obtaining automated *in situ* reports of turbulence encounters from commercial aircraft; (2) development of an automated system for detecting in-cloud turbulence using Doppler weather radar data; (3) development and implementation of an automated turbulence diagnosis, nowcasting and forecasting system called Graphical Turbulence Guidance or GTG; and (4) high-resolution simulation studies of observed turbulence events to better characterize the nature and genesis of free atmosphere turbulence The products developed here have reached a level of maturity that allows them to be used operationally by pilots and route planners in tactical and strategic planning for avoiding turbulence or mitigating encounters. One important aspect of all products is that they provide an aircraft-independent measure of atmospheric turbulence known as the eddy dissipation rate or EDR ($m^{2/3}/s$).

AUTOMATED *IN SITU* MEASUREMENTS

Despite the continued reporting of the frequency and severity of turbulence encounters, our understanding of the nature and genesis of this complex atmospheric phenomenon remains limited. Research into the nature and causes of free atmosphere aviation-scale turbulence has been limited in part by a lack of reliable data. Verbal pilot reports (PIREPs) have typically been the only source of information about the location and severity of turbulence at flight levels. These reports are, unfortunately, incomplete (reporting is voluntary), and highly subjective (what one pilot views as "moderate" might be perceived as "light" or

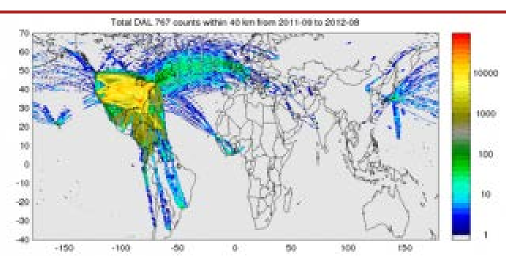

Figure 1. Tracks of several Delta Air Lines 767-300ER and 767-

400ER aircraft. The color scale is the frequency of occurrence along particular tracks.

"severe" by another). Further, recent investigations into the accuracy of PIREPs have indicated an average position error of about 50 km, or several grid points with current operational numerical weather prediction (NWP) model grid spacings. While NWP models are very useful in forecasting other atmospheric hazards, they are of limited value here given that turbulence exists for short periods of time and in small geographical areas. In order to improve the detection and forecasting of turbulence, it is clearly essential to upgrade the turbulence observation and reporting system and to create empirical means for obtaining more abundant, reliable data. In pursuit of this goal, we are in the process of augmenting, and eventually replacing, the PIREPs with *in situ* observations from selected commercial aircraft. These observations and dissemination of them are completely automated, and provide a measure of atmospheric turbulence intensity levels (EDR). The *in situ* EDR system consists of a simple software upgrade to the aircraft's ACMS (Aircraft Condition and Monitoring System), and no hardware changes are required.

FY2013 Accomplishments

Currently the *in situ* EDR software package is implemented on about 80 United Airlines (UAL) 757-200 aircraft, 90 Delta Air Lines (DAL) 737-700 and 737-800 aircraft, and 30 DAL 767 (-300ER and -400ER) aircraft. Importantly, some DAL aircraft provide measurements globally as indicated by the flight tracks shown in Fig. 1. This algorithm is expected to be implemented on other aircraft in the coming years. Commercial vendors are also beginning to provide automated *in situ* EDR estimates, and one work area this year was to develop EDR estimation standards to insure that all EDR estimation methods provide similar results, at least within the operational needs.

FY2014 Plans

We are currently in discussions with Southwest Airlines, Air France, British Airways, Lufthansa, and DAL to implement the algorithm on parts of their fleets

REMOTE SENSING MEASUREMENTS

In order to give pilots better information about potentially hazardous regions of turbulence in thunderstorms before they encounter them, RAL scientists developed the NEXRAD Turbulence Detection Algorithm (NTDA) to use ground-based Doppler radar data to remotely detect turbulence within clouds. The algorithm runs on data from each radar, processing each "tilt" or "sweep" independently to obtain estimates of eddy dissipation rate (EDR). The results are merged with measurements from other radars and mapped to chosen flight altitudes. The initial version of the NTDA was adopted by the National Weather Service and implemented on all of its radar systems in 2007 and 2008. Since then, a number of advancements have been made to the NTDA to increase its coverage, accuracy, speed and maintainability, and to accommodate NEXRAD changes like the adoption of dual-pol and the implementation of a new spectrum width estimator. Recently, the NTDA has been modified to run on radars in Taiwan, as well.

FY2013 Accomplishments

In 2013, the NTDA was modified to run in Taiwan on four Doppler weather radars, including three Gematronik radars and one NEXRAD. This new version of NTDA—called the NCAR Turbulence Detection Algorithm in Taiwan—required simulating the Gematronik signal processing and operational modes to update the NTDA's quality control procedures, along with adaptations for differences between the Gematronik and NEXRAD radars and their data. The NTDA processing and 3-D mosaic system was integrated into the prototype version of the Advanced Operational Aviation Weather System (AOAWS) that supports the Taiwan CAA (see Figure 2).

The NTDA-2.5 processing and mosaic system continued to run in real-time at NCAR RAL, using data from 133 NEXRADS to produce CONUS 3-D grids of in-cloud EDR every 5 minutes at a resolution of 2 km horizontally and 3,000 ft vertically.

NTDA data were used to analyze the development of turbulence inside thunderstorms and relate turbulence intensity and volume to the occurrence of lightning. The correlation between these quantities may be used in conjunction with future geostationary satellite lightning mapping data to help diagnose likely regions of turbulence in regions not served by Doppler radar.

FY2014 Plans

NTDA will continue to run as a real-time prototype over the CONUS, providing data used for the development of turbulence nowcast products and scientific investigations of the development of convective storms. It will be adapted as needed to accommodate changes to the NEXRAD radars. Additional testing and software modifications to the Taiwan

implementation will continue before the new version of the Taiwan AOAWS system becomes operational in late 2014.

NOWCASTING/FORECASTING TURBULENCE

RAL has been developing and testing aviation-scale turbulence forecast algorithms that provide forecasts out to 18 hours. These algorithms are based on operational NWP model output and are updated hourly. The version that is used over the Continental U. S. (CONUS) is termed the GTG (Graphical Turbulence Guidance product). It relies on the WRF RAP NWP model (http://rapidrefresh.noaa.gov/) output and provides what amounts to an ensemble weighted mean of various turbulence diagnostics output as EDR ($m^{2/3}$ /s) on designated flight levels. The output is available to interested users on NOAA's ADDS web site (http://www.aviationweather.gov/adds/). An example is shown in Fig. 3.

In addition to the GTG *forecast* system (forecasts updated hourly), we are currently developing a *nowcast* system, GTG-N, which will provide rapid (every 15 min) updates and makes heavy use of the latest available turbulence observations from the *in situ* EDR estimates, PIREPS, NTDA, and other sources (e.g., satellite-based inferences) on a GTG background. This will tremendously enhance pilot situational awareness, especially for turbulence associated with thunderstorms (convectively-induced turbulence or CIT). Special diagnostics (termed DCIT, Diagnose Convectively-Induce Turbulence) are being developed to predict areas of likely near-cloud turbulence. DCIT has been developed by using statistical learning techniques in conjunction with a large database of *in situ* EDR reports and collocated radar, satellite, lightning, and NWP model-derived data fields.

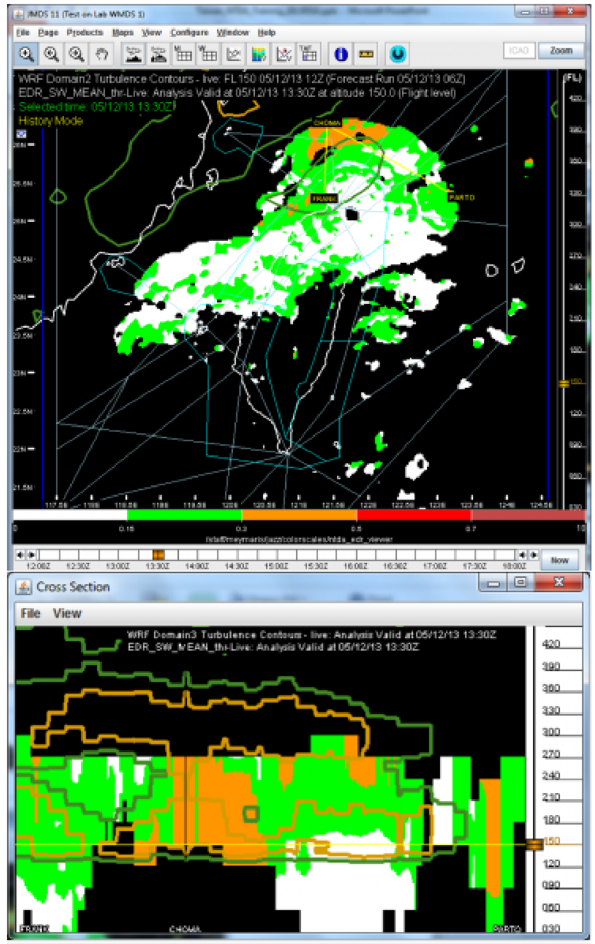

Figure 2. (Left) Plan view of Taiwan AOAWS NTDA EDR at 15,000 ft, 13:30 UTC on 5/12/13, with GTG/ITFA 6-hour forecast contours valid at 12:00 UTC overlaid. (Right) A cross-section view. NTDA complements the GTG forecast by supplying real-time, high-resolution detection of in-cloud turbulence.

FY2013 Accomplishments

The Graphical Turbulence Guidance version 2.5 (GTG2.5), which provides WRF RAP–based forecasts of turbulence, was developed and became "operational" on 1 May 2012 when the WRF-RAP replaced RUC at NCEP. In 2013 a major upgrade to the GTG product (GTG3) was prepared for release in mid 2014. The upgrades include (1) the inclusion of specific mountain-wave turbulence (MWT) predictive algorithms to better forecast this source of clear-air turbulence over the mountainous regions of the western U. S., (2) the prediction of turbulence at low levels, i.e., below 10,000 ft MSL (the current GTG2.5 version provides predictions only above 10,000 ft MSL), and (c) the inclusion of the GTG Nowcast component, which uses observations merged with short-term forecasts to provide EDR maps updated at 15 min intervals. Work was begun on an Alaska turbulence prediction system as well as a global forecast system.

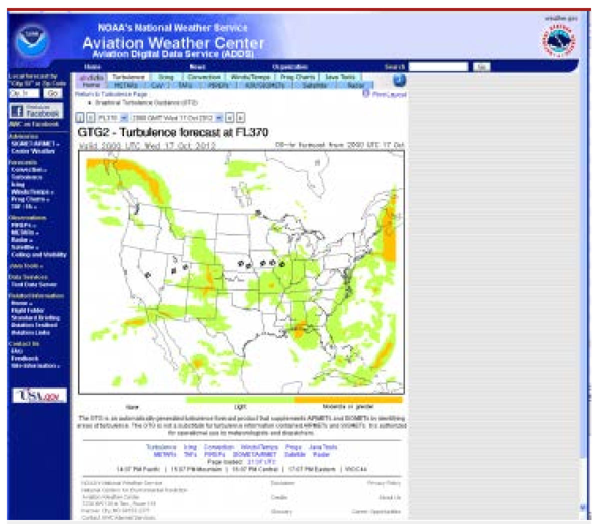

Figure 3. Example GTG2.5 output as it appears on NOAA's Experimental ADDS website.

FY2014 Plans

GTG3/GTGN will be independently evaluated by NOAA's GSD verification group. Provided the outcome of that is positive, GTG3 will replace the current GTG2.5 product on NOAA's ADDS website sometime in mid-2014. Continued test and evaluation of the Alaska and global products will continue. Research on developing algorithms for forecasting convectively-induced turbulence (CIT) will begin.

CHARACTERIZATION EFFORTS

Substantial effort has been invested in developing a better physical understanding of the mechanisms responsible for CIT and CAT with the long-term goal of providing better operational turbulence forecasts. These studies make use of high-resolution nested (WRF) numerical simulations that have outer computational domains large enough to capture the relevant large-scale processes and inner domains fine enough to capture the turbulence generating mechanisms. CIT cases in particular are difficult to pinpoint, partly because conventional observations (PIREPs) are too imprecise to locate the exact time and place of the occurrence. Thus the *in situ* EDR reports provide and important source for identifying turbulence events. An example is shown in Fig. 4, which shows tracks of *in situ* EDR reports superposed on satellite imagery. The red dots indicate near-cloud “severe” turbulence intensity reports which ostensibly occur in the clear air. Simulations of these events indicate that gravity (or buoyancy) waves play an important role in organizing and contributing to the generation of turbulence.

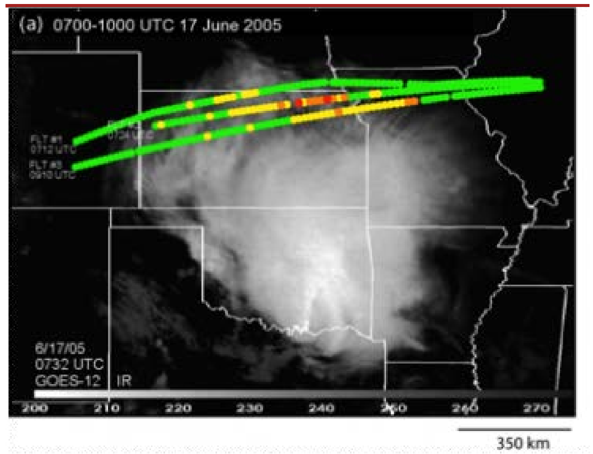

Figure 4. Examples of near-cloud turbulence as deduced from comparisons of satellite imagery to *in situ* EDR reports (dots). Color code for EDR reports is green, yellow, orange, red for smooth, light, moderate, and severe turbulence, respectively. Left panel is an example of above-cloud turbulence related to the banding in the satellite imagery. Right panel is an example of near-cloud turbulence which turned out to be related to gravity waves propagating horizontally away from the storm.

FY2013 Accomplishments

By careful examination of observations (PIREPs and *in situ* EDR reports) we have isolated several cases in which pilots experienced wave motion and turbulence, but in areas not close to mountains. The implication is that these events are related to gravity waves generated by other sources besides topography. Simulations of these events will be undertaken to isolate the cause of the turbulence.

Other cases were identified that are related to the presence of transverse bands similar to those in Fig. 4 but in cirrus associated with jet streams. High-resolution simulations of these events have been undertaken. In one case the bands seem to have a character very much like the case shown in Fig. 4, but in the other, different mechanisms seem to be at play.

FY2014 Plans

We will continue to isolate cases and resolve the turbulence sources. This will lead to a better understanding of turbulence in the free atmosphere which in turn should suggest improved forecasting strategies. Since this work is unique and original we anticipate several publications to be forthcoming on the results.

‹ Prediction of Storm Hazards for Aviation   up   Ceiling and Visibility Research and Development ›

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CEILING AND VISIBILITY RESEARCH AND DEVELOPMENT

BACKGROUND

Impacted ceiling and surface visibility (C&V) conditions represent a costly source of flow capacity reduction for air terminals servicing high-volume commercial traffic. Further, these conditions pose a major safety risk for general aviation (GA) operations and critical operational limitations for helicopter-based emergency medical services and off-shore oil production facilities. RAL's work toward automated real-time C&V diagnoses and probabilistic forecasts will help address the human-based decisions made in these applications today and will provide the quantitative forecast grids needed by the automated decision support systems that are critical to future operations under NextGen.

FY2013 ACCOMPLISHMENTS

C&V Analysis Product for Alaska

In past years, RAL has worked to develop a web-based CONUS C&V analysis product targeted to improve users' visualization of local and regional-scale ceiling and visibility conditions – a high priority for the general aviation and helicopter emergency medical service communities. That product was implemented for operational use in July of 2012. See http://www.aviationweather.gov/adds/cv/.

Late in FY2013 RAL initiated work toward a similar capability for Alaska, where complex terrain, long distances and heavy reliance upon small aircraft make impacted C&V conditions particularly hazardous to aviation operations. To ensure that our work best addresses the operational needs of the aviation community, RAL is closely partnering with the NWS Alaska Aviation Weather Unit.

The development is made especially challenging by sparse C&V observations and strong geographic influences on cloud and moisture fields. Accordingly, RAL's work will investigate three resources not used in the CONUS product: 1) the WRF Rapid Refresh model (to help fill data-void areas); 2) FAA weather cameras that provide real-time surveillance at over 216 sites); and 3) polar-orbiting satellite data from NOAA and NASA (to augment limited GOES coverage in the region). These data will augment the use of real-time METAR observations across the state. Data from weather camera sites is expected to play an important role in the product, but yields an image processing challenge in deriving useable meteorological information from real-time images.

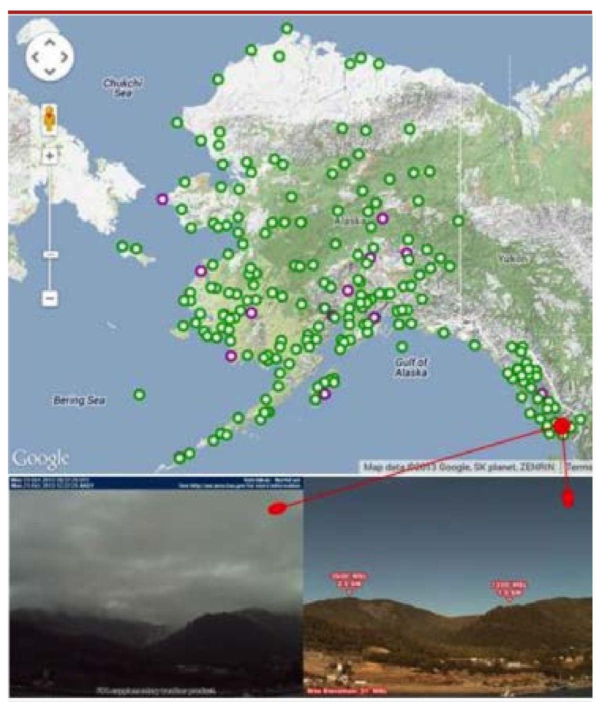

Figure 1: Top: Locations of FAA weather cameras reporting real-time images at 10 minute frequency. Lower Left: Image showing impacted conditions at Ketchikan in SE Alaska. Lower Right: A "control" image for comparison showing clear daytime conditions in

The weather camera image pair shown in Fig. 1 shows impacted vs. clear conditions in Ketchikan.

Ketchikan.

RAL C&V Forecast Method Builds on Current Forecast Skill

Under funding provided by FAA and NOAA, RAL is developing a 1-10 hr automated C&V forecast system for hourly production of both probabilistic and deterministic (yes/no) forecasts for CONUS airports. Our approach seeks to make best practical use of existing operational forecast resources such as NOAA's Localized Aviation MOS Program (LAMP) and the WRF Rapid Refresh model (RAP). Both resources show forecast skill for C&V, but neither utilizes the skill of the other to boost performance. Thus, they serve today as separate and unrelated guidance sources for aviation weather forecasters.

RAL's approach seeks to bridge LAMP and RAP through a unique blending method, yielding a net gain in forecast skill over either resource taken alone. By embedding RAL's resource blending approach within the current operational production cycle for hourly LAMP forecasts, the improved forecasts would be distributed across the existing NOAA network as an improved LAMP product, without need for costly new data streams or forecaster visualization tools. Our work toward this forecast approach proceeds in partnership with LAMP and RAP developers and is yielding improved forecast skill in prototype tests. One important finding is outlined below:

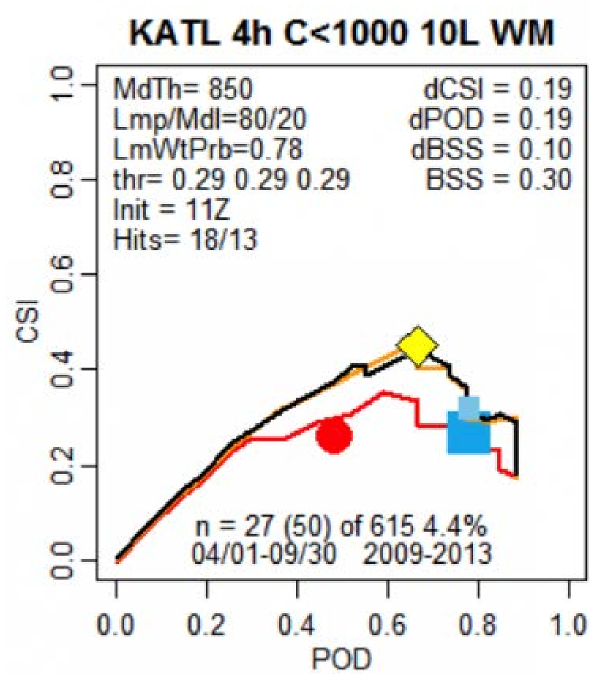

Figure 2: Validation results comparing the skill of 4hr forecasts for ceiling less than 1000 ft above ground level in Atlanta. Critical success index (CSI) is shown by the Y axis, probability of detection (POD) by the X axis. Higher values of CSI and POD are desired. LAMP deterministic forecast skill is shown by the red dot, corresponding RAP model skill by the light blue square, and RAL algorithm skill by the yellow diamond. These results cover the warm season (April thru Sept) over the period 2009 through 2013. In this case, the RAL algorithm yields a significant increase in skill over LAMP and RAP forecasts.

FY2014 PLANS

C&V Analysis Product for Alaska

Development work will address use of model data to provide information in data-sparse areas, first-generation usage of polar orbiting satellite data, and a first look at methods to derive meaningful information from weather camera data. We plan to have a first-generation analysis algorithm in place for demonstration by the end of the year.

C&V Forecasting Algorithm

NCAR will aid NOAA's Model Development Laboratory as they carry out an independent verification of RAL's forecast algorithm performance. Following this evaluation, we expect to work with NOAA to 1) assess the feasibility of implementing the algorithm operationally; and 2) form a plan and timeline for operational implementation.

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INTEGRATION OF WEATHER INFORMATION INTO AIR TRAFFIC MANAGEMENT DECISIONS FOR REDUCED WEATHER IMPACT

BACKGROUND

Since weather conditions can seriously restrict aircraft operations and levels of service available to system users, the manner in which weather is observed, forecast, disseminated, and used in making air traffic management (ATM) decisions is of critical importance to the operation of the United States' National Airspace System (NAS). As the United States moves toward significantly increasing the capacity of the NAS through implementation of the Next Generation Air Transportation System (NextGen), integrating weather information (and associated uncertainty) into ATM decision-making processes is critical. RAL has been a significant contributor to this effort of developing advanced concepts of weather translation and integration.

METHODOLOGIES FOR ESTIMATING PROBABILISTIC WEATHER-RELATED IMPACTS ON AVIATION

Daily ATM planning utilizes weather predictions with forecast horizon of 12 hours and longer for high-impact weather systems, such as hurricanes and winter storms, particularly for transoceanic flights. Strategic ATM planners look for detailed information about weather systems, including storm structure, intensity, organization, location and timing, and associated forecast uncertainty.

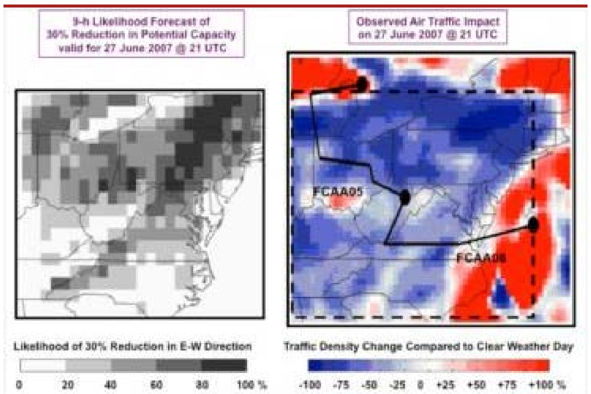

Figure 1. Prediction of likelihood to encounter a 30% reduction in potential capacity (left) and observed traffic impact on 27 June 2007 at 21 UTC (right).

RAL has been developing advanced concepts of using ensemble model forecasts to create probabilistic weather-related impact predictions for use today by ATM planners and for future incorporation into largely automated decision support tools. One novel approach that was developed under NASA sponsorship utilizes storm characteristics (e.g., intensity and depth) and observed pilot behavior to deviate around storms to create a convective weather avoidance field (a technique developed by MIT Lincoln Laboratory), which subsequently is subjected to Metron's MinCut technique (a method to compute flow bottlenecks) that determines an expected capacity reduction due to the presence of storms. These procedures are applied to every ensemble forecast member in order to generate a probability distribution of potential capacity reduction for each spatial domain of interest (e.g., sectors or centers) that can be visualized as likelihood to loose a certain fraction of available airspace due to the presence of hazardous weather (Figure 1). This approach was presented by Steiner et al. (*Air Traffic Control Quarterly*, 2010).

FY2013 Accomplishments

During the summer of 2013 the 10-member ensemble forecasts generated by the Air Force Weather Agency (AFWA) have been accessed in real time and subjected to the capacity reduction estimation procedure outlined above. The resulting

likelihood forecasts of losing a fraction of the potentially available capacity (Figure 2) have been sent to the NWS Aviation Weather Center (AWC) for use as a first guess convective storm impact prediction utilized during the Aviation Weather Testbed exercises.

FY2014 Plans

The likelihood predictions of potential capacity reductions based on using the AFWA ensemble forecasts will continue and be made available again to the AWC Aviation Weather Testbed next summer as first-guess impact predictions for development of the daily Aviation Weather Statements. Significant effort will be devoted to the calibration of these capacity reduction predictions.

We will continue to use ensemble-based approaches to provide improved guidance for convective weather hazards for transoceanic flights. This effort considers exploring the concept described above to highlight potential capacity impacts due to convective storms in oceanic airspace.

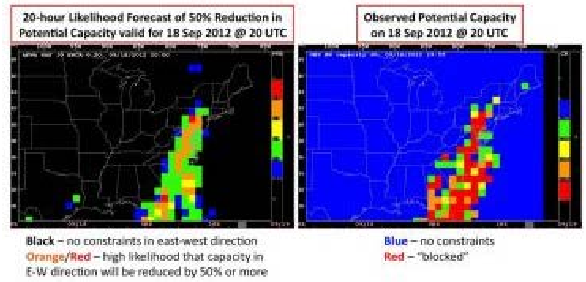

Figure 2. Prediction of likelihood to encounter a 50% reduction in potential capacity (left) and observed potential capacity on 18 September 2012 at 20 UTC (right).

ATM – WEATHER INTEGRATION PLANNING

Version 3.2 of the NextGen Concept of Operations (2011) provides an overall, integrated view of NextGen operations from the present through 2025 and beyond, including key transformations from today's operations. It serves as a steering vision for the ultimate form of the NextGen end state, guiding the latest version of the NextGen Implementation Plan released in April 2013. RAL's foundational research and transition of aviation-specific weather continues to impact planning for performance-based measures that make NextGen work—i.e., navigation, collaboration, reduced horizontal and vertical separation, traffic flow management, terminal efficiencies such as low visibility operations at airports, and separation management. RAL has taken the initiative to lead part of the effort to consolidate promising tools and methods that have potential for translation of weather constraints into ATM impact; integration into NextGen systemic representations; evaluation for system performance and feedback; and simulation of traffic flows in the presence of weather constraints for cost-benefit analyses of alternative solutions. This effort focuses on near-term R&D needed for IOC while ensuring these early steps are consistent with mid-term NextGen implementation goals. It also assures input plus feedback into the aviation weather R&D being defined for the FAA's Aviation Weather Research Program (AWRP) and Reduce Weather Impact (RWI) programs, both part of the FAA's Aviation Weather Division.

FY2013 Accomplishments

RAL's accomplishments fall into three areas: The AWRP, the Weather Technology in the Cockpit (WTIC) Program, and the Common Support Services–Weather (CSS-Wx) Program. Many of the accomplishments have been in the standards and performance-based metrics definition—through the RTCA, SAE, and various international data format, management, and communications bodies (weather data exchange model definition, WXXM). The AWRP continues to showcase RAL technology transition expertise through internet dissemination via systems such as Aviation Digital Data Service (ADDS, Experimental and Operational).

The growing WTIC program in RAL had many significant accomplishments. In 2013, the RTCA Special Committee 206 published two new documents—the revised "Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (AUTOMET)" (DO-252); and the AIS and MET Delivery Architecture Recommendations for weather data downlink and crosslink. RAL is a charter member of this body, interfacing with academia, industry, and government while significantly contributing to the preparation and review of these guidance documents. RAL also led the FAA Mobile MET program that defined a concept of use and infrastructure for portable device dissemination of aviation weather. This program is a multi-year effort that will eventually prototype a weather dissemination tool for mobile devices that might be used to further explore pilot and controller needs. In 2012, RAL led a significant simulation study of the use and display of oceanic weather information in the FAA William J. Hughes Technical Center (WJHTC) Research Cockpit Simulator in Atlantic City (Figure 3). The FAA Technical Report documenting results of the simulation was published in FY13. This effort will lead to further oceanic weather R&D with uplink of information to actual passenger flights (Figure 4). RAL also contributed to an SAE Aerospace Recommended Practice document on cockpit display of data linked weather information. This document is the result of over three years of collaborative effort with industry, government, and RAL participation. The symbology defined here will form the basis of cockpit weather displays in the near- and far-term (out to 2025).

Finally, the RAL-led NNEW program transitioned to a procurement action for the FAA and assumed a new moniker, the Common Support Services – Weather (CSS–Wx) Program. RAL continues its interface with the JPDO and other government-industry fora to update JPDO planning on an annual basis.

FY2014 Plans

Future integration planning and implementation for the mid-term NextGen vision will require meaningful collaboration with recognized leaders in national airspace system performance and flow constraint impact. RAL is pursuing joint efforts with the Mitre Center for Advanced Aviation System Development (CAASD) and industry that will potentially conduct laboratory evaluations of one or more weather translation-to-impact capabilities, integrated with prototype ATM decisions support tools. Other initiatives through FAA sponsorship will explore first-order integration of weather information to support decision making on the flight deck as well as collaboration with air traffic managers and controllers. We will document the results of the investigated translation capability algorithms and of the integration of the information into ATM decisions support algorithms, in the context of the NextGen mid-term vision contained in the NextGen Implementation Plan.

Figure 3. A photo of the RCS during the simulation. Airbus A-320/330 flight deck.

ATM – WEATHER INTEGRATION ACTIVITIES WITHIN NOAA

Under an Aviation Weather Cooperative Agreement (AWCA) with NOAA, RAL continues to facilitate collaborative work on weather integration and to transition that work from research to operations across federal agency lines for NextGen interim capabilities. The collaborative effort in FY13 has been defined in general terms to include turbulence, ceiling and visibility, and in-flight icing with a specific focus on developing and using human-over-the-loop (HOTL) forecast techniques.

FY2013 Accomplishments

For in-flight icing: Activities centered on advances surrounding the Interactive Correction in 4 Dimensions (IC4D) system. IC4D runs on a workstation at NCAR and is monitored to ensure it is operating properly and that the output looks correct. We update the system as needed to keep in pace with that being used at AAWU. Additionally, work has continued to improve the Forecast Icing Product (FIP), the output of which is input into IC4D for analysis and adjustment.

For turbulence: Accomplishments included support activities for the development and testing of a global turbulence forecast product based on the CONUS GTG for eventual WAFC implementation, and publication of a collaborative article for Geophysical Research Letters which reviewed the state-of-the-art understanding of the nature and sources of atmospheric turbulence for aviation.

For ceiling and visibility: R&D was directed toward forecast methods that could be used in an automated ceiling and visibility forecast system (CVF), including work focused on development of a self-adjusting method to determine optimal probability thresholds needed to derive deterministic forecasts from probabilistic forecast data. The advantage of such an algorithm will be its ability to self-adjust to accommodate seasonal and year-to-year variability. Better thresholds are expected to yield better deterministic forecasts.

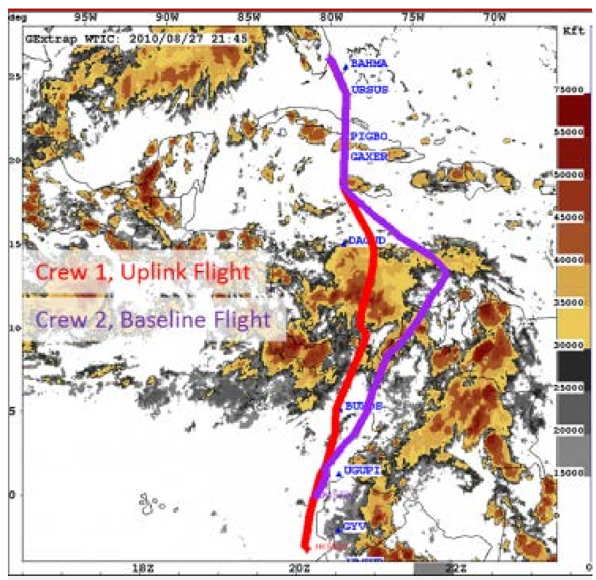

Figure 4. Graphical depiction of the GOES-East derived cloud top heights (30Kft and 40Kft contours) from 27 Aug 2010. Crew 1 (uplink) and Crew 2 (baseline) flight tracks for the entire route are shown. This shows the flight route efficiency gained through uplink/update of strategic oceanic weather information.

FY2014 Plans

The NOAA Aviation Weather Cooperative Agreement will continue to facilitate limited collaboration between RAL and the NWS with its focus on HOTL, and within the general framework described above.

ATM/WEATHER INTEGRATION OUTREACH ACTIVITIES

RAL participated in many of the outreach venues available to further weather R&D, harmonization, and integration into ATM decision support tools. Notable events included new technology workshops sponsored by the FAA, NASA, and the Air

Traffic Control Association (ATCA).

FY2013 Accomplishments

Presentations that were specifically focused on the weather integration problem were given by RAL staff at the FAA/NASA/ATCA New Technologies Workshop in Atlantic City, NJ in May 2013, and the AMS ARAM Conference in January 2013. RAL also participated in FAA and industry advisory committees such as the RTCA, SAE G-10 (weather displays on the flight deck), and the Friends and Partners of Aviation Weather (FPAW). We provided expertise on weather technologies as well as received feedback from industry and government on how we are meeting respective user needs.

FY2014 Plans

RAL will participate in the 2014 ATCA/NASA/FAA New Technologies Workshop and the ATCA Annual Meeting, as well as continue to play a critical role in RTCA and SAE for a. RAL will continue to participate in as many team partnerships as feasible to ensure and support a comprehensive transfer of our technology to NextGen implementation plans.

‹ Ceiling and Visibility Research and Development up Dissemination of Aviation Weather Information ›

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DISSEMINATION OF AVIATION WEATHER INFORMATION

BACKGROUND

The Next Generation Air Transportation System (NextGen) is now taking shape on the design boards of several federal agencies. NextGen has been parsed into several components, each with its own associated R&D and acquisition effort. One such effort is dedicated to developing the weather information needs of NextGen and providing common weather-related decision information to all stakeholders within the system. The NextGen System is a national priority to meet the expanding air transportation needs of the U.S. in the 21st century. Since weather conditions can seriously restrict aircraft operations and levels of service available to system users, the manner by which weather is observed, forecast, disseminated, and used in decision–making is of critical importance.

RAL's activity in dissemination of aviation weather information is concentrated in three areas:

1. Common Support Services – Weather (CSS-Wx), developing next generation technology and infrastructure for dissemination of weather data to US Government and other users;
2. Aviation Digital Data Service (ADDS), delivering weather data and support services to the aviation community using the Internet; and
3. Weather Technology in the Cockpit (WTIC), developing methods for making the best weather information available to pilots for decision-making in the cockpit.

COMMON SUPPORT SERVICES – WEATHER (CSS-WX) PROGRAM

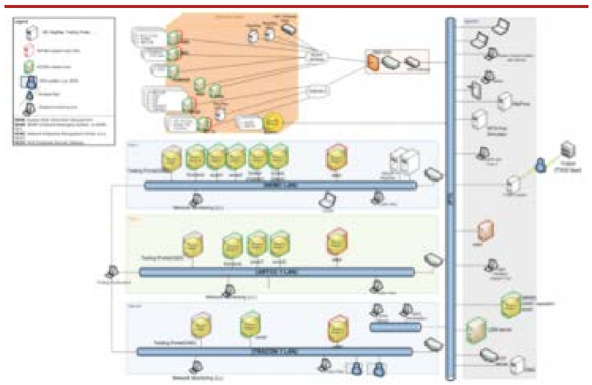

Figure 1. Diagram of Capability Evaluation with tiered data distribution.

For the past few years RAL has been engaged in developing standards and technology for the NextGen Network Enabled Weather (NNEW) Program. NNEW has been the FAA portion of a joint program with NOAA to develop next generation technology and infrastructure for dissemination of weather data to US government and other users. NNEW's goal has been to enable ubiquitous access to aviation weather data anywhere an appropriate network connection is available. NNEW has transitioned into the FAA's acquisition process, and become part of a larger related program called Common Support Services, and has been renamed CSS-Wx.

CSS-Wx achieves its goal by using a service-oriented architecture (SOA) approach in which existing Internet technology is leveraged to build weather data directory and delivery services that conform to international standards. CSS-Wx is combining a data directory service using OASIS ebXML Registry/Repository (Reg/Rep) standards with data servers based on the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards. Using these technologies, it is possible to build complex, dynamic weather systems in which data sources and

clients can be developed and modified independently but remain compatible while optimizing data latency and network bandwidth. RAL's participation in this program is sponsored by the FAA CSS-Wx Program Office and work is conducted collaboratively with the FAA's William J. Hughes Technical Center, MIT/Lincoln Laboratories, the MITRE Corporation, and NOAA.

FY2013 Accomplishments

In FY2013, RAL updated the WCSRI capabilities to address needs identified by a FAA program that is acting as a pre-production user of the weather data dissemination technologies of NextGen. RAL also assisted the FAA in refining technical materials for a Request for Proposal for a commercially provided CSS-Wx system. In addition, RAL acted as the FAA's technical expert and worked with experts from the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO) to establish new XML based weather data standards

FY2014 Plans

The focus for FY14 is supporting the FAA's acquisition process for CSS-Wx, including the completion of the various components of the Reference Implementation to be provided to the successful vendor as a basis for their development. RAL will also continue its work on XML based weather data standards in concert with ICAO and the WMO.

AVIATION DIGITAL DATA SERVICE (ADDS) PROGRAM

ADDS is a dissemination program that uses web pages to distribute aviation weather data. There are two instances of ADDS web pages: Experimental ADDS which is run at NCAR and Operational ADDS which runs at the NWS Aviation Weather Center in Kansas City. RAL uses Experimental ADDS to expose new prototype weather products to aviation users and gather feedback on the products' utility. Operational ADDS provides weather products that have been through the full review and approval process for operational use in aviation.

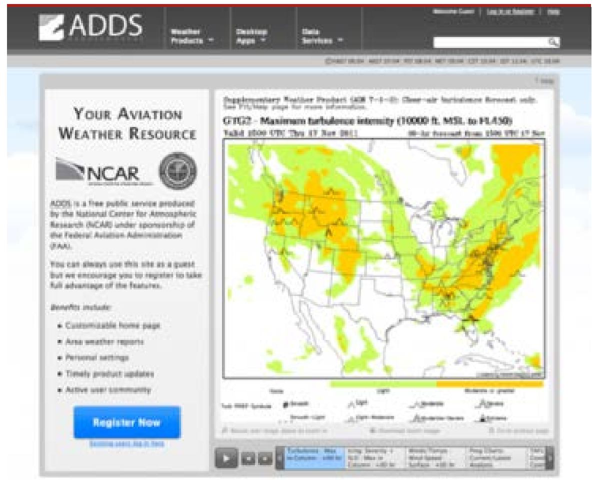

Figure 2. The Experimental ADDS Web site.

FY2013 Accomplishments

In FY2013 ADDS continued to provide critical weather information to a broad cross-section of the aviation community, 24 hours a day, 7 days a week. NCAR's ADDS web site delivered real time aviation weather information to 500,000 different users every month.

FY2014 Plans

In FY2014, RAL will continue to serve the needs of the aviation community by providing the latest weather information.. In addition to on-going, routine activities in support of the system, a phased convergence effort will bring experimental and operational ADDS into closer alignment in order to make the transition of new capabilities more efficient.

WEATHER DISSEMINATION TO THE FLIGHT DECK - WEATHER TECHNOLOGY IN THE COCKPIT (WTIC) PROGRAM

One of the programs led by the FAA's Aviation Weather Office (AWO) is Weather Technology in the Cockpit (WTIC). RAL took the initiative several years ago to create a government and industry consensus document that became an initial version of the WTIC Concept of Operations. The WTIC Program Office now uses this document to build the NextGen WTIC Program, one of the legs of the future Air Traffic Control (ATC) system's collaborative triad (the others being ATC/ATM and airline dispatch or flight operations control). Throughout 2012, RAL was a working member of two joint industry/government committees under the auspices of the RTCA and SAE G–10 that are chartered to establish data link and cockpit weather display standards and requirements for NextGen. European consensus through Eurocae and Eurocontrol is a prime focus for these efforts as plenary meetings alternate between Europe and the USA and include high–level representatives from the European FLYSAFE and SESAR programs.

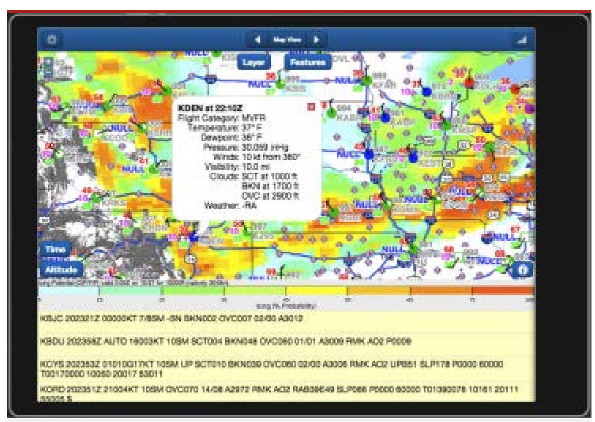

Figure 3. WTIC MobileMet Application Prototype screen

Certain SAE and RTCA/Eurocae document development efforts will continue through 2014. The goal of these joint working committees is to ensure that these capabilities are harmonized between North America and the European Union and to

promote the use of standard weather information on all aircraft flying between the two continents. In a new WTIC effort started in 2012, RAL is studying the requirements and technologies that would enable pilots to gain the advantages inherent in the rapidly emerging world of mobile technologies, including both tablets and phones.

FY2013 Accomplishments

- RAL continued to be a lead participant in the WTIC Concept of Operations and weather requirements/specifications development associated with uplink and downlink of weather data and information. This included RAL participation on two RTCA committees in addition to the SC206, relating to uplink, downlink, and crosslink of meteorological information supporting the new capabilities contained in the NextGen vision.
- In a new WTIC effort referred to as MobileMet, RAL provided a comprehensive technology assessment of mobile devices for use in delivery of weather information to the cockpit. RAL also conducted a broad survey of the needs and expectations of users in relation to mobile devices for aviation weather delivery. In addition, RAL developed and delivered prototype application based on the user needs survey.

FY2014 Plans

- Continue support of national and international activities to develop standards for cockpit dissemination and use of weather information.
- Support a formal FAA user evaluation of MobileMet prototype application and add further capabilities to the application.

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OCEANIC WEATHER

BACKGROUND

The Next Generation Air Transportation System (NextGen) is a national priority to meet the air transportation needs of the U.S. in the 21st century – in particular, a significant growth in demand for air traffic services, possibly on the order of three times today's demand levels. Since weather conditions can seriously restrict aircraft operations and levels of service available to system users, the manner by which weather is observed, forecast, disseminated, and used in decision-making is of critical importance. Aviation users operating within oceanic and remote regions have limited access to high-resolution (temporal and spatial) weather products that depict the current and future locations of deep convection and turbulence.

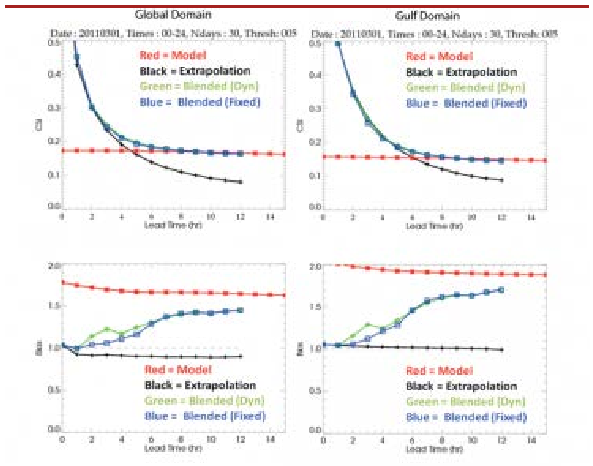

Figure 1. Critical Success Index (CSI) and bias of global domain (left column) and Gulf of Mexico domain (right column) for GFS model (red), extrapolation (black), dynamical blending (green) and fixed weight blending (blue) rain rate forecast based on one month of data (March 2011). The rain rate threshold is 0.5 mm/hour.

To address these needs, RAL scientists have been developing weather products related to the oceanic/remote occurrence of deep convection and turbulence from clear air (CAT) and convectively-induced (CIT) sources. For convection, the Oceanic Convection Diagnosis and Nowcasting system has been under development for the past several years to detect and forecast deep convection using satellite-based methodologies in combination with numerical model results. These methods have been implemented both regionally (i.e., the Gulf of Mexico/Caribbean area), as well as globally. Another effort, the Storm Forecasting Project, blends numerical weather prediction results with observations to produce extrapolation forecasts from 1 – 12 hours of the rain rate and the cloud top height. For turbulence, a methodology developed for the continental U.S. (CONUS) Graphical Turbulence Guidance (GTG) and GTG Nowcast (GTG-N) products is being extended to produce estimates of CAT and CIT over a global domain. A new investigation into the utility of global ensemble forecasts to provide probabilistic guidance for convective storms is underway. Accomplishments and plans related to the ongoing convection and turbulence weather products are discussed below.

STORM FORECASTING PROJECT

This feasibility study produced 0 – 12 hour blended convective forecasts over the Gulf of Mexico and global domains to be used for aviation planning and situational awareness. Blended forecasts of extrapolated satellite data (rain rate) and Numerical Weather Prediction (NWP) results were created. Collaborators in this effort include the Naval Research Laboratory-Monterey and the Northern Gulf Institute. This project ended in FY2013.

FY2013 Accomplishments

Seamless, blended 0 – 12 hour forecasts were created for satellite-derived rain rate data and Global Forecasting System (GFS) NWP results using two methodologies: "fixed weights" and "dynamical weights". In the fixed weight scheme, a simple weighted average of the two forecasts, based on prior performance scores, was used to create the blended forecast. In the dynamical weighting scheme, weights were calculated according to the most recent performance scores and could change daily and/or regionally. Using data from March 2011, validation results compared extrapolation method, model results, and blended forecasts for rain rate thresholds of 0.5 mm/hour and 2.0 mm/hour and were applied over a greater Gulf of Mexico domain and over a global domain. Both domains showed similar performance. The dynamical weighting scheme resulted in a slight performance improvement over fixed weights in the 2 – 6 hour lead times. The bias suggested blending forecasts are over-forecasting.

The same processes used for rain rate field were also applied to the cloud top height field. However, careful evaluation of the GFS convective cloud top height versus NRL satellite-derived cloud top height revealed large discrepancies between them that disallowed an acceptable blended forecast.

GLOBAL TURBULENCE

Under funding from a NASA grant, the GTG algorithm and software developed for use in CONUS airspace under the FAA Aviation Weather Research Program was adapted to utilize GFS model data and create turbulence forecasts for use in global turbulence decision support. Additionally, satellite-based diagnostics and convective nowcasts were collected and analyzed as first steps toward developing a global turbulence nowcast capability.

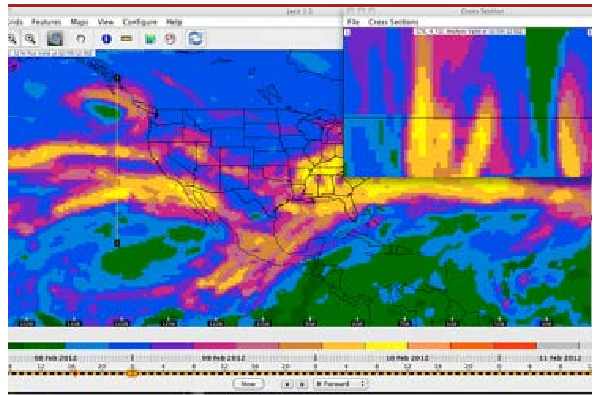

Figure 2 . Prototype Global GTG 12-hour forecast valid 9 February 2012 00 UTC, displayed via a web-accessible Java display tool. A vertical cross-section along the north-south transect depicted in the western Pacific appears in a separate window and is overlaid in the upper right.

FY2013 Accomplishments

The global GTG prototype developed in FY2012 continued to run in real-time, and its global 0 – 48 hour gridded turbulence forecasts were provided to the Aviation Weather Center for evaluation (Figure 2). The GTG software was modified to run on data from the ECMWF and UK Met Office global NWP models, and RAL personnel attended the World Area Forecast Center (WAFC) coordination meeting to plan future contributions.

FY2014 Plans

With funding from NOAA and the FAA, work in FY2014 will be directed toward harmonization of the global turbulence forecasts produced by the Washington and London WAFCs via development of a version of GTG that uses both the GFS and UK Met Office models, as well as development of a global GTG-N product that fuses NWP and satellite-derived turbulence diagnostics. The resulting turbulence nowcasts and forecasts will address clear-air, mountain-wave and convectively-induced turbulence sources in a unified fashion for global aviation users, providing a replacement of the current World Area Forecast System (WAFS) gridded turbulence product, which is comprised of only the Ellrod Index. RAL will continue collaborating with NOAA and UK Met Office personnel to facilitate the further development and ultimate transition to operations of this technology.

PROBABILISTIC GUIDANCE OF CONVECTIVE HAZARDS

Prediction of convective storms into the future is burdened with significant uncertainty. Use of ensemble forecasts is one way of trying to characterize forecast uncertainty. A recently initiated effort aims to develop a forecast product that provides probabilistic guidance on convective storm hazards for transoceanic flights with lead times of 24 – 36 hours. This product is based on a methodology that utilizes global ensemble forecasts and extracts relevant information to identify convective storm hazards.

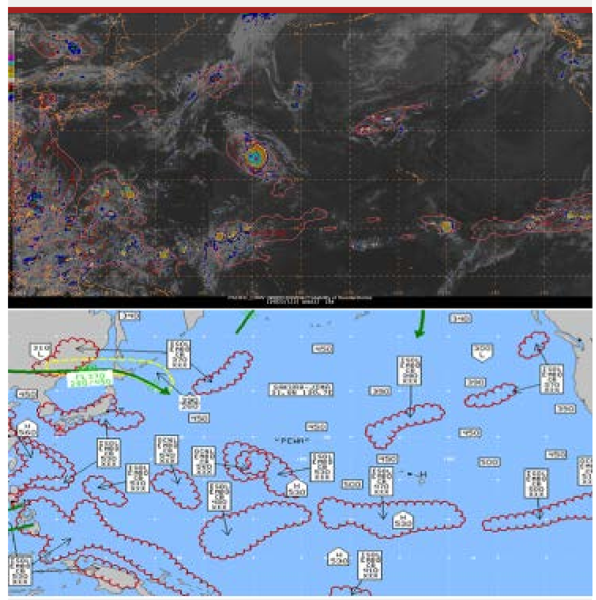

Figure 3. Thirty-hour probabilistic guidance of convective storm hazards valid at 12 UTC on 22 August 2013 (shown are the 20%, 40%, and 60% likelihood contours), overlaid on GOES 13 infrared imagery. The bottom panel shows the corresponding SIGWX Chart.

FY2013 Accomplishments

Efforts during this past year have focused on the development of an initial methodology to characterize oceanic convection based on global ensemble forecasts, and the computational infrastructure for a prototype was set up. The current version 1 utilizes global ensemble forecasts from the United States and Canada's numerical prediction centers, although ensemble data from additional centers are being explored in an offline mode. We are currently using model-predicted precipitation as a proxy for convective storms, and early assessment has been based on CMORPH data. The initial domain is focused on the northern Pacific, with domain expansions to follow with future upgrades. Significant effort is going into development of a "truth field" based on satellite and global lightning data to enable assessment and calibration of the probabilistic guidance on convective storm hazards. The truth field development is largely based on previous NASA-funded efforts for the detection and nowcasting of oceanic convection that can be viewed at http://www.rap.ucar.edu/projects/ocn/realtime_sys.

Since earlier this summer, the NWS Aviation Weather Center (AWC) is receiving version 1 products generated by our prototype system and they have been evaluated as part of the Aviation Weather Testbed (Figure 3).

FY2014 Plans

During the coming year, the prototype capability will be further enhanced based on performance assessment and feedback received from AWC forecasters. In addition, we aim to achieve a good version of the truth field as well, as the performance assessment hinges on that. The collaboration with AWC will continue, as we enhance this product and expand the domain.

‹ Dissemination of Aviation Weather Information   up   New and Emerging Applications ›

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Identify, explore, develop and implement advanced weather decision support systems for new and emerging user sectors.

- Surface Transportation Weather
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- Weather Prediction Statistical Optimization
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SURFACE TRANSPORTATION WEATHER

BACKGROUND

RAL is a key contributor to the research and development of the weather component of the Federal Highway Administration's wireless Connected Vehicle program. RAL also continues to support the adoption of the winter Maintenance Decision Support System (MDSS) technology across the nation.

In the coming year, RAL will continue to expand efforts by developing transportation decision support systems focusing on traffic, incident, and emergency management and maintenance beyond snow and ice control by seamlessly blending the strategic prediction components of the system with tactical short-term weather and road condition technologies.

FY2013 ACCOMPLISHMENTS

Pikalert™ Vehicle Data Translator

Figure 1. Schematic of the connected vehicle concept.

The Connected Vehicle program has three main goals: to increase safety, mobility, and environmental efficiency. This program will ultimately provide vehicle probe data (including weather data) from millions of vehicles that will be available to the weather community to support the diagnosis and short-term prediction of weather and road conditions (Figure 1). With funding and support from the USDOT Research and Innovative Technology Administration (RITA) and direction from the Federal Highway Administration's (FHWA) Road Weather Management Program, RAL conducted research in FY13 to continue development of the prototype Pikalert Vehicle Data Translator (VDT). The VDT incorporates vehicle-based measurements of the road and surrounding atmosphere with other, more traditional weather data sources, and creates road and atmospheric hazard products for a variety of users. Analysis in FY13 focused on two key areas: creating the Pikalert Enhanced Maintenance and Decision Support System (EMDSS) which incorporates Connected Vehicle technology into the MDSS, and developing the Pikalert Motorist Advisory and Warning (MAW) System which provides hyper-local and rapid-update road weather warnings to the travelling public. These two applications were developed in FY13 and will be evaluated in the states of Minnesota, Michigan, and Nevada in the coming winter.

The Pikalert EMDSS represents the latest innovation in snow control. Building on years of MDSS development, the Pikalert EMDSS incorporates Connected Vehicle data into the forecast and decision process. As a result, end users can obtain information along the entire stretch of roadway, and not just at Road Weather Information System (RWIS) sites. This enables maintenance providers to better monitor and react to changing road conditions. They will be better equipped to make spot treatments on the road, improving safety, mobility, and reducing the environmental impact of de-icing chemical.

The Pikalert MAW is a revolutionary approach to providing hyper-local, near real-time road weather information for the travelling public. Incorporating Connected Vehicle data, the MAW provides current inferences for visibility, road condition, and road precipitation. It also blends the Connected Vehicle data with a forecast engine to provide 24-hour forecasts of road weather conditions. Using the MAW, drivers will be able to plan routes in advance of their travel, including knowing which way to go and whether to delay travel. While on the road, a phone application keeps drivers abreast of changing road weather conditions.

Maintenance Decision Support System (MDSS)

The federal prototype MDSS was deployed over the State of Alaska in order to further some much needed road weather research in a high-latitude and extreme-cold region of the world. Along with a deployment of the MDSS, Connected Vehicle research is also being performed with 20 Alaska Department of Transportation vehicles equipped with weather instrumentation. Also unique to this project is research that involves gridding the pavement temperature forecast. Alaska is a perfect candidate for this research because so much of the state has no road weather observations. The gridded forecast, which is being spun-up using the NWS National Digital Forecast Database, enables the state maintenance agencies to access road weather forecasts in extremely remote areas of the state. An expanded Connected Vehicle network is likely in the near future that will enable these remote areas to actually be observed using public and private vehicles.

The MDSS project at Denver International Airport (DIA) continued in FY13 and is now an important tool for the ground operations personnel at DIA. Research on improving the very short-term forecast and treatment recommendations will be conducted in the coming year. The MDSS system will also be ported to a web-based environment (as opposed to the present Java-based) in FY2014. This will enable the DIA staff to access the MDSS through their personal computer and their tablets and cellular phones. This capability is being leveraged through the interface work that was performed for Alaska during FY13.

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RENEWABLE ENERGY

BACKGROUND

Since 2009 RAL has collaborated with university researchers, DOE labs, commercial partners, and other NCAR entities to develop methods to more accurately analyze and predict wind power in support of the renewable energy industry. Projects have focused on resource assessment, analysis of the interaction between atmosphere and operating wind turbines, and real time forecasting to improve operations and economics of incorporating wind energy into the power mix, and characterization and quantification of variability in wind energy. While initial research and development efforts focused on wind energy applications recently these have been extended to solar energy.

FY2013 ACCOMPLISHMENTS

Xcel Energy Variable Energy Forecasting System Project

In FY2013, RAL commenced a two-year collaborative project with Xcel Energy Services, Inc. with the goal to extend existing wind power forecasting capability developed in the previous phase of the collaborative effort. The wind prediction technology summarized in Figure 1 helps operators make critical decisions about powering down traditional coal- and natural gas–powered plants when sufficient winds are predicted, enabling increased reliance on alternative energy while still meeting the needs of customers. Utilization of the initial day-ahead forecasting system resulted in significant savings for the utility and the rate payer (Mahoney et al. 2012, Haupt et al. 2013). NCAR is now extending these capabilities to address a wide range of forecasting needs related to efficient wind power integration: enhancing the short-term forecasting for energy dispatching and forecasting extreme events. New forecasting capabilities also include probabilistic estimates of wind power via an analog ensemble approach and load forecasting capability is being developed for more effective wind energy integration into the power grid. To better forecast loads distributed solar energy production forecast system is also under development.

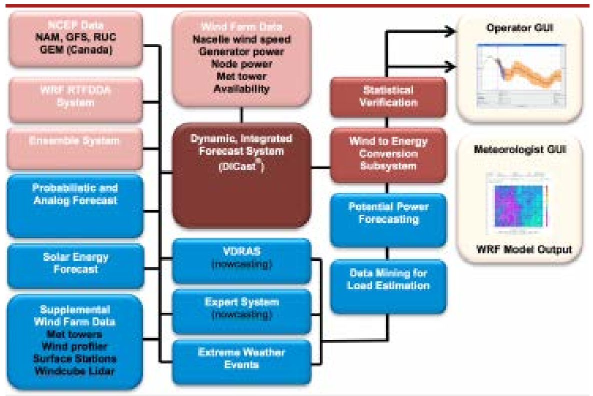

Figure 1. Schematic diagram of the comprehensive wind power forecasting system.

The numerical weather prediction portion of the forecasting system incorporates observations of current atmospheric conditions from satellites, aircraft, weather radars, ground-based weather stations, and even sensors on the wind turbines. The information is then utilized by the Real-Time Four-Dimensional Data Assimilation System (RTFDDA), which continuously updates the WRF model simulations with the most recent observations.

Initial forecasting capabilities developed by RAL focused on day-ahead forecasting. The goal was to minimize root square error in wind power forecast for energy trading purposes. This was accomplished using our own Dynamic Integrated Forecasting System (DICast®). DICast® statistically optimizes the forecasts based on current observations, climatological data, and real-time validation of the model predictions while customized displays provide grid operators with a best forecast that includes error estimates as well as meteorological plots to visualize the weather graphics.

The current project emphasizes improving the short-term forecasting capability, which is designed to improve forecasts of wind energy ramp events. One aspect of the system is NCAR's Variational Doppler Radar Analysis System (VDRAS, Sun and Cook, 1997; Sun and Zhang, 2008;

Sun et al., 2010). VDRAS is designed to use all available weather data: surface and upper observations, NEXRAD data, and aircraft observations, as well as any supplemental weather observations including meteorological tower data, nacelle winds, wind profilers and surface stations in proximity to wind parks. We have applied VDRAS to analyze and forecast wind fields at wind plants in Eastern Colorado (Figure 2). The short-term forecasting system based on VDRAS provides wind forecast within first two hours and thus it is particularly useful for wind ramp forecasting. Integrating VDRAS output with the DICast forecast is expected to lead to better estimates of rapid wind speed changes.

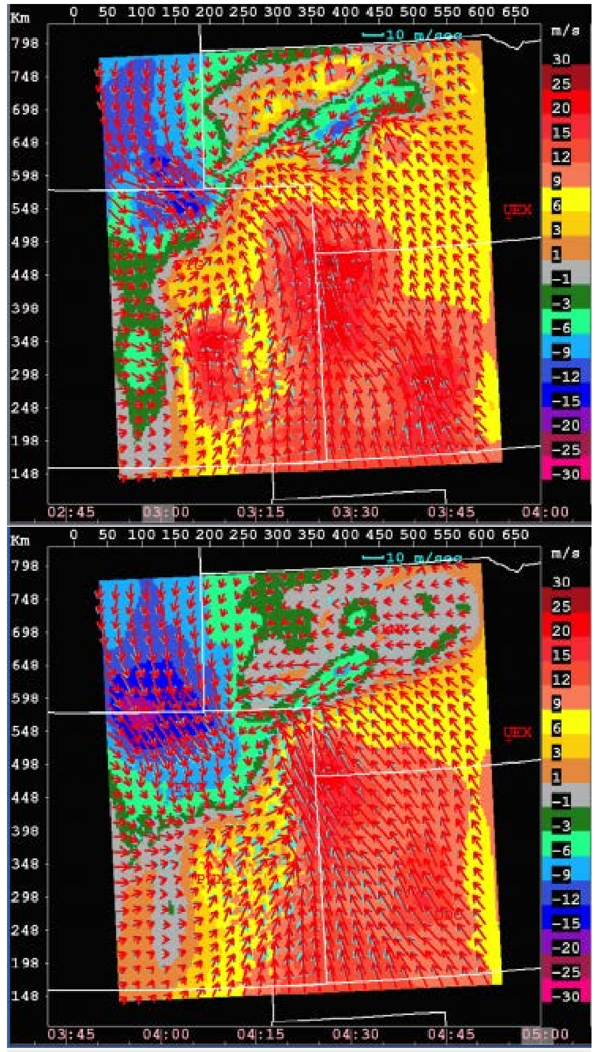

Figure 2. VDRAS analysis (left panel) and two-hour forecast (right panel), shown are results obtained using two vertical resolutions, dz=300m (color contours) and dz=200m (vectors).

Another novel capability being added to Xcel Energy's forecasting system is icing prediction. In cold climates icing can significantly reduce wind power production even under very favorable wind conditions. Ice accretion on turbine blades reduces the effective lift and therefore reduces the rotor torque, resulting in significantly reduced performance that can lead to cut-outs. Freezing precipitation including snow, freezing drizzle and ice accretion is poorly observed by standard surface observation systems and by radar. Among developed technologies is a freezing drizzle algorithm that uses air temperature and the raw vibration frequency of a freezing precipitation sensor. This algorithm has been successfully demonstrated at several airports in support of deicing services (Politovich et al, 2010). Building on existing expertise in aircraft anti-icing projects at NCAR, developed with Federal Aviation Administration sponsorship for over a decade, these algorithms are now being adapted for application to wind turbine operations. Freezing precipitation and icing alerts delivered by this new system resulted in avoidance of engine damage due to ingestion of ice and improved deicing operations. The approach and associated algorithm developed for aircraft decision support system is applied to wind turbine icing in order to produce more accurate wind power forecasts under such adverse weather conditions. The freezing drizzle algorithm is being refined to utilize data from the icing sensors installed at wind parks. Vibration frequency data from the sensors is be integrated with collocated air temperature data to generate icing accretion information.

RAL is also collaborating with Pennsylvania State University scientists who are conducting laboratory and numerical experiments on ice accretion on turbine blades. These experiments are designed to determine the effect of blade rotation speed and pitch angle on ice accretion and consequently the effect of ice accretion on power output. This study will enable improved wind power forecasts in icing conditions.

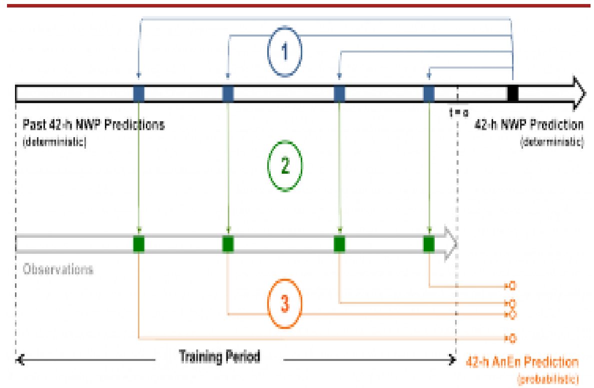

Figure 3.Schematic representation of the process for finding four members of the analog ensemble (AnEn) at one forecast lead time.

Another new capability that is being provided is advanced diagnosis and warning of high speed cut-outs, which will enhance overall forecast system performance. High-speed cut-outs are predicted through analysis of standard practices at wind parks of interest and development of a diagnostic algorithm to determine when high speed cut-outs are occurring.

An ongoing challenge in wind power prediction is the quantification of uncertainty in any given forecast. The accuracy of wind power forecasts depends on a number of factors, including boundary and initial conditions, accuracy of parameterizations of physical processes, as well as inherent limits to predictability. For that purpose we use a novel technique based on the analog ensemble described by Delle Monache et al. (2011, 2013). The analog ensemble approach combines real-time and

historical data from state-of-the art numerical weather prediction models and extensive records of wind power observations to provide reliable quantification of the forecast uncertainty and accurate power forecast of day-ahead lead times (Figure 3). The analog method has shown great value for improving both the best prediction and in quantifying its uncertainty.

Finally, the DICast system will be applied and enhanced for load forecasting by synthesizing weather forecasts and observed (historical) load data to provide more accurate forecasts of future loads based on past behavior.

Solar Power Forecasting

In 2013, RAL embarked on a major DOE-funded effort to advance the state-of-the science of solar power forecasting. This work is in partnership with the National Renewable Energy Laboratory, Brookhaven National Laboratory, National Oceanographic and Atmospheric Administration; universities – Penn State, Colorado State, Hawaii, Washington, and University of Buffalo; utilities – Long Island Power and Light, Public Service of Colorado, Sacramento Municipal Utility District, Southern California Edison, and the Hawaiian Electric System; independent system operators (ISOs) – New York Power Authority, Xcel Energy, California ISO, and Hawaiian Electric; and commercial forecast providers – Telvent DTN, Atmospheric and Environmental Research, Global Weather Corporation, and MDA Information Systems.

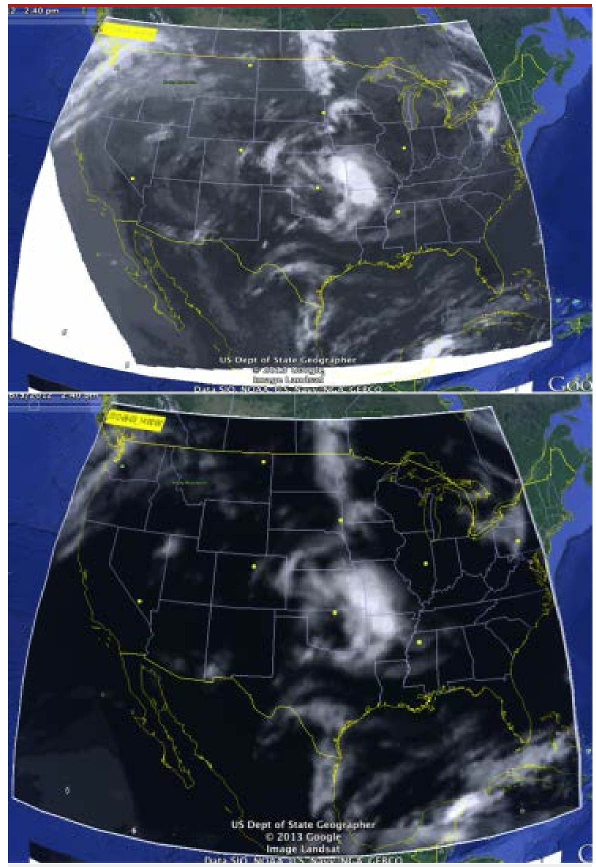

Figure 4. The Rapid Update WRF cloud forecast (right) agrees well with the GEOS Imager cloud observations (left).

The primary objective of this project is to develop a solar power forecasting system that advances the state-of-the-science through cutting edge research, tests it in several high penetration solar utilities and ISOs, and disseminates the research results widely to raise the bar on solar power forecasting technology. To reach this goal requires basic and use-inspired research in targeted core areas. Metrics are being developed in collaboration with DOE, the other DOE-funded team led by IBM, and with significant involvement of stakeholders. These metrics measure improvements in solar forecasts, the resulting power predictions, and value to the utility or ISO.

Advances are also being made in solar radiation measurement and cloud observation and tracking techniques, as well as in their use for short-range prediction. This includes working with BNL on total sky imaging (TSI) technology. Three TSIs have been purchased for deployment in Xcel Energy's solar farms in the San Luis Valley of Colorado. NCAR is also working with NOAA and CSU on advancing the use of satellite data in models. A new method for integrating multiple satellite inputs and using that information to project cloud shadows onto the earth's surface and advects the clouds using cloud vectors has been developed. A second new technology has been developed to fully assimilate these multiple sources of cloud data (satellite data and TSI images) into a rapid update version of WRF that advects the diagnosed clouds using the WRF dynamical core and computes the resulting irradiance (see Figure 4). Finally, new methods are being devised to statistically predict irradiance that includes identifying regimes and correlating cloud properties to irradiance attenuation (Figure 5).

Methods to quantify and track aerosols that affect cloud formation and radiative transfer, including the prediction of aerosols, haze, and contrails, are being investigated. Other efforts focus on assimilation of cloud observations from various sources into numerical weather prediction (NWP) models, and the integration of new cloud physical processes and parameterizations into those models. Radiative transfer through distinct types of clouds and aerosols, NWP modeling capabilities tuned for solar radiation at specific locales, and a new shallow convective scheme are resulting in a new version of the Weather Research and Forecasting (WRF) model tuned to solar irradiance prediction – WRF-Solar. The team is working closely with scientists at NOAA to translate the research toward operational use in the High Resolution Rapid Refresh (HRRR) system.

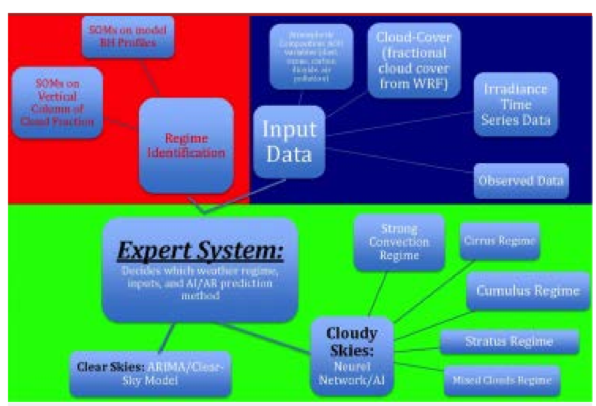

Figure 5. Statistical learning system for short-range prediction that

includes pattern analysis for cloud regime identification (top left) based on multiple source of data (top right) that combine to produce an expert system based on cloud regime (bottom).

These new technologies must be blended seamlessly and delivered to the utilities and ISOs. Thus, statistical learning methods are needed to blend the disparate forecast models, and real-time learning techniques are needed to optimize irradiance forecasts under dynamic conditions. Irradiance-to-power conversion methods are also important to providing the users with the type of data that they require. Finally, economic analysis is assessing the value of the forecast improvements.

The research in FY13 is focused toward deploying a prototype solar forecasting system that will be tested in collaboration with utilities and ISOs in geographically diverse areas, including Long Island, Colorado, coastal California, and Hawaii. Each component of the system is in the process of being verified and validated using evaluation techniques developed specifically for the project through in-depth interactions with stakeholders. The system will be deployed within operational environments of utility and ISO partners with engagement of the commercial forecast providers, who tailor the methods to the needs of the deployment. The quasi-operational forecasts will be provided for a full year to allow sufficient time for full assessment of their value. The results will be widely disseminated through publications, workshops, and software. The impact of this effort will be enhanced solar forecasting that is integrated into utility operations, advancing the potential penetration of renewable energy.

Off-Shore Wind Energy Projects

RAL staff have been working on several DOE-funded projects aimed at advancing offshore wind energy. These projects are focused on enhanced understanding and characterization of the interactions between the ocean and the atmosphere in order to better predict winds over rotor disks for both locating wind plants and for forecasting power for plant operations. Analysis of available offshore observations is combined with modeling efforts to develop improved marine boundary layer parameterizations, as well as improved ocean-atmospheric coupling techniques, with a goal to reduce market barriers to offshore wind energy. One of the projects, in collaboration with Penn State University, is developing a "Cyber Wind Facility", a computational facility akin to a field wind turbine test facility that blends models across scales. In 2013, NCAR and PSU worked together to integrate time varying mesoscale forecasts with large eddy simulations (LES) of the atmosphere in the vicinity of a wind farm. A second project combines the efforts of staff in RAL and MMM seeks to characterize the coupling between wind, wave states and stratification toward reducing errors and uncertainties in hub-height wind speed and rotor-plane shear prediction. A third project expects to improve understanding of the complex interactions between the atmosphere and the ocean surface. This knowledge will be used to develop improved marine boundary layer (MBL) parameterizations, as well as improved ocean-atmospheric coupling techniques. These projects will lead to better modeling capability to reduce market barriers to developing offshore wind energy.

Lidar Support for Wind Energy

RAL’s vertically profiling Windcube lidar was used to measure wind turbine wakes in an operating wind farm in FY13. Measurements by the Windcube lidar were first validated at the National Renewable Energy Laboratory’s National Wind Technology Center during the spring 2013. Wind speed and wind direction measured by the lidar were compared with measurements obtained from a 120 m tall instrumented tower and an identical Windcube lidar owned by the University of Colorado. Following the validation, from June to September 2013, the NCAR/RAL lidar was deployed in an operation wind farm in Story County Iowa as a component of the Crop and Wind Experiment 2013 (CWEX2013, Figure 6). At CWEX2013 RAL collaborated with the University of Colorado and the Iowa State University. In addition to RAL’s lidar, two identical lidars owned by the University of Colorado, a scanning lidar on loan from Leosphere, and 14 flux measurement towers were deployed in proximity to lidars by the Iowa State University. The observations from CWEX2013 will be used to study wind turbine array effects with focus on multiple wind turbine wakes. The goal of CWEX is to measure wind turbine wakes and study the effect of turbulent mixing induced by operating turbines on surface fluxes of heat and moisture, and thus, on crops. These observations will also be used to validate a parameterization of an operating turbine, a generalized actuator disk model, implemented in the Weather Research and Forecasting model.

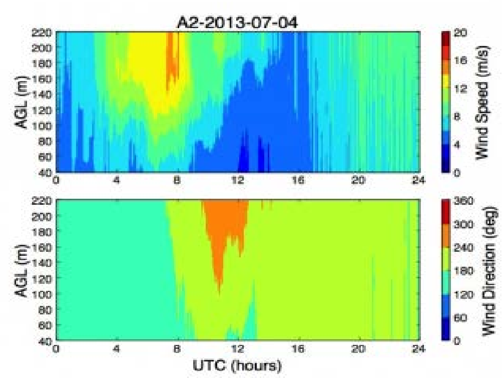

Figure 6. Wind speed (top panel) and wind direction (bottom panel) measured by NCAR’s Windcube lidar (A2) on July 4, 2013 (figure prepared by Jiwan Rana, Univ. of Colorado). Notice low-level jet with the peak wind speed between 180 and 200m, and wind veering with height as the stably-stratified boundary layer evolves.

Wind Turbine and Turbine Array Wake Characterization

The effects of operating wind turbine rotors on atmospheric flows can be

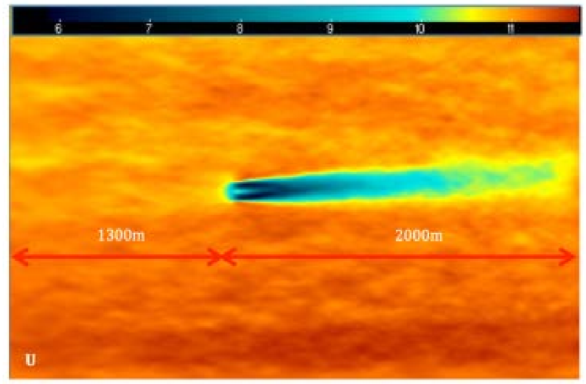

Figure 7. Turbine wake simulated using WRF-LES with a generalized actuator disk model.

represented using a generalized actuator disk model. To further study these effects, RAL scientists have implemented a generalized actuator disk model in the Weather Research and Forecasting (WRF) model to examine wind turbine wakes, their structure and interaction in wind turbine arrays, as well as their effect on transport processes in atmospheric boundary layers using the large-eddy simulation (LES) approach. In collaboration with the Lawrence Livermore National Laboratory (LLNL), RAL scientists have validated the generalized actuator disk model in WRF-LES using the data from the Turbine Wake and Inflow Characterization Study (TWICS) experiment (Figure 7). TWICS experiment took place at the National Wind Technology Center (NWTC) test site of the National Renewable Energy Laboratory (NREL) in the spring of 2011 and involved measuring a 2.3 MW turbine wake using National Oceanic and Atmospheric Administration's (NOAA's) High Resolution Doppler Lidar (HRDL). The validated generalized actuator disk model implemented in WRF will advance the capability to model details of flow through wind turbine arrays under a wide range of atmospheric conditions and thus will become an advanced tool for wind resource assessment and wind turbine array performance evaluation as well as turbine load calculations.

Analog Ensemble for Wind Resource Assessment

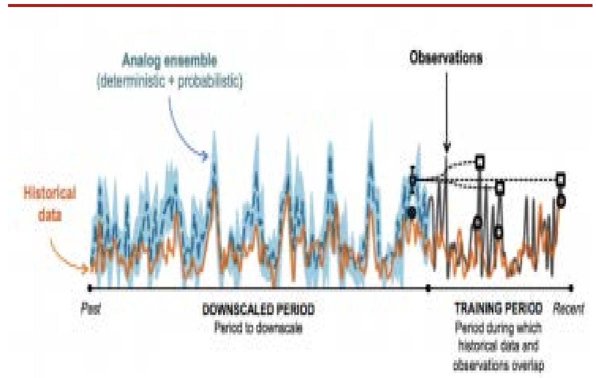

Figure 8. Sketch of the functioning of the analog ensemble method for one analog predictor, the analog trend reduced to one time step, and when retaining the best three analogs.

As part of an NREL-funded project, a new method has been proposed and demonstrated for the long-term estimate of the wind speeds at a target site, a key step in wind resource assessments. Analog ensemble (AnEn) techniques have been used with success previously for short-term weather predictions (e.g., Delle Monache et al. 2013). In the context of the wind resource assessment, the analog-ensemble method draws on the information contained in the historical data of multiple physical quantities over the period these data overlap with the observations (known as *training period*; typically 365 days) of the quantity of interest (known as *predictand*; the wind speed in this study). The relationships derived within the training period are then applied to reconstruct the on-site wind speed over the period for which there are no observations (hereafter referred to as *reconstructed period*, e.g., the past 20 years before the measurement campaign started).

More precisely, this is a three-stage process that is executed independently at every target site for every hour, *t,* of the reconstructed period, as sketched in Figure 8. First, the historical value of multiple physical quantities (known as *analog predictors*; e.g. wind speed itself, wind direction, pressure, etc.) is retrieved for a time window (known as an *analog trend*) centered around time *t* (black dot in Figure 8). The analog predictors are selected beforehand based on their known or anticipated correlations to the predictand. Second, other historical cases with conditions similar to those in the target window are identified (known as *analogs*) by looking at a time window (known as the *analog search window*) centered around the same hour of the day for every day in the training period, and ranked by closeness of the match. Analogs may therefore come from any day in the training period. Using multiple predictors helps distinguish the analogs by identifying specific weather regimes relevant to the predictand. Third, the *K* best analogs (*K* is the *number of analogs*; black circles) are selected, and the corresponding observed values of the predictand are retrieved (black squares). The latter are the *ensemble members* for hour *t*.

The final result is the *analog ensemble*, i.e., a set of *K* wind speed values for every hour *t* of the reconstructed period. The assumption is that if analogs are found, their errors will likely be similar to the error of the historical time step used to reconstruct, and thus, the error that can then be inferred and corrected. It has been demonstrated that:

- The AnEn can be used effectively for wind resource applications;
- The AnEn provides an accurate long-term wind resource estimate at target sites;
- The AnEn reliably quantifies the uncertainty allowing for cost-effective decision making;
- The AnEn is a computationally inexpensive method.

We are in the process of testing AnEn for 15 locations provided by NREL, over which we will perform a throughout

assessment of AnEn performance by assessing its statistical consistency, reliability, spread-skill relationship, and resolution.

PLANS FOR FY2014

FY2014 will continue to be an exciting time for renewable energy research at RAL. New collaborations with national laboratories, university scientists, and private companies will advance the state-of-the-science necessary to make a large penetration of renewable energy capacity feasible. In FY2014 significant efforts will be focused on developing comprehensive wind power forecasting capabilities that, in addition to current wind power forecasting system will include capabilities for short-term forecasting, forecasting of extreme events, and load forecasting. RAL and its partners are also in the process of implementing a new solar forecasting system for both utility scale and distributed solar facilities. In addition analog ensemble methodology will be further advanced and applied to a range of renewable energy related projects to quantify uncertainty.

Other plans include:

- Continued collaboration with Xcel Energy to enhance the Wind Power Prediction System, including predicting icing, high speed cutouts, load forecasting, short range forecasting, enhancing power conversion algorithms, etc.
- Continued collaboration with many partners under DOE funds to implement, deploy, and test a solar power forecasting system.
- Collaboration with NREL and the University of Colorado to deploy a vertically pointing lidar to study wind turbine wakes and to model those wakes using LES techniques.
- Expansion of the wind forecasting capability into new areas, including mountainous and coastal sites.
- Assist NREL with resource assessment and developing measurement programs in developing countries, including Bangladesh.
- Work with partners at Colorado State University to quantify how wind power can be integrated with storage and other types of energy units to supply reliable power
- Work with colleagues at Penn State University to assess the feasibility of integrating wind turbines into buildings
- Work with partners at Colorado School of Mines to analyze how wind power forecasting can help smooth the demand/variable energy balance when applying smart grid concepts
- Work with partners at the University of Colorado to study the impact of atmospheric stability and shear on wind power production, validated WRF-LES with a generalized actuator disk for wind turbine array simulations using CWEX experimental data, and combine observations and numerical simulations to study wind turbine wakes and interactions
- Work with partners at Penn State to include mesoscale model data in a coupled multi-scale cyber wind facility
- Work with partners at Penn State to adapt icing algorithms to wind energy applications
- Expand calibration of the uncertainty in wind forecasting systems in conjunction with other laboratories and with commercial partners
- Downscale model solutions for resource assessment
- Apply new artificial intelligence techniques to wind prediction problems
- Work on improving offshore hub-height wind speed and wind shear prediction
- Improve marine boundary layer parameterization to better account for the interaction between the sea surface and the atmosphere.

REFERENCES

Delle Monache, L., T. Nipen, Y. Liu, G. Roux, and R. Stull, 2011: Kalman filter and analog schemes to post-process numerical weather predictions. *Mon. Wea. Rev.*, ***139**, 3554–3570.*

Delle Monache, L., F. A. Eckel, D. Rife, B. Nagarajan, and K. Searight, 2013: Probabilistic weather predictions with an analog ensemble. Mon. Wea. Rev., 141, 3498–3516.

Haupt, S.E., W.P. Mahoney, and K. Parks, 2013: Wind Power Forecasting, in *Weather Matters for Energy*, Troccoli, Dubus, and Haupt, eds, Springer, in press.

Mahoney W. P., K. Parks, G. Wiener, Y. Liu, W. L. Myers, J. Sun, L. Delle Monache, T. Hopson, D. Johnson, S. E. Haupt, 2012: A Wind Power Forecasting System to Optimize Grid Integration. IEEE Trans. Sustain. Energy, **3**, 670-682.

Sun, J. and N. A. Crook, 1997: Dynamical and microphysical retrieval from Doppler radar observations using a cloud model and its adjoint: Part I. model development and simulated data experiments. J. Atmos. Sci., **54**, 1642–1661.

Sun, J., and Y. Zhang, 2008: Assimilation of multiple WSR_88D Radar observations and prediction of a squall line observed during IHOP. *Mon. Weather Rev.*, **136**, 2364–2388.

Sun, J., M. Chen, and Y. Wang, 2010: A frequent-updating analysis system based on radar, surface, and mesoscale model data for the Beijing 2008 forecast demonstration project. *Weather Forecast.*, **25**, 1715–1735.

Politovich, M. K., C. A. Wolf, F. McDonough, J. Haggerty, 2010: Potential Upgrades to the Current and Forecast Icing Algorithms. AIAA paper 2010-81111 presented at the AIAA Atmospheric and Space Environments Conference, 2-5 August, Toronto, Ontario Canada.

‹ Surface Transportation Weather | up | Weather Prediction Statistical Optimization ›

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WEATHER PREDICTION STATISTICAL OPTIMIZATION

BACKGROUND

RAL is a leader in the development of intelligent weather prediction systems that blend data from numerical weather prediction models, statistical datasets, real time observations, and human intelligence to optimize forecasts at user–defined locations. The Dynamic Integrated Forecast System (DICast®) and Location Optimized Gridded & Integrated Forecast System (LOGICast™) are examples of such technology. DICast® is currently being used by three of the nation's largest commercial weather service companies. There is a growing desire in industry to have fine–tuned forecasts for specific user–defined locations. This trend is clear in the energy, transportation, agriculture, and location–based service industries. RAL's expertise in meteorology, engineering, and applied mathematics and statistics, is being utilized to address society's growing need for accurate weather information.

FY 2013 ACCOMPLISHMENTS

During this year new models were integrated into the DICast consensus forecast. In particular the High-Resolution Rapid Refresh (HRRR) model was added to improve the short term (0-15 hour) forecast. The HRRR model's precipitation forecasts are quite skillful in this time range due in part to the incorporation of radar data in the model's initial conditions and the model's frequent update cycle. The statistical improvements in DICast's short term precipitation forecasting have been significant.

DICast's impact on wind energy forecasting has led to its use in other renewable energy arenas. In particular, it is currently being used as the forecast integration module for a DOE-funded solar energy forecasting project. In this project DICast has been modified to make forecasts of Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and diffuse irradiance at locations where partnering utilities are providing observational data.

Internal to DICast, precipitation forecast methods continue to evolve. The use of observed lightning data has led to iterative improvements in the short-term probability of thunder forecasts. The quantity and probability of precipitation forecasts was reviewed based on user feedback and algorithm improvements due to the HRRR model integration are currently being evaluated.

Significant improvements were also made to the Logicast system, the gridded version of DICast. Based on user feedback, enhancements were made to Logicast's precipitation forecasts (QPF, Probability of Precipitation, and Probability of Thunder). The HRRR model was also integrated into Logicast to improve the near term precipitation predictions. In some cases the system modifications mentioned above have led to other issues requiring resolution. For example, forecast temporal consistency at the end of the HRRR forecast period must now be resolved. Logicast was also extended to handle larger mesonets aiding in improving Logicast's predictions away from rich observation regions. The quality of the observations incorporated in Logicast is key to Logicast's improved performance so work is continuing on metrics to define the optimal use of observational sites in the generation of Logicast forecasts.

Simplifying and optimizing the implementation of the road temperature model, METRo, has led to a 100x speed up in the DICast-driven Maintenance Decision Support System (MDSS) which produces road condition forecasts and treatment recommendations. The MDSS is currently being used in several states and Canadian provinces by various Departments of Transportation to aid in winter road maintenance decision making. This simplification and optimization of METRo has allowed us to incorporate considerably more sites for timely road condition and treatment forecasts.

FY 2014 PLANS

Areas of development for the next fiscal year include:

- Development of a module that will automatically determine the optimal combination of precipitation forecasts
- Integration of solar irradiance nowcasts into DICast
- Evaluation of DICast's skill in solar energy forecasting
- The evaluation of alternative wind power forecasting techniques

‹ Renewable Energy | up | Advanced Operational Aviation Weather System (AOAWS) ›

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ADVANCED OPERATIONAL AVIATION WEATHER SYSTEM (AOAWS)

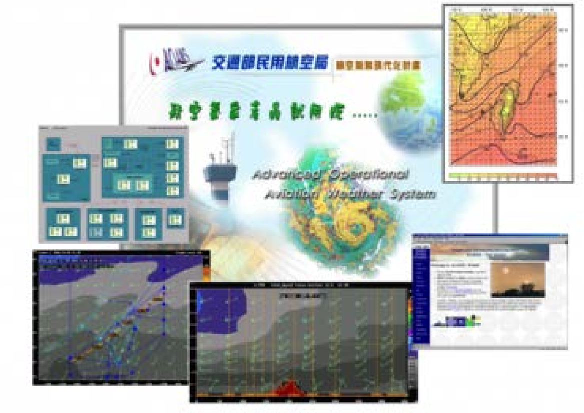

Figure 1: Composite image showing several AOAWS end-user display screens.

BACKGROUND

Since 1998, RAL and MMM have collaborated in the development of an Advanced Operational Aviation Weather System (AOAWS) for the Civil Aeronautics Administration (CAA) of Taiwan. The AOAWS provides the CAA, the airlines, and the flying public with state-of-the-art aviation weather technology to detect and forecast hazardous weather phenomena that affect aviation operations, airspace efficiency, and capacity and safety at Taiwan's major hub airports. In 2010, NCAR's local Taiwan technology partner became International Integrated Systems, Inc (IISI).

Major components of the AOAWS include: Low-Level Wind Shear Alert Systems (LLWAS Phase III) at Songshun and Taoyuan International Airport; the WRF model which provides regularly-updated forecasts on two domains with grid spacing of 20km, and 4km; the Java-based Multi-dimen□ional Display System (JMDS), which integrates all available real-time observational data and displays the information automatically to aviation forecasters and flight planning specialists; a web-based display system (WMDS) that displays most of the data available on the MDS on a CAA website for users (e.g., pilots and dispatchers) to view the AOAWS weather products remotely; and an AOAWS System Monitor Display (SMD) that provides system and networking activity information and alerts to the operators if any one of the sub-systems is not running smoothly. Since 2010, the WRF modeling enhancements are being developed by NCAR/MMM under a separate research agreement with the Taiwan Central Weather Bureau (CWB).

FY2013 ACCOMPLISHMENTS

The AOAWS program continued to conduct research and development in the areas of turbulence and in-flight icing, improvement in the display of information to end-users in dispatch and flight service stations with the replacement of technologically-dated displays with modern Java-based display JMDS. There were also engineering infrastructure refinements improving the overall performance of the AOAWS that included integration and display of GOES and Meteosat geostationary weather satellite products and AMDARs.

The effort to transfer the Current Icing Product (CIP) product was completed, complementing the Forecast Icing Product (FIP) product; this work leverages research being conducted by RAL for the FAA's Aviation Weather Research Program. A sample image of the CIP is shown in Figure 2. Work to integrate and refine the NTDA algorithm continued.

In collaboration with a user group from the CAA’s Taipei Area Control Center (TACC) an in-depth analysis of their weather information needs with respect to air traffic management systems was performed. The results were presented in a report along with a conceptual framework for

high-impact weather integration into the CAA's Air Traffic Management (ATM) system that follows trends in the FAA's NextGen modernization effort.

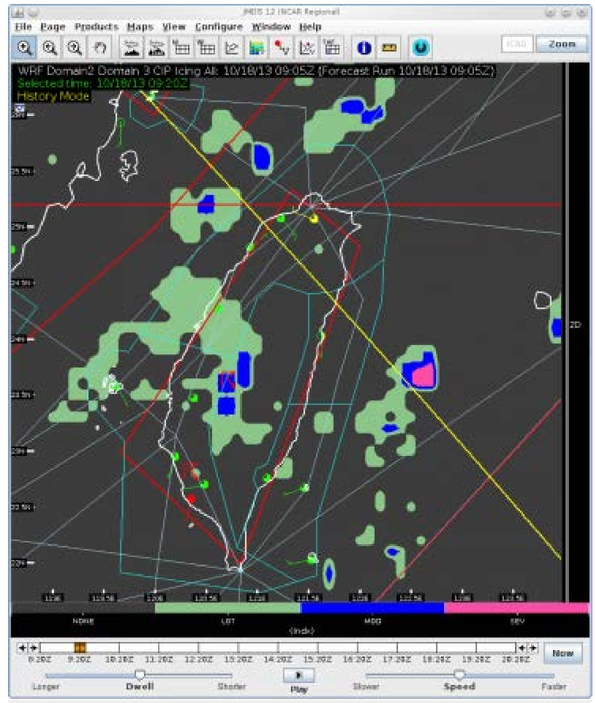

Figure 2: Composite image showing the Current Icing Product (CIP) on the AOAWS end-user display screen.

FY2014 PLANS

The development of the Nexrad Turbulence Detection Algorithm (NTDA) and display application upgrades will be completed, and the new capabilities will be integrated, tested, and become operational in the AOAWS in 2014. Verification and tuning of the CIP and NTDA products will be conducted. Enhancement of the ceiling and visibility product will be performed with the addition of a real-time verification component. A user-configurable external data server will be developed, allowing the Taipei Aeronautical Meteorological Center (TAMC) additional independence and control of sharing data products with its various aviation industry collaborators and partners. Rigorous testing of the entire AOAWS system will be conducted to ensure a high level of serviceability for the end users.

Several other international aviation programs are planned for 2014. NCAR is working with Advanced Radar Corporation (ARC) to develop a microburst detection algorithm and system tuned to ARC's radar technology for deployment in Rwanda. Another project will study the rainfall-storm and wind shear phenomena at airports in Africa. NCAR/RAL is often requested to apply its expertise in assisting foreign governments to modernize their aviation systems.

‹ Weather Prediction Statistical Optimization up National Security Applications ›

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NATIONAL SECURITY APPLICATIONS

Significantly advance our understanding of mesoscale and urban-scale weather and climate processes, especially in the boundary layer, and our ability to forecast these atmospheric conditions operationally for the purpose of providing forecasters, decision makers, and emergency managers with accurate information to save lives and property.

- Operational Numerical Weather Prediction and Improved Data Assimilation
- Statistical and Dynamical Mesoscale Climate Downscaling
- Atmospheric Transport and Dispersion of Hazardous Materials Research and Development

‹ Advanced Operational Aviation Weather System (AOAWS) up Operational Numerical Weather Prediction and Improved Data Assimilation ›

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OPERATIONAL NUMERICAL WEATHER PREDICTION AND IMPROVED DATA ASSIMILATION

BACKGROUND

Over the past several decades, RAL has developed and deployed complex computer-based operational systems for analyzing and forecasting climate and weather at high resolution worldwide. This development is built upon the Laboratory's deep foundation of applied scientific research and engineering. Systems and their products are tailored to each project to maximize the benefit to the sponsors and end-users. For example, improved analyses and forecasts at Army test ranges saves millions of tax dollars by identifying when weather suitable for testing will occur, and improves safety by predicting conditions that would be hazardous to personnel and materiel. Other domestic and international projects include forecasting for wind farms at resolutions that can approximate large eddies within the atmosphere's boundary layer; new, innovative ways to supply models with current observations from radar ; and exploring how urban development affects the weather, and how that weather in turn affects the health of people living in urban areas. In this section of the Annual Report, we describe our work in the following areas:

‹ National Security Applications up Four-Dimensional Weather System (4DWX) ›

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FOUR-DIMENSIONAL WEATHER SYSTEM (4DWX)

BACKGROUND

Since the middle 1990s, the U.S. Army Test and Evaluation Command (ATEC) has sponsored RAL to conduct research, development, and technology-transfer of the Four-Dimensional Weather (4DWX) system. 4DWX is an advanced numerical weather prediction (NWP) system that analyzes current weather and makes detailed predictions of weather over the next several days. 4DWX's NWP core is the Weather Research and Forecasting (WRF) Model, the current industry standard. 4DWX ingests observations into the NWP core through NCAR's Real-Time Four-Dimensional Data Assimilation (RTFDDA) scheme. 4DWX is used by ATEC forecasters at eight test ranges (Fig. 1) across five major climate zones. RAL improves 4DWX regularly, updating software and/or

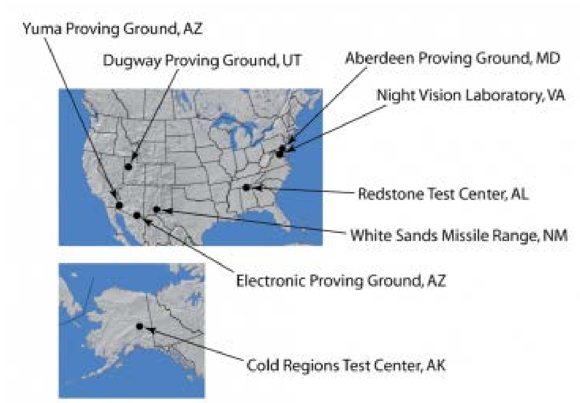

Figure 1. Army test ranges that use 4DWX.

hardware for ATEC one or more times per year.

4DWX provides ATEC forecasters the technology and expertise they need to produce weather forecasts and analyses at the scales, and with the accuracy and utility, required to support safe and cost-effective Department of Defense (DoD) testing. For NCAR one of the most attractive elements of the 4DWX project is that the ATEC test ranges serve as natural laboratories for atmospheric research, complete with dense observing networks and specialized data that permit study of mesoscale and microscale phenomena in complex terrain. Continual improvements to 4DWX and to community numerical weather prediction models, such as the WRF Model, are made possible through this collaboration.

FY2013 ACCOMPLISHMENTS

Advanced Data Assimilation

The project continues to rely on RTFDDA as one way to ingest observations and define the atmosphere's current state for 4DWX's NWP core, the WRF Model. RTFDDA involves modifications to an NWP model's predictive equations so the model can be gently adjusted, or nudged, toward observed conditions during the model's analysis stage, before the forecast stage begins. The scheme is computationally efficient and preserves the precise timing of observations, which gives 4DWX a particularly accurate depiction of the weather at any instant. RTFDDA continues to show itself superior to, or the equal of, many alternative methods of data assimilation in operational systems. It has recently been upgraded to include several new features. RTFDDA now assigns quality flags to observations within the analysis and forecast cycling, rather than as a pre-processing step, providing more accurate and stable assessments of each observation's usefulness in data assimilation. RTFDDA also has an improved means of dealing with cases when an observing site's actual elevation differs significantly from the simulated terrain height in the model.

RAL is in the final stages of developing a hybrid approach to data assimilation, 4D-REKF (4-Dimensional Relaxation Kalman Filter), which incorporates the cutting-edge ensemble Kalman filter data assimilation scheme into the RTFDDA framework. 4D-REKF inherits all the advantages of RTFDDA but with much better algorithms that will lead to better use of observations —especially observations from remote-sensor platforms—and to better accuracy and reliability. A research version of this new, advanced hybrid scheme continues to be refined in anticipation of prototypical deployment in 2014.

In 2013, RAL operated a real-time, prototypical system for ingesting observations from radars into 4DWX and other NWP modeling systems. The method is based on coupling RTFDDA with NCAR's Variational Doppler Radar Assimilation System (VDRAS), and it includes the effects of the latent heating that can be inferred from radar reflectivity. VDRAS assimilates series of real-time radar observations (radial velocity and reflectivity) from single or multiple Doppler radars, then uses a fast numerical model to make frequently updated short-term forecasts of dry flow in the planetary boundary layer. The prototypical system is a platform for improving the system within the demands of a real-time environment as a last step before deploying it operationally at Aberdeen Proving Ground, MD in 2014.

Ensemble Forecasting

Since 2007, Dugway Proving Ground (DPG) has used an ensemble four-dimensional weather system (called E-4DWX) developed by RAL. E-4DWX provides a suite of 30 forecasts valid at the same place and time, each producing slightly different but similarly realistic forecasts. Differences among ensemble members are induced by varying initial conditions, boundary conditions, model physics, and model cores. The ensemble captures the forecasts' probability information that varies with changes in weather regime.

A subset of output from E-4DWX is calibrated—that is, made statistically consistent with observations so that the probability of E-4DWX's forecasts being realized represents the observed probability. By using a method known as quantile regression, the distribution of ensemble forecasts (i.e., quantified by the mean, spread, and higher moments) is adjusted

toward the actual probability distribution of weather as determined through observations. The benefits of calibration include: 1) reducing forecast error and biases, producing a calibrated ensemble mean that has on average one half the error variance of any single ensemble member; 2) predicting accurate likelihoods of extreme and potentially devastating weather; and 3) providing a measure of forecast uncertainty through the dispersion among ensemble members. Calibration is performed on moments of the overall probability distribution function, no matter the size of the ensemble membership from which the distribution is created, as opposed to calibrating output from specific ensemble members. This makes E-4DWX particularly robust, even if individual members of the ensemble fail at some point during the forecast.

E-4DWX was the first dedicated operational high-resolution ensemble to be used by the U. S. Department of Defense. Since E-4DWX went into operation, not a single test at DPG has been canceled due to unpredicted adverse weather. Enhancements to E-4DWX in 2013 include new weather maps and graphics for the forecasters and improvements in the calibration sub-system. The schemes used to generate perturbations among ensemble members were also improved.

Experimental Very Large-Eddy-Scale (VLES) Simulations

On several projects, including this one funded by ATEC, RAL is experimenting with VLES simulations in a real-time framework. Current experiments are focused on Granite Peak at DPG, where the local winds driven by complex terrain are notoriously difficult to forecast. Granite Peak is also the site of the MATERHORN (Mountain Terrain Atmospheric Modeling and Observations Program) field project. The goals of MATERHORN include improving understanding, analysis, and fine-scale modeling of boundary-layer processes in complex terrain. Data from airborne Doppler lidar from the field project are being used to assess and improve our VLES modeling.

Forecasts of Severe Weather

The 4DWX system has components that predict severe weather on two scales: the next few hours, based on both observations and model predictions blended via the AutoNowcaster, and the next few days, based on model predictions alone. The AutoNowcaster now employs the dual polarization data newly available from the NEXRAD network. Two new predictor fields have also developed and tested, frontogenesis and Q-vectors, and an algorithm for predicting hail is being refined. RAL is collaborating with John Mecikalski of the University of Alabama-Huntsville to see whether his SATCAST (Satellite Convection Analysis and Tracking) application can be used to provide additional interest fields in the AutoNowcaster. Finally, RAL continues to refine its algorithms for short-term and longer-term prediction of lightning at the ranges by sharpening the forecasts, accounting for lightning in the anvil cirrus clouds of storms, and refining displays.

Coupled Applications

Direct weather analyses and predictions from 4DWX and E-4DWX are the core of the weather information used by forecasters at the ATEC ranges, but that information can be made even more valuable when it is supplied to decision support systems (DSSs) that simulate how the weather affects other processes and conditions, such as sound propagation and the transport and dispersion of airborne hazards. Examples of DSSs that have been linked to 4DWX and/or E-4DWX include:

- Noise Assessment and Prediction System (NAPS)
- Second-order Closure Integrated Puff (SCIPUFF) model
- Lewis Rocket Trajectory Model
- Open Burn / Open Detonation Model (OBODM)

Currently, we are modifying the RAL's Graphical Turbulence Guidance (GTG) for use by ATEC in support of tests that involve unmanned aircraft systems. This new application will be added to the suite of 4DWX decision support systems.

Composites of lake temperature for NWP models

In 2013,RAL designed and implemented a method for using data from NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) instruments aboard polar-orbiting satellites to create composites of water-surface temperatures of large inland lakes. For an NWP model to work well, it requires detailed and accurate observations, including of water temperatures at the model's lower boundary. We had previously developed a product for characterizing sea-surface temperatures for NWP. We extended and significantly improved that approach in the new lake-surface product, which appears to be more accurate and detailed than other standard products (Fig. 2). Details of the method are described in the paper by Grim et. al. (2013).

4DWX Web Portal

The primary interface to the 4DWX system at all ATEC ranges continues to be the 4DWX Portal (Fig. 3). The portal's flexibility, accessibility, modularity, and extensibility are ideally suited to the customized weather support that RAL provides to forecasters who have eagerly welcomed how the Portal improves their workflow. Weather maps and related graphics from 4DWX include optional color palettes that can be seen by the color-blind (Fig. 4). By using web forms designed in RAL, forecasters can more efficiently customize their weather maps. The Portal's dashboard has a flexible, configurable layout, with streamlined access to portlets for coupled applications. The list of output formats that the Portal supports includes the third-party BUFKIT and RAOB applications. In 2013, a portlet was added that displays recent and historical verification metrics for 4DWX. The Verification portlet permits forecasters to assess the system's recent performance in several combinations of dimensions (Fig. 5).

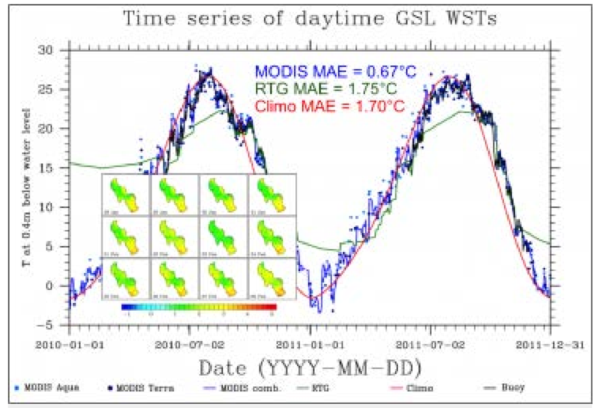

Figure 2. Time series of the Great Salt Lake's water-surface temperature (WST) at the location of a reference buoy in 2010–2011 from several different sources: MODIS aboard *Aqua* (light blue dots), MODIS aboard *Terra* (dark blue dots), a combination of MODIS from *Aqua* and *Terra* (medium blue line), the Real-Time Global (RTG) product from NOAA (green line), a climatography developed by Alcott et al. (2012) (red line), and the buoy (black line). Mean absolute errors (MAEs) for three time series are listed at the top, based on the buoy as truth. The inset shows twelve consecutive days of water temperature from RAL's newly developed product (temperature is shaded in ºC according to the color bar). When compared with the two-year dataset from the buoy, RAL's product is the most accurate of these standard sources of data for NWP.

Integrated Data Viewer (IDV)

RAL collaborates with UCAR's Unidata program to include among 4DWX's display options the Integrated Data Viewer (IDV), which is a sophisticated, flexible, Java-based application for analyzing and displaying geophysical data. IDV is the primary means by which range forecasters explore in greater depth the weather analyses and forecasts from 4DWX. This more complex and flexible exploration complements the "virtual map wall" that is available through the 4DWX Web Portal, whose purpose is to provide the easiest and quickest interface to a standard suite of pre-generated weather maps. IDV is also a research tool and is employed by scientists and engineers during their testing, development, and refinement of 4DWX.

Figure 3. Front page of the 4DWX Portal at three ranges: Electronic Proving Ground in AZ, White Sands Missile range in NM, and Dugway Proving Ground in UT. From each page, forecasters can access model output, current and historical observations at the stations shown in red on the maps, a tool for issuing weather warnings, radar displays, and more.

SELECTED KEY PLANS FOR FY14

Customize its highly successful GTG technology to support tests that involve unmanned aircraft systems which have become a mainstay at several ranges. A prototype of the system will be run in real-time, and performance metrics will be collected and used for further tuning.

Generate for one range a multi-decadal archive of mesoscale reanalyses to create a detailed climatography for use by forecasters to help with long-range scheduling of the optimal time, day, season, and location for testing under specific weather conditions. With lessons learned from this initial climatography, RAL will do the same for the seven other ranges, provided sufficient computer time is available.

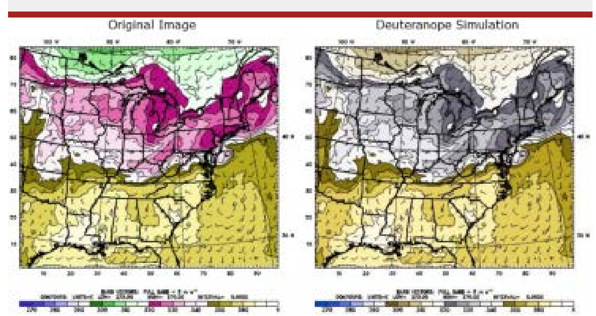

Figure 4. Examples of the two color palettes available through the 4DWX Portal. Each panel is a map of near-surface potential temperature. The left panel shows the map's appearance to those with no color-blindness. The right panel simulates how the map appears to those with deuteranope color-blindness (courtesy of vischeck.com).

Design and implement a set of algorithms to evaluate the quality (often called-quality control or quality-assurance) of each observation in the long-term and rich datasets collected at each of the ATEC ranges. This is the first step to enabling 4DWX and coupled applications to read and respond to quality-control flags so that observations can be used in the manner most appropriate for the model or application.

Evaluate a method of producing probabilistic forecasts that relies on archives of observations and model predictions to collect an ensemble of prior forecasts made under analogous weather patterns. Predictions from analog-based methods are inherently calibrated, so an extra calibration step is not required. If this analog-based approach seems promising, NCAR will develop a prototype for operational installation at one of the ATEC ranges, focusing on weather phenomena that are particularly troublesome to forecasters and range operations, such as

cold-air damming at Aberdeen Proving Ground, MD.

Make hybrid radar data assimilation in 4DWX fully operational at Aberdeen Proving Ground, MD.

Continue to emphasize outreach and training as a core component of the 4DWX project through the conduct of forecaster training at NCAR, and through teleconferences, on-line documentation, and visits to ranges.

Continue to support the the MATERHORN field campaign, providing data and advice to investigators and, in return, receive datasets and other material from the field campaign to aid model development and technology transfer to ATEC.

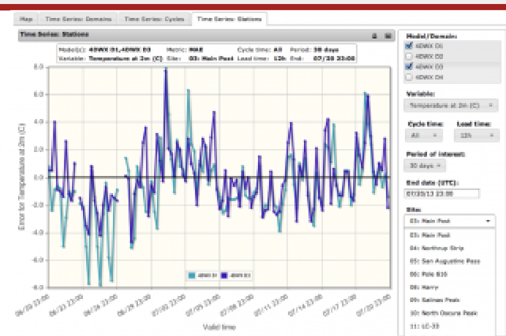

Figure 5. Screenshot of 4DWX Verification portlet. This example shows two 30-day time series of 4DWX's error in 2-m temperature (domain 1 in light blue, domain 3 in dark blue) at Site #3, Dugway Proving Ground, UT.

REFERENCES

Grim, J. A., J. C. Knievel, and E. T. Crosman, 2013: Techniques for using MODIS data to remotely sense lake water surface temperatures. J. Atmos. Oceanic Technol., in press. DOI: 10.1175/JTECH- D-13-00003.1.

‹ Operational Numerical Weather Prediction and Improved Data Assimilation | up | Real-Time Four-Dimensional Data Assimilation (RTFDDA) and Forecasting Advances ›

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REAL-TIME FOUR-DIMENSIONAL DATA ASSIMILATION (RTFDDA) AND FORECASTING ADVANCES

BACKGROUND

Many applications, including military tests and operations, renewable energy assessment and prediction, weather-related emergency response etc., desire high-resolution, rapid-update, high-accuracy, and customized weather information for focused regions. RTFDDA is a Real-Time, Four-Dimensional, Data Assimilation and forecasting system that has been developed particularly for such applications. It differs from other contemporary data assimilation approaches in that the observations are assimilated at their observation time rather than binned by time window. It is also blind to model inadequacy; no formal treatment is needed, making it a good choice particularly for forecasting

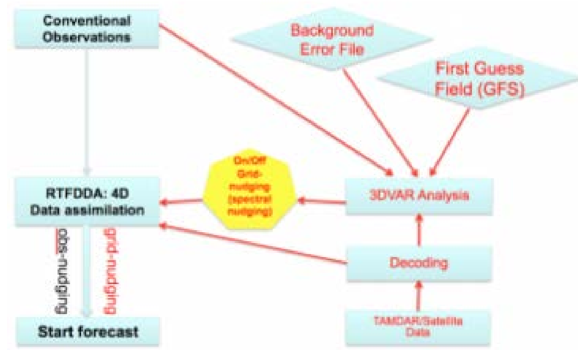


Figure 1. Schematic diagram of the RTFDDA-3DVAR hybrid data assimilation system.

sensible weather near the Earth's surface.

The overarching goal is providing the best-possible weather information for target applications and regions. This requires timely processing of all available observations, and assimilating them into advanced mesoscale WRF and/or MM5 models that have been tuned for the regions. The WRF RTFDDA allows for smooth and uninterrupted assimilation of diverse weather observations and produces physically consistent and dynamically balanced 4D weather analyses and "cloud/precipitation "spun-up" predictions. In the past 13 years, RTFDDA has been applied to over 40 weather-critical applications across the US and the globe.

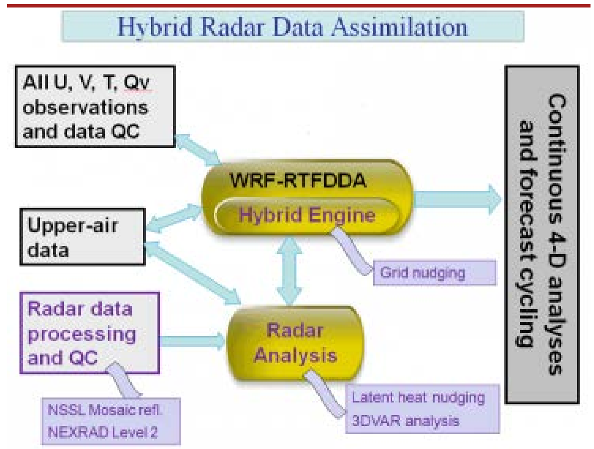
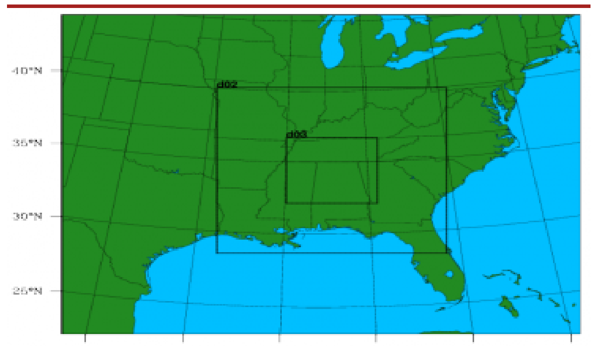


Figure. 2 Schematics of the coupled system of radar data assimilation and RTFDDA.

The RTFDDA data assimilation technologies include Newtonian relaxation based "observation-nudging" and "analysis-nudging" FDDA schemes, WRF-DA (3/4DVAR), DART-EnKF, GSI, and the development of a new 4-dimensional relaxation ensemble Kalman filter (4D-REKF) FDDA scheme, and a hydrometeor-latent-heat-nudging (HLHN) radar data assimilation scheme. These technologies are configured to formulate a hybrid data-assimilation engine to meet the specific requirements for each application.

Significant research and engineering has been put into advancing the science, accuracy, and capabilities of the RTFDDA system. In the last 5 years, RTFDDA has evolved from a single mesoscale deterministic analysis and forecasting system to a modeling capability suite that integrates ensemble prediction technology (Ensemble-RTFDDA), regional climate downscaling with four-dimensional data assimilation (Climate-FDDA) and microscale NWP with refined LES model grid with spacing order 10-100 meters (RTFDDA-LES). The advanced RTFDDA suite produces customized, high-resolution and ultra-high-resolution precision weather analysis and forecasts, probabilistic weather forecasts, and multi-year/multi-decadal microclimatology analyses for a given target region. In addition, WRF-Chem has been assessed and is being added to RTFDDA for forecasting sand and dust storms.



FY 2013 ACCOMPLISHMENTS

RTFDDA-3DVAR Hybrid Data Assimilation

One of the challenges for numerical weather prediction in weather data sparse regions (e.g., over oceans, the Middle East, Africa etc.) is the lack of in-situ observations needed to properly initialize models. An RTFDDA-3DVAR hybrid data assimilation scheme (Fig. 1) has been developed for incorporating unconventional observations, especially remote-sensing measurements such as satellite radiance, for model initialization. RTFDDA-3DVAR hybrid data assimilation also works to assimilate Doppler radar radial velocity observations in RTFDDA. A major characteristic of the RTFDDA-3DVAR hybrid data assimilation technology is that it inherits the full advantage of the RTFDDA ability to generate 4-D dynamically consistent and physically spun-up analysis and forecasts. In FY2013 we focused on applying and testing this technology for the development of operational NWP systems in the Middle East.

Hydrometeor and Latent Heat Nudging (HLHN) and 3DVAR Radar Data Assimilation

Incorporating radar data assimilation (RDA) capability into the real-time operational framework of RTFDDA has been one of the major undertakings of RTFDDA development. To assimilate radar radial winds and reflectivity into the WRF-based RTFDDA system, a hybrid approach that couples RTFDDA and 3DVAR with a hydrometeor and latent heat nudging (HLHN) technique has been developed (Fig. 2). During FY2013, extensive research and testing of the RTFDDA-3DVAR/HLHN hybrid radar data assimilation system were performed. Retrospective case studies were conducted for domains centered at three locations: the Colorado Front Range, the Army Aberdeen Test Command (ATC) range and Redstone Test Command (RTC) range. Several alternative configurations of 3DVAR and latent heating adjustment have been tested through the retrospective studies (Figs. 2, 3). Through verification and parallel testing, this advanced radar data assimilation scheme continues to be refined. A prototype RTFDDA-3DVAR/HLHN hybrid system was run locally in real-time environment for the ATC domain. Monitoring and assessment are on-going with the objective to tune the code and configuration parameters for the ATC domain. Plans have been made to release the code to ATEC range users in late 2013.

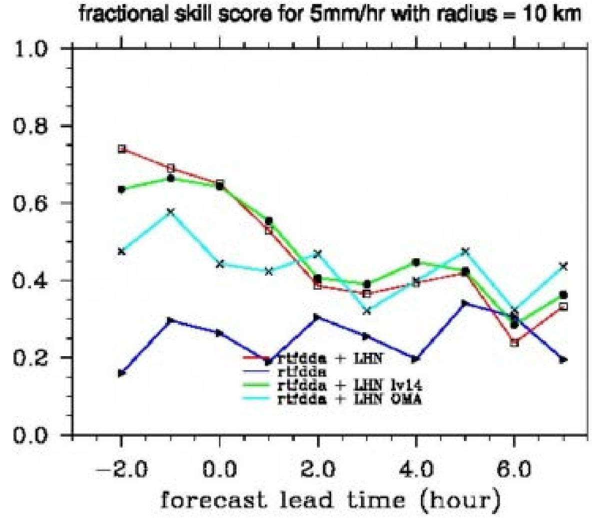


Figure. 3 Evaluation of radar data impact from a case study for the RTC domain. The event consists of several episodes of convection during November 26-27, 2012. The skill scores are calculated for 7 forecasts from RTFDDA run without RDA (blue), and RTFDDA with RDA using three different LHN options: lowest heating level at 900 mb (red), lowest heating level at 800 mb (green) and nudging heating rate based on the observation-model differences (cyan) instead of the observed heating rate.

Sand and Dust forecasting with WRF-Chem

During FY2013, an initial dust forecast capability for Saudi Arabia based on the fully coupled WRF-Chem was explored. Major steps taken to accomplish this task include (a) assessing the modern technologies for dust forecasting in Saudi Arabia, (b) designing proper algorithms and a system for implementation, and (c) producing sample dust forecasting results through a case study to demonstrate feasibility and capability. Fig. 4 shows the observed and simulated AOD (aerosol optical depth) at Solar Village during the March 2009 severe dust storm over Saudi Arabia, compared to observed AOD.

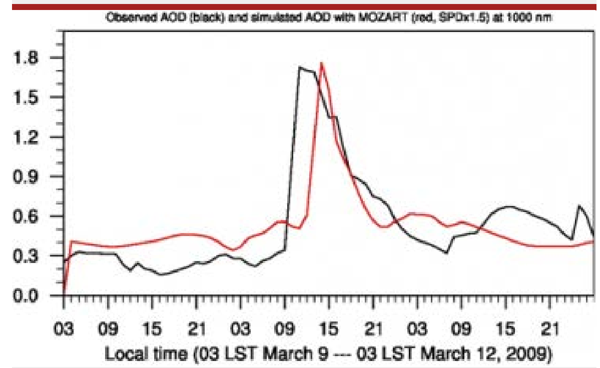


Figure 4. Observed AOD (black line) and WRF-Chem simulated AOD (red line) at 1000 nm at Solar Village (24.91°N, 46.40°E) driven by the Final Analysis (FNL) with using the WRF-Chem default chemical background data, and with the surface wind speed in the model dust emission flux increased by a factor of 1.5 during the period of 03 LST March 9 through 03 LST March 12, 2009. The WRF-Chem model simulations were initialized at 03 LST March 9, 2009.

Advances in Observation Quality-Control and Assimilation

Quality control of observations is essential to RTFDDA. Because observations are ingested into the full physics WRF, interacting with the model dynamics and physics directly, even a few bad observations can seriously affect the model reliability and performance. In FY2013, a new online QC scheme was developed. It corrects observation and model inconsistencies resulting from differences between model terrain heights and observation station elevations. These data-processing and quality-control procedures significantly enhance RTFDDA data assimilation and forecasting accuracy and system operation reliability (Fig. 5).

Improvements to RTFDDA Post-processing

The post-processing of model data for visualization, bias correction and verification, was improved for convenient configurations for different real-time forecast systems. Its efficiency was improved with a new data flow, a better parallelization, and running different configurations on a single computing cluster. To meet special project needs, specific products have been added with an increased frequency (every 15 minutes) to visualize and verify wind energy and surface station forecasts. Two statistical post-processing methods were

implemented, an analog-based method and quantile regression, for wind production facilities and forecasts for surface observations so that the forecast pdf better matches the observed pdf.

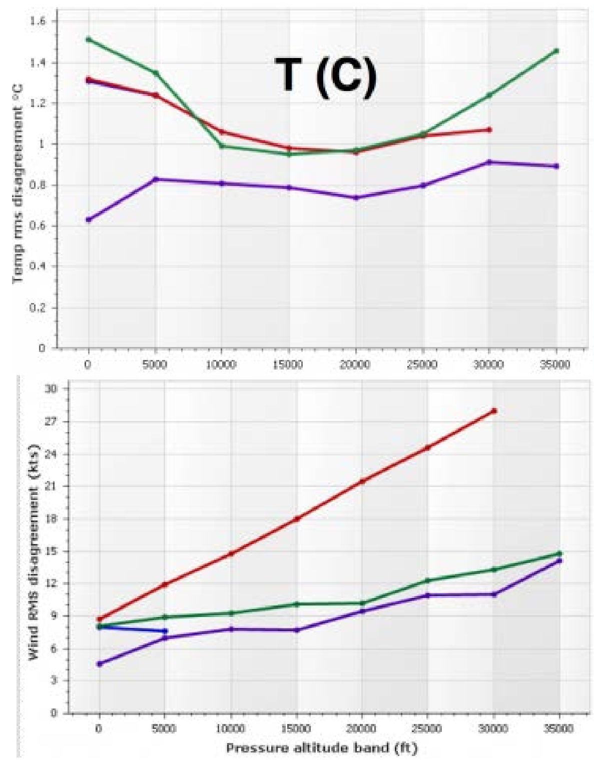


Figure 5. Statistics of RMSE of temperature (upper) and Wind (bottom) during 10 and 17 January 2012 for the AIRDAT NAM offline QC system (red), MM5-RTFDDA off line QC system (green), and the WRF-RTFDDA online QC system (purple).

PLANS FOR FY 2014

RTFDDA is a continuously evolving forecasting system. Research and development of all major RTFDDA components is ongoing. This includes tuning real-time operational forecasts for existing and new deployments. Fundamental WRF model and data assimilation advances by the RTFDDA group, and the broader community, are also continually absorbed into the RTFDDA system. In particular, the RTFDDA WRF will be upgraded to stay aligned with the WRF community updates. All operational RTFDDA systems will be upgraded to WRF Version 3.5.1 by the middle of FY2014.

We will continue to develop and test the RTFDDA-3DVAR/HLHN hybrid radar data assimilation system. The system for the Army ATC domain will be monitored and upgraded. The system will be tested in a Front Range domain for short-term forecasting of warm-season convection in the summer of 2014. Scientific research will be focused on improving the derivation of rain, snow, and graupel mixing ratios from radar reflectivity in the hybrid radar data assimilation system. Investigations will begin on assimilation of polarimetric radar products and lightning data in the hybrid RDA system.

The post-processing (calibration), and associated verification suite in RTFDDA will be improved to: a) produce pin-point meteograms and profiles at 5-minute time intervals, and b) develop bias-correction and calibration algorithms for station variables based on weather-pattern clustering classifications.

Two sand and dust storm forecasting systems will be developed for the Middle East using RTFDDA and WRF-Chem for the Middle East

‹ Four-Dimensional Weather System (4DWX) up Operational RTFDDA ›

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2013 RAL ANNUAL REPORT

OPERATIONAL RTFDDA

BACKGROUND

To meet the need for high-resolution, accurate, and rapidly updated weather information for weather-critical applications directed at national defense and security, energy, and health, RAL continues to advance and deploy its Real-Time Four-Dimensional Data Assimilation (RTFDDA) and forecasting system. RTFDDA has been deployed to provide real-time operational weather services for over 50 weather-critical applications by US government agencies and international organizations over the US and other global regions. This section reviews the operational RTFDDA NWP projects during FY2013:

1) US Army Test and Evaluation Commands (ATEC) test ranges

2) MAGEN for the Government of Israel

3) Ensemble wind prediction for State Grid Corporation of China (SGCC)

4) WRF-RTFDDA for wind power prediction of Xcel Energy

5) CONUS-scale RTFDDA Operation for Panasonic Weather Solutions

6) Microscale RTFDDA Forecasting System for South Korea

7) RTFDDA High-resolution Reanalysis and Nowcasting for Shenzhen, China

8) Modernization of Numerical Weather Prediction in Saudi Arabia

9) Bolivia Hydrological Prediction using WRF model

FY2013 ACCOMPLISHMENTS

1. US Army Test and Evaluation Commands (ATEC)

RTFDDA system serves eight Army test ranges located in the US and also supports on-demand test missions of ATEC in other regions over the globe. One ensemble-RTFDDA system and a deterministic RTFDDA-LES system have been set up for operational forecasts at the Army Dugway Proving Ground, Utah. More detail on specific advances made in ATEC modeling systems can be found at the 4DWX section of this report.

2. MAGEN for Israeli Government

MAGEN (Model for Advanced GENeration of 4D Weather) employs RTFDDA and WRFDA-3DVAR hybrid data assimilation technologies to provide high-resolution weather guidance over Eastern Mediterranean region. The second and final MAGEN system was delivered to the IAF facility in Israel, passing the on-site acceptance test, and running in its own operational environment. The scientific achievements from the previous year were applied to the MAGEN system application software. The technology transfer was conducted through on-site training and updates to the MAGEN system technical manual. A new research topic began soon after the completion of the MAGEN Phase I project. The main objective of this follow-on project is a proof of concept of extending the capabilities of the existing MAGEN hybrid system with data assimilation in an added 1.1 km grid to provide improved nowcast and forecast performances over simple diagnostic models, by better resolving local circulations such as land/sea breezes and katabatic/anabatic winds. Other goals include evaluating the effects of using the initial/boundary conditions provided by the European Centre for Middle-range Weather Forecasts (ECMWF), and investigating the optimal deployment of a sounding system to achieve the main objective.

3. Ensemble Wind Prediction for State Grid Corporation of China (SGCC)

To support wind power integration into the SGCC electric grids, NCAR collaborates with the Chinese Electric Power Research Institute (CEPRI) and applies Ensemble-RTFDDA (E-RTFDDA) technologies for wind power prediction at SGCC. In 2013, NCAR developed a real-time E-RTFDDA system for wind prediction at wind farms over the northwest provinces of China. Fig. 3a shows 80-m AGL wind speed for nested Domain 2 (Dx = 8.1 km) and Domain 03 (Dx = 2.7 km); Domain 3 shows much more refined features in the winds valid at 1800 UTC 18 April 2013. To assess the E-RTFDDA system for wind prediction at wind production facilities, case studies were performed to compare the model output with met-tower data of several wind farms provided by CEPRI. The result shows that the ensemble system is capable of capturing the ramp-up events quite well. In order to drive CEPRI’s Artificial Neural Network (ANN) based real-time wind-power forecast systems, CEPRI required one year reforecasts of the ensemble system. By the end of FY2013, six months of reforecast (for 2012) had been completed.

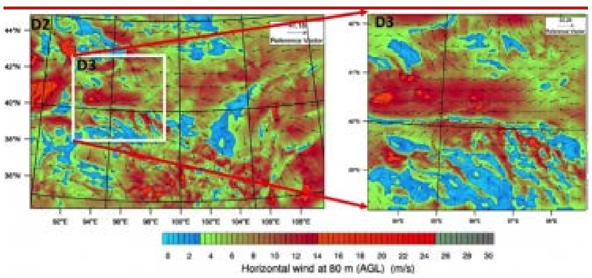

Figure 3a. 80-m AGL wind speed valid at 1800 UTC 18 April 2013 for d02 (Dx = 8.1 km; left panel) and d03 (Dx = 2.7 km ; right panel).

4. WRF-RTFDDA for Xcel Energy Wind-Power Prediction

Deterministic WRF enhancements

The NCAR-Xcel wind power prediction collaboration has moved into its third phase in which enhancements are being made to the WRF-RTFDDA system. The goal is to further improve WRF-RTFDDA’s hub-height wind prediction at wind farms by improving the model’s boundary layer and

land surface schemes, and refining the algorithms for assimilation of turbine Nacelle wind speed (Fig. 4a), wind direction, and temperature. A next-generation RTFDDA data assimilation technology called Four-Dimensional Relaxation Ensemble Kalman Filter (4D-REKF), recently developed at NCAR, will be applied in the Xcel WRF-RTFDDA system, which is expected to improve the impact of wind farm and other data on model wind forecasts.

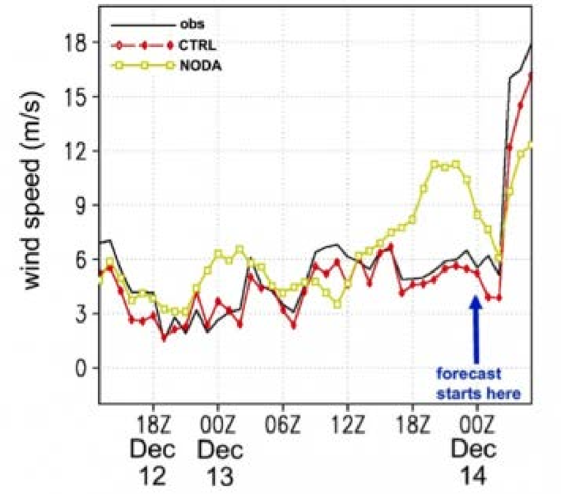

Figure 4a. Time series of farm-averaged hub-height wind speed for a wind farm in Northern Colorado from observations (black), WRF control experiment assimilating turbine observations with enhanced nudging coefficients, and WRF experiment without wind farm data assimilation (yellow). In this "idealized" experiment, the only data assimilated were the wind farm data (from 1200 UTC 12 December to 0000 UTC 14 December) with enhanced nudging coefficients to study its maximum impact with enhanced nudging coefficients. The wind farm data helped to remove the spurious wind ramp and improved on the magnitude on the actual wind ramp.

Another major research area is focused on simulation and prediction of microphysical hydrometeors, including supercooled liquid water and wet snow in the lowest 100 – 200m layer, to support wind-turbine icing prediction. Turbine blade icing can impede power production of turbines and/or potentially damage the turbines themselves.

5. PWS CONUS-scale RTFDDA Operation

NCAR and PWS (Panasonic Weather Solutions; formerly AirDat LLC.) have been long-term partners in developing RTFDDA technology for TAMDAR (Tropospheric Airborne Meteorological Data Reporting) data quality-control, optimization of TAMDAR impact in regional NWP, and in developing operational RTFDDA forecasting systems. A CONUS-scale operational WRF-based RTFDDA data assimilation and forecasting system at 12/4-km resolution was deployed at PWS in 2009, and has been continuously running since then. In FY2013, the errors of the 2-m temperature and 10-m wind predictions of NCAR-PWS system were analyzed for the period of June 2009 through September 2010. It was found that the biases of both wind and temperature forecasts vary greatly seasonally and diurnally, with dependency on the forecast length, station elevation, geographic location, and meteorological conditions. As an example, Fig. 5a shows the temperature and wind-speed biases as a function of forecast lead-time for 00 UTC (late afternoon over CONUS) cycle and 12 UTC (early morning over CONUS) cycle. It can be seen that warm (positive) biases in nighttime and cold (negative) biases in the afternoon are evident for temperature (wind speed) during the evaluation period.

Figure 5a. Temporal variations of the domain-averaged daily temperature biases (upper panels) and wind-speed biases (lower panels) as a function of forecast lead time for the 00 UTC cycle (left panels) and 12 UTC cycle (right panels) during the period of May 22, 2010 through September 9, 2010.

6. Microscale RTFDDA Forecasting System for South Korea

Since 2011, NCAR/RAL has been collaborating with the Korea Meteorology Administration (KMA) on ultra-high-resolution WRF-RTFDDA forecast system development to support wind power forecasting at offshore and inland wind production facilities. FY2013 marks the third phase of the KMA project, which is focused on a feasibility study of the NCAR RTFDDA-3DVAR-HLHN (Realtime four dimensional data assimilation, WRF 3D variational data assimilation, and hydrometeor and latent heat nudging) hybrid system for assimilating Doppler radar data available over the South Korean Peninsula. The goal is to enhance 0–12h precipitation forecasts from the KMA-NCAR RTFDDA modeling system. KMA and other Korean agencies operate a dense radar network (Fig. 6a). A heavy rainfall case during 2011 was selected to test the NCAR RTFDDA-RDA scheme. Heavy rainfall around Seoul (587 mm) and the region close to Siheung in late July 2011 triggered flash floods and landslides that killed about 70 people and caused some of the worst flooding in the Korean Peninsula in 100 years. The forecasts by operational weather services at that time did not perform well and

greatly underestimated the rainfall that occurred. The RTFDDA system simulated this storm reasonably well. Fig. 6b shows the average precipitation accumulation time series from 261 stations starting from 1300 UTC 26 July 2011.

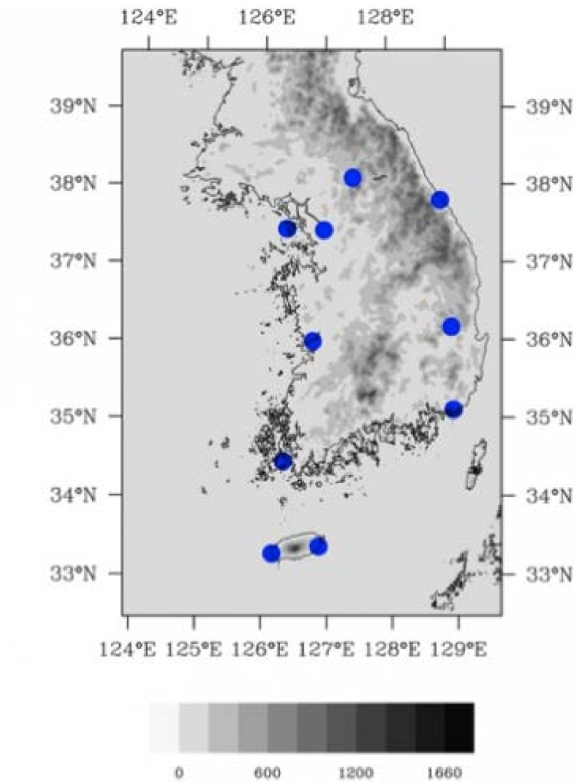

Fig. 6a. Locations of Doppler radars in the Korean Peninsula.

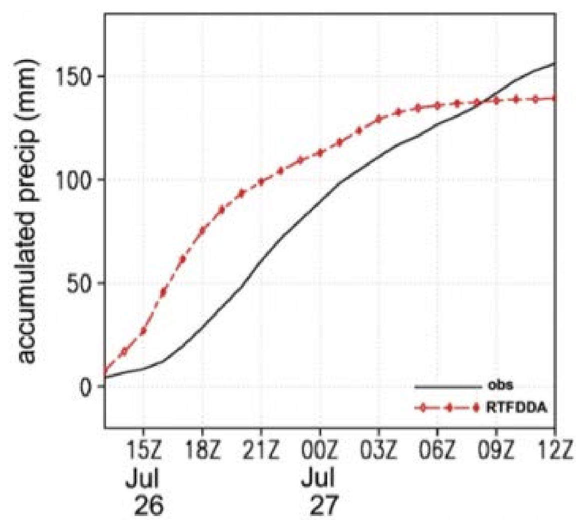

Fig. 6b. Time series of accumulated precipitation averaged from 261 stations from the Korean Peninsula from rain gauge observations (black) and d03 RTFDDA (red).

7. RTFDDA High-resolution Reanalysis and Nowcasting for Shenzhen, China

Shenzhen is a major city located in the Pearl River Delta in southern China. The municipality covers an area of 2,050 square kilometers including urban and rural areas. NCAR collaborated with Shenzhen Meteorological Bureau to develop a RTFDDA modeling system for improved predictions over the Shenzhen area. The specific goal is to effectively integrate a high-density observation-network with advanced remote sensing instruments, including ultra-dense surface Automatic Weather Station (AWS), wind profilers, radiometers, met-towers, Doppler radars, the Global Positioning System (GPS), lightning, and other platforms into the RTFDDA system to provide continuous weather analysis and forecasts, and generate a five-year microclimatology for the Shenzhen metropolitan and surrounding area. The modeling system was configured with four nested domains with horizontal grid sizes at 27km, 9km, 3km and 1 km, respectively (Fig. 7a). The 1-km domain covers Shenzhen municipality, Hong Kong, and the neighboring area.

The main accomplishments in FY2013 include: 1) designing and developing software programs to collect, process, and archive the historical weather observations for the last five years with NCAR data quality control; 2) installing the RTFDDA technologies at Shenzhen Meteorological Bureau, and optimizing the model configuration, physical parameterization and data assimilation according to the Shenzhen geographic environment (in particular, recent urbanization), prevailing weather regimes, and observation availability; and 3) setting up the model system for real-time, rapid-updated microscale weather analysis and nowcasting, and preparing the model system for production of multi-year microclimatology for the Shenzhen megacity and surrounding areas with automatic continuous updates

8. Modernization of Numerical Weather Prediction in Saudi Arabia

RAL scientists have conducted fundamental studies of prevailing and extreme weather, and climate in the Middle East. The goal is better understanding of underlying weather mechanisms in that region to provide solid foundation in the regional numerical weather prediction

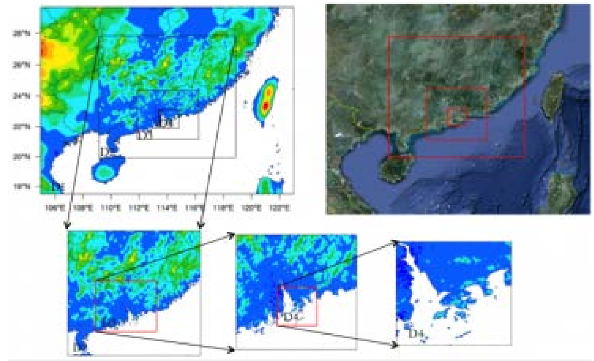

Fig. 7a. The model domain configuration for real-time high-resolution weather analysis and production of 5-year microclimatology for Shenzhen metropolitan areas. The terrain height is shown in color shades.

model development. RAL scientists and engineers have developed algorithms to collect all possible weather observations from the region, and perform extensive data quality control. An advanced real-time forecasting system was developed based on RTFDDA-WRF3DVAR hybrid data assimilation technology, and implemented at the Presidency of Meteorology and Environment (PME), Saudi Arabia, for real-time weather forecasting. The scientists and system administrators at RAL traveled to Jeddah, Saudi Arabia, and installed and tested hardware, software and the forecasting system. The system has been running in real-time operational mode since June 2013. The forecasts show high skill, as illustrated in Fig. 8a. On-site training of the forecasting system to PME staff was offered at PME. Additionally, the dust-storm prediction capability within the forecasting frame has been explored and investigated. Recently, a proposal for developing real-time dust-storm forecast capability was submitted.

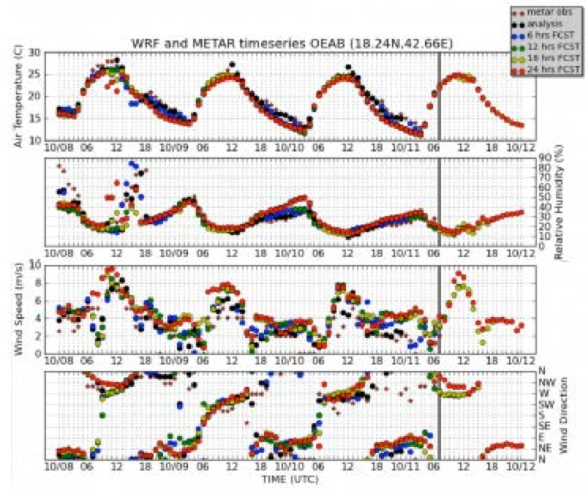

Figure 8a. WRF forecasts of near surface air temperature, dew point temperature, wind speed, and wind direction vs METAR observations (red stars indicate the observations, black dots are WRF reanalysis while color dots represent the forecasts with various advance time)

9. WRF Modeling for Bolivia Hydrological Prediction

The “WRF-3DVAR Data Assimilation System for Bolivian Forecast Improvement” project aimed at improving short-term weather forecasts for the Bolivian domain through the assimilation of conventional weather observations. Key accomplishments in FY2013 include (a) designing the WRF-based Grid-Nudging-3DVAR hybrid system and conducting sensitivity tests using WMO decoded data, and NCEP PREPBUFR data, (b) assessing the system performance for precipitation simulations within the 0-24 forecast length for two heavy rainfall cases, (c) setting up and running the model system on the sponsor’s Linux cluster in an operational mode, and (d) conducting remote training sessions on the use of the hybrid system for the sponsors and writing user’s guide and technical descriptions of the WRF-based Grid-Nudging-3DVAR hybrid system. Fig. 9a shows 24-h accumulated rainfall derived from the satellite images and the model simulations. WRF-3DVAR grid-nudging hybrid system presents improvement to WRF-only forecasts without data assimilation.

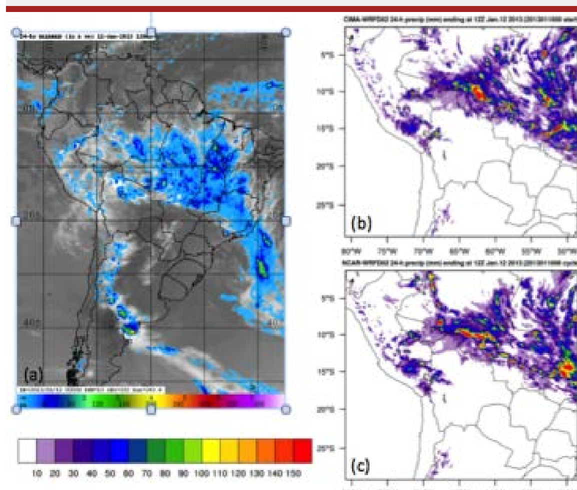

Figure 9a. 24-h accumulated rainfall (mm) between 12Z January 11 and 12Z January 12, 2003 from (a) satellite images compiled by the Naval Research Laboratory, (b) community WRF simulations, and (c) Grid-Nudgting-3DVAR hybrid system simulations. The color bar at the bottom left is for the model simulations.

PLANS FOR FY2014

Development of real-time systems is ongoing. This work includes advancing the core model sciences and technologies as well as enhancing the capabilities of operational systems. Plans for RTFDDA work for the Army Test and Evaluation Command and the Israeli Air Force are described in more detail in those sections of this report. Below are the plans for other RTFDDA projects.

China Electric Power Research Institute: We will collect and process the SGCC wind production facility data to be assimilated into the E-RTFDDA system and used for E-RTFDDA forecasts calibration. The ensemble perturbation approaches will be enhanced to include the WRF Stochastic Kinetic Energy Backscatter Scheme (SKEBS), ensemble filters, and more global models for boundary conditions. We also plan to expand the NWP

effort at CEPRI to provide weather service for solar energy, electric-grid load, and high-impact severe-weather forecasts, and support the development of SGCC intelligent grid systems.

Xcel Energy: Research will be conducted to enhance the Xcel Energy WRF-RTFDDA system by optimizing the wind production facility data assimilation, including assimilating new data (wind direction and temperature measured directly by wind turbines) and refining the weighting functions. Special attention will be put on improving WRF-RTFDDA capabilities with respect to wind ramp and turbine icing prediction.

Panasonic Weather Solutions: A major goal will be to enhance the NCAR-PWS CONUS-scale 4-km operational RTFDDA system with assimilation of radar reflectivity to improve its 0 - 12 hr prediction, especially during severe weather situations. The RTFDDA-HLHN RDA scheme will be applied and the NSSL multi-radar, multi-sensors, (MRMS) 3D radar reflectivity mosaic will be assimilated.

Korea Meteorology Administration: Research will continue aimed at enhancing the KMA RTFDDA capabilities for more effective assimilation of the dense and diverse weather observations (especially from the Doppler radar network) over the Korean Peninsula. The July 2011 Korean flood will be used as a case study for assessing and refining RTFDDA-3DVAR-HLHN for the KMA RTFDDA system. NCAR and KMA will also explore cloud analysis and assimilation schemes to expand KMA RTFDDA for solar energy prediction.

Shenzhen Meteorological Bureau: We will continue to optimize the WRF-RTFDDA setting for SZMB area to reduce the simulated wind bias, especially over the ocean; continue to implement/improve the radar data assimilation for the real-time system at Shenzhen area; and complete a five-year microclimatology reanalysis and develop the model output statistical analysis tools.

Presidency of Meteorology and Environment, Saudi Arabia: We will continue to improve the forecasting system, documenting the system including the User's Guide for PME staff, and providing on-site training. We will also develop an initial real-time dust storm prediction system and launch a demonstration real-time dust storm forecasting capability.

Finally, collaborative proposals to develop new RTFDDA-based NWP systems are being written to address specific weather forecasting needs in countries in the Middle East, Africa and Central Asia.

‹ Real-Time Four-Dimensional Data Assimilation (RTFDDA) and Forecasting Advances up Mesoscale Ensemble Data Assimilation and Prediction System ›

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MESOSCALE ENSEMBLE DATA ASSIMILATION AND PREDICTION SYSTEM

BACKGROUND

Given the chaotic nature of the atmosphere and the imperfections of numerical weather prediction (NWP) models, probabilistic forecasts are imperative for applications. To address this need, RAL has been developing an Ensemble Real-Time Four-Dimensional Data Assimilation (E-RTFDDA) and forecasting system. This WRF-based mesoscale ensemble has been deployed to support US Army test range operation and real-time wind energy prediction. Unlike most other mesoscale ensemble systems, E-RTFDDA is a multi–model, multi–scale, and rapidly cycling data assimilation and prediction system with multiple perturbation approaches. The continuous cycling mechanism of E-RTFDDA allows the model to produce accurate nowcasts and short-term forecasts. Since 2011, an innovative ensemble data assimilation algorithm known as four-dimensional relaxation ensemble Kalman filter (4D-REKF) has been under development, to replace the simpler Cressman-type “observation-nudging” FDDA in E-RTFDDA with a flow-dependent weighting. The research and development of E-RTFDDA is currently through the sponsorship of the Army Test and Evaluation Command, Xcel Energy and China State Grid projects, whose broad objectives and progress are also discussed in this annual report.

FY2013 ACCOMPLISHMENTS

Research and development activities for the Ensemble RTFDDA (E-RTFDDA) during FY2013 were focused in three areas: 1) enhancements to the ensemble perturbation methods, 2) development of 4D-REKF, and 3) ensemble system deployment including advances in post-processing and calibration.

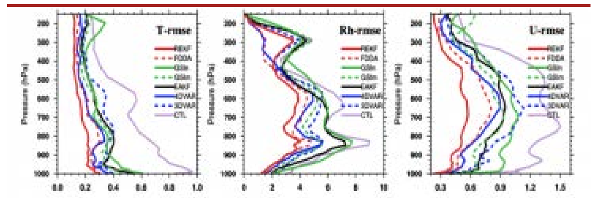

Figure 1. Comparison of the RMSE of 12hr forecasts of temperatures (T), relative humidity (Rh), and zonal wind component (U) of WRF that are initialized from 12h data assimilation using Cressman-type observation-nudging (FDDA), 4DREKF (REKF), WRFDA 3DVAR and 4 DVAR, DART-EnKF (EAKF), and two versions of GSI (GSIm and GSIn) for an OSSE study. The WRF Forecast without data assimilation is denoted as CTL.

In FY2013, two E-RTFDDA systems, each with 15 WRF and 15 MM5 members, were continuously operated: one at the US Army Dugway Proving Ground to support routine tests and test planning, and one for Xcel Energy to provide ensemble wind forecasts at Xcel facilities located in Colorado, Minnesota, Texas and New Mexico. In addition, two new 30-WRF-member E-RTFDDA systems were implemented to provide wind forecasts to support China State Grid wind integration. Bias correction and probability calibration have been developed to produce value-added probabilistic forecast products for end users.

RAL continued to enhance the E–RTFDDA perturbations approaches, adding WRF-NMM (non-hydrostatic mesoscale model) members to the system; the Canadian GEM (Global Environment Multiscale) and Japanese Meteorological Administration GSM (Global Spectral atmospheric Model) model outputs were used to enhance E-RTFDDA boundary condition perturbations; the NCAR DART ensemble Kalman filter (EnKF) tools were also integrated with E-RTFDDA to enhance E-RTFDDA initial condition perturbations. The NCAR DART-EnKF (Data Assimilation Research Testbed-Ensemble Kalman Filter) system was integrated into E-RTFDDA to enhance the E-RTFDDA system in both member perturbations and data assimilation. The enhancement allows DART EnKF to take advantage of E-RTFDDA by means of deriving error covariance using the multiple perturbation E-RTFDDA forecasts; meanwhile, the updated EnKF means and a subset of the EnKF members are used to perturb the initial conditions in E-RTFDDA.

Major work on 4D-REKF FY2013 included testing and optimizing the 4D-REKF code and algorithms, preparing for real-time operational runs. Because it is impractical to directly compute and communicate the entire Kalman gain to the nudging scheme, several more efficient approaches for computing the Kalman gain, while maintaining adequate accuracy, were tested. The schemes include a 2D mathematical fitting function, a ray-tracing method and a "nearest-point" approach. It was found that the "nearest-point" method presents the best trade-off between accuracy and efficiency for the Kalman gain computation. To handle diverse observation types, two kinds of Kalman gain computation were designed. For fixed stations, the Kalman gains are calculated at the exact station locations. For time-space changing observations such as aircraft weather reports, the Kalman gains are computed at regular grid points and then interpolated to the observation locations.

To validate the 4D-REKF data assimilation system, OSSE experiments based on perfect-model and perfect-observations assumptions were conducted. For comparison, WRF 3DVAR, 4DVAR, Gridpoint Statistical Inerpolation (GSI), and NCAR DART-EnKF have also been tested with the same OSSE framework. The verification results of this OSSE study indicate that 4D-REKF outperforms other existing WRF data assimilation technologies. Figure 1 is an example showing the bias and RMSE of various meteorological variables in 4D-REKF at the end of 6-hour data assimilation in comparison to those of WRF 3DVAR, 4DVAR, NCAR DART-EnKF, and GSI. The bias and RMSE in the standard FDDA (distance-dependent weighting) are also shown in the figure.

The 4D-REKF FDDA scheme was deployed as a component of the operational E-RTFDDA system running at the US Army Dugway Proving Ground, Utah. Assessment of the impact of 4D-REKF is on going, but the preliminary results suggest that the raw Kalman gains computed from the ensemble forecasts are not sufficiently accurate. Further refinements to the Kalman gains estimation and new hybrid Kalman gain schemes were formulated and are being tested.

FY2014 PLANS

E-RTFDDA will be further enhanced in the following areas:

- Evaluation of WRF-NMM, SKEBS, and DART EnKF components and conduct forecasting experiments to provide guidance for configuring optimal E-RTFDDA systems according to the requirements of special applications.
- Integration and assessment of more global model outputs to improve the specification of the lateral boundary conditions perturbation for E-RTFDDA.
- Continued refinement of ensemble Kalman gain computation for 4D-REKF and enhance 4D-REKF with cross-variable

(covariance) observation-nudging capabilities. In particular, this new capability will be applied to assimilate Doppler-radar radial velocities.

- Implementation of 4D-REKF for real-time operations at US Army Dugway Proving Ground, and verify the advantages.
- Continued improvement of the ensemble forecast verification and calibration algorithms. The Quantile Regression (QR) calibration approach will be reformulated to train the correction according to weather regimes. Improvement of the definition and determination of analogs for post-processing will also be considered.
- Continued E-RTFDDA technology transfer through developing new collaborations with U.S. and international agencies.

‹ Operational RTFDDA up Fine-Scale Precision NWP: WRF-RTFDDA-LES ›

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FINE-SCALE PRECISION NWP: WRF-RTFDDA-LES

BACKGROUND

Demands on fine-scale precision weather forecasts from weather-sensitive organizations are rapidly increasing. To meet their needs, NCAR-RAL takes advantage of its advanced real-time four-dimensional data assimilation (RTFDDA) weather forecasting system and the increased computing power to start to research the feasibility of NWP capability on sub-kilometer Very-Large-Eddy Simulation (VLES) scale down to Large Eddy Simulation (LES) scale. The newly developed WRF-RTFDDA-LES system can be directly nested inside a parent mesoscale system. This fine-scale forecasting system provides detailed weather information that can be integrated to improve operational and logistic effectiveness of a multi-faceted prediction system. Fundamental

research on various fine-scale weather scenarios including tornado storm and wind farm turbulence has been conducted in the course of developing the WRF-RTFDDA-LES modeling system; this work has been adapted for research and operation by several meteorological agencies.

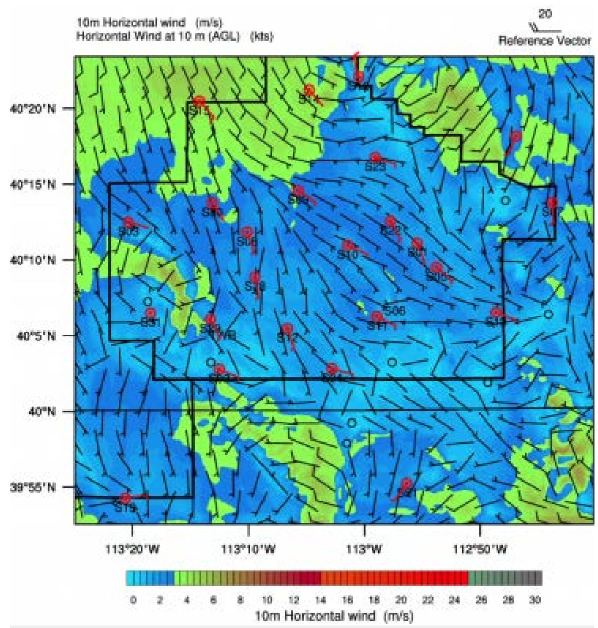

Figure 1. An example of WRF-RTFDDA-VLES real-time analysis of surface winds on Domain 4 (Dx=300m), valid at 02:00 UTC October 11, 2013. Color shades and black wind barbs: analyzed surface winds. Red wind barbs: observations of Dugway Proving Ground Mesonet surface stations.

FY2013 ACCOMPLISHMENTS

Research on WRF-RTFDDA-LES during FY2013 was mainly focused on implementation and evaluation of a real-time modeling system for the US Army's Dugway Proving Ground, in Utah. This included a study of multi-scale flow interactions at Granite Mountain with an LES-scale system.

RAL staff implemented RTFDDA-LES for Dugway Proving Ground, and configured it with four nested-grid domains, with grid sizes of 8.1, 2.7, 0.9 and 0.3 km, respectively. Real-time experimental forecasting runs began in August 2012. The system assimilates all available observations, including the dense network of observations at DPG. An example of real-time VLES analysis of surface wind is shown in Fig. 1. Staff also implemented a second WRF-RTFDDA-VLES system for a coastal region over South Korea, with a VLES-grid domain covering a large offshore wind production facility. Verification of the real-time analyses and forecasts shows the benefits of the ultra-high-resolution NWP system in resolving realistic sub-mesoscale flows; it also exposes artificially amplified turbulence over broad spatio-temporal scales that demands improvement at VLES-scales.

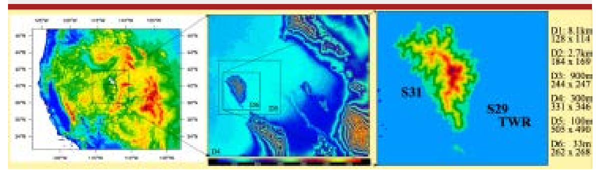

Figure 2. Simultaneous multi-scale WRF-RTFDDA-LES simulations with six-nested-grid domains using grid intervals varying from 33m to 8.1km.

To validate the VLES capability, a simulation was conducted with six nested-grid domains (two extra nested domains with grid sizes of 100m and 33m, respectively [Fig. 2]) were added to the DPG RTFDDA-VLES. The study focused on the Granite Mountain (~60 km^2) and neighboring areas at DPG, the site of MATERHORN, a university-led field study. The simulation period was for two days in May 2012, and model results from Domain 6 (at 33m grid interval) provide a true LES-scale NWP reference to assess VLES (Domains 4 - 5) model. Verification results show increasing ability of the VLES model over the mesoscale model in resolving the fine-scale flow features, especially wind ramps (e.g. Fig. 3), and confirm the validity and value of VLES-scale NWP (Fig. 4). They also indicate the need for improvement to the sub-filter-scale models for VLES.

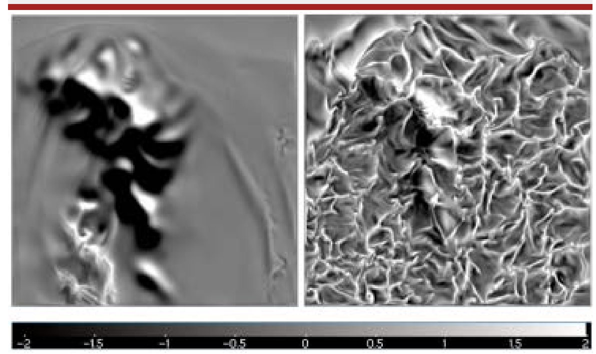

Figure 3. Snapshots of WRF-RTFDDA-LES simulation of early morning (left panel valid at 11:00 UTC, May 4, 2012 with a stable boundary layer) and around-noon (right panel valid at 17:32 UTC, May 4, 2012 with a convective boundary layer) at 33-m grid intervals. The field shown is the model vertical velocity at 200 m above ground level (m/s).

FY2014 PLAN

In the coming year, we plan to further study and evaluate the WRF-RTFDDA-LES modeling system by focusing on refinement of the fine-scale forecasting capability, and to develop tools to improve the use and visualization of VLES forecasts by end-users. Research will also continue on developing VLES forecast verification strategies, as well as on investigating LES-scale data assimilation algorithms.

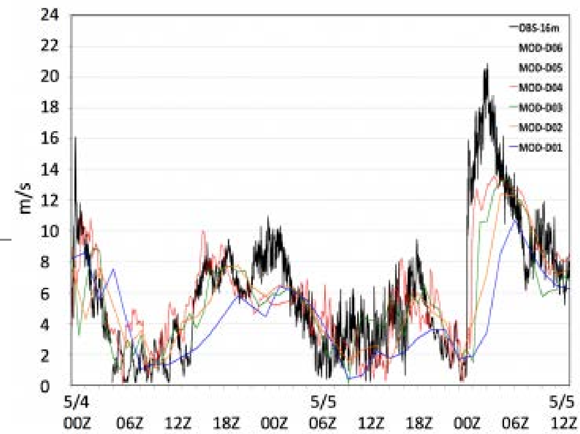

Figure 4. Comparison of WRF-RTFDDA-VLES simulations of 16-m AGL wind speed at different model resolutions with tower measurements from May 4 to 5, 2012. (Domain 1: Dx=8.1 km; Domain 2: Dx=2.7 km; Domain 03: Dx=0.9 km; Domain 4: Dx=0.3 km). VLES (D04) simulation results suggest advantages over the mesoscale models (D01 – D03).

‹ Mesoscale Ensemble Data Assimilation and Prediction System

up

Analog Ensembles ›

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ANALOG ENSEMBLES

BACKGROUND

The analog of a forecast for a given location and time is defined as the observation (or analysis grid point) that verified when a past prediction matching selected features of the current forecast was valid. A novel ensemble design, called analog ensemble (AnEn), was proposed in 2011. The best analogs of a deterministic Numerical Weather Prediction (NWP) are combined to form an ensemble and to generate skillful and reliable probabilistic predictions (Delle Monache et al. 2011, 2013). Work to improve understanding and applications has continued.

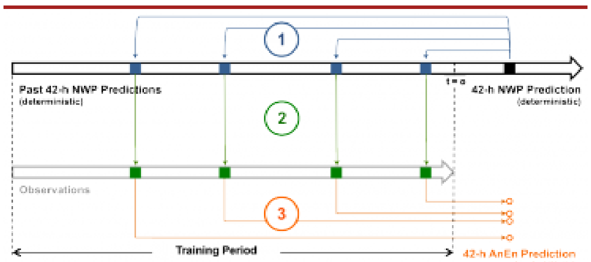

Figure 1. Schematic representation of the process for finding four members of the analog ensemble (AnEn) at one forecast lead time.

As shown in Fig. 1, the AnEn method generates ensemble members for a prediction at a given location and forecast lead time via three main steps

using a history of cases, called the analog training period, in which both the NWP deterministic prediction and a verifying observation are available. Analogs are sought independently at each location and for each lead time (black square in step 1). The best-matching historical forecasts for the current prediction are selected as the analogs (blue boxes in step 1). An analog may come from any past date within the training period, i.e., a day, week, or several months ago. Next, each analog's verifying observation is selected as a member of AnEn (green boxes in step 2). Taken all together, these observations constitute the ensemble prediction for the current forecast (orange circles in step 3).

FY2013 ACCOMPLISHMENTS

An in-depth analysis of the AnEn performance for the 0-48 h prediction of 10-m wind speed and 2-m temperature was presented by in Delle Monache et al. (2013). The salient aspects of this technique are:

- The use of a higher resolution model (since only one real-time forecast is needed);
- No need for initial condition and model perturbation strategies to generate an ensemble;
- Intrinsically reliable forecasts (i.e., no postprocessing required);
- Ability to capture the flow-dependent error characteristics;
- Superior skill in predicting rare events when compared to state-of-the-science postprocessing methods.

The analog ensemble has also been applied with success to the prediction of hub-height winds and power, for wind energy applications (Alessandrini et al. 2013). When compared to advanced power prediction systems such as the one based on the European Centre for Medium-Range Weather Forecasts (ECMWF), the AnEn exhibited superior skill at a lower computational cost. For power generation, it exhibits a superior skill for the probabilistic prediction of rare events when compared to other state-of-the-science calibration methods.

FY2014 PLANS

In FY14 the potential of the analog ensemble technique will be further explored for several applications, including wind and solar power forecasting, the generation of probabilistic weather predictions over a 2/3D grid, and the prediction of tropical cyclones intensity.

REFERENCES

Alessandrini, S., L. Delle Monache, S. Sperati, J. Nissen, 2013: A novel application of an analog ensemble for short-term wind power forecasting. Submitted to *Renewable Energy*.

Delle Monache, L., T. Nipen, Y. Liu, G. Roux, and R. Stull, 2011: Kalman filter and analog schemes to post-process numerical weather predictions. *Mon. Wea. Rev.*, *139, 3554–3570.*

Delle Monache, L., F. A. Eckel, D. Rife, B. Nagarajan, and K. Searight, 2013: Probabilistic weather predictions with an analog ensemble. Mon. Wea. Rev., 141, 3498–3516.

‹ Fine-Scale Precision NWP: WRF-RTFDDA-LES up Ensemble Data Assimilation for Wind Prediction and Model Error ›

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ENSEMBLE DATA ASSIMILATION FOR WIND PREDICTION AND MODEL ERROR

BACKGROUND

Work began in FY2013 to improve understanding of the complex interactions between the atmosphere and the ocean surface. This knowledge will be used to develop improved marine boundary layer (MBL) parameterizations, as well as improved ocean-atmospheric coupling techniques, significantly reducing market barriers to offshore wind energy. Goals include more accurate predictions of turbine hub-height winds in marine environments, resulting in improved power prediction and potentially saving millions of dollars for the wind energy industry, and improved wind resource assessment techniques in marine environments. This work is funded as part of the Department of Energy effort “U.S. Offshore Wind: Removing Market Barriers”.

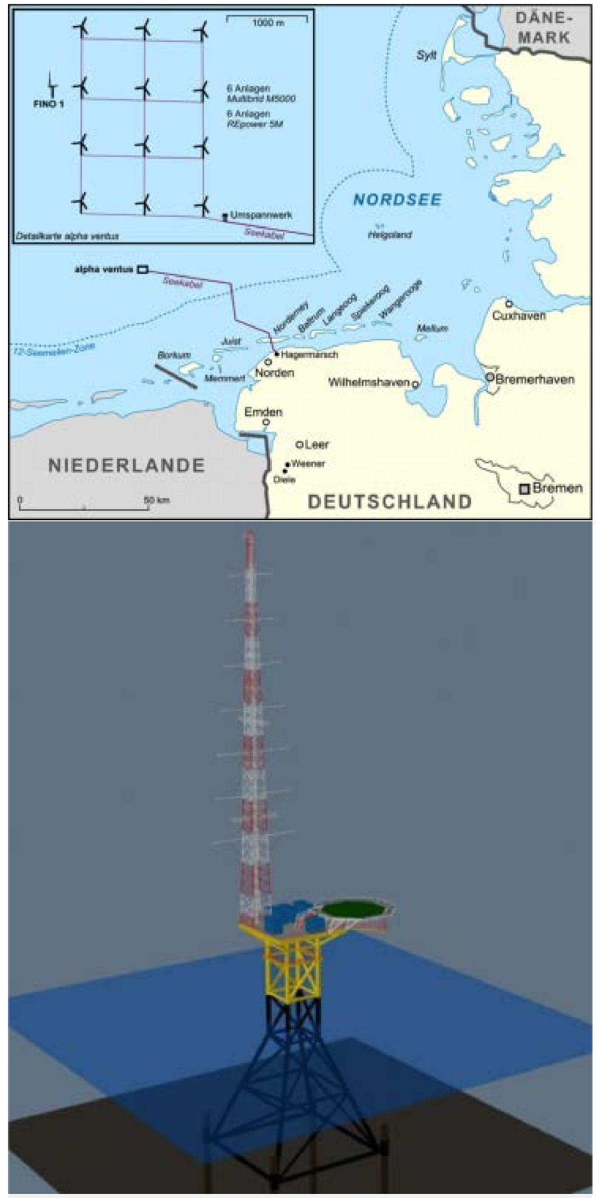

Figure 1 Location and configuration of the FINO 1 platform. Images are from www.fino1de.

FY2013 Accomplishments

The project started in late April 2013, and in the first year there were three main foci: (1) collect observational data sets, quality control, formatting, and analysis for 1-Dimensional experiments, (2) implementation of two-way coupling between WRF Single Column Model (SCM) and the wave model WaveWatch III, and (3) perform state estimation (SE) experiments with WRF SCM/Data Assimilation Research Testbed (DART).

Data collection is nearly completed, and the conversion of the data sets in DART format is underway. Location for the experiments, i.e., FINO 1 in the North Sea (Fig. 1), and periods suitable for the SE experiments (several months of 2006, Fig. 2) have been selected. SCM coupling with WaveWatch III is ongoing and about 30% completed. Work toward state estimation experiments has just begun with WRF runs that will provide boundary conditions for the SCM/DART experiments.

FY2014 Plans

In FY14, will we perform SE experiments with WRF/DART in whichWRF will be run with both SCM and 3D configurations to study model error related to the simulation of the MBL in an ensemble data assimilation framework. The expectedoutcome of the project is an improved understanding of the complex interactions between the atmosphere and ocean surface. This knowledge will be used to develop improved MBL parameterizations, as well as improved atmosphere-ocean coupling techniques, significantly reducing market barriers to offshore wind energy.

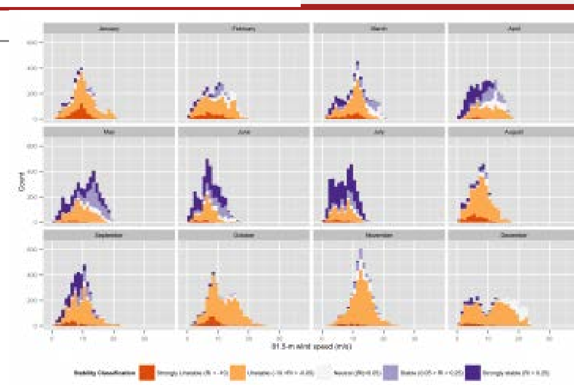

Figure 2 Monthly distributions of wind speed and stability. Stability data are plotted as a function of the 81.5 m wind speed

‹ Analog Ensembles   up   High Performance Computing for Operational Modeling ›

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HIGH PERFORMANCE COMPUTING FOR OPERATIONAL MODELING

BACKGROUND

RAL's research and development in advanced, small-footprint computing is focused on providing scalable solutions to high-resolution numerical modeling with demanding data storage requirements. By keeping abreast of the increasing speed and density of rack–mounted cluster computing, RAL delivers climate analyses and real–time weather predictions that fit into an ever-decreasing footprint. As hardware vendors continue to provide higher density computing, RAL is able to move toward more green computing, with lower power and cooling requirements.

An important feature of RAL/NSAP's computing design is its ability to provide solutions across computing scales. Given the need to deploy systems that range in size from 32 cores to 832 cores, and applications that range from global climatologies to large eddy simulations, the flexibility and extensibility of the computing architecture becomes a critical component for success.

FY2013 ACCOMPLISHMENTS

Computing

In order to effectively utilize core-dense compute resources (nodes) for parallel codes (such as the WRF numerical weather prediction model) as well as serial based post-processing, various software layers have been under examination to improve performance across differing job sizes. During FY13 the testing, analysis and impact measurements have included everything from Intel compilers, differing versions of openmpi, Linux kernel power features, as well as combinations of Infiniband (IB) OpenFabrics Enterprise Distribution (OFED) software stacks and Fourteen Data Rate (FDR) IB equipment. Through the evaluation of these tools, technical staff can help assess specific efficiencies that can be gained when sizing hardware architectures to varied job-type and runtime requirements, or to assess how non-local, hosted HPC centers might benefit NSAP projects by utilizing shared computing resources in the future.

Storage

RAL continues to utilize improvements in data storage management through the deployment of NAS (network attached storage) systems that are simultaneously accessible by a variety of project clusters. The transition away from RAID disks that were directly attached to a single computing cluster to NAS data repositories that are accessible across the local area network has been accompanied by greater reliability, increased data accessibility, and less time spent on storage maintenance by system administrators and users. In addition to the increased reliability, the NAS solution provides a growth path that allows for incremental additions to data storage, while maintaining consistent, logical namespace. The end result is that data users no longer have to spend time juggling datasets across individual disks, leaving it to the NAS architecture to manage the mapping between logical and physical space.

Further enhancing the scalability of application to storage performance are parallel IO access methods, which each server uses to access file systems over a dedicated gigabit to 10Gigbit network. The parallel NFS standard minimizes hot-spot contention for data sets and provides a topology where high demand IO requests are balanced over dozens of disk spindles and network ports to provide streaming of data in both write or read modes.

At the end of FY13 NSAP had approximately 208TB of highly fault-tolerant, parallel, network attached storage deployed, with the capability to increase by 100s of TB in FY14 and beyond. In addition to available storage, as a result of commensurate networking upgrades, the data throughput potential to backend storage has grown to 60 Gbps, providing bandwidth for the increasing demands of higher resolution weather and climate forecasting.

Monitoring

In addition to continued expansion into smaller and more-efficient use of computing and storage resources, FY13 accomplishments include expansion in the use of network-enabled system monitoring and performance analysis tools at the data management layer. Through the deployment of these tools, technical staff receive email alerts and are able to evaluate a historical record of metrics graphically to help diagnose both system and application scalability. The extensible community-supported, plug-in architecture allows developers to easily adapt existing monitoring examples to varied applications across different computing architecture without the need to write code from the ground up.

FY2014 PLANS

With current CPU and Infiniband specifications likely to remain stable in FY14, plans are underway to improve software efficiency and scalability by utilizing the Intel compiler in operational forecasts, test and deploy vendor-specific Infiniband OFED drivers and fabric features, and construct RTFDDA and CFDDA software installations in a more portable distribution method.

The combination of these enhancements will allow NSAP to deploy, execute and benchmark various forecast configurations on remote-hosted, or cloud-based HPC environments with greater ease and flexibility. NSAP realizes that trends in hardware consolidation and secured cloud computing will put an emphasis on multiple platform and remote execution of forecast and climate codes now and in the future.

‹ Ensemble Data Assimilation for Wind Prediction and Model Error | up | RTFDDA-3DVAR Hybrid System for the Middle East ›

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Search

RTFDDA-3DVAR HYBRID SYSTEM FOR THE MIDDLE EAST

BACKGROUND

MAGEN (Model for Advanced GENeration of 4D Weather) is an on-going RAL program that applies and improves the NCAR/RAL WRF-based Real–Time Four–Dimensional Data Assimilation (RTFDDA) and forecasting system to provide high-resolution weather guidance over the Eastern Mediterranean region at 3.3km grid intervals. The project goal is to use the WRF-RTFDDA system to provide improved forecasts of prevailing, high–impact mesoscale weather processes, including land–sea breezes, dynamically and thermodynamically induced topographic flows, low–level jets and wind shear, coastal clouds, localized fogs, and severe weather and precipitation associated with low pressure systems during the wet seasons. To meet these requirements, an ambitious research effort has been undertaken to enhance the RTFDDA system with several improvements that are applicable to local weather regimes, data availability, and the operational needs of the sponsor in this unique geographical region that is characterized by mountainous terrain and intricate land-water contrasts.

FY2013 ACTIVITIES

The second and final MAGEN system was delivered to the Israeli Air Force; the system passed the on-site acceptance test and is now running in its own operational environment. The final stage of the technology transfer was accomplished through on-site training and updates to the MAGEN system technical manual. A new effort was also begun to develop a proof of concept for extending the capabilities of the existing MAGEN hybrid system with data assimilation. A new 1.1 km grid is expected to provide improved nowcast and forecast performances over simple diagnostic models by better resolving local circulations such as land/sea breezes and katabatic/anabatic winds. Other goals include evaluating the effects of using the initial/boundary conditions provided by the European Centre for Middle-range Weather Forecasts (ECMWF), and investigating the optimal deployment of a sounding system to achieve the main objective. Two intensive observation field campaigns have been planned to facilitate the investigation; the first of which has been concluded and the scientific experiments are underway.

‹ High Performance Computing for Operational Modeling | up | Statistical and Dynamical Mesoscale Climate Downscaling ›

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STATISTICAL AND DYNAMICAL MESOSCALE CLIMATE DOWNSCALING

BACKGROUND

“Climate downscaling" is a practice whereby coarse-resolution climate data -- which comes from global atmospheric reanalyses (e.g., the "NCEP/NCAR Reanalysis") or global climate models (GCMs) -- is fed to physically-based or empirically-based techniques to simulate regional- or local-scale climate at much finer spatial and temporal resolution. The need for climate downscaling has grown tremendously in the past decade, as the scientific community endeavors to address an increasing number of weather and climate impacts issues related to agriculture, water resources, human health, etc. These issues are generally local or regional in scope, and therefore require fine-scale climate datasets. Climate downscaling can be accomplished by either "statistical" or "dynamical" means or a combination of the two, as described below. It can also focus on either historical climate (reanalyses) or future climate (forecasts).

Statistical downscaling empirically relates coarse-resolution atmospheric reanalysis or GCM output to some regionally representative, observationally-based dataset from the recent past (e.g., weather station and balloon measurements, radar reflectivity, satellite radiances, regional reanalyses). These statistical relationships, which implicitly account for biases in the GCM due to inadequate resolution of terrain or deficiencies in the treatment of fine scale physical processes, can then be used to downscale both the present-day and future GCM data. Statistical downscaling has the advantage that it is computationally inexpensive, and therefore generally enables users to downscale many GCMs to obtain a probabilistic estimate of regional climate change outcomes. However, it has some important limitations, including the assumption of stationarity if applied to the future, and general ignorance of physical relationships across space and time. Dynamical downscaling, described below, can overcome some of the problems of statistical downscaling but is computationally expensive to implement.

Dynamical downscaling employs a high-resolution regional climate model (RCM) --such as the Weather Research and Forecasting Model (WRF), driven at its boundaries by larger-scale (typically global and course-resolution) climate reanalyses or forecasts, to simulate climate variability at finer spatial and temporal resolution over a region and scale of interest. Because a physical model is used, spatial and temporal relationships are preserved at the fidelity offered by the downscaling model. One common limitation that results from the computational expense is a general inability to produce probabilistic simulations or forecasts with ensembles.

Hybrid statistical/dynamical downscaling techniques developed at RAL combine dynamical and statistical methods to produce high-resolution regional climate projections that are dynamically consistent, account for non-linear climate processes, properly characterize uncertainty, and--importantly--can be relatively economical to produce. Several hybrid techniques have been developed and/or applied within RAL. These include the Monte Carlo downscaling technique ("MC"; Rife et al. 2012) and the Analog-Ensemble technique ("AnEn"; Delle Monache et al. 2011). RAL scientists work on a variety of applications that employ dynamical, statistical, and hybrid downscaling techniques, some of which are described below.

FY2013 ACCOMPLISHMENTS

Analog Ensemble for Wind Resource Assessment

As part of a NASA-funded project, a new method has been proposed and demonstrated for the long-term estimation of the wind speeds at a target site, a key step in wind resource assessments (Vanvyve et al. 2013). Analog ensemble (AnEn) techniques have been used with success for short-term weather predictions (e.g., Delle Monache et al. 2013). In the context of the wind resource assessment, the AnEn method draws on the information contained in the historical data of

multiple physical quantities over the period these data overlap with the observations (known as training period; typically 365 days) of the quantity of interest (known as predictand; the wind speed in this study). The relationships derived within the training period are then applied to reconstruct the on-site wind speed over the period for which there are no observations (hereafter referred to as reconstructed period, e.g., the past 20 years before the measurement campaign started).

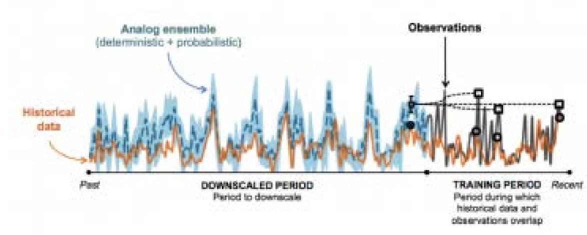


Figure 1. Sketch of the functioning of the analog ensemble method for one analog predictor, the analog trend reduced to one time step, and when retaining the best three analogs.

More precisely, this is a three-stage process that is executed independently at every target site for every hour t of the reconstructed period, as sketched in Fig.1. First, the historical value of multiple physical quantities (known as analog predictors; e.g. wind speed itself, wind direction, pressure, etc.) is retrieved for a time window (known as an analog trend) centered around time t (black dot in Fig. 1). The analog predictors are selected beforehand based on their known or anticipated correlations to the predictand. Second, other historical cases with conditions similar to those in the target window are identified (known as analogs) by looking at a time window (known as analog search window) centered around the same hour of the day for every day in the training period, and ranked by closeness of match. Analogs may therefore come from any day in the training period. Using multiple predictors helps distinguish the analogs by identifying specific weather regimes relevant to the predictand. Third, the K best analogs (K is the number of analogs; black circles) are selected, and the corresponding observed values of the predictand are retrieved (black squares). The latter are the ensemble members for hour t.

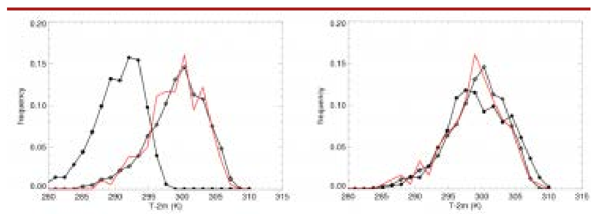
The final result is the analog ensemble, i.e., a set of K wind speed values for every hour t of the reconstructed period. The assumption is that errors in the analogs are likely to be similar to the error in the current prediction. The result is a set of errors for inferring the current error. Vanvyve et al. (2013) showed:

- The AnEn can be used effectively for wind resource applications;
- The AnEn provides an accurate long-term wind resource estimate at target sites;
- The AnEn reliably quantifies the uncertainty allowing for cost-effective decision making;
- The AnEn is a computationally inexpensive method.

Dynamical Downscaling Computational Cost Reduction via the Analog Ensemble

The AnEn technique has been tested for the first time as a way to reduce the computational cost of dynamical downscaling over a 3-dimensional grid. The AnEn algorithm has been implemented to extend a high-resolution model estimate from one to several years. A coarser model run is assumed to be available over several years (e.g., 10), while a finer-resolution model estimate is assumed to be available over only a subset (e.g., 1 year) of that period. The period over which both coarse and fine model runs are available is called training period, whereas the period over which only the coarse run is available is called the downscaling period. For a given grid point and time of the downscaling period, the coarse run is downscaled as follows: first the best matches (i.e., similar coarse runs) are sought over the training period. Then, the fine-resolution runs corresponding to the best coarse run matches are selected as analogs. This set of best analogs forms AnEn, and they can be seen as samples of the probability density function that downscales the time considered over the downscaling period. This procedure is then repeated independently (and possibly in parallel) for every grid point and time of the downscaling period. Preliminary tests indicate the ability of this approach of reducing the cost of dynamical downscaling by a factor between 5-10, depending on the location and the required accuracy. Tests are ongoing to assess in depth the accuracy and reliability of this approach, as well as the ability of AnEn to preserve the 3-dimensional physical structure of the atmospheric flow.

Future Climate Dynamical Downscaling



Dynamical downscaling is a computationally intensive method whereby fine-scale details of the atmosphere may be portrayed by running a limited area numerical weather prediction model (often called a regional climate model, RCM) nested within a coarse resolution global reanalysis or global climate model (GCM) output. As part of a NASA-funded project, we have assessed a sampling techniques to dynamical downscale a subset of representative days such that the statistical properties of the

subset of dynamically downscaled day approximate those obtained when dynamically downscaling the entire period of interest (Pinto et al. 2013). Two sampling techniques were explored: one in which days are randomly selected; the other in which representative days were chosen (or targeted) based on a set of selection criteria (example in Fig. 2). The relative merit of using random sampling versus targeted random sampling was assessed by the ability of the downscaled subset to approximate the statistical properties of daily mean 2 m air temperature (T2M). Downscaled results obtained by using a random sample that is just 5% of the entire population approximates the first two moments of T2M from the full population to within 0.3 K on average. Targeted random sampling can reduce the mean absolute of these estimates by as much as 30% locally. The estimation of more extreme values of the distribution of T2M using these sampling techniques is more uncertain but can still be estimated to within 1 K at the 90% confidence level using just 10% of the entire population. The potential reduction in computational cost afforded by these sampling techniques could greatly benefit applications requiring high-resolution dynamically-downscaled depictions of regional climate, including cases where ensembles of regional climate simulations are required to properly characterize uncertainty.

Figure 2. Distributions of T2M obtained for the (left) Rocky Mountains (RM : 40N, 107E) training grid point and (right) Great Plains (GP: 40N, 100E) training grid point for full-period GCM (black line with filled circles), full period of dynamical climate downscaling (black line with open diamonds), and from a sub-sample obtained using targeted random sampling at the corresponding training grid point and a sample size of 180 (red).

Global Climatological Analysis Tool

RAL scientists continue to support the DoD's National Ground Intelligence Center (NGIC) in its mission of assessing the consequences of the transport and dispersion of accidental and intentional releases of hazardous materials into the atmosphere. This is done by providing the agency with access to the RAL-developed GCAT (Global Climate Analysis Toolkit) system. GCAT is a fully automated dynamical downscaling system that allows NGIC scientists to remotely generate a high-resolution 30-year climatography for any region on the Earth. GCAT is based upon Climate Four-Dimensional Data Assimilation (CFDDA) technologies.

During FY2014 several capabilities were added to GCAT. A fourth domain at 1.1-km grid increment was added to the WRF C-FDDA, enabling NGIC to conduct transport and dispersion analyses at very fine scale. The capability to automatically classify WRF output fields into climatological regimes was extended to this fourth domain. The method is based on the Self Organizing Map (SOM) artificial neural network pattern recognition technique. Figure 3 shows the results of a SOM classification, in which 30 months (May 1981-2010) of WRF 1.1km hourly outputs were used to estimate the main six regimes of the wind flow over the Energetic Materials Research and Testing Center in Socorro, NM. The six regimes that have been identified are given with their frequency of occurrence and their most representative days, which are chosen based on their Euclidian distance to each SOM node. Weather data valid for the representative days provides better forcing to NGIC's transport and dispersion climatological studies, as they didn't undergo averaging which can destroy important model physical properties (balance etc.) available with dynamical downscaling.

Also during FY2013, the Second-order Closure Integrated PUFF (SCIPUFF) transport and dispersion model was implemented for execution for each dynamical downscaling simulation. This way, SOMs can be built based on plume dosage, in addition to weather variables, when analyzing the past climate.

Finally, the system began shifting from the NCAR-NCEP Reanalysis Product update NNRP2 data set to the Climate Forecast System Reanalysis data set for initial and lateral boundary conditions. The CFSR is on a 0.5-degree grid as opposed to the NNRP's 2.5 degree grid. Also, the model underlying CFSR is newer than NNRP, resulting in more accurate reanalyses.

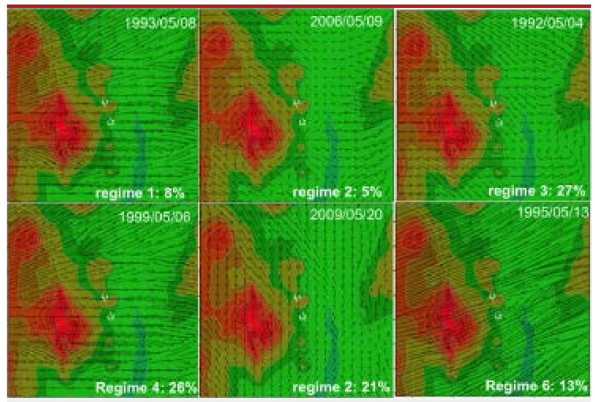


Figure 3. Typical days based on SOM classifications for dowscaled historical flow during May over Socorro, NM.

FY2014 PLANS

While the sampling technique allows one to select a subset of representative global GCM days, the resulting dataset is necessarily discontinuous. Another technique that we would like to explore to downscale future climate projections is the AnEn technique (Delle Monache et al. 2011, 2013), which can be applied to efficiently extend a short, continuous dynamically downscaled dataset to a multi-decadal downscaled dataset. These increased efficiencies could allow for utilization of finer resolution and/or more complex model physics in the dynamical downscaling. Alternatively, or, in addition, the increased

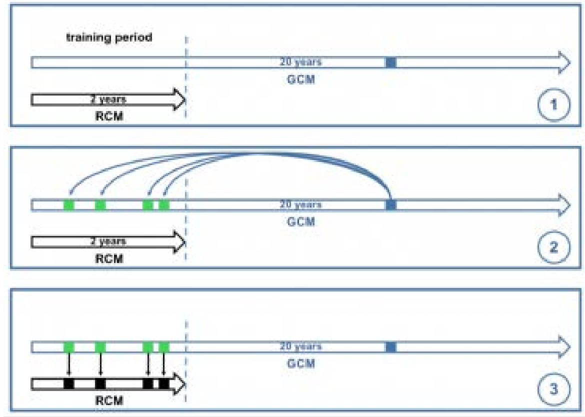


Figure 4. Main steps of the analog ensemble (AnEn) method to downscale future climate projections.

efficiency could allows for high resolution downscaling of multiple GCM or GCM scenarios to better estimate uncertainty due to model physics assumptions or unknown socio-economic responses.

Figure 3 shows how the AnEn algorithm could be applied to downscale future climate projections. Given 20- and 2-year GCM and RCM estimates, respectively, the portion over which these sets overlap is the training period (which is contiguous in Fig. 4 only for illustration purposes only). The goal is to generate an ensemble of downscaled estimates of key fields for the 18-year GCM period not included in the training set. Given a GCM realization for a given point in space and time (blue square, panel 1), the best GCM matches in the training set are found (four green boxes, panel 2), where the degree of analogy is determined with the metric described in Eq. (6) of Delle Monache et al. (2011). Next (panel 3), the corresponding (in time and space) RCM estimates are selected (four black boxes). This group of four RCM estimates comprises a four-member AnEn. The procedure could be repeated independently for each variable and for each point in space and time of interest.

During FY2014, GCAT and the underlying C-FDDA will undergo several enhancements. First, it will be updated to the latest version of WRF (v3.5.1). Initial and boundary conditions will be unified so that CFSR is exclusively used (and CFS-Forecast for downscaled foreacasts). Precipitation assimilation through a variational retrieval of moisture profiles based on observed precipitation will be evaluated. Probabilistic post-processing with surface observations and the WRF single-column model will be evaluated. Finally, the GCAT codes will be ported to DoD High-Performance Modernization Program (HPCMP) machines will reduce RAL's dependence on single-use local machines.

REFERENCES

Delle Monache, L., T. Eckel, D. Rife, B. Nagarajan, and K. Searight, 2012: Probabilistic weather prediction with an analog ensemble. Submitted to Mon. Wea. Rev.

Delle Monache, L., T. Nipen, Y. Liu, G. Roux, and R. Stull, 2011: Kalman filter and analog schemes to post-process numerical weather predictions. Mon. Wea. Rev., 139, 3554–3570.

Pinto, J., A. Monaghan, L. Delle Monache, E.Vanvyve, and D. Rife, 2013. Regional assessment of a targeted random sampling technique for more efficient dynamical climate downscaling. Conditionally accepted, Journal of Applied Meteorology and Climatology.

Rife, D.L., E. Vanvyve, J.O. Pinto, A.J. Monaghan, C.A. Davis, and G.S. Poulos, 2012: Toward robust and efficient climate downscaling: Application to wind energy. J. Appl. Meteor. Climatol., doi:10.1175/JAMC-D-12-016.1 in press.

Wood, A.W., L.R. Leung, V. Sridhar, and D.P. Lettenmaier, 2004, Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs. Climatic Change, 62, 189-216.

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ATMOSPHERIC TRANSPORT AND DISPERSION OF HAZARDOUS MATERIALS RESEARCH AND DEVELOPMENT

BACKGROUND

Atmospheric releases of hazardous materials, either accidental or intentional, continue to pose a viable threat to both United States citizens, as well as troops abroad and at home. To counter this threat, RAL is actively supporting research and the development of novel techniques and systems which can be used to more accurately simulate the atmospheric state and evolution of the released material in both time and space, for planning, real-time response, and forensic purposes.

HAZARDOUS MATERIAL SOURCE TERM ESTIMATION

In addition to needing a representative description of the atmospheric state (past, present, and future), Atmospheric Transport and Dispersion (AT&D) modeling systems also require precise specifications of the material release characteristics (e.g. location, time, quantity). For most real-time response scenarios, the specifics of the material release will be unknown, with only ancillary concentration sensor measurements available.

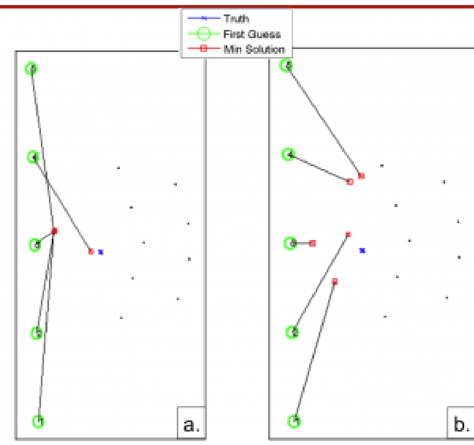

Figure 1: VIRSA test results when minimizing: (a) source location, mass, and time (Version 1.0) and (b) source location, mass, and time, plus wind speed and wind direction (Version 2.0). Black dots denote the location of material sensor observations, and the blue X denotes the true source release location. Green circles denote the first guess source release locations from which the VIRSA system initializes and converges to a minimum solution, as denoted by the red boxes.

Algorithms and techniques to characterize the source and material are actively being developed at RAL to quickly reconstruct and estimate the source release using these limited sensor observations. In particular, RAL is actively developing a tailored Source Term Estimation (STE) and hazard refinement system, called the Variational Iterative Refinement STE Algorithm (VIRSA). VIRSA is a combination of models that include: the Second-order Closure Integrated PUFF model (SCIPUFF), its corresponding STE model, a hybrid Lagrangian-Eulerian Plume Model (LEPM), its formal numerical adjoint, and the software infrastructure necessary to link them. SCIPUFF and its internal STE model are used to calculate a “first guess” source estimate based on available hazardous material sensor observations and meteorological observations. The LEPM and corresponding adjoint are then used to iteratively refine the "first guess" source and wind estimate using variational minimization techniques.

Version 1.0 of this system was successfully integrated into the US Department of Defense (DoD) emergency response modeling systems—HPAC (Hazard Prediction and Assessment Capability) and JEM (Joint Effects Model) in FY2012. This version of VIRSA includes the capability to refine the "first guess" source location, mass, and release time utilizing material sensor observations and meteorological observations provided in the North Atlantic Treaty Organization (NATO) Nuclear Biological and Chemical (NBC) messaging format. Version 2.0 is currently under development and scheduled for release in FY2014. This version will include the capability to refine the wind fields (wind speed and direction), in order to provide a better estimate of the source release characteristics and resulting downwind hazard.

Specific accomplishments since the last reporting period and plans for next fiscal year are summarized below.

FY2013 Accomplishments

- Successfully modified the VIRSA system to include wind speed and wind direction, in addition to source mass, location, and time, in the cost function minimization procedure. Preliminary testing and evaluation has shown general improvement in the VIRSA solution, as compared to v1.0 (Figure 1).
- Made substantial progress developing an ensemble-based methodology to include and incorporate uncertainty information into the VIRSA solution. This methodology has been shown to drastically reduce the complexity of the overall cost function surface, and thus improve the overall performance of the minimization process, as illustrated in Figure 2.

FY2014 Plans

Refine methods for incorporating wind speed and direction information into the cost-function minimization process.

- Refine and evaluate methods for incorporating uncertainty information into the cost-function minimization process.
- Begin integration of v2.0 into HPAC and subsequent verification and validation of the integrated system.
- Begin integration of v2.0 into JEM and subsequent verification and validation of the integrated system.

VIRTUAL ATMOSPHERIC DISPERSION FIELD TESTING

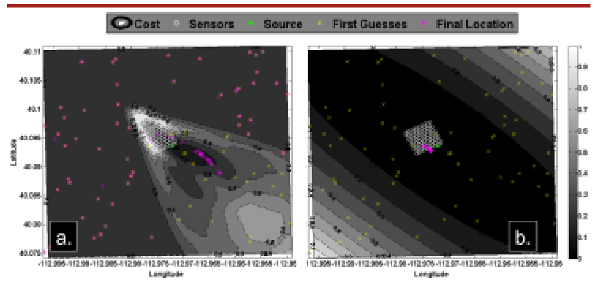

Figure 2: Cost function surface maps and VIRSA solutions when utilizing: a) no uncertainty information (unconstrained) and b) uncertainty information derived via an ensemble based method (constrained). White circles denote the material sensor locations, while a green star denotes true source release location. First guess and final estimated source release locations are highlighted in yellow and pink, respectively.

In order to more robustly test and evaluate the evolving VIRSA system, RAL has developed the Virtual Threat Response Emulation and Analysis Testbed (VTHREAT), enabling simulation of physically realistic hazardous release scenarios, placement of material and meteorological sensors, and extraction of the resulting synthetic sensor readings. VTHREAT utilizes research grade Numerical Weather Prediction (NWP) and Atmospheric Transport and Dispersion (AT&D) models to generate high-resolution realizations of the turbulent atmospheric boundary layer and the resulting turbulent transport of materials released in the synthetic environment. More specifically, VTHREAT is currently leveraging the Large Eddy Simulation (LES) capabilities provided by the Weather and Research Forecast (WRF) NWP model, combined with continued advancements being made with the NCAR Lagrangian Particle Dispersion Model (LPDM). The resulting environmental simulations can then be sampled utilizing a variety of material and meteorological sensor models, which emulate the operating characteristics of the sensing modality. These tools have been incorporated into a consolidated software application, which allows a user to easily load existing virtual test simulations, visualize the 4-dimensional environment, place material and meteorological sensors within that environment, and save the sensor readings for later analysis or as input to downstream sensor information systems. The GUI architecture is currently based on the National Aeronautics and Space Administration (NASA) World Wind Java Geospatial Visualization Platform, which provides access to a variety of external web map server (WMS) services and datasets.

Specific accomplishments since the last reporting period and plans for next fiscal year are summarized below.

FY2013 Accomplishments

- Completed the transition from EULAG (Eulerian/semi-Lagrangian fluid solver) to WRF (Weather Research and Forecasting) for providing LES generated environmental conditions.
- Began development and evaluation of the Lagrangian Particle Dispersion Model (LPDM), which now utilizes a 2-particle relative dispersion modeling framework, to more accurately simulate near source dispersion.
- Added the capability to include various background aerosols, which cause detection interference, within the environmental simulation.
- Developed and integrated algorithms into VTHREAT, which predict various field test performance metrics, based on the planned test sensor makeup and layout.
- Generated a large library of synthetic environment and associated material release scenarios (21 cases), which can be used by the VTHREAT tool to generate a large quantity of synthetic sensor measurements.
- Successfully ported the VTHREAT application from the Macintosh Operating System (OS) to the Windows OS platform to better support external users.
- Delivered the VTHREAT application to the Institute for Defense Analysis (IDA) to support their ongoing third party evaluation of Source Term Estimation (STE) algorithms.

FY2014 Plans

- Continue validation of the WRF LES capability.
- Expand the VTHREAT synthetic environment and release scenario library to include urban environments/scenarios.

Complete the testing and integration of the latest 2-particle version of LPDM, into the VTHREAT application.
- Port the LPDM to GPU’s so that transport and dispersion solutions can be efficiently computed.
- Link VTHREAT with other analysis models such as health-effects models.

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MESOSCALE MODELING SYSTEMS

BACKGROUND

The Developmental Testbed Center (DTC; http://www.dtcenter.org) – a distributed facility with components in the Joint Numerical Testbed (JNT; http://www.ral.ucar.edu/jnt) at NCAR's Research Applications Laboratory (RAL) and the Global Systems Division (GSD) of NOAA's Earth System Research Laboratory (ESRL) – facilitates the transfer of research results into operations and provides the research community with an easily accessible state-of-the-art Numerical Weather Prediction (NWP) system for research. At this time, the DTC's main focus is on mesoscale forecasting systems, with a goal of accelerating the rate at which new mesoscale modeling technology is infused into operational weather forecasting. The DTC meets its goals by maintaining and supporting community codes that represent the latest NWP technology, performing extensive testing and evaluation of new NWP technology, maintaining a state-of-the-art verification package, and connecting the NWP research and operational communities through its visitor program.

FY2013 ACCOMPLISHMENTS

Community Codes

Community code is a free and shared resource with distributed development and centralized support. The DTC's community code efforts are collaborative activities with developers at NCEP's Environmental Model Center (EMC), NCAR's Mesoscale and Microscale Meteorology (MMM) Division, NOAA/ESRL/GSD, NOAA's Geophysical Fluid Dynamics Laboratory and the University of Rhode Island (URI). During 2013, the DTC supported the following software packages for the community:

- Weather Research and Forecasting (WRF; http://wrf-model.org) – NWP model + pre- and post-processors
- Model Evaluation Tools (MET; http://www.dtcenter.org/met/users) – Verification package including standard verification techniques, as well as more advanced techniques
- Gridpoint Statistical Interpolation (GSI; http://www.dtcenter.org/com-GSI/users) – Data Assimilation System
- WRF for Hurricanes (http://www.dtcenter.org/HurrWRF/users) – Coupled model capabilities (atmosphere and ocean) in support of tropical cyclone forecasting

Periodic public releases of each package include the latest developments of new capabilities and techniques. Prior to each official release to the user community, the DTC ensures the integrity of all community code software components through a broad range of testing. The DTC also strives for system evolution, in particular through increased interoperability of existing system components, as well as adding new capabilities or techniques. In addition, the DTC provides user support for these packages in the form of Users' Guides, webpages, email helpdesks, and online and on–site tutorials.

Testing and Evaluation

The DTC provides a trusted facility that developers and the operational community can rely on for unbiased assessments of the operational prediction systems and potential new additions to those systems. Testing and evaluation undertaken by the developers of new NWP techniques from the research community are generally focused on case studies. However, in order to adequately assess these new technologies,

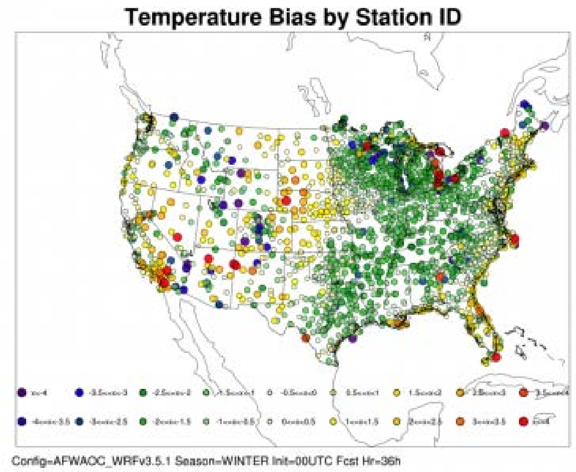

Figure 1. Median 2 m AGL temperature bias (°C) by observation station aggregated over the 00 UTC initializations at the 36 hour forecast lead time (valid at 12 UTC) for the AFWA operational configuration using WRF version 3.5.1 during a winter season (January – March 2012).

extensive testing and evaluation must be performed to ensure they are indeed ready for operational consideration. Testing and evaluation by the DTC focuses on either extended retrospective time periods or real–time forecast experiments. These forecasts can be generated by the DTC or provided by external modeling groups. The DTC's evaluations include use of standard verification techniques, as well as new verification techniques in some cases. All verification statistics include a statistical significance (SS) and practical significance (PS) assessment when appropriate.

Two mesoscale NWP systems utilized in both research and operational forecasting applications around the world include the Weather Research and Forecasting (WRF) model and the NOAA Environmental Modeling System (NEMS). Due to the increasing number of approaches developed in the NWP research community, it is necessary to rigorously test select techniques and evaluate the performance for specific applications. During 2013, the DTC performed evaluations for a variety of testing activities including model inter-comparisons and stand-alone Reference Configurations. Results associated with model inter-comparisons can be accessed on the DTC website at http://www.dtcenter.org/eval and RC results can be found at http://www.dtcenter.org/config. Information distributed on each website includes a description of the model configuration and the extensive testing that was performed. An executive summary of the results is provided, along with the full set of verification plots, which include additional spatial and temporal breakdowns (e.g., Fig 1).

Comprehensive test and evaluation activities performed during 2013 included:

- WRF v3.4 (see: http://www.dtcenter.org/eval/meso_mod/afwa_test/wrf_v3.4) in a functionally similar environment to Air Force Weather Agency (AFWA) operations, including a 6-hour "warm-start" spin up and data assimilation. Impacts of initializing WRF with output from two different versions of AFWA's Land Information System (LIS) were assessed for one full year.

- WRF v3.4.1 (see: http://www.dtcenter.org/eval/meso_mod/topo_wind)using the ARW High-Resolution Window (HIRESW) forecast system physics suite run operationally at the NCEP and two newly available surface drag parameterization schemes (topo_wind=1 and 2). Nested 15/5km CONUS domains were simulated for one full year to investigate the impacts of the new topo_wind options on the high surface wind speed bias often observed in WRF, especially over plains and valleys. (See Figs. 2 and 3)

- WRF (v3.4, v3.4.1, v3.5) (see: http://www.dtcenter.org/eval/meso_mod/version_tne) version testing for one particular configuration of the Advanced Research WRF (ARW) dynamic core to monitor forecast performance through time. The testing spanned a warm season and a cold season to capture the model performance over a variety of weather regimes.

Mesoscale Model Evaluation Testbed

In order to assist the research community with conducting detailed case study testing of newly developed techniques, the DTC has established and is maintaining the Mesoscale Model Evaluation Testbed (MMET; http://www.dtcenter.org/eval/meso_mod/mmet). The motivation of MMET is to assist the research community in efficiently demonstrating the merits of a new development that could positively impact an operational configuration in the future.

MMET provides a variety of initialization and observation data sets for a number of routine, high-impact and field campaign cases. Baseline

Figure 2. Time series plot of 10 m AGL wind speed (m s^{-1}) for median bias over the 5 km CONUS verification domain aggregated across an entire year of cases (July 2011 – June 2012) for the 00 UTC initializations. The baseline configuration is shown in green, the TWIND1 configuration in red, and theTWIND2 configuration in blue. The vertical bars attached to the median value represent the 99% CIs.

results for select operational configurations are also produced by the DTC in a functionally similar environment to operations and made available through MMET. Through the common framework provided by MMET, researchers have the ability to perform direct comparisons between multiple innovations tested by the research community and/or against the baseline operational configurations established by the DTC.

MMET has also been established to support the broader goal of streamlining the path to potential operational use for promising new science innovations developed in the research community. A testing protocol document detailing a three-stage process of testing conducted by the research community, DTC and, ultimately, operational centers, discusses the research to operations (R2O) process further. It is believed that, with better coordination among the NWP community as a whole, major benefits towards improving model physics can be realized, resulting in more accurate and reliable operational NWP forecasts.

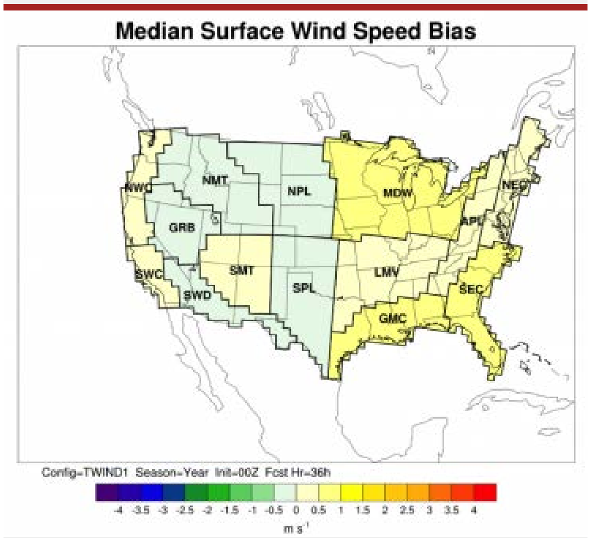

Figure 3. Regional median bias for 10 m AGL wind speed (m s^{-1}) over the 5 km CONUS verification domain for the TWIND1 configuration aggregated over the 00 UTC initializations at the 36 h forecast lead time for an entire year of cases (July 2011 – June 2012).

FY2014 PLANS

In the coming year, the DTC will continue to support various community codes, including the WRF model and post–processor, coupled model capabilities, MET, and GSI. The DTC will also help organize and support tutorials on the community codes that it supports, related to mesoscale models, data assimilation, hurricanes, and forecast verification.

While the DTC will continue WRF-based T&E activities for the foreseeable future in context of RCs, WRF for hurricanes, and various ensemble configurations, it has become necessary to broaden the scope of internal T&E activities to include new software frameworks (e.g., NEMS) utilized by the relevant operational centers (e.g., NOAA). This effort is vital for the DTC to continue to serve as a bridge between research and operations and work is on-going on this front.

‹ Numerical Systems Testing and Evaluation | up | Advanced Verification Techniques and Tools ›

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ADVANCED VERIFICATION TECHNIQUES AND TOOLS

BACKGROUND

Forecast verification and evaluation activities typically are based on relatively simple metrics that measure the meteorological performance of forecasts and forecasting systems. Metrics such as the Probability of Detection, Root Mean Squared Error, and Equitable Threat Score provide information that is useful for monitoring changes in performance of single aspects of forecast performance with time. However, they generally do not provide information that can be used to improve forecasts, or that can be helpful for making decisions. Moreover, it is possible for high quality forecasts– such as high-resolution forecasts – to have very poor scores when evaluated using these standard metrics, while poorer quality forecasts may score higher. In response to these limitations, the RAL Verification Group develops improved verification approaches and tools that provide more meaningful and relevant information about forecast performance. The focus of this effort is on diagnostic, statistically valid approaches, including feature–based evaluation of precipitation and convective forecasts, distribution–based approaches that can provide more meaningful information (for forecast developers as well as forecast users) about forecast performance. In addition, the RAL Verification Group develops forecast evaluation tools that are available for use by members of the operational, model development, and research communities. Development and dissemination of new forecast verification approaches requires research and application in several areas, including statistical methods, exploratory data analysis, statistical inference, pattern recognition, and evaluation of user needs.

FY2013 ACCOMPLISHMENTS

Spatial verification methods and the spatial method inter–comparison project

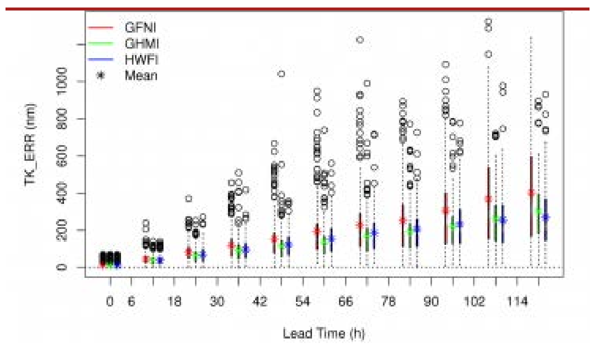

Figure 1: Boxplots of Hurricane Forecast Track Error by forecast lead time for three numerical model forecasts.

The initial forecast verification methods intercomparison project focused on comparing the capabilities of newly developed spatial forecast verification methods. That project was completed in 2011 and resulted in a special collection of articles in the journal *Weather and Forecasting.* A second intercomparison project, developed in partnership with international collaborators, was known as the Mesoscale Verification Intercomparison in Complex Terrain (MesoVICT) effort. Detailed MetoVICT planning took place at the European Meteorological Society annual meeting in September 2013. The cases for this project include more complex terrain and wind verification. Datasets will be made available to participants in the near future, and initial results from the experiments are expected to be presented at the WMO 6th International Verification Methods Workshop in New Delhi from 17-19 March, 2014.

To simplify the use of many of the spatial verification methods for the MesoVICT and other efforts, the RAL verification group has developed a spatial verification methods package in the R programming language (SpatialVx; **www.r-project.org**). The package is still under development and currently includes features-based verification, neighborhood methods, kernel smoothers, and many other statistical and image-based verification approaches.

The extension of object–based and other spatial verification approaches is in progress and will continue into the next fiscal year. Fields other than precipitation have been examined with promising results.

The Method for Object-based Diagnostic Evaluation (MODE) tool has been extended to include the time dimension and this extended version of MODE will be implemented in a future release of the Model Evaluation Tools (MET). Another spatial verification method--image warping--has also been extended by E. Gilleland and has been documented in an NCAR Technical Report (available at http://opensky.library.ucar.edu/collections/TECH-NOTE-000-000-000-850).

The Model Evaluation Tools (MET)

The Model Evaluation Tools (MET) (http://www.dtcenter.org/met/users/) is a freely available software package for forecast evaluation that was developed and is supported by RAL/JNT staff. MET Version 4.1 was released to the community in June 2013 and Version 4.2 will be released during spring 2014. Currently MET has more than 2000 registered users, with about half of them from the university community. In preparation for the next release, development has focused on new data formats for data assimilation and land surface verification, as well as cloud verification approaches and observations. The METViewer system, a capability for storing MET verification statistics in a database and analyzing and displaying the results, is undergoing a complete GUI redesign. METViewer plots are highly configurable, based on MET or other verification results contained in a database. METViewer is used by the DTC for testing and evaluation activities, and has also been installed at the National Centers for Environmental Prediction.

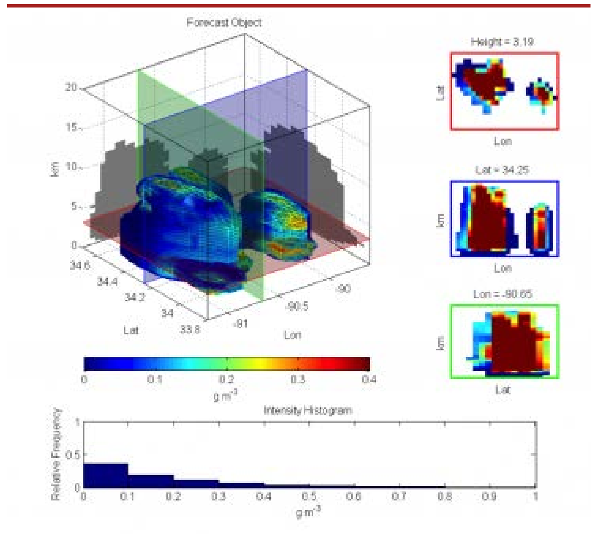

Figure 2: 3-D modeled cloud objects corresponding to an isolated thunderstorm. Upper-left panel shows outer surfaces of the clouds in the domain, with three planar cross sections through parts of the domain shown at right. The lower panel shows a histogram of cloud liquid water content for all cloudy grid boxes in this domain. The satellite evaluation tools were enhanced to include the evaluation of aviation relevant cloud properties. In FY 2013, these tools were be evaluated during winter- and summer time demonstration experiments at AWC.

A major effort this year has focused on completion and release of new tropical cyclone (TC) forecast evaluation tools. The MET TC package was released with MET4.1 in June of 2013. This package replicates current verification capabilities of the National Hurricane Center, but in an easily extensible, widely available, and supported package. Basic track and intensity verification statistics are produced. In addition, the package is designed to give the user an extensive variety of filtering and plotting options. For example, Figure 1-1 shows the track error distributions for three forecasts by lead time. In the future, more advanced verification methods for tropical cyclones will be included in this package.

Use of satellite information for verification

This research is in collaboration with scientists and engineers at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University. The research team is developing and adapting statistical techniques to make full use of satellite observations for evaluations of forecast cloud products and features that will help identify why particular algorithms or numerical parameterizations of clouds are sometimes deficient. This year, vertical satellite cross sections from A-Train satellites were used along with traditional horizontal observations from MODIS to determine the three dimensional attributes of clouds, as shown in Figure 2. During FY2013, a new capability to handle MODIS satellite observations was added to MET and released with version 4.1 of the software. An interactive tool, designed to help identify appropriate MODE parameter settings for the cloud comparisons, was demonstrated and evaluated at the National Weather Service's Aviation Weather Center during a winter experiment. This tool may be released to the public in the future. In addition, aviation applications were identified through interactions with the operational aviation weather forecasting community.

FY2014 PLANS

The MET release in 2014 will include updated tropical cyclone verification capability, new data formats, and enhanced cloud and ensemble verification methods. The capability to handle additional satellite observations will also be included in a future MET release. Further research on appropriate methods for evaluating forecasts through time will be conducted and included in a later MET software release if appropriate. Further, the object time tracking extension to MODE will be made operational and included in the next release of MET. Experimental use of MODE on fields other than precipitation will continue. The METViewer software GUI redesign will be completed, to increase usability and user friendliness.

Implementation of MesoVICT will be a focus for the next year, in collaboration with international members of the verification community. Initial results will be presented at the International Verification Methods Workshop. The image warping and MODE tools will be included in this project. A scientific publication about the A-Train satellite work has been submitted and will be published in the coming year.

‹ Mesoscale Modeling Systems up Data Assimilation ›

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DATA ASSIMILATION

BACKGROUND

The goal of the Data Assimilation Team (DAT) is to help accelerate transitions from research to operations in the area of data assimilation. To accomplish this, the DAT provides a pathway for transitions between the data assimilation research and operational communities. In particular, in collaboration with the research and operational centers (e.g., NCEP), the DAT has built and maintains a code management framework for distributed development of new capabilities and advances in data assimilation. To facilitate use of the operational DA system by the research community, the DAT provides operational capabilities to the research community in a timely manner, with complete user support and annual training opportunities. In addition to community support activities, the DAT conducts testing and evaluation of state-of-the-art data assimilation techniques within a software and computing environment that is functionally similar to the operational environment. These testing activities provide a rational basis for enhancement of operational data assimilation techniques and systems, and, eventually, improvement of numerical weather prediction forecasts and analyses. Much of this works is done under the auspices of the Developmental Testbed Center (DTC).

FY2013 ACCOMPLISHMENTS

Code Management and Community Support

The DAT currently maintains and supports a version of the Gridpoint Statistical Interpolation (GSI) data assimilation (DA) system with community features (http://www.dtcenter.org/com-GSI/users/index.php). The GSI system is the operational data assimilation system for various forecasting and analysis systems and applications. One of the recent operational applications is the operational implementation of GSI at the Air Force Weather Agency (AFWA) put in place in July 2013. To accommodate all the operational applications and coordinate distributed development, the DAT continued to maintain the code management plan and organize the GSI review committee meetings and code review activities. In a joint effort with NCEP and the Joint Center for Satellite Data Assimilation (JCSDA), the DAT hosted two GSI outreach events for the first time at the new NOAA building (National Center for Weather and Climate Prediction) in College Park, Maryland. The DAT continued to provide code releases and community support through the entire year.

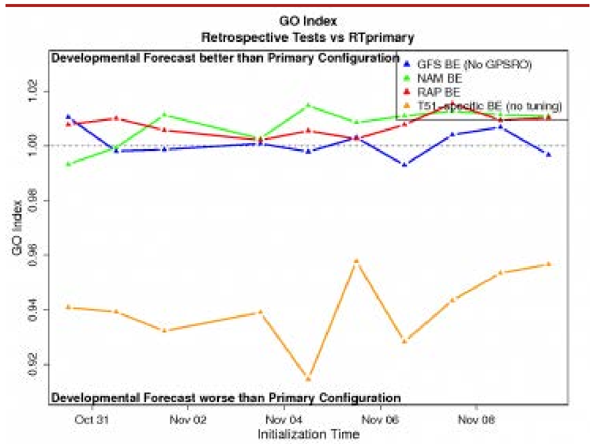

Figure 1. GO index of NAM (green), RAP (red), GFS (blue), and T51-ARW (orange) background error runs vs. AFWA's configuration during a 2-week retrospective period. GO index is a weighted sum of skill scores computed for wind speed (at 250 hPa, 400 hPa, 850 hPa and surface), dew point temperature (at 400 hPa, 700 hPa, 850 hPa and surface), temperature (at 400 hPa and surface), height (at 400 hPa), and mean sea level pressure. If GO index is bigger (smaller) than 1, the specific background error experiment performs better (worse) than the primary configuration (AFWA's configuration).

Testing and Evaluation

During FY2013, the DAT focused on two major activities: GSI baseline tests for AFWA and GSI based hybrid variational and ensemble (GSI-hybrid) tests for HFIP. Both activities were geared to investigate alternative systems/configurations and evaluate their performance for specific operational applications. These tests provided a good evaluation of the GSI/GSI-hybrid system by applying GSI in regional areas beyond the U.S. domain, which is the primary domain for most of the regional GSI applications at NOAA, as well as using the new GSI-hybrid technique for tropical storm forecasts. Such evaluations are valuable to general researchers and users of the forecasts, in addition to the specific sponsors.

The DAT redesigned its GSI baseline tests with the motivation to assist AFWA in determining an appropriate GSI configuration for operational implementation. The tests conducted at the DAT were aligned with the AFWA real-time parallel GSI runs. While the AFWA runs focused on evaluating the overall performance of GSI, the DAT tests focused on testing incremental changes. The DAT configured a functionally similar testing environment to the AFWA pre-operational configuration (POC) and the testing components were selected based on the ongoing testing results and consultation with AFWA. In particular, the DAT evaluated the then current GSI configuration from AFWA and proposed a new configuration by conducting a series of experiments assessing the following areas:

- NOAA's prescribed static background error statistics for Global Forecast System (GFS), Northern American Mesoscale (NAM), and RAPid refresh (RAP)
- Regional background error generation methods (National Meteorological Center (NMC) and ensemble perturbation mthods) and background error tuning for the AFWA system
- Data impacts of Global Positioning System (GPS) radio occultation (RO) observations
- Channel selection and impact study for radiance data assimilation

As part of the effort to improve the Hurricane WRF (HWRF) initialization system, the DAT worked closely with the system developers to test a minimal hybrid variational-ensemble DA system for an experimental basin-scale HWRF domain. The ensemble input for this system came directly from NCEP's GFS ensembles. Due to the contributions from the ensembles, the background errors in this hybrid DA system involve two parts: static (variational) background errors computed from past forecasts and the background errors computed from real-time ensembles. Consequently, the information contained in the combined background error statistics is flow-dependent with more realistic representation of cross-covariance among variables. Figure 2 is an example to show the analysis responses to assimilation of a vertical profile of radiance data using such a hybrid system versus the traditional three dimensional variational (3D-Var) GSI. The information from the radiance (brightness temperature) observations was well spread to the wind field with much bigger wind analysis increments, while the 3D-Var generated limited increments for wind field. Consequently, the circulations around the weather system in the domain were changed.

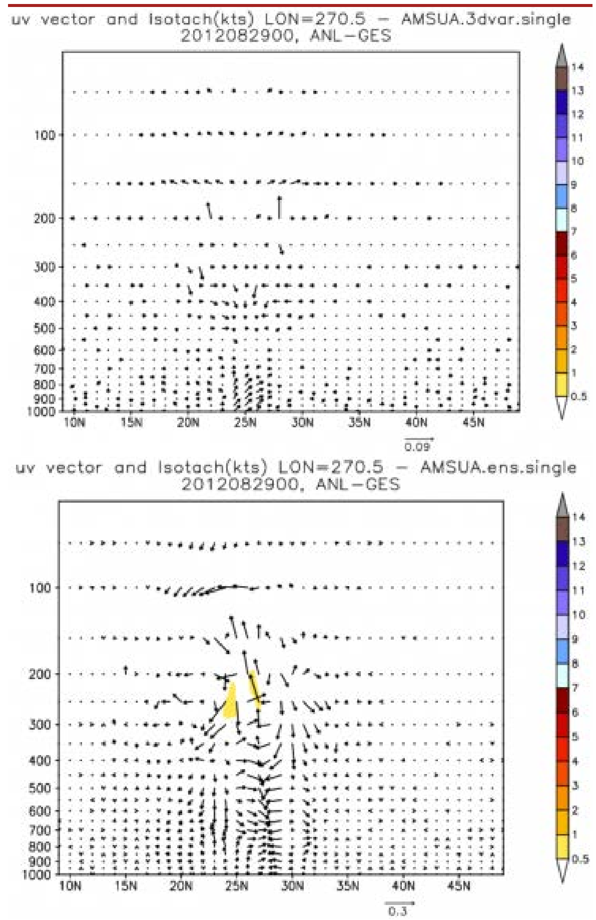

Figure 2. Vertical cross-sections of analysis increments for wind vectors and isotach (kts) generated from the radiance assimilation tests using the traditional 3D-Var GSI (upper panel) and the minimal GSI-hybrid system (lower panel). A profile of radiance data centered at 272E, 25.12N were assimilated in both experiments at 00Z, August 29, 2012.

The DAT examined the cycling schemes for the DA and forecast system and impact of satellite radiance data assimilation on the tropical storm forecasts. During the tests for the tropical storms in August of 2012, a degradation stemming from the cycling system was found especially when the storms approached land. Further diagnostics suggested that the asymmetric distribution of the conventional observations within the domain, in addition to a model bias, accumulated with time and led to bigger track and intensity forecast errors. With satellite radiance data assimilated in large scales (27km outer domain), the track forecasts were improved slightly at longer lead times. However, by average, data assimilation in this basin scale domain showed limited impacts on analyses and forecasts. More investigation on assimilating data in vortex scales is required.

The proper representation of the model background errors is critical for optimal model initialization and hence for forecast performance. The background errors can be adjusted through tuning static background error factors (e.g., length scale, variance), tuning the relative contributions of both static and ensemble statistics in the cost function during its minimization, or applying ensembles that better represent the model errors. The DAT examined two of the options during this fiscal year: tuning the static background error variances for the control variables and relative weightings for static and ensemble background errors. Among the various options tested, the experiment with 50% static and ensemble background error contributions appeared to be the optimal configuration. The scaling factors used for the WRF-NMM configuration formerly used for the NAM application were the optimal set up for this basin scale GSI-hybrid system versus the other existing NCEP configurations of these factors.

FY2014 PLANS

The DAT will continue its GSI code management and community support efforts to facilitate the transitions from research to operations. The DAT will initiate a collaborative effort to implement a code management plan for the NOAA Ensemble Kalman Filter (EnKF), the ensemble data assimilation system as part of GFS. With support, the DAT will continue testing of the GSI data assimilation system (GSI baseline test) in applications that are relevant for sponsors and the research community to ensure the integrity and robustness of the data assimilation techniques and systems. The DAT will also continue to investigate the latest hybrid technique in regional applications in higher resolution and vortex scales.

‹ Advanced Verification Techniques and Tools up Tropical Cyclone ›

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TROPICAL CYCLONE

BACKGROUND

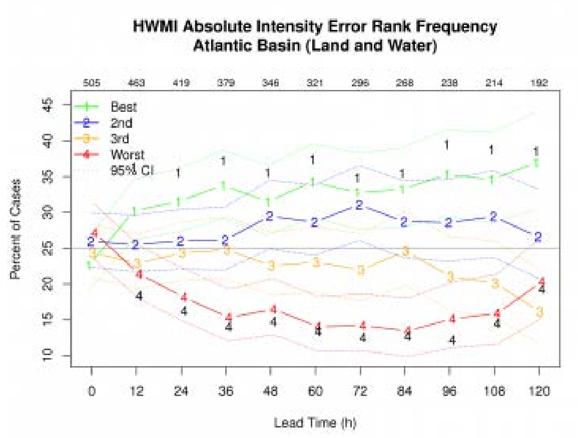

Fig. 1: Example rank frequency plot comparing a stream 1.5 candidate performance to top-flight models.

The focus of the JNT's Tropical Cyclone Modeling Team (TCMT) is the evaluation of experimental models for tropical cyclone forecasting (http://www.ral.ucar.edu/jnt/tcmt/). The primary sponsor of this work is NOAA's Hurricane Forecast Improvement Project (HFIP; http://www.hfip.org/). The goals of HFIP are to improve the accuracy and reliability of hurricane forecasts; to extend the lead time for hurricane forecasts with increased certainty; and to increase confidence in hurricane forecasts. Achieving these goals requires major investments in enhanced observational strategies, improved data assimilation and numerical weather prediction (NWP) systems, and expanded forecast applications based on high resolution and ensemble-based NWP systems. HFIP's modeling efforts are organized into three development paths. Stream 1 refers to the yearly upgrades made to operational NWP capabilities, Stream 2 refers to efforts that require multiple years to enhance operations, and Stream 1.5 refers to improved models and/or techniques that the National Hurricane Center (NHC), based on prior assessments, wants to access in real-time during a particular hurricane season but that cannot be made available by the operational modeling centers in a conventional production mode. During each hurricane season, HFIP conducts an experiment, referred to as the Demonstration (Demo) Evaluation, which attempts to demonstrate model capabilities that go well beyond the current capabilities of the operational global and regional models. In addition, a Retrospective Evaluation is conducted during the pre-hurricane season for modeling systems that wish to be considered for inclusion in Stream 1.5 during the upcoming Demo.

In addition to the JNT's evaluation of experimental tropical cyclone forecast models, JNT staff affiliated with the Developmental Testbed Center (DTC) work closely with the NCEP's Environmental Modeling Center (EMC) to support the operational Hurricane WRF (HWRF) forecast system to the research community and test new capabilities coming from the research community to determine their potential for improving the forecast skill of HWRF. The primary sponsors of this work are HFIP and NOAA's Office of Atmospheric and Oceanic Research. The goals of this work are to accelerate the improvement in tropical cyclone forecasts by providing a more timely mechanism for transitioning research into operations.

FY2013 ACCOMPLISHMENTS

During FY2013 the TCMT focused on several activities related to HFIP. In particular, the TCMT led the planning and evaluation of the 2013 Stream 1.5 Retrospective evaluation. TCMT also enhanced the near real-time multi-model ensemble forecast and display system (http://www.ral.ucar.edu/projects/hfip/d2013/forecasts/) and provided participants access to track, intensity, and diagnostic products for the 2013 HFIP Forecast Demonstration (http://www.ral.ucar.edu/projects/hfip/d2013/data_output/). In addition, TCMT staff supported the development of the HFIP Real-time Display System (http://www.hfip.org/products). The TCMT HFIP data service supported the archiving and dissemination of TC forecasts from the Demo, as well as past retrospective analyses, to the HFIP community through the development of an HFIP data archive service. The service uses RAMADDA (Repository for Archiving, Managing and Accessing Diverse DAta) to provide HFIP scientists access to hurricane track and intensity (Tier 1) forecasts, gridded

forecast fields (Tier 2), and diagnostics products that are available at: https://verif.rap.ucar.edu/repository..

A specific testing and evaluation methodology was developed for the evaluation of the 2013 Stream 1.5 candidate models, which included evaluation of the uncertainty in verification measures through confidence intervals and paired statistical tests that take into account the error distributions for model-based tropical cyclone track and intensity forecasts. This methodology provided a consistent set of results that allowed the forecasts from the various models to be comparably and fairly evaluated. Each Stream 1.5 candidate was evaluated based on three basic criteria: 1) performance relative to each of 2012 top-flight operational models, 2) performance relative to the top-flight operational models as a group, and 3) impact on the performance of the model consensus guidance, either by adding the Stream 1.5 candidate to the consensus members or replacing the comparable member, or if the candidate model was a consensus itself, performance relative to the consensus. One major improvement to the TCMT's evaluation system was the addition of the Model Evaluation Tools-Tropical Cyclone (MET-TC) verification package developed and supported to the community by the DTC. This new software provides more efficient and flexibility processing and analysis of the verification results. Figure 1 shows an example of the rank frequency method used to compare the candidate's performance to the top-flight models as a group. A detailed report was written for each candidate model, which summarized results of the evaluation. These reports, which were provided to NHC and the HFIP Project Office, were used to make decisions regarding which models would be included as Stream 1.5 models, and demonstrated to NHC forecasters during the 2013 hurricane season.

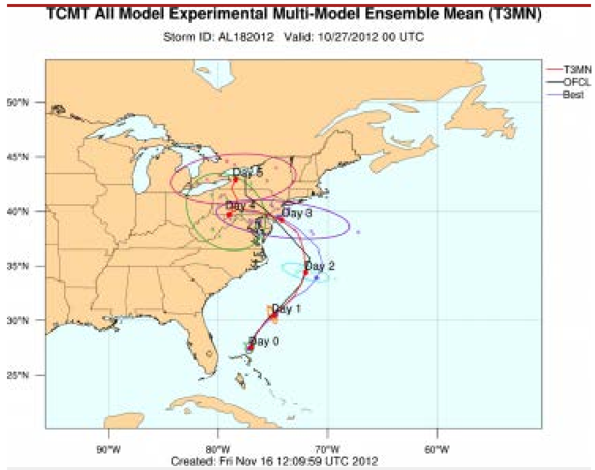

Fig. 2: Ellipse forecast product for Hurricane Sandy. The example forecast product is from the 00 UTC 27 October 2012 initialization.

The Stream 1.5 evaluation included TC cases from the past three (2010-2012) hurricane demonstration periods (August 1 – October 31). Information on the methodology, cases, participating modeling groups, verification results and reports is all available on the TCMT 2013 Retrospective Testing website (http://www.ral.ucar.edu/projects/hfip/h2013/). Nine research model configurations were included in the 2013 evaluation. Both global and mesoscale numerical weather prediction (NWP) systems were included, as well as ensemble and statistical forecast systems for predicting hurricane intensity.

In addition to the annual Stream 1.5 evaluation, the TCMT is conducting an evaluation of retrospective forecasts from three modeling groups to provide an assessment of the impact of both standard aircraft reconnaissance data and tail Doppler radar (TDR) data on the skill of hurricane forecasting systems. Each modeling group provided a control forecast for which their data assimilation system did not ingest any aircraft reconnaissance data. This control forecast will be evaluated against the standard operational baselines to determine whether the control is as skillful as the current operational NWP guidance. In addition to the control forecasts, each group provided retrospective forecasts for at least two additional configurations. The first configuration assimilated only standard aircraft reconnaissance data and the second configuration assimilated both standard aircraft reconnaissance data and TDR data. Two of the groups also provided retrospective forecasts for a fourth configuration that only assimilates TDR data. The control forecast from each group is being used as the baseline to evaluate the relative performance of their corresponding forecasts that included assimilation of aircraft reconnaissance data.

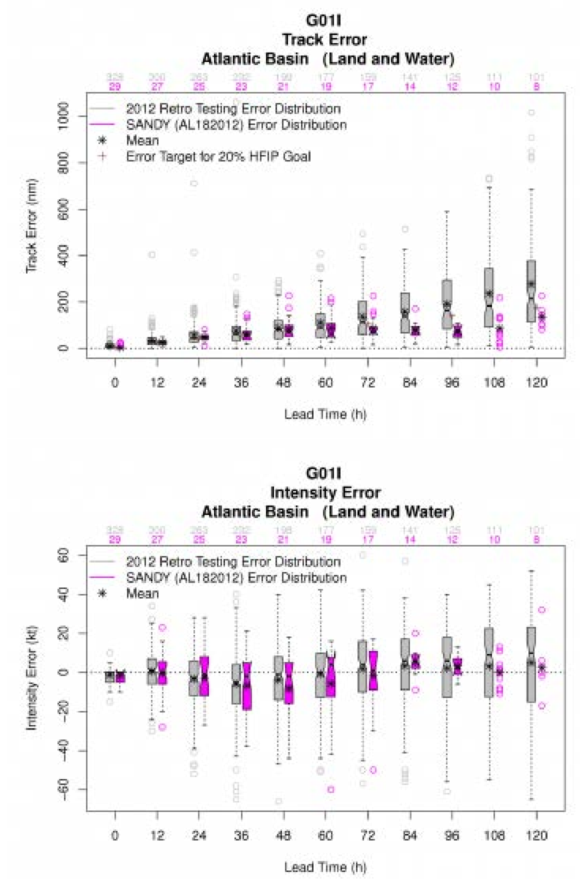

Fig 3: Comparison of the track (top panel) and intensity (bottom panel) of the first member of the GFDL ensemble for Hurricane Sandy (October 2012) in comparison to the model performance for the 2012 retrospective evaluation.

The TCMT has continued to develop a multi-model ensemble forecast product for the 2013 HFIP Demonstration. Three different ensemble forecasts were constructed: (1) Stream 1.5 forecasts only; (2) Stream

1.5 and 2 forecasts; and (3) all available forecasts (Stream 1.5, Stream 2, operational models). The real-time display system, which was redesigned for the 2013 Demo, includes track, intensity, and ellipse products of forecast tracks for the three sets of forecasts, along with best track, and official NHC forecasts. An example of the ellipse track product for Hurricane Sandy is shown in Fig. 2.

The TCMT has conducted case study analyses of individual tropical cyclones (see Fig. 3) and entire season evaluations of the performance of HFIP Stream 1, 1.5, and 2 model forecasts produced as part of the Demo. For the 2013 hurricane season, the analyses have been enhanced through development of new tools to evaluate individual storms as well as tools to create an evaluation across accumulated storm information throughout the hurricane season. TMCT has built a graphical user interface to display the evaluation results on the TCMT HFIP website (see Demo 2012 results for an example: http://www.ral.ucar.edu/projects/hfip/d2012/verify/). The HFIP Demo verification focuses on track and intensity errors and uses a methodology consistent with the retrospective analysis for each evaluation. The methodology includes interpolating late model forecasts, use of the MET-TC software to compute errors, construction of homogeneous samples for model inter-comparisons, and assessment of error distributions and statistical significance when applicable. New evaluation products are being developed. For example, the TCMT is developing revision products to examine the consistency of forecasts for a given valid time for varying lead times.

FY2014 PLANS

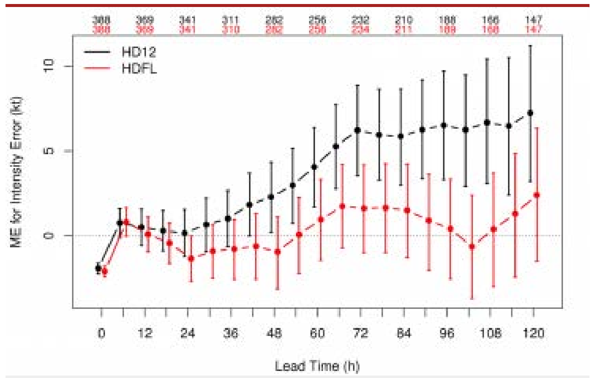

Fig. 4: Mean intensity errors (kt) for 2012 North Atlantic storms for HD12 (black) and HDFL (red) as a function of forecast lead time. The 95% confidence intervals are included, and the sample size is listed above the plot.

During FY2013, the DTC's Hurricane team conducted an extensive retrospective test for the 2012 hurricane season (35 complete storms) to test the hypothesis that HWRF forecasts could be improved by removing an artificial reduction in the magnitude of the atmosphere-ocean fluxes in the Princeton Ocean Model for Tropical Cyclones (POM-TC). This hypothesis stemmed from a diagnostic evaluation of retrospective HWRF forecasts for the 2011 hurricane season against a buoy climatology performed by AOML/HRD that showed the HWRF ocean cooling under and behind hurricanes was smaller than observed. The POM-TC fluxes in 2011 HWRF were multiplied by 0.75 because earlier HWRF pre-implementation testing and experience with the coupled GFDL model indicated POM-TC overcooled. While a reduction of a few percent can be physically justified because the removal of momentum due to surface gravity wave growth and propagation is not represented in HWRF, the 0.75 factor is largely an overestimation. This retrospective test included two HWRF configurations: the control (HD12) and a modified version in which the full fluxes were restored (HDFL). Results for the North Atlantic basin indicated track forecast errors (not shown) were similar between the two code versions, but the HD12 positive intensity bias was, for the most part, eliminated in HDFL (Fig. 4). This result led EMC to include this change in the 2013 HWRF operational baseline, which EMC tested over three seasons and accepted. Detailed results can be found at http://www.dtcenter.org/eval/hwrf_hdfl_hd12/.

In FY2014, tropical cyclone track and intensity forecasts collected during the HFIP 2013 Demo will be evaluated using consistent tools and approaches for all models. Retrospective model testing and evaluation will be undertaken once again, in collaboration with NHC and a variety of research and operational modeling groups. Evaluation for the aircraft reconnaissance data impact study will be completed. Statistical approaches will be developed and implemented for the evaluation of other relevant attributes of tropical cyclone forecasts. The real-time monitoring system will continue to be enhanced with additional display graphics and evaluation products. New diagnostic products will be developed to aid in interpretation and understanding of the verification results, and a near real-time verification capability will be in place for the 2014 Demo Experiment. The tropical cyclone database will continue to be enhanced with additional datasets of track and intensity, diagnostic products, and gridded fields. The DTC's Hurricane team will continue to support the current HWRF capability to the community and undertake an extensive retrospective test of the impact of replacing the operational microphysics and radiation schemes with the more sophisticated Thompson microphysics and the RRTMG radiation schemes.

‹ Data Assimilation up Ensemble Modeling Test and Evaluation ›

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ENSEMBLE MODELING TEST AND EVALUATION

BACKGROUND

The goal of the Ensembles team is to provide a pathway between ensemble research and operational capabilities. An environment has been established for the objective testing and evaluation of state-of-the-art ensemble techniques in the areas of (1) ensemble configuration, (2) initial perturbations, (3) physics perturbations, (4) statistical post-processing, (5) products and display, and (6) verification. Much of this work is done under the auspices of the Developmental Testbed Center (DTC). The DTC currently focuses its ensemble testing and evaluation activities on cloud-scale and mesoscale ensemble prediction.

2013 ACCOMPLISHMENTS

The Ensembles team established a functionally similar operational environment for NCEP's Short-Range Ensemble Forecast (SREF) system on NOAA's supercomputer Zeus. This preparatory work was necessary to allow the planned testing activities in the context of testing for both NOAA's Environmental Modeling Center (EMC) and Hydrometeorology Testbed (HMT). The initial focus is on evaluating the impact of changes in ensemble initialization, physics options, and horizontal grid spacing using the Advanced Research WRF (ARW) subset of SREF. Table 1 summarizes the basic properties of the ensemble configurations used to address these questions. Ensemble runs for the transition month of May 2013, were made for the Operational and Experiment 1 configurations. May was selected because it captured one of the most active severe weather months in recent history, providing an interesting dataset for future in-depth studies. For these tests, the ensemble was comprised of a control member, three members with negative initial condition perturbations and three members with positive initial condition perturbations. All members were initialized from the same initial data used for the SREF. Preliminary evaluation suggests there are reductions in error when the SREF members are run at 9-km grid spacing. In some cases the reductions appear to be statistically significant.

Ensemble property	Operational	Experiment 1	Experiment 2
Microphysics	SREF	SREF	HMT
Initial Perturbations	SREF	SREF	SREF
Grid Spacing	16 km	9 km	9 km

Table 1. List of ensemble configurations that will be used to assess the impacts of grid spacing and microphysics scheme on forecast skill

In addition to the test and evaluation work described above, the Ensembles team also hosted Dr. Sai Ravela from Massachusetts Institute of Technology through the DTC Visitor Program. Dr. Ravela developed a Field Alignment technique that potentially can be very useful for assessment of forecast errors and bias correction. The code was ported to NOAA's supercomputer Zeus and is now available for the community

to use. Some preliminary testing of the approach was performed. The four panels in Fig. 1 illustrate the technique's application to the 12 hour MSLP forecast from the GEFS unperturbed member valid on 6 September 2011 at 12 UTC. On this day, Hurricane Katia was located in the Caribbean region and classified as a category 3 hurricane, with maximum sustained wind speeds between 111 and 139 mph. The total error or RMSE (upper left panel) was notably large (~2.2 hPa). After the Field Alignment was applied, the error was reduced to ~1 hPa (lower left panel). Interestingly, the difference between the "aligned" forecast and the original forecast (lower right panel) resulted in a larger calculated RMSE (~2.23 hPa) than the difference between the analysis and the original forecast. Importantly, the application of the FA technique resulted in a remarkable reduction of the total error.

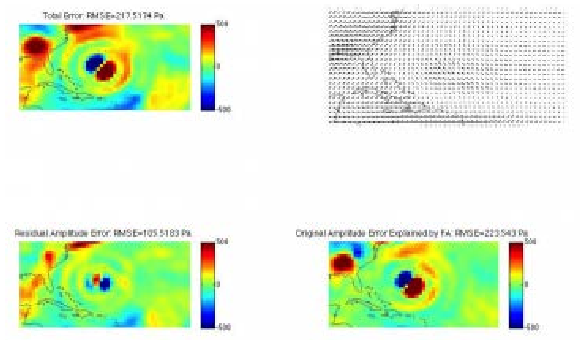

Figure 1. a) Total error, b) estimated displacement vector, c) amplitude error, and d) change between the original and "aligned" forecast for Field Alignment technique applied to 12 hour MSLP forecast from the GEFS unperturbed member initialized at 00Z on 6 September 2011.

FY2014 PLANS

Ensemble runs for Experiment 2 will be completed and extensive diagnostics and evaluation will be performed using the Model Evaluation Tool (MET). Both single-value and probabilistic measures will be aggregated over the entire month of study for all configurations. In addition, a configuration with an improved dynamical downscaling perturbations technique will be run to assess the impact of this new initialization technique.

‹ Tropical Cyclone | up | Tailored Modeling Systems ›

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TAILORED MODELING SYSTEMS

BACKGROUND

As high-resolution regional models (e.g., Weather Research and Forecasting [WRF]) become more skillful and computing hardware becomes less expensive, the use of models for meeting the specialized operational needs of various stakeholders is growing rapidly. Even though the modeling software and hardware are easy to acquire, it is still very challenging to optimize the overall system performance to meet specific needs, to verify the model skill on small scales, to develop specialized model-output products and visualization tools, and to educate the users about best practices in using the high-resolution model products. Given RAL's experience working hand-in-hand with users in an end-to-end process, RAL has provided community support to many groups by partnering to develop special modeling capabilities and applications. Building upon expertise in NWP solutions, RAL has built a program to develop tailored modeling systems for international partners optimized for the end-users' region of interest and applications.

Forecast verification and evaluation is often an unseen partner in engineering and scientific advances. Verification provides systematic and objective evaluation of the quality or performance of a forecast. In turn, this process allows comparisons to be made between versions in the development of an advanced forecast system. RAL has developed significant expertise in developing customized verification systems to meet the needs of its end-users in assessing the performance of new tailored modeling systems. The following section provides an example of tailored modeling and verification system for the weather service in Saudi Arabia.

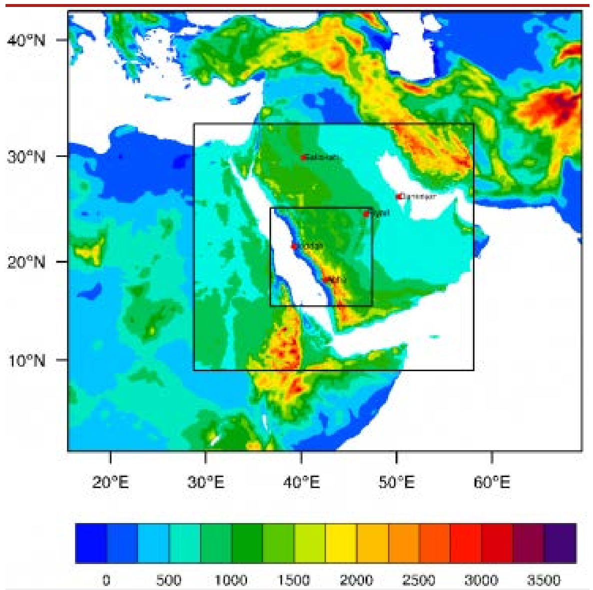


Fig. 1: The forecast domain of the new PME WRF-data assimilation forecast system.

FY13 ACTIVITIES: DEVELOPMENT OF A FORECAST SYSTEM FOR SAUDI ARABIA

The goal of this project is to improve and modernize the numerical weather prediction (NWP) capability for the Saudi Arabia Meteorological Service's Presidency of Meteorology and Environment (PME) through the implementation of a WRF model and data assimilation system. The project is implementing the NCAR/RAL Joint Numerical Testbed (JNT) Model Evaluation Tools (MET) for real-time model evaluation, as well as an advanced forecast display system. The project is also building a dust forecast capability for the region and providing hands-on training to forecasters and scientists.

For the NWP component of the project, the WRF-ARW (Weather Research and Forecasting – Advanced Research WRF core) model and an RTFDDA (Real-Time Four-Dimensional Data Assimilation and forecasting system) and WRF-3DVAR (Three-Dimensional Variational data assimilation) hybrid data assimilation system has been implemented at PME. This system, referred as to "RTF3H" (Real-time RTFDDA-3DVAR Hybrid) has replaced the existing WRF system implemented by NCAR in 2010.

The new PME WRF-data assimilation system has been configured with

three nested domains. The location and the details of the domains are shown in Fig. 1. The resolution of the domains is 21.6 km (outer), 7.2 km (middle), and 2.4 km (inner) domains. The domain size and resolution was optimized to meet the spatial and temporal requirements of PME with the available computing power of the Linux cluster acquired specifically for the project. Note that the inner domain was configured to provide high-resolution forecasts to key cities of Saudi Arabia. The modeling system updates the forecasts four times/day with 6 hour analyses (data assimilation) and 72/72/48 hours forecasts and one cold-start at the 18Z cycle. The NCEP 0.5° GFS is used for the initial and lateral boundary conditions.

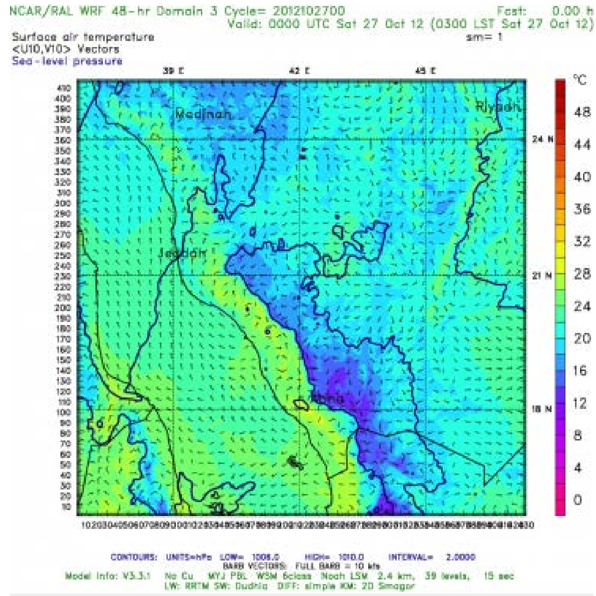


Fig. 2: Example forecast product of surface temperature, winds, and sea level pressure.

The modeling system has been configured using the following WRF Physics packages: single-moment 3-class microphysics, RRTMG solar and long-wave radiation, Noah 5-layers land surface model, MYJ PBL scheme, Kain-Fritsch cumulus parameterization. The RTF3H data assimilation system utilizes standard observation data sources: NCEP QC-ed global OBS set, raw WMO OBS collections, MADIS, and METAR observations.

The system has been operational since June 2013 with this initial operational configuration. Forecast products from the PME WRF-data assimilation system can be accessed through the project website: http://saudi-c3.rap.ucar.edu/cgi-bin/model/ugui?range=GWPME.

A new visualization system was developed to support the display of the forecast and verification products for PME. Additionally, NCAR has implemented a monitoring system to provide a summary of model operations. The graphics are created using the NCAR Command Language (NCL) and are available through the PME forecast website. An example forecast product is shown in Fig. 2.

The near real-time verification system has been developed using the MET framework. MET is designed to evaluate the new NWP forecasts using standard WMO point surface and upper air observations and gridded radar derived quantitative precipitation estimates as a reference. The verification system utilizes the METViewer visualization system to generate and display the evaluation graphics. The verification results can be viewed in real-time on the project website:

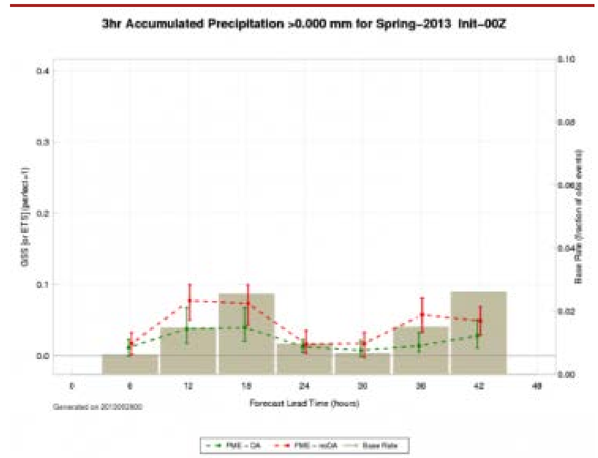
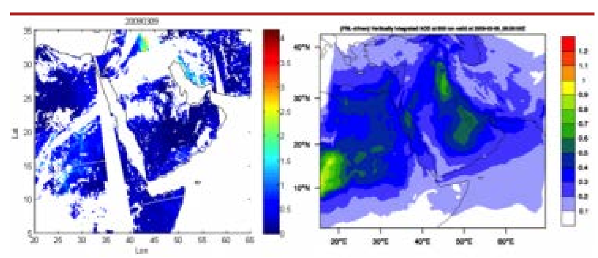


Fig. 3: Example output of the PME verification system with statistics aggregated by the season.

http://saudi-c3.rap.ucar.edu/cgi-bin/met/ugui_met?aggregate=Week. An example verification product aggregated by season is shown in Fig. 3. The statistic shown is Gilbert Skill Score (GSS or Equitable Threat Score). PME-with data assimilation (DA) is shown in green. The scores for the older WRF system are shown in red. The Base Rate (gray histogram) reflects the sample climatology.

The project is also focused on developing a dust forecast capability for Saudi Arabia. The WRF-Chem modeling system was selected as the dust forecast system. WRF-Chem, the fully coupled chemistry model within WRF, is a state-of-the-art system for simulation and prediction of weather, climate, air quality and dispersion of dust and pollutants.



In WRF-Chem, the air quality component is fully consistent with the meteorological component: both systems use the same transport scheme (mass and scalar preserving), the same grid (horizontal and vertical components), the same physical schemes for subgrid-scale transport, and the same time step for transport and vertical mixing. Applications of WRF-Chem include (a) prediction and simulation of weather, regional and local climate, (b) simulation of the release and transport of constituents, (c) prediction of O_3, UV radiation, dust, fire,

and $PM_{2.5}$, PM_{10}, and (d) study of processes that are important for global and regional climate change issues. WRF-Chem dust forecast capabilities are being evaluated for several dust events in Saudi Arabia. An example of a dust forecast compared to MODIS satellite observations is shown in Fig. 4. The plot shows that WRF-Chem resolves the band of elevated AOD reasonably well in terms of spatial location and temporal evolution for this event.

Fig. 4: MODIS AOD (left panel) and WRF-Chem simulated AOD (right panel) at 500 nm valid at 11 LST 09 March 2009.

FY2014 ACTIVITIES

The focus of the project in FY2014 will be on continued development of the WRF data assimilation system, implementation of an operational dust forecast capability, development of additional verification products, and enhancement of the forecast display system. In addition, there will be an extensive education and outreach activity which will include several hands-on training workshops.

‹ Ensemble Modeling Test and Evaluation up Hydrometeorological Applications ›

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HYDROMETEOROLOGICAL APPLICATIONS

Provide relevant information to water resource decision makers through directed and basic research and development in hydrometeorology, aerosol-precipitation interactions, precipitation nowcasting, microphysical modeling, and winter weather.

- Short-Term Explicit Prediction (STEP) Program
- Advances in Land Surface Modeling
- Aerosols and Precipitation
- Winter Weather
- Western Water
- Climate Change and Water
- Probabilistic Hydrologic Forecasting at Lead Times from Minutes to Seasons
- Fully-coupled Hydrometeorological Modeling with WRF-Hydro
- Water, Energy and Food Security

‹ Tailored Modeling Systems up Short-Term Explicit Prediction (STEP) Program ›

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SHORT-TERM EXPLICIT PREDICTION (STEP) PROGRAM

BACKGROUND

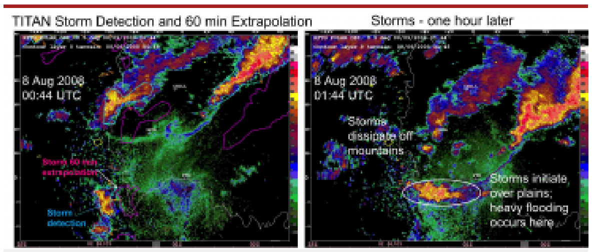
The Short-Term Explicit Prediction (STEP) Program is a multi-NCAR Laboratory activity with the overarching goal to improve the short-term (0-36 hours) forecasting of high-impact weather events such as severe thunderstorms (heavy rain, tornados, downburst, flash flood, lightning and hail), winter storms (snow, freezing rain and drizzle), and hurricanes. The STEP program emphasizes several research areas that are crucial for advancing the science and application of the short-term prediction of high-impact weather, through collaborative effort incorporating national and international scientists, engineers, and operational personnel from universities, government institutions and the private sector. Most of the forecasting/nowcasting systems and analysis tools developed under STEP are available to the communities for the support of research and real-time operations.

In FY13, STEP focused on two major research themes: (1) the development of an end-to-end hydrometeorological system to improve flash flood prediction; and (2) observational field programs that enhance our understanding and prediction of convective precipitation.

RAL led the effort in the first theme and played important roles in the second theme. The development of the end-to-end hydrometeorological system required the collaboration of scientists and engineers with different skills in several areas including quantitative precipitation estimation (QPE), nowcasting, data assimilation and numerical weather prediction (NWP), verification, and hydrological prediction. Through an integrated effort of studying 10 historical Front Range flash flood cases, various components of the end-to-end system were improved and major accomplishments were achieved toward the ultimate goal of developing a fully coupled end-to-end hydrometeorological system. These accomplishments are summarized below.

MAJOR ACCOMPLISHMENTS

Nowcasting Convective Precipitation over Complex Terrain



The over-arching goal of this STEP project is to provide accurate forecasts of precipitation amount and to improve flash flood prediction. Thus, under STEP funding RAL, MMM and EOL, have been conducting research to develop a QPE, heavy rainfall and streamflow prediction system for the Rocky Mountain Front Range using , nowcasting techniques and numerical forecast models. Ten historical Colorado flash flood events from 2008-2012 are being analyzed and data run through

the components of an end-to-end prediction system to assess the performance of these capabilities for predicting heavy rainfall, flash floods and stream flow. In partnership with Colorado State University's CHILL radar staff, Front Range Observational Network Testbed (FRONT) data was collected on four additional heavy rainfall and flash flood events that occurred along the Front Range during August 2013. These fourteen cases are being used to improve the performance of heavy rainfall and streamflow prediction algorithms. A Denver flash flood event on 8 August 2008 was chosen as a focal point case for testing and evaluating all applications. Research highlights and results are provided in the following paragraphs.

Figure 1. Left panel: Radar reflectivity image from 8 August 2008 at 00:44 UTC, one hour prior to the flash flood over Denver Colorado, with TITAN automated storm detections (blue polygons) and 60 min storm extrapolation nowcasts (magenta polygons) overlaid. Right panel: Radar reflectivity image at 01:44 UTC, at the time of the flood illustrating the storm initiation and intensification that occurred and was not nowcast by the TITAN algorithm.

Given the typical small-scale and quickly-evolving nature of flash flood events particularly over complex terrain, it was no surprise that the NWP model forecasts for the ten historic cases were not able to predict flash flood occurrence and rainfall intensities on the spatio-temporal scales needed. The NWP models were only able to provide reasonable forecasts of precipitation accumulation on the one synoptically-driven day.

Predicting the precise location of convective heavy rainfall is, for the present, only possible on the nowcasting time scale. Nowcasting techniques that include the AutoNowcaster thunderstorm nowcasting (ANC) system, the 4-D Variational Doppler Radar Analysis System (VDRAS), and the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) extrapolation software package were run on the 8 August 2008 case. The TITAN extrapolations, shown in Figure 1, illustrate the challenges in accurately predicting flash floods even on the one-hour time scale because significant intensification and initiation of storms occur and are not captured by general extrapolation techniques. Thus prediction of heavy rainfall depends on observing and predicting mesoscale and storm-scale features. Figure 2 demonstrates how the ANC identified the collision of two convergence lines in the region of heavy rain in an area where VDRAS was indicating strong convergence.

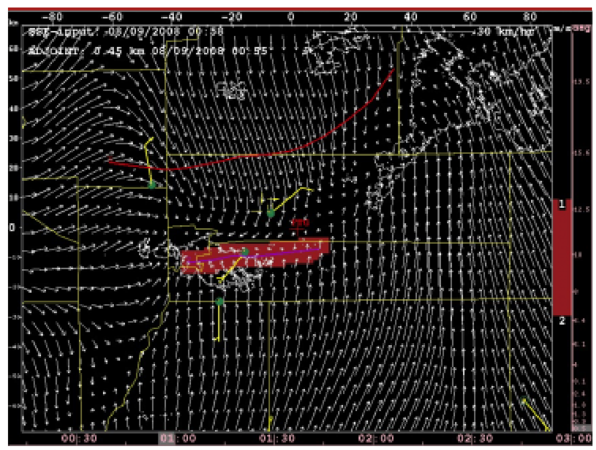
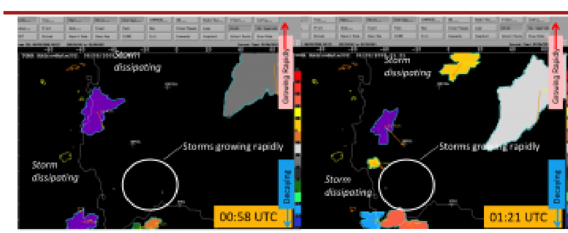


Figure 2. White wind vectors show strong mesoscale convergence into the region of developing heavy rainfall. Wind vectors are based on VDRAS analysis. The red color area is a 60 min prediction by the AutoNowcaster where the red and purple convergence lines are nowcast to collide. The heaviest rain occurred in the western half of the collision zone.

In addition monitoring the characteristics and evolution of individual convective storms is necessary to determine which storms cause heavy local rainfall. Figure 3 shows that for the Aug 8 2008 case, monitoring not only surface convergence regions, but storm growth, storm mergers, and storm motion relative to a global mean motion are important in prediction of heavy rainfall events.



Normalized storm growth rate is calculated from the change in storm area over time.

A number of preliminary studies have been initiated focusing on the unusual, extreme Front Range heavy rainfall event during September 2013; initial results were presented at an NCAR seminar later that fall. The critical nature of mesoscale features in determining where the heaviest rainfall occurred was again evident during this event, particularly in respect to low-level upslope winds relative to the terrain and mesoscale circulation and convergence features (see Fig. 4). Detailed examination of quantitative rainfall estimation for the 24 h period from 11-12 September 2013 heavy rainfall event has begun using different Z-R relationships and examination of the dual-polarization radar fields from the Denver operational NEXRAD radar. A particularly interesting feature of the event was the small raindrops that occurred that indicated the event was more tropical in nature than is customary in Colorado. Note in Fig. 5 how a tropical Z-R relationship was much more accurate in estimating the rainfall compared to the typical Z-R relationship for Colorado.

High-resolution analyses based on radar observations

The success of nowcasting precipitation with ANC depends on the mesoscale predictor fields, which can be provided by the high-resolution analysis system, VDRAS. VDRAS is a 4D-Var (4-dimensional variational) based data assimilation system that aims at high-resolution analysis using Doppler radar observations. VDRAS was run for the 10 historical flash flood cases over a Front Range domain that is covered by the operational radars KFTG (Denver) and KCYS (Cheyenne) with a 2km horizontal resolution. The high-resolution analyses were used as

predictors in ANC to demonstrate the importance of the mesoscale wind convergence obtained by VDRAS in prediction of convective initiation. Figure 6 shows the VDRAS vertical velocity at 1km above ground level (AGL) overlaid by the wind vectors at 150m AGL for the case of August 8-9, 2008. It is evident that the initiation of convection occurs in the region of high vertical velocities. The vertical cross-section clearly depicts the updraft resulting from the convergence of northerly flow associated with a cold front passage and the warm southerly flow.

Figure 3. One of the predictor fields for nowcasting storms that may produce heavy rainfall.

VDRAS was also run for the Great Front Range Flood of September 2013. Figure 7 shows the VDRAS wind at 0130 UTC and 0300 UTC in one of the most intensive precipitation periods. It reveals the enhancement of southeasterly flow by a meso-cyclone circulation and the intensification of northeasterly flow near the Colorado-Wyoming border.

The merging of these winds in Boulder and Larimer Counties strengthens the upslope lifting. These detailed wind and convergence analyses with a frequent update cycle of ~10 minutes can provide mesoscale predictors for ANC nowcasting system and therefore have a potential to improve the quantitative precipitation nowcasting. Further in-depth studies for this flood case are underway.

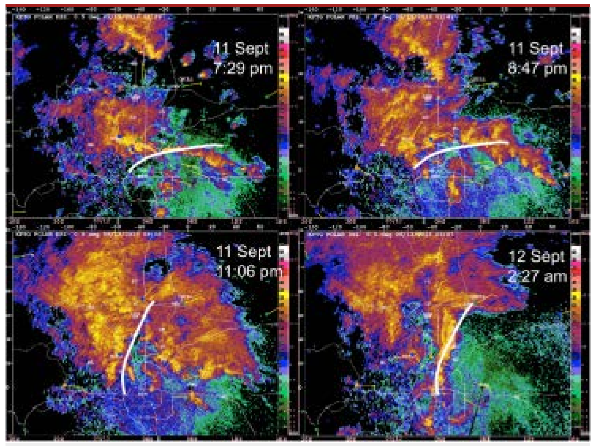


Figure 4. Radar reflectivity and low-level surface station winds (barbs) at four different times during 11-12 September 2013 illustrating the evolution of the low-level upslope winds relative to the terrain and mesoscale circulation and convergence features that played important roles in determining where the heaviest rainfall occurred.

Development of an Operational Flash Flood Prediction Capabilities

Operational flash flood watches and warnings today are issued based primarily on meteorological forecast criteria, rainfall rate and duration threshold exceedance or detection of rapidly rising waters. The criteria for issuing flood watches and warnings rely on relationships between historical rainfall-runoff relationships. While useful, such approaches can limit the lead time available to emergency responders, decision makers and affected citizenry. Reliance on historical relationships can result in significant forecast uncertainty when watershed conditions have undergone significant change such as those induced by wildland fire or rapid urbanization. Furthermore, reliance on past measurements of rainfall and runoff is highly problematic for areas without long records of precipitation and streamflow. As such, flash flood forecasts in mountain front regions like the Colorado Front Range where long-term observations are sparse and where rapid landscape change is occurring possess a large degree of uncertainty. These uncertainties stem from both the quality of the assumed underlying relationships between rainfall and streamflow as well as the lack of spatial detail from which such relationships were derived. The end result is that many data poor regions in smaller tributary stream and river systems lack skillful flash flood forecasting capabilities.

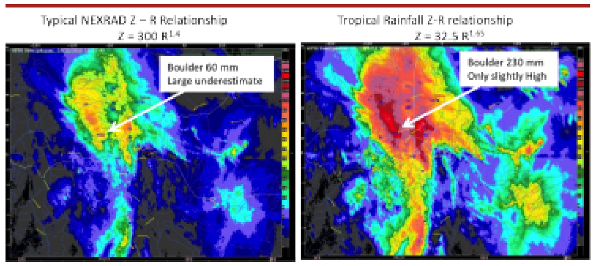


Figure 5. Plots of 24 h precipitation accumulation totals derived from radar reflectivity (Z) – rainfall (R) (Z-R) relationships. Left panel: Precipitation accumulations are underestimated using a typical NEXRAD Z-R relationship. Right panel: Precipitation accumulations obtained from a "tropical" Z-R relationship represents more closely the actual rainfall that occurred.

The STEP program addresses this issue through the development and implementation of an end-to-end, physics-based (as opposed to empirically-based), flash flood prediction system. Our work has three main components: 1) dataset collection and quality control, 2) operational system implementation and 3) product generation. Within the first component we have developed methodologies to collect, in real-time, several different radar-based QPE products along with available surface rain gauge and stream gauge data. Synthesis and quality-control of these products allows us to generate reasonable initial conditions for hydrological model forecasts. Under the second component, we have implemented the WRF-Hydro modeling architecture to ingest both radar QPE products and quantitative precipitation forecast (QPF) output from numerical weather prediction models to make hydrological forecasts on a gridded, 100-meter resolution stream channel network across the Colorado Front Range. Under the third component we have created an initial set of tools to generate forecast products from WRF-Hydro model output including predicted versus observed streamflow hydrographs and animations of streamflow forecasts for various Front Range river systems. A prototype of this operational capability was working during the Great Flood of 2013 which dumped in excess of 15 inches of rainfall in 5 days along the Colorado Front Range. Example forecast products generated from the WRF-Hydro system are

shown in Figure 8 below. While much work remains to assess and improve the quality of these streamflow forecasts, it is clear that the high spatial and temporal information produced by the WRF-Hydro forecast system captured several of the most severe flood waves that emerged from the Front Range foothills region and that the system has the capability to provide flood risk information with a level of spatial fidelity that is directly usable by emergency responders and the public.

Development of an end-to-end verification capability

Forecast evaluation is a critical element of the end-to-end hydrometeorological prediction system being developed within STEP. The evaluation component of the project focuses on the assessment of the contributions of each component of the system, from QPE to quantitative precipitation nowcasting (QPN) and QPE, to forecasting streamflow. By applying diagnostic approaches for evaluating the forecasts, it will be possible to assess the strengths and weaknesses of the particular components of the system. In addition, overall performance information will provide guidance for applications of the system. During 2013, initial evaluation approaches were applied to forecasts from the set of ten historical cases that were selected to use in developing the initial forecasting system, and the results were demonstrated to the project team for their assessment of which aspects of the verification were most informative. The initial focus has been on model-based QPF from the Weather Research and Forecasting (WRF) model, for two of the extreme precipitation events included in the historical cases.

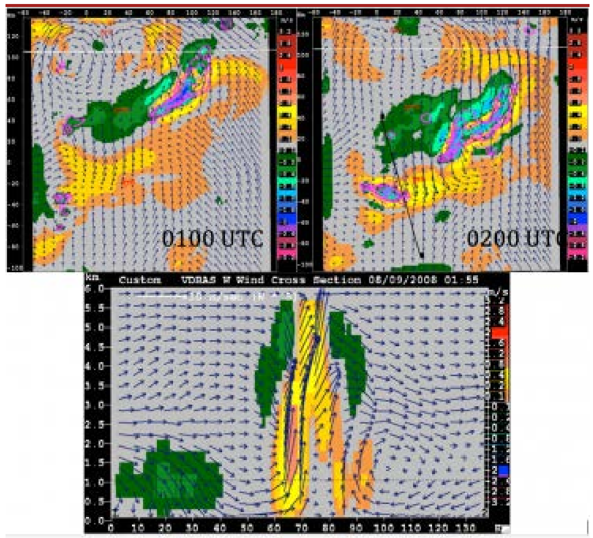


Figure 6. VDRAS analyses valid at 0100UTC (upper left) and 0200UTC (upper right), showing the vertical velocity (color shade) and reflectivity greater than 30 dBZ (magenta contour), overlaid by wind vectors. The lower panel shows the vertical cross-section across the black line indicated on the upper right panel.

The project team selected both traditional and advanced spatial methods for the initial studies. While traditional verification approaches provide some useful information for evaluating and comparing model versions, especially during periods of heavy precipitation, they generally suggest that the sample forecasts did not have any skill, even though they may contain some useful information. Alternative spatial methods – the Fractions Skill Score (FSS; Roberts and Lean 2008) and the Method for Object-based Diagnostic Evaluation (MODE; Davis et al. 2009) – both provided more guidance regarding which aspects of the forecasts are providing meaningful information about performance.

For example, Figure 9 shows distributions of forecast and observed precipitation for a flooding case from 2011, for two lead times (6 h and 23 h) from a baseline WRF forecast initialized at 0000 UTC. It is apparent that the baseline WRF model forecasts had a different distribution of predicted precipitation than was observed. In particular, the WRF predictions produced a large number of small precipitation values that were not observed. For this case, the Stage IV precipitation analysis was used as the QPE field for the verification. Figure 10 shows an example of a performance diagram for this case; this diagram (based on work of Roebber 2009) provides a way to visualize several different contingency table statistics simultaneously, including the Probability of Detection (POD), Success Ratio (SR, equal to one minus the False Alarm Ratio), the Critical Success Index (CSI), and frequency bias. This diagram suggests that the best performance is associated with low precipitation thresholds and depends on the lead time of the forecast; the subsets with the largest CSI values also have large frequency bias.

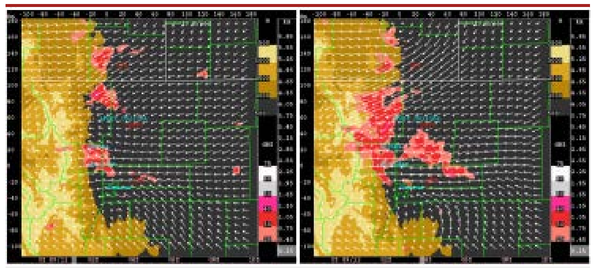


Figure 7. VDRAS wind analyses valid at 0130 UTC (upper left) and 0300 UTC (upper right) on 12 September 2013. The storms are indicated by red shades with reflectivity greater than 25 dBZ. The Front Range with topographical height greater than 2000m is shown by yellow shades.

In contrast, Figure 11 shows results from an application of MODE, showing centroid (location) differences between matched precipitation regions in the forecast and observation fields for two lead times. This diagnostic plot suggests that there were very different patterns of offsets between the forecast and observed storm systems at the two different lead times. Other information that can be obtained from the MODE approach concern the forecast storm size (somewhat too small), intersection area between the predicted and observed systems (very small), and the precipitation intensity (somewhat too large on average and too small in the extreme). Additional analyses of this case and the other historical cases are being undertaken to examine the performance of enhanced forecasts.

Improving QPF by assimilating radar observations

One of the keys to improve qualitative precipitation forecast and hence streamflow prediction is to obtain better initial conditions by assimilating high-resolution observations such as those from Doppler radars. Considerable efforts were devoted to the improvement of WRF-based data assimilation systems so that radar observations can be effectively used in establishing the initial conditions of WRF. To support the collaborative effort of developing the end-to-end hydrometeorological system, WRF forecasts initialized by North American Model downscaling and by WRF 3DVar data assimilation without radars were produced for the 10 historical cases. A detailed case study was conducted for a Denver flash flood case that occurred on August 8-9, 2008. Radar observations were assimilated for this case with a 3km domain that covers eight NEXRADs. Figure 12 compares the 6-h (00-06 UTC) accumulated precipitations between the experiments without and with radar observations, verified by the Stage IV precipitation analysis.

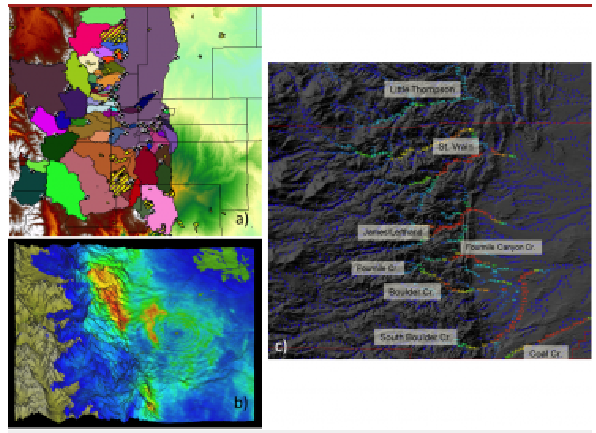
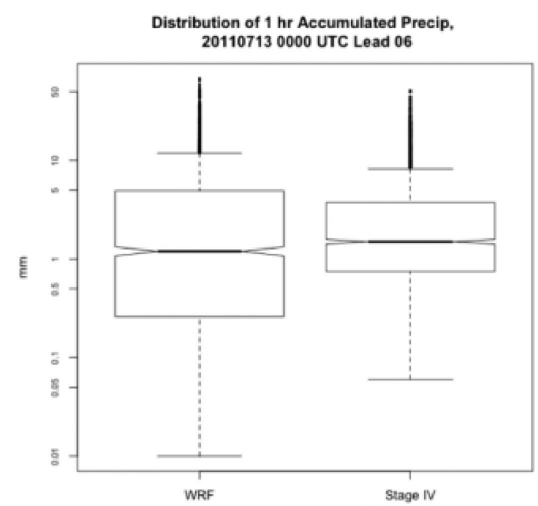


Figure 8. a) Map of the Front Range flash flood prediction domain, b) Map of accumulated rainfall from 00z on 11 Sep. through 23z on Sep. 13 (colorscale ranges from 0-15 inches with warm colors having the most precipitation), c) Snapshot of streamflow values during peak runoff period around 1:15 a.m. local time on 12 Sep. (colorscale of streamflow values ranges from 0-50 cubic meters per second with warm colors having higher flow values)

One of the new developments that aimed to improve the convective-scale data assimilation and QPF was to change the momentum control variables from the original stream function and velocity potential in the WRF 3D/4DVar system to the direct west-east and south-north wind components. Experimental results with the multiple flash flood cases showed encouraging results from using the new control variables. Figure 13 compares the FSSs (Fractions Skill Scores) from two experiments that use the two sets of momentum control variables respectively. It is shown that the new control variables of u-wind and v-wind produce significantly improved precipitation forecast skills.

Improving WRF physics for improved prediction of high impact weather

a. Impact of microphysics and radar data assimilation on squall line simulation



A case study was conducted to investigate the impact of model microphysics parameterization on short-term forecasts of convective initiation, evolution, and quantitative precipitation forecasts (QPF). In order to promote more accurate initiation of convective features in the simulations, RAL's Real-Time Four-Dimensional Data Assimilation (RTFDDA) system that utilizes a latent heat nudging technique was used. Numerical experiments were conducted to test the radar data assimilation technique, as well as to evaluate the effect of changes in the microphysics scheme.

The event studied was a squall line observed on 20 June 2007 in central Oklahoma. Convective activities initiated over the Great Plains in the afternoon of 19 June, leading to the development of separate mesoscale convective systems in the evening. These systems merged, forming a squall line with a trailing stratiform region around 05 UTC of 20 June. Idealized simulations of the case have previously shown the parameterization for raindrop breakup to have a strong influence on the evolution of organized convection via its impact on the cold pool (Morrison et al. 2012).

The RTFDDA was run on a 3-km domain, assimilated radar data of reflectivity mosaic at 00-05 UTC of 20 June, and then produced forecasts valid at 06-12 UTC. The numerical experiments show that radar data assimilation improved the squall line forecasts consistently (Figure 14). The simulated cold pool was better defined in the radar assimilation runs than in the no-radar assimilation runs. However, even with radar data assimilation, the simulated cold pool was still too weak compared to surface station observations. An examination of the raindrop sizes showed that the simulated median drop sizes were generally larger than what was observed by the disdrometer. The microphysics scheme was

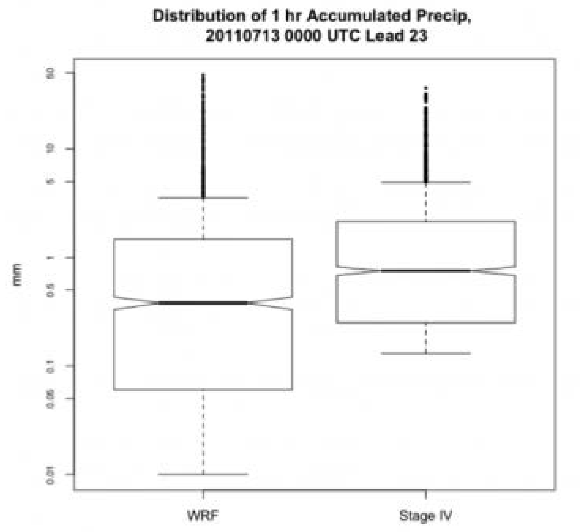


Figure 9. Distributions of precipitation amounts for baseline WRF forecast grid and Stage IV observation grid, for two lead/valid time on 13 July 2011. The center of the box represents the median value; bottom and top of the box are the 0.25th and 0.75th quantile values of the distributions, and lines inside an outside the boxes designate expected extremes (points beyond these "whiskers" are outliers). The notches in the boxes represent 0.95th confidence intervals around the medians.

then modified to increase the drop breakup efficiency. Preliminary testing showed that the modified scheme impacted the simulated squall line in the right direction.

b. Improving the Thompson microphysical scheme

During 2013, the Thompson et al (2008) microphysics scheme in WRF was upgraded to directly couple the radiative-effective radius of water drops and ice crystals computed directly within the microphysics scheme and passed to the radiation scheme. This modification causes cloud characteristics to directly change radiation as occurs in the real atmosphere as compared to the inherent assumptions of particle size within the radiation scheme. The newly coupled physics were used in one of the OU-CAPS Spring Experimental Forecast ensemble members during their real-time forecast exercise in May and early June 2013. Analysis of 29 days of 48-hour forecasts is underway to compare the sensitivities to surface temperature and precipitation as well as cloud properties in conjunction with geostationary satellite data when using the uncoupled versus coupled physics. A journal manuscript is being prepared to present the methodology and results.

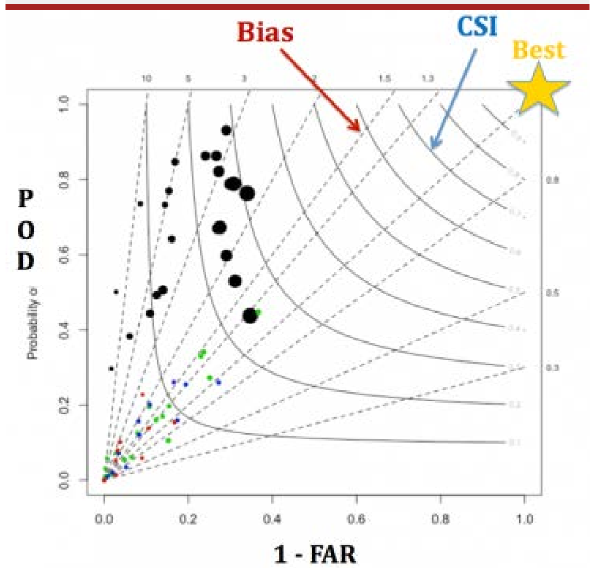


Figure 10. Performance diagram (Roebber 2009) showing multiple verification statistics for the 13 July 2011 case. This diagram simultaneously shows POD, 1-FAR, CSI, and Frequency Bias values for various lead times and precipitation thresholds. The different colors represent the precipitation thresholds used to define the precipitation events and individual points represent different forecast lead times. The best scores are in the upper right corner; bias values close to one are typically considered optimal.

FY2014 PLANS

Examination of the historical flash flood cases will continue and each of the components in the end-to-end hydrometeorological system will be further developed in preparation for a real-time test that is planned for the mid-late summer in 2014 in the Front Range region. One of the important planned activities will be the engineering effort to couple components, creating an end-to-end system that can be operated in real time. Beginning in the summer of FY2014, the FRONT (Front Range Observational Network Testbed) facility will begin to operate, collecting data from NCAR's S-Pol and CSU's CHILL dual-polarization radars, which will provide additional observations for use in this STEP project. Detailed plans for FY14 are summarized below:

QPE and nowcasting

- Document and evaluate the different Z-R relationships for QPE and conduct research to automatically determine the appropriate Z-R relationship to use for the meteorological situation
- Evaluate the performance of the nowcasting techniques for prediction of heavy rainfall for several of the 14 historic flood events
- Evaluate the performance of the nowcasting techniques for prediction of heavy rainfall during the great Front Range floods (10-15 September)
- Contribute to a BAMS article on the Front Range floods
- Run the QPE and nowcasting techniques in real-time during July-August 2014 using the FRONT datasets and evaluate performance

VDRAS high-resolution analysis

- Improve the analysis by considering the observation time at each radar beam
- Test the new version of VDRAS with the terrain effect and evaluate its impact
- Implement VDRAS on a new cluster machine
- Test a configuration for a summer 2014 real-time implementation

Flash flood prediction

- Improve the groundwater and channel flow physics components in the WRF-Hydro system to improve the recession characteristics of flood events
- Increase the number and type of QPE and QPF products ingested into the WRF-Hydro system with the goal of developing more probabilistic forecasts of streamflow and flooding threat
- Continue evaluation and use of different polarimetric QPE products in the creation of hydrologic forecasts
- Implement a new methodology for incorporating high-time frequency nowcasts of precipitation into the WRF-Hydro system
- Work with emergency managers and local forecasters to improve the quantity and quality of forecast products for dissemination

Verification

- Continue to examine and enhance the spatial verification methods to be utilized in evaluations of forecasts produced in summer 2014
- Implement a near-real-time evaluation system that will produce verification information on a regular basis, as well as for important events, during summer 2014
- Consider the use of probabilistic QPE fields as a way to take into account important aspects of observation uncertainty in the verification.
- Include capabilities to evaluate the streamflow forecasts in the summer 2014 evaluations.

WRF-based Radar data assimilation

- Continue improving the capability of WRF 3D/4DVar for radar data assimilation
- Test an update cycle strategy that is suitable for the Front Range area
- Configure and install 3D/4DVar on Yellowstone to get ready for real-time execution during the summer

WRF physics improvement

- Refine the hybrid radar data assimilation system with improved mixing ratio relationships to improve forecasted convective initiation and evolution
- Configure and install RTFDDA on Yellowstone to get ready for real-time exection during the summer
- Develop a 3-moment graupel/hail hybrid category in the Thompson microphysics scheme to improve forecasted convective storm structure, evolution, and QPF.

‹ Hydrometeorological Applications up
Advances in Land Surface Modeling ›

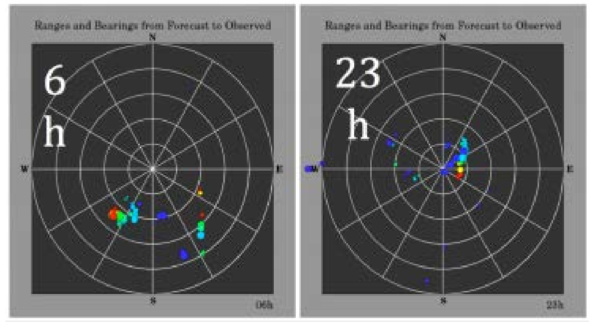


Figure 11. Centroid differences from application of MODE to the 13 July 2011 precipitation forecasts, for lead times of 6 and 23 h. The diagram depicts both the direction and magnitude of the forecast displacement from the observed storm area. Individual points represent different definitions of objects by MODE, with point sizes representing different radius values used to define the smoothing to be applied, and colors representing the threshold value used to define the extent of the precipitation area included in the final MODE objects.

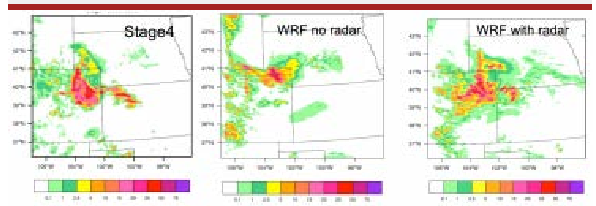


Figure 12. 6-h accumulated precipitation observations (00-06 UTC, August 9, 2013) from the Stage IV analyses (left), WRF forecasts valid at the same time period without radar data assimilation (middle), and WRF forecast with radar data assimilation (right).

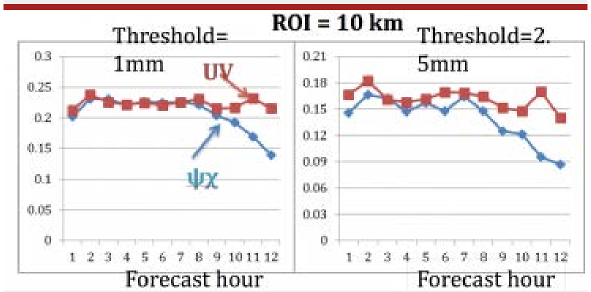


Figure 13. Comparison of Fractions Skill Scores (FSS) with a radius of influence of 10 km, between two forecast experiments with stream function and velocity potential (blue line) and u-wind and v-wind as momentum control variables. The FSSs are computed over 29 forecasts conducted for 7 of the 10 historical flash flood cases.

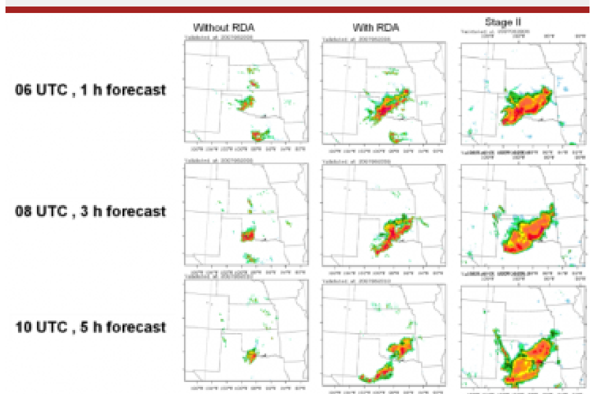


Figure 14. Hourly rainfall from RTFDDA forecasts with no radar data assimilation (left column) and with radar data assimilation (middle column), and Stage II estimates (right column).

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ADVANCES IN LAND SURFACE MODELING

DIAGNOSING CURRENT LAND SURFACE MODELS' ABILITY TO REPRESENT SNOWPACK EVOLUTION IN COMPLEX TERRAIN AND FORESTED CENTRAL ROCKIES

The timing and amount of spring snowmelt runoff in mountainous regions are critical for water resources management. This study developed an integrated data set including snow water equivalent (SWE) observations from 112 SNOTEL sites in the Colorado Headwaters region for the 2008 water year, 2004-2008 observations (surface heat fluxes, radiation budgets, soil temperature and moisture) from two AmeriFlux sites (Niwot Ridge and GLEES), MODIS snow cover, and river discharge. These data were used to evaluate the ability of six land-surface/snow models (Noah, Noah-MP, VIC, CLM, SAST, and LEAF-2) in simulating the seasonal evolution of snowpack in central Rockies (Chen et al., 2013).

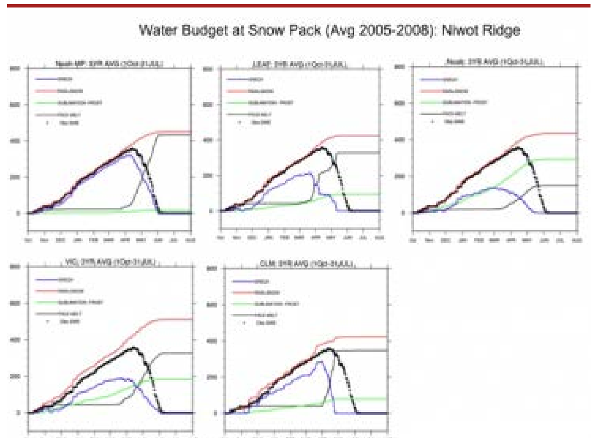


Figure 1. Water Budgets at the snowpack. Thick black dots are observed SWE (mm), blues line are simulated SWE (mm), red lines are accumulated (1 October – 31 July) rain plus snowfall (mm), green line are accumulated sublimation minus frost (mm), and black lines are accumulated melted snow amount (mm). They are averaged for 2005-2008 at the Niwot Ridge site.

All models captured the seasonality of SWE evolution fairly well, although they underestimated both early-spring (March-April) snow accumulation and late spring ablation. Underestimating snowmelt from mid-May to mid-June allowed models to compensate for lower SWE in spring, and consequently resulted in a prolonged snow season. No single model performed the best (or the worst) to reproduce three important features of snow evolution: maximum SWE depth, and the timing of maximum and minimum SWE. Models exhibited large disparities in simulating the surface energy partitioning, which is equally important for correctly representing snow-atmosphere interactions in weather and climate models. All models were able to simulate increased snow albedo following fresh snowfall and its reduction due to snow aging and compaction, but they differed substantially in the magnitude and diurnal cycle of albedo. All models, especially Noah and VIC, underestimated the solar energy absorbed at the forest-soil-snow interface from December to March and produced too little outgoing long-wave radiation and sensible heating returned to the atmosphere, which can be a crucial deficiency for coupled weather and climate models. Those model disparities and deficiencies can be further traced by examining the treatment (or lack of it) of turbulence and radiation processes within and under the vegetation canopy. Excessive shortwave and longwave radiation transfer from canopy to ground/snow often led to larger sensible heating from canopy to ground/snow surface, and resulted in larger, undesired weekly SWE change in both accumulation and ablation phases. Differences in treating under-canopy radiation and turbulence processes are ultimately reflected in snowpack water

budgets as shown in Fig. 1. Noah and VIC produce the highest sublimation, which is approximately half of the total amount of rain and snow. All models but CLM start melting snow in mid-March. While snowmelt processes mainly control Noah-MP snow disappearance, Noah is the only model producing sublimation amount larger than snowmelt amount for the Niwot Ridge site.

Reference:

Chen et al. 2013: Modeling snowpack evolution in complex terrain and forested Colorado Headwaters region: A model inter-comparison study. To be submitted in November 2013.

2. INVESTIGATING IMPACTS OF BEETLE-CAUSED MORTALITY

Observations obtained at the Glacier Lakes Ecosystem Experiments Site (GLEES) from 2005-2007 (pre-beetle) and from 2009-2010 (post-beetle) are combined with Noah-MP model simulations to assess surface energy and hydrological impacts of Engelmann spruce mortality 2-3 years following spruce-beetle attack. Increased albedo results in more reflected solar radiation and less net radiation, but the magnitudes of these post-beetle changes are smaller than or comparable to their annual variability. The dominant and greater-than-annual-variability signals are a large reduction (27%) in summer daytime evaporation and a large increase in sensible heat fluxes (25%), leading to increased Bowen ratio. Model sensitivity simulations indicate greater seasonal variations at tree-stand scales by incorporating dieback tree effects: more spring snowmelt and runoff, less spring-summer transpiration, and more arid soil in summer and fall (Fig.2). This modeled trend is similar to runoff changes in harvested forests where reduced forest density and cover results in more spring snowmelt and annual water yields. Effects of snow albedo change due to litter cover under dieback trees alter simulated seasonal snowmelt and SWE but not the annual total of runoff and evaporation, and they are relatively smaller compared to the effect of leaf loss. This study highlights the need to include the transient effects of forest disturbances in modeling land-atmospheric interactions and their potential impacts on regional weather and climate.

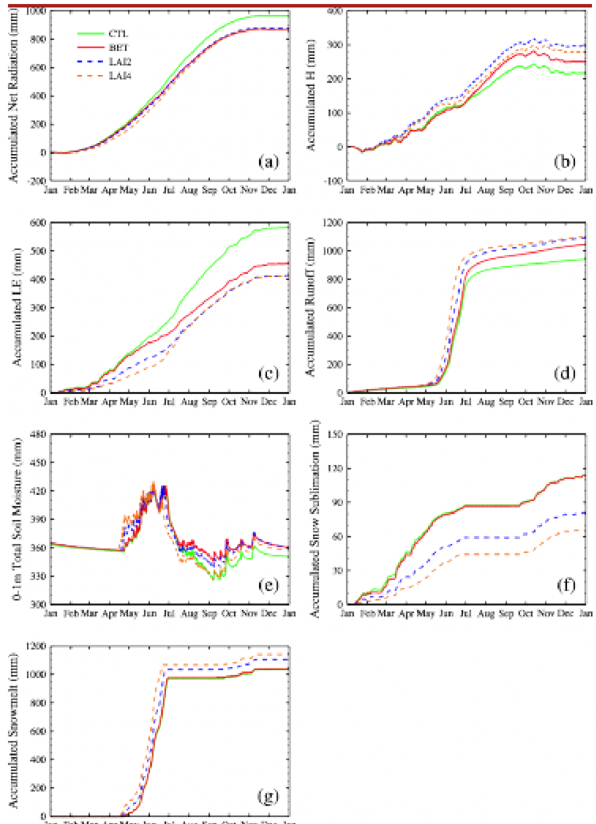


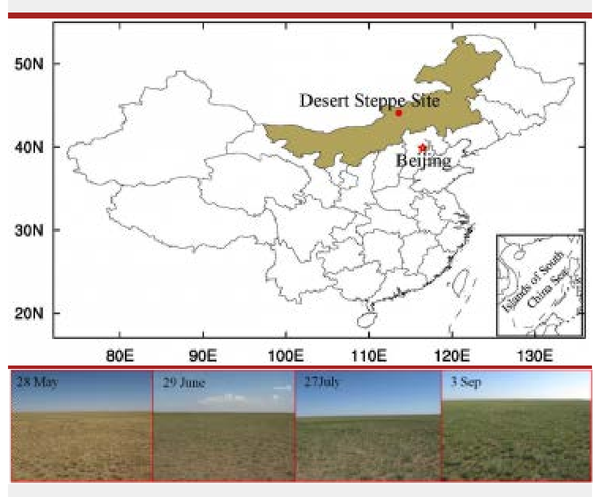
Figure 2. Simulated hydrological cycles averaged for 2009-2010 by Noah-MP with beetle-mortality (BET) and the uncertainties of LAI changes (LAI2 and LAI4). (a) accumulated net radiation; (b) accumulated sensible heat flux; (c) accumulated evaporation; (d) accumulated runoff; (e) daily averaged soil moisture in the first 1m soil depth; (f) accumulated snow sublimation; (g) accumulated snowmelt.

Reference:

Chen F., G. Zhang, M. Barlage, Y. Zhang1, C. Wiedinmyer, J. A. Hicke, A. Meddens, G. Zhou, W. J. Massman, and J. Frank, 2013: An Observational and Modeling Study of Impacts of Beetle-caused Mortality on Surface Energy and Hydrological Cycles. Agric. Forest Meteorol. Submitted.

3. IMPROVING SURFACE HEAT AND WATER VAPOR EXCHANGE SIMULATION IN A SEMI-ARID DESERT STEPPE ENVIRONMENT

Zhang et al. (2013a) analyzed the variability of canopy resistance and associated driving environmental factors over a desert steppe site in Inner Mongolia (Fig.3), China, through the use of eddy-flux and meteorological data collected from 2008 to 2010. Distinct seasonal and interannual variabilities in canopy resistance were identified within those three years, and controlled primarily by precipitation. Strong interannual variability was found in vapor pressure deficit (VPD), similar to that of air temperature. Based on the principal component regression method, the analysis of the relative contribution of five major environmental factors including soil-water content (SWC), leaf-area index (LAI), photosynthetically active radiation (PAR), VPD, and air temperature to canopy resistance showed that canopy-resistance variation was most responsive to SWC (with > 35% contribution), followed by LAI, especially for water-stressed soil conditions (> 20% influence) and VPD (consistently with an influence of approximately 20%). These analyses were used to develop a new exponential function of water stress (Fig. 4)



for the Jarvis scheme, which substantially improved the calculation of canopy resistance and latent heat fluxes, especially for moist and wet soils, and effectively reduced high bias in evaporation estimated by the original Jarvis scheme. This study highlighted the important control of canopy resistance on plant evaporation and growth for the investigated desert steppe site with relatively low LAI.

Figure 3. Location of the desert steppe observation site in Inner Mongolia, China. Upper panel: shaded area is Inner Mongolia and red dot is the approximate location of the site. Lower panel: seasonal vegetation change over this site for 2008.

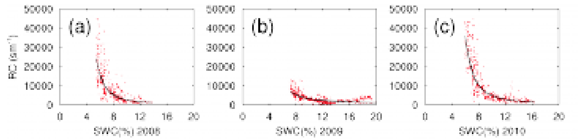


Figure 4. Relationship between canopy resistance and soil water content in 2008 (a), 2009 (b) and 2010 (c). The lines represent equation (10), (11) and (12) respectively.

Furthermore, Zhang et al. (2013b) assessed the ability of the Noah LSM to simulate surface heat fluxes for this site through addressing uncertainties in precipitation forcing conditions, rapidly evolving vegetation properties, soil hydraulic properties (SHPs), and key parameterization schemes. 3-year (2008-2010) observed surface heat fluxes and soil temperature over this desert steppe site are used to verify model simulations. The proper seasonal distribution of precipitation along with more realistic vegetation parameters can improve the simulation of sensible heat flux (SH) and the seasonal variability of latent heat flux (LH). Correctly representing the low surface exchange coefficient is crucial for improving sensible heat flux (SH) for short vegetation like this desert steppe site. Relating the Czil coefficient in the Noah surface exchange coefficient calculation with the canopy height (h) improves the simulated SH and the diurnal range of soil temperature over the simulation compared to using the default constant Czil. The newly developed exponential water stress formulation improves the partitioning between soil evaporation and transpiration. It is found that the surface energy fluxes are very sensitive to SHPs. This study stresses the important role of the proper parameter values and appropriate parameterizations for the surface exchange coefficient and water stress function in canopy resistance in capturing the observed surface energy fluxes and soil temperature variations for this desert steppe site.

Reference:

Zhang, G., G. Zhou, F. Chen, and Y. Wang, 2013a: Variability of Canopy Resistance over a Desert Steppe Site in Inner Mongolia, China. Advances in Atmospheric Sciences, in press.

Zhang, G., G. Zhou, F. Chen, M. Barlage, and L. Xue, 2013b: A trial to improve surface heat exchange simulation through sensitivity experiments over a desert steppe site. J. Hydromet, accepted.

4. ASSESSING EFFECTS OF GROUNDWATER INTERACTION ON REGIONAL CLIMATE SIMULATIONS

The new Noah-MP model includes a new capability to represent groundwater-vegetation-atmosphere interactions. This study used the Noah and Noah-MP land surface models with multiple groundwater sub-models to assess how the treatment of canopy processes and interactions with deep groundwater affect six-month regional climate simulations in two contrasting years, 2002 and 2010. Unlike the free drainage models, the models with groundwater modeling capability produce upward flux from the aquifer at different periods in the simulation (Fig. 5). The Noah soil moisture is always lower than in Noah-MP, which is likely due to model climatology differences. The inter-model Noah-MP soil moisture and latent heat flux results are consistent with recharge differences: the stronger upward flux capability with interactive groundwater results in the highest soil moisture and latent heat flux of the Noah-MP models. The effect of groundwater interaction is particularly evident when analyzing net water flux at the soil surface but its influence on precipitation is small, which may result from negligible differences in convective precipitation. The Noah-MP model, independent of the groundwater option, improves upon a cold and dry bias in the spring Noah simulations both during the day and night. The results for summer are region-dependent and also differ between year and time of day. For a majority of the simulation period, there is little groundwater effect on the Noah-MP near-surface diagnostic fields. However, when the Noah-MP model produces large warm/dry biases in the 2010 summer, the aquifer interactions in Noah-MP improve the air temperature bias by 1 – 2°C and dew point temperature bias by 1°C.

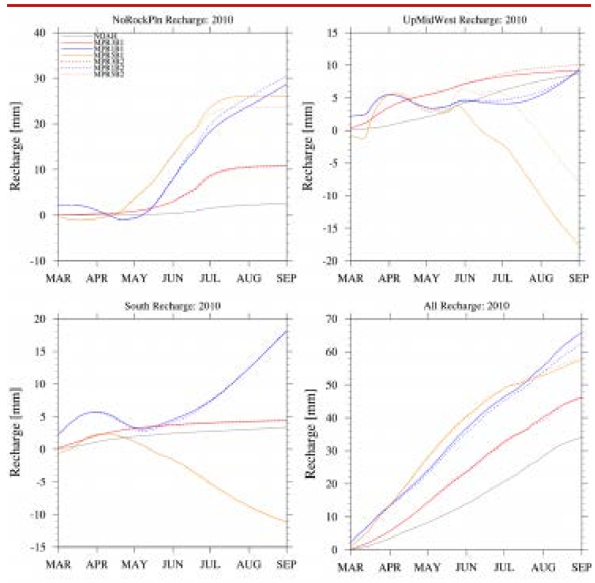


Figure 5. Accumulated recharge [mm] defined as water flux out of the lower boundary of the 2-meter soil column in the four models: Noah (grey), Noah-MP R3 (red), Noah-MP R1 (blue) and Noah-MP R5 (orange). Dashed lines are the Noah-MP options with the B2 soil moisture function. Negative slope implies upward transport. The panels are the three analysis regions and total domain (lower right).

Reference:

Barlage, M., M. Tewari, F. Chen, G. Miguez-Macho, Zong-Liang Yang, and G.Y. Liu, 2013: The Effect of Groundwater Interaction in North American Regional Climate Simulations with WRF/Noah-MP. *Climatic Change,* Submitted.

5. DEVELOPING A MOSAIC APPROACH IN THE WRF-NOAH FRAMEWORK

The current WRF-Noah modeling framework only considers the dominant land-cover and land-use type within each grid cell. To assess the impact of subgrid scale variability of land-cover composition, a mosaic/tiling approach has been developed and evaluated in the coupled WRF-Noah modeling system (Li et al., 2013). The mosaic approach uses a number (N) of tiles to represent a sub-grid scale land-cover category. This new approach was tested for a clear-sky day and a rainfall period over a heterogeneous urban/suburban region. Evaluated against observational data (surface flux measurements, MODIS land surface temperature product, and radar rainfall estimates), the new mosaic approach produces a better performance. The mosaic WRF-Noah will be released in the community WRF in 2014.

Reference:

Li, D., E.Bou-Zeid, M. Barlage, F. Chen, J.A. Smith, 2013: Development and evaluation of a mosaic approach in the WRF-Noah framework. J. Geophys. Res., accepted.

‹ Short-Term Explicit Prediction (STEP) Program up Aerosols and Precipitation ›

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AEROSOLS AND PRECIPITATION

INDIA CAIPEEX PROGRAM

The Indian Institute of Tropical Meteorology (IITM) initiated a multi-year national research program, the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX), in 2008. In 2011, Phase II of CAIPEEX was executed, and an intensive observation period (IOP) from August to November was conducted. RAL provided overall scientific guidance to this effort, working closely with scientists from IITM and the University of the Witwatersrand, South Africa. Local logistical support was contracted with Krishi Consultants.

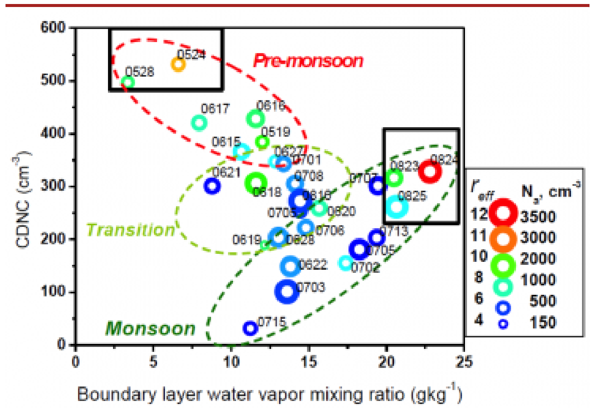

Figure 1. Variation of CDNC with boundary layer water vapor for cloud observations during CAIPEEX Phase I. Labels are marked with date of observation (mmdd: month and day) and grouped (shown with ellipses) into pre-monsoon, transition and monsoon periods. Rectangular boxes show observations with two extreme conditions of water vapor and high pollution. The aerosol number concentration (Na) is color-coded, and the size of the symbols reflects the cloud-averaged effective radius (r_{eff}), as shown in the legend.

CAIPEEX has collected a large data set that describes the contrasting aerosol and cloud microphysical properties over India. These data were collected during the pre-monsoon and the monsoon periods as well as the transition period between the two. Aerosols over the Indo-Gangetic Plains as well as over the elevated slopes of the Himalayas have received growing attention in recent years due to their potential effects on the seasonal evolution and long-term variability of the summer monsoon. A subset of the CAIPEEX research flights were conducted in and around convective clouds over the foothills of the Himalayas during the spring and summer of 2009. Figure 1 shows averaged cloud droplet number concentration (CDNC), plotted against boundary layer water vapor mixing ratio, cloud averaged effective radius (r_{eff}), and aerosol number concentration (N_a). Each point in the figure corresponds to a CAIPEEX cloud observation. Three regimes based on the available water vapor in the boundary layer and the progression of the monsoon are identified, and shown as ellipses in Figure 1. This analysis shows a very dry regime in the pre-monsoon, a moderately wet transition, and a wet regime during the monsoon. Within the monsoon regime, the CDNC increases with an increase in water vapor mixing ratio. Observations in the monsoon and pre-monsoon regime show relatively high droplet number concentrations. These observations were conducted in the Ganges valley during the pre-monsoon (0524 – May 24th and 0528 – May 28th) and the active monsoon (0823 – Aug 23rd, 0824 – Aug 24th, 0825 – Aug 25th) periods. The high CDNC monsoon cases are associated with very moist and polluted conditions. During the pre-monsoon, cloud microphysics may be characterized as "super-continental", meaning that the cloud droplets are very small and delay the formation of

warm rain.

FY 2013 Accomplishments

During FY 2013 RAL collaborated with IITM on various data analysis topics including (1) the identification of ice hydrometeors in optical array probes, (2) the conversion of supercooled cloud and rain drops into ice hydrometeors, as a function of temperature and aerosol concentration, (3) aerosol new particle formation and its impact on cloud microphysics, and (4) the effects of aerosol with different microphysics and chemistry on the development and evolution of the drop size distribution at cloud base.

The following journal articles resulted from the RAL-IITM collaboration during CAIPEEX:

Prabha, T. V., S. Patade, G. Pandithurai, A. Khain, D. Axisa, P. Pradeepkumar, R. S. Maheshkumar, J. R. Kulkarni and B. N. Goswami, 2012: Spectral width of premonsoon and monsoon clouds over Indo-Gangetic valley, J. Geophys. Res., 117, D20, doi:10.1029/2011JD016837.

Prabha, T. V., A. Karipot, D. Axisa, B. P. Kumari, R. S. Maheskumar, M. Konwar, J. R. Kulkarni, and B. N. Goswami, 2012: Scale interactions near the foothills of Himalayas during CAIPEEX, J. Geophys. Res., 117, D10, doi:10.1029/2011JD016754.

Freud, E., D. Rosenfeld, D. Axisa, and J. R. Kulkarni, 2011: Resolving both entrainment-mixing and number of activated CCN in deep convective clouds, Atmos. Chem. Phys. Discuss., 11, 9673-9703, doi:10.5194/acpd-11-9673-2011.

FY 2014 Plans

Collaborative analysis between RAL and IITM is leading to advances in the understanding of monsoon clouds over the Indian subcontinent. Increasing air pollution over this region could modify the radiative balance through direct, indirect, and semi-indirect effects associated with aerosols. These analyses are motivating new studies to investigate aerosol-cloud sensitivities in the region.

STUDIES OF EMISSIONS AND ATMOSPHERIC COMPOSITION, CLOUDS AND CLIMATE COUPLING BY REGIONAL SURVEYS (SEAC^{4}RS)

Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC^{4}RS), a NASA field campaign, was based out of Ellington Field in Houston during August and September 2013. The study focused on pollution emissions and the evolution of gases and aerosols in deep convective outflow, and the influences and feedbacks of aerosol particles from anthropogenic pollution and biomass burning on meteorology, clouds and climate. The project required three aircraft to accomplish these goals. The NASA DC-8 provided observations from near the surface to 12 km, the NASA ER-2 provided high altitude observations reaching into the lower stratosphere as well as important remote sensing observations connecting satellites with observations from lower flying aircraft and surface sites. The SPEC Learjet obtained aerosol and cloud microphysical measurement in convective clouds and convective outflow.

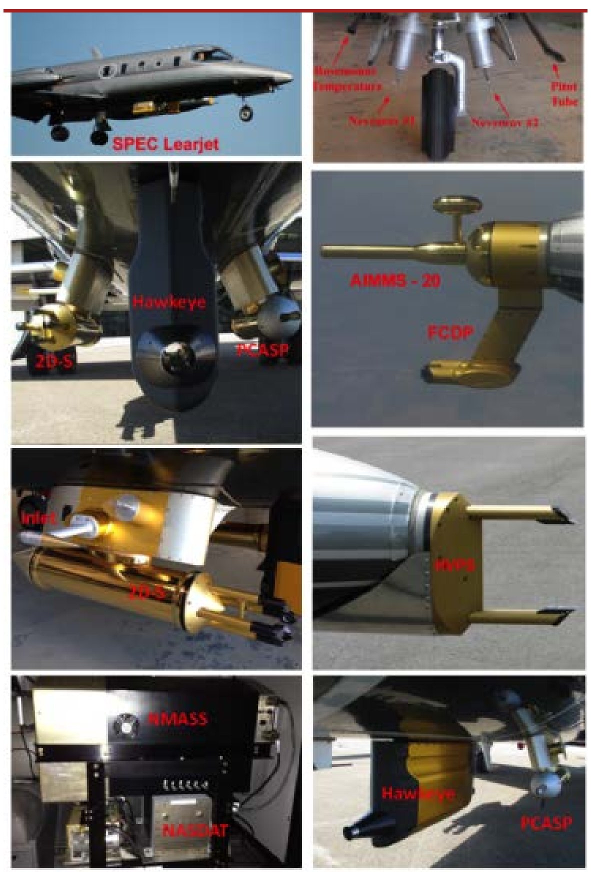

Figure 1: SPEC Learjet and instrumentation as deployed during SEAC^{4}RS.

FY 2013 Accomplishments

During the SEAC^{4}RS field campaign, SPEC Inc. and NCAR collaborated to deploy instruments on all three aircraft: the NASA DC-8, NASA ER-2 and the SPEC Learjet. In addition, the University of Denver (DU) deployed aerosol instruments onboard the SPEC Learjet. SPEC, NCAR and DU staff participated in the field project and provided support for their operation.

Table 1 lists the SPEC instruments installed on the NASA ER-2 and DC-8. The FCDP on the ER-2 provide measurements of ice concentrations in cirrus clouds while the particle probes on the DC-8 provide measurements of microphysical properties in a variety of clouds measured by the DC-8, ranging from low-level maritime stratocumulus

cloud to cirrus and overshooting tops.

Table 1: Cloud instrumentation deployed on the NASA ER-2 and DC-8

Aircraft	Instrument	Property Measured	Diameter Size Range
ER-2	Fast Cloud Droplet Probe (FCDP)	Cloud droplet/ice particle size	2 to 50 µm
DC-8	Fast Cloud Droplet Probe (FCDP)	Cloud droplet/ice particle size	2 to 50 µm
DC-8	2D-S (Stereo) Optical Array spectrometer	Cloud hydrometeor size and image	10 µm to 3 mm
DC-8	High Volume Precipitation Spectrometer (HVPS)	Cloud hydrometeor size and image	150 µm to 2 cm
DC-8	Cloud Particle Imager (CPI)	Cloud hydrometeor size and image	

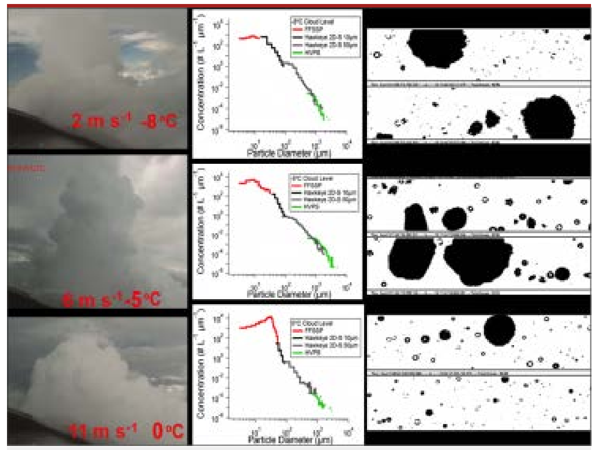

Figure 3: Cloud microphysical properties at 0 °C, -5 °C and -8 °C as measured by the FFSSP, the Hawkeye 2D-S 10 µm, the Hawkeye 2D-S 50 µm and the HVPS. The left panel shows cloud pictures from the forward facing camera(including updraft speed and temperature), the middle panel shows the combined particle size distribution, and the right panel shows a sample of the 2D-S 10 µm images.

The SPEC Learjet, also deployed during SEAC^{4}RS, was equipped with a complete suite of cloud microphysical probes (e.g., FCDP, FFSSP, 2D-S, CPI, HVPS, Nevzorov LWC/TWC) and instruments measuring state variables (e.g., temperature, pressure) and aircraft parameters (e.g., altitude, position, heading, airspeed). In addition to SPEC's cloud spectrometer probes, the Learjet was also equipped with the DU Nucleation Mode Aerosol Size Spectrometer (NMASS) and with a Passive Cavity Aerosol Spectrometer Probe (PCASP) that was modified to reduce the volume flow rate with increasing altitude above the boundary layer. With all these instruments onboard, the Learjet was able to comprehensively document regions of warm rain, supercooled water drops, mixed-phase and glaciated regions of cloud, including images of ice particles (ranging from a few micrometers to several millimeters) that are automatically classified into ice particle habits. The aerosol instrumentation also permitted the identification of the formation and growth of new aerosol particles in regions affected by deep convective outflow. The photos in Figure 2 show the installation of the various instruments on the Learjet as deployed during the SEAC^{4}RS field campaign.

During SEAC^{4}RS the Learjet flew coordinated flights with the NASA DC-8 and ER-2. The Learjet conducted cumulus investigations and anvil sampling. An example of data from these flights is shown in Figure 3 and Figure 4 from 12 August 2013 when the DC-8, ER-2 and Learjet made a coordinated flight in the southeastern US. The Learjet sampled the variation of the cloud drop size distributions (DSD) with altitude near Huntsville, Alabama. Figure 3 shows the particle size distributions measured at 0 °C, -5 °C and -8 °C by the FFSSP, the Hawkeye 2D-S 10 µm, the Hawkeye 2D-S 50 µm and the HVPS in a convective cloud element that was still growing at significant updraft velocities. The cumulus investigation shows that the mixed phase region of this cloud was producing precipitation. However the warm part of the cloud had an active coalescence process, which produced large drops that formed graupel. After the cumulus investigation, the Learjet and DC-8 sampled anvil cloud that was being generated by convection in the same region. Figure 4 shows an example of CPI images of ice particles with some complex aggregated structures and also some spherical ice particles that could have originated from nearby convective elements.

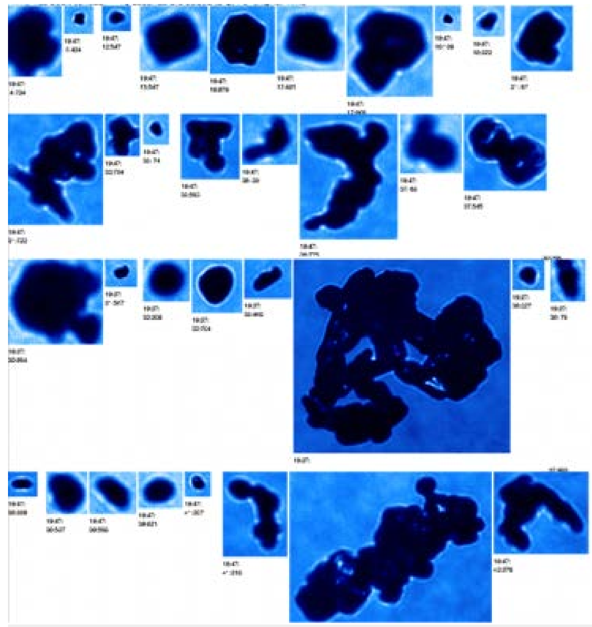

Figure 4: Example CPI images observed during a climb into the anvil after cumulus cloud investigation.

FY 2014 Plans

The NASA DC-8, NASA ER-2 and the SPEC Learjet flew over 50 flight missions, mostly over the southeastern United States. The heavily instrumented aircraft measured cloud, aerosol and trace gas properties, at times flying simultaneously through storms and above them to maximize data capture. Analysis of these flights will commence once all the data have been processed. The analysis will consist of studies related to aerosol and cloud hydrometeor microphysical properties, such as the effect of aerosol on warm rain and mixed phase cloud, the microphysics of anvil cloud, and aerosol new-particle formation in the vicinity of clouds.

‹ Advances in Land Surface Modeling up Winter Weather ›

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WINTER WEATHER

WYOMING WEATHER MODIFICATION PILOT PROGRAM

Background

The Wyoming Weather Modification Pilot Program (WWMPP), funded by the State of Wyoming through the Wyoming Water Development Commission (WWDC), is an orographic cloud seeding research program covering three target areas (the Medicine Bow Range, Sierra Madre Range and Wind River Range). It is unique among state-sponsored programs in that it includes a substantial independent evaluation component to determine the feasibility of cloud seeding and to quantify its effectiveness. The logistics, infrastructure, and operations of the program are covered under a contract with Weather Modification Inc. (WMI), while the evaluation activities fall under a separate contract with the Research Applications Laboratory (RAL) of the National Center for Atmospheric Research (NCAR).

Figure 1. Composite satellite view of Wyoming. Yellow areas denote the three mountain ranges in the winter orographic cloud seeding program: Medicine Bow, Sierra Madre, and Wind River. The randomized seeding experiment involves only the two southern ranges, the Medicine Bows and Sierra Madres.

Both short-term research projects and long-term operational programs to increase snowpack by seeding clouds have been carried out for well over fifty years. Average increases of 10 to 15% have been reported in some research experiments, but the topic remains controversial and many operational programs and scientific experiments have ended without conclusive results. Because of the large natural variability of precipitation, and the relatively small seeding effect expected, multiple layers of evidence, both statistical and physical, are required to provide a consistent picture of the effect of cloud seeding.

The evaluation of the WWMPP is based on this two-pronged approach: a) a statistical experiment to collect a randomized set of seeded and unseeded cases, and b) exploratory observations to investigate the different physical processes in cloud seeding to show that the seeding hypothesis is physically-based. Collaborations with other scientists, particularly those at the University of Wyoming, have led to "piggy-back"

Figure 2. Orographic clouds over the Medicine Bow range.

studies applicable to the assessment of seeding impacts on precipitation formation and eventually on streamflows.

FY2013 Accomplishments

Cloud Seeding Evaluation Studies with the WRF Model

One of the primary advances in the evaluation of orographic cloud seeding has been the use of high resolution mesoscale models. The Weather Research and Forecast (WRF) model has been used in this project to evaluate seeding potential using an AgI point-source module to represent the release of AgI from ground-based generators (Xue et al. 2013a, b). The WRF model with this AgI cloud seeding parameterization was used to assess the potential impact of seeding over the Wind River Range (WRR) in Wyoming. (This Range was seeded as part of the WWMPP based on pre-determined criteria.)

Two cases were simulated by the WRF model with the AgI cloud seeding parameterization in Large Eddy Simulation (LES) mode over the WRR. The first case, on 20 December 2010, was not actually seeded; the other is an actual seeding case from 20 February 2011. The LES domain is illustrated in Figure 3. The domain consists of 240 by 240 grid points in the horizontal with a grid spacing of 667 m. The time step is 0.5 second for these two cases. Our recent findings (Xue et al. 2013c) indicate that the LES simulation with a grid spacing around 500 m can produce reasonable AgI dispersion features compared to LES simulations with 100-m grid spacing. Both cases were initialized with RTFDDA-WRF analysis data in the 2-km grid spacing domain with a three-hour spin up.

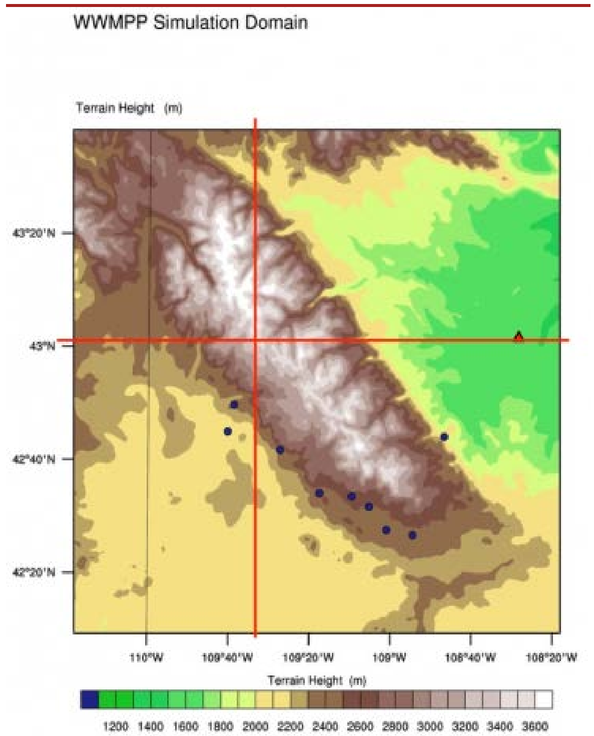

Figure 3 – LES model domain of the Wind River Range. The generators are indicated by blue circles. The red triangle is the sounding location (Riverton, WY). Red lines indicate the cross section locations showed in Fig. 6.

20 December 2010 case

For this case a 12-hr control simulation was conducted from 20 Dec 2010 0000 UTC to 1200 UTC. Seeding was simulated from 20 Dec 2010 0000 UTC to 1000 UTC. All nine ground-based seeding generators were turned on. The observed and model simulated sounding at Riverton at 20 Dec 2010 0000 UTC is plotted in Figure 4. Although the model simulated a more moist atmosphere above 700 hPa, it captured the low level winds and thermodynamics well. The low-level conditions are the main determinant in the AgI dispersion over the mountain and in further interactions between AgI particles and clouds.

To evaluate the model's performance, the 12-hr accumulated precipitation simulated by the model (for the control run) is illustrated in Figure 5 with the corresponding observed snow water equivalent (SWE) from all the SNOTEL sites in the domain overlaid with the same color scale. The model under-predicted the precipitation on the upwind side, but reproduced the precipitation pattern on the downwind side relatively well.

The vertical cross sections noted in Fig. 4 are plotted in Fig.6 at the mid-time of the simulation for AgI number concentration, temperature, cloud water mixing ratio, and ice saturation ratio. The SLW was very high (~1 g kg^{-1}) and extended vertically to ~6 km MSL. The AgI particles dispersed into the cloud and thus a positive seeding effect might be expected.

Figure 7 depicts the simulated seeding effect in the form of precipitation difference on the ground between the seeding and control simulations. Positive seeding effects were simulated over most of the downwind slope. The negative simulated seeding signals along the ridge of the

WRR indicate that precipitation formation was delayed or the precipitation pattern was shifted downwind by the seeding materials. The small-scale “noisy” signals close to the northern boundary are due to numerical boundary effects and should not be interpreted as physical results. The simulated seeding effects in acre-feet and percentage are listed in Table 1.

Figure 7 *– Precipitation differences (mm) on the ground between the seeding and control simulations.*

20 February 2011 case

In this case, seven ground generators (as shown in Fig. 3) were turned on from 20 Feb 2011 1120 UTC to 1600 UTC, and were simulated with the seeding run. The control simulation was conducted for 12 hours, from 20 Feb 2011 0400 UTC to 1600 UTC. The observed and model-simulated sounding at Riverton at 20 Feb 2011 1200 UTC is plotted in Figure 8. The model simulated a warmer and moister atmosphere below 700 hPa, but the general inversion feature and low level wind field were well captured by the model.

The general precipitation pattern is simulated fairly well in the control run, except for the northwestern area in the domain (Fig. 9). The cross sections (Fig. 10) show that AgI particles were dispersed over the mountain. However, the system is colder and thus has much less SLW (~0.2 g kg^{-1}) compared to the 20 Dec 2010 case. Therefore, a smaller simulated seeding effect is expected as compared to the 20 Dec 2010 case.

Figure 8 *– Same as Fig. 4 except for the 20 Feb 2011 case at 1200 UTC.*

Figure 9 *– Same as Fig. 5 except for the 20 Feb 2010 case.*

Figure 11 shows that the positive simulated seeding effect is confined to a small area over the upwind slope and over the ridge of the WRR. No negative seeding effect was simulated. The magnitude and area of the simulated seeding effect are much smaller than those of the 20 Dec 2010 case. The control precipitation during the seeding period (acre-feet), average precipitation rate (mm h^{-1}), absolute simulated seeding effect (acre-feet), and relative simulated seeding effect (in percent) are listed in Table 1.

Figure 10 *– Same as Fig. 6 except for the 20 Feb 2011 seeding case at 1300 UTC.*

Figure 11 *– Same as Fig. 7 except for the 20 Feb 2011 case.*

Summary

Two wintertime ground-based orographic seeding cases over the Wind River Range have been simulated by the WRF model coupled with the AgI cloud seeding parameterization in LES mode. Both cases show positive simulated seeding effects over the WRR, but the magnitudes and spatial patterns are very different. Table 1 lists the control precipitation (0000 – 1200 UTC for 20 Dec 2010 case and 1000 – 1600 UTC for 20 Feb 2011 case), average precipitation rate during the same

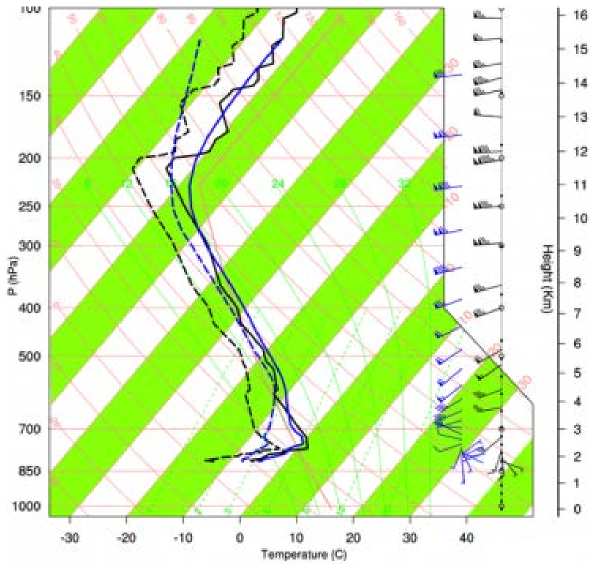

Figure 4 – Thermodynamic diagram of the observed sounding (black) and model-simulated sounding (blue) at Riverton at 20 Dec 2010 0000 UTC. Solid lines are temperature and dashed lines are dew point temperature.

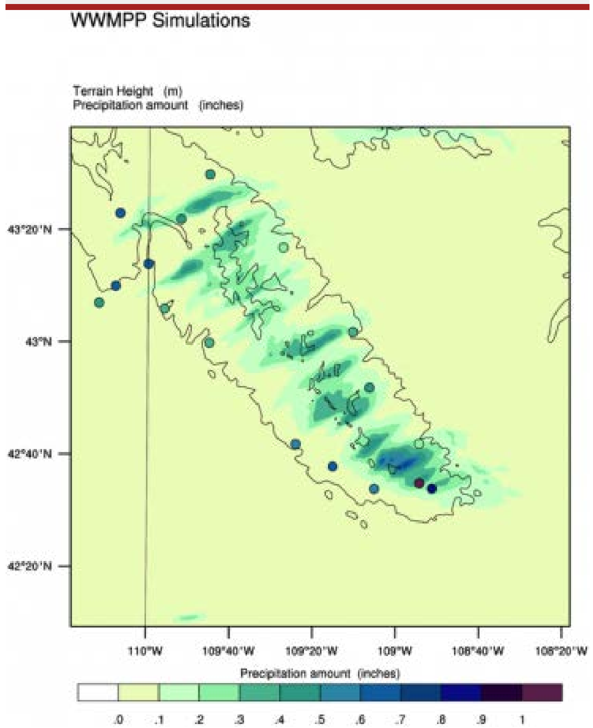

Figure 5– LES simulated control precipitation accumulation (inches) and observed SWE of all SNOTEL sites in the domain (color filled circles). The color scale is the same for these two fields.

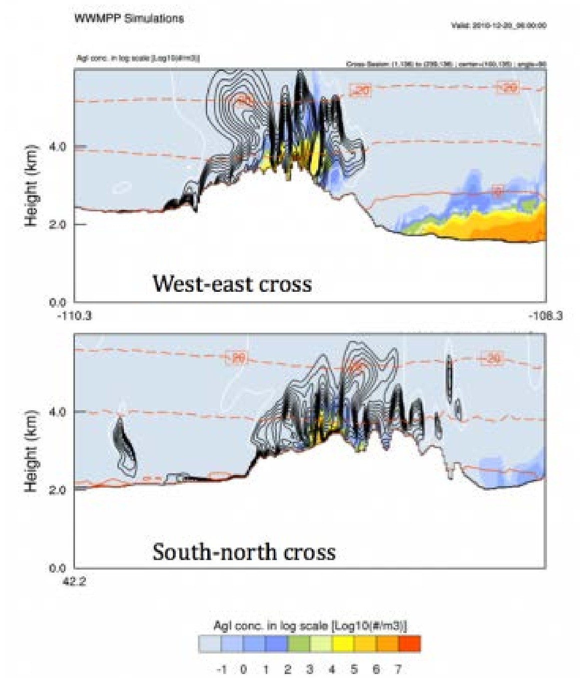

Figure 6 – Cross sections showing AgI number concentration (color shaded, m^{-3} in logarithmic scale), temperature (red lines), cloud water mixing ratio (black contours with 0.1 g kg^{-1} interval) and areas of ice saturation ratio greater than 1.04 (white outlines).

periods, and simulated seeding effects for both cases.

The results are consistent with the finding in Xue et al. (2013a, b) that the simulated seeding effect is inversely related to the natural precipitation efficiency. In the 20 Dec 2010 case, when the storm was relatively warm, ice processes were not active enough to convert SLW into precipitation, which resulted in high SLW and low precipitation rate. Under these conditions, AgI particles enhanced the ice initiation and thus accelerated ice-water interactions and precipitation formation. The result was a positive simulated seeding effect over a broad area. On the other hand, in the 20 Feb 2011 case, the storm was cold enough to actively initiate ice processes naturally. Under such conditions, natural precipitation efficiency was higher, and much lower SLW content reduced the effectiveness of the AgI particles. Therefore, a smaller positive seeding effect was simulated.

Table 1 *– Accumulated precipitation of control simulation (acre-feet), average precipitation rate (mm h^{-1}), absolute simulated seeding effect (acre-feet), and relative simulated seeding effect (%) for both cases.*

	20 Dec 2010	**20 Feb 2011**
P (acre-feet)	23494	26219
PR (mm/h)	0.13	0.28
ΔP (acre-feet)	1099	326
ΔP/P (%)	4.68	

Planned Studies

A set of simulations of natural and seeded orographic clouds over the WRR will be conducted for the entire month of February 2013 to examine longer term impacts of seeding.

In addition, a pre-ASCII case (2009 field campaign) was simulated by the WRF model with the AgI cloud seeding parameterization in LES mode at 100-m grid spacing. Observations from several instruments have been analyzed and compared with the model results. The simulated AgI impact on the cloud microphysics and the precipitation on the ground were also investigated in detail. The work will be summarized in a two-part paper that is in preparation. The results from the WRR simulations and the pre-ASCII case will be presented in the WWMPP final report.

IDAHO POWER PROJECT

Background

Idaho Power conducts a winter cloud seeding program to augment snowfall along the Snake River Basin and its tributaries for hydro-generation purposes. The program is presently focused in two areas; the Payette River watershed and the upper Snake River system in eastern Idaho (Figure 11).

Figure 11. Map of the Snake Watershed in Idaho (large red outline) and existing ground generator sites on a map of

terrain height (m; color shading). The Payette River Basin target area is located in the western Snake watershed, north of Boise and is also outlined in red. The Upper Snake River Basin target area is located in Eastern Idaho, also outlined in red. Ground generator locations are identified as circle and triangle symbols, and color-coded as white (Payette), blue (north Eastern Idaho), and green (south Eastern Idaho). The circles are Idaho Power owned generators, and the triangles are generators operated by Let it Snow.

Plans are being developed for potential expansion into the Salt and Wyoming rivers in Western Wyoming. For the past year RAL has conducted a numerical modeling “Phase Three” study (a 2-year long phase) to provide real-time and retrospective model-based guidance on the effectiveness of cloud seeding using ground generators and aircraft tracks. The primary goal of Phase Three is to develop and implement a real-time cloud seeding forecast guidance system using the Weather Research and Forecasting (WRF) model and the newly developed cloud seeding module utilized in Phases One and Two.

FY2013 Accomplishments

In the first year of the Phase Three effort, RAL has successfully developed a prototype real-time cloud seeding decision algorithm, collaborated with the University of Arizona (UofA) to adapt the cloud seeding module onto the UofA real-time WRF forecast model, run a research version of WRF on a UofA computing cluster for tailored precipitation and cloud seeding forecasting relevant to the Idaho Power cloud seeding operations during the 2012-2013 winter season, and simulated cloud seeding effects for the 13 cases that were seeded by Idaho Power in that winter season (hereafter, the retrospective cases).

The principles of this algorithm are based upon assessing the presence of the basic conditions required for a positive cloud seeding effect. These basic conditions have been categorized into two sets of criteria: microphysical and dispersion. Then if both sets of criteria are met for either a ground or airborne case for a given target region, a process to define the case times is called. This entire process is executed to determine the suitability of both ground and airborne seeding separately for each of three target regions as shown in Fig. 11.

Once both microphysical and dispersion criteria are met for a given target region, for ground or airborne seeding, the algorithm needs to define the times the cases should be called for. The strategy for calling cases differs for ground versus airborne seeding. The essential process, however, follows a similar method in which at every 30-minute time step the algorithm assesses if the microphysical and dispersion criteria are met within a moving time window.

The real-time seeding decision algorithm and real-time cloud seeding forecast model ran successfully all season. The prototype algorithm called seeding in 175 48-hr forecasts, which were then simulated by the real-time cloud seeding forecast model. The breakdown by each target region and seeding type is depicted in Table 2.

Table 2. The number of 48-hour seeding forecasts called, the number of discrete seeding cases called, and the average time of the seeding cases for each region and seeding type (GS= Ground seeding and AS= Airborne seeding). PAY = Payette, NEID = North Eastern Idaho, and SEID = South Eastern Idaho.

The number of cases called by the algorithm was determined to be high, as several of these cases simulated weak seeding enhancements (Figure 13). Nonetheless, the algorithm certainly performed well at identifying possible seeding scenarios. Most of the retrospective cases fell in the lower simulated seeding effect range as compared with all of the real-time cases simulated seeding effects (Figure 13). Three “high priority” retrospective cases tended to have the best simulated seeding effects of all of the retrospective cases (Figure 13). Results of the real-time seeding forecast model confirmed previous sensitivity studies (Xue et al. 2013a,b) that indicated the best seeding effects are during periods with lower natural precipitation, even in an absolute precipitation simulated enhancement (calculated in acre feet) perspective.

Figure 13. Absolute (acre feet; left) and relative (% change; right) seeding effects simulated in each 48-hour seeding forecast (blue dots) over the full model domain plotted versus the natural (or control) precipitation accumulation in that same 48-hour period (acre feet). The results of the 13 retrospective (actual seeded) cases are overlaid as red dots.

Additional work conducted thus far in Phase Three included simulating and analyzing three cases using the HYSPLIT back trajectory model to assess optimal seeding locations. This analysis has revealed that ground-based seeding is most often able to influence lower-level clouds (< 500 m Above Ground Level). SNOTEL data has been quality-controlled for two water years, and preliminary data from the 2012-2013 season has been compared with the model output from the real-time forecast model over the Payette basin, indicating that the model performs fairly well on a daily basis for most sites, however the model over predicts precipitation at several of those sites for high precipitation events. Observed LWP from radiometers were also compared to model forecasts. The comparisons indicated that the model did a good job in capturing the distribution and magnitude of the super cooled liquid water contents.

We have also worked to develop plans for a new field program. Several planning meetings have been held and a white paper has been created and distributed to the National Science Foundation for feedback. The proposed field campaign is called "Seeded and Natural Orographic Wintertime clouds -- Idaho Experiment (SNOWIE)" and would serve to validate the new cloud seeding model. Based on feedback from NSF, we intend to submit our proposal in the summer of 2014 and will plan to conduct the program in winter 2015-2016. Additionally, two peer-reviewed journal articles have been accepted for publication, and three additional papers are in preparation, documenting the results of the cloud seeding module and modeling research conducted for Idaho Power.

FY2014 Plans

- Adjust the seeding decision algorithm to remove low-impact seeding cases and retain high-impact cases for the 2013-2014 season.
- Investigate the use of high-resolution modeling simulations of seeding combined with observations to statistically evaluate cloud seeding effects.
- Submit SNOWIE proposal to NSF.
- Investigate the potential seeding impact of current seeding facilities on the Green River Basin and Boise/Woods Basin.
- Publish three journal papers.

PARTICIPATION IN THE WMO SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT (SPICE)

Background

NCAR/RAL with NOAA funding teamed with the NOAA CRN program to host the U.S. site for the World Meteorological Organization's (WMO) Solid Precipitation InterComparison Experiment (SPICE). This program, scheduled to run from November 2012 through May 2015, is an international effort to evaluate the performance of automated gauge/shield combinations for measuring solid precipitation. A key element of this program is the establishment of a reference standard for snowfall and snowdepth measurement.

Countries from around the world with significant winter weather are participating in this study, providing a testbed for evaluating various sensors, gauges and wind shields. In addition to hosting the U.S. SPICE site, NCAR has also been designated as the main data repository for all participating sites and will make the data available to the international community through the SPICE web data portal located on the Marshall web page.

FY2013 Accomplishments

A suite of over thirty precipitation gauge/shield combinations from various manufacturers were deployed at the Marshall site in the fall of 2012. Data were collected during the winter and evaluated over the summer. The reference standard gauge was established during the summer of 2013 using data from Marshall and other SPICE sites at a meeting in Davos, Switzerland. The reference and vendor gauges were calibrated and tested in preparation for the official start of the program in October 2013.

FY2014 Plans

Data will be collected from all thirty gauges at the Marshall field site (including the reference standard gauge/shield systems), and archived and displayed on the NCAR/RAL web page in real-time. A data quality algorithm will be developed by NCAR/RAL that will be applied to all the data for post-analysis purposes. Analysis of the performance of the manufacturers' gauges relative to the reference standard gauges will be conducted. NCAR/RAL will participate in future SPICE leads meetings during which the analysis of the data will be reviewed and refined in preparation for the publication of a final report in 2015.

‹ Aerosols and Precipitation up Western Water ›

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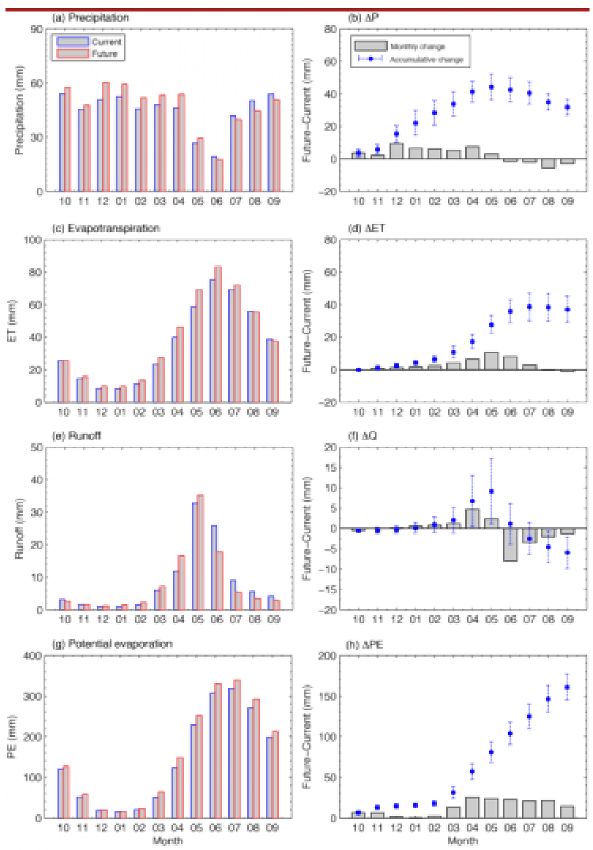
WESTERN WATER

BACKGROUND

NSF base funding supports the NCAR Water System research program. Within that larger program, RAL conducts a Colorado Headwaters project that examines the impact of climate change on water resources in this critical region. In FY2013 researchers have continued their analysis of different scenarios of mid-21st century future hydroclimate with continuous, 8-year, very high resolution (4km) regional climate model simulations using the Weather Research and Forecasting (WRF) model. New analyses of these continuous 8-year climate downscaling runs are generating new insights into how the partitioning of the hydrologic cycle will change under a warmer climate.



Caption. (a) Seven-year climatology of monthly precipitation from the 4-km current and future simulations averaged over the Headwaters domain. (b) Difference in the seven-year average monthly precipitation (bars) and accumulation of the differences (dots)

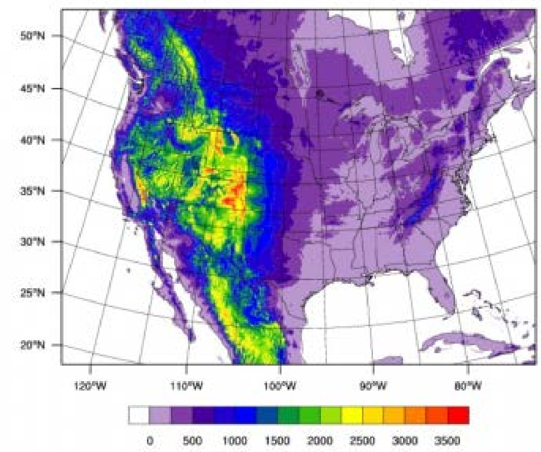
FY 2013 ACCOMPLISHMENTS

The climate sensitivities obtained from 4-km WRF simulations differ from the current statistically-based guidance being provided to water managers. WRF shows wintertime increases in precipitation in the Colorado Headwaters that are consistent with a warmer and moister atmosphere, and occur when topography is adequately resolved by the regional climate model. There is now a critical need to understand the differences in the portrayal of climate change impacts on water resources obtained using different methods (e.g., dynamical WRF simulations vs. statistical downscaling), and, thus, the effectiveness of traditional climate impact assessments to support adaptation planning and decision making.

Research in the Colorado Headwaters project during FY 2013 has focused on evaluating changes in the partitioning of precipitation between evapotranspiration (ET) and runoff under a changing climate, and how climate change may affect the future availability of water resources. As one specific example of this research, the figure below illustrates the seasonal cycles of precipitation, ET, runoff, and potential

evaporation (PE) for the current and future periods. The monthly changes in precipitation due to climate change are dominated by increases during winter (through May) and then decreases during summer, resulting in a net increase in precipitation of 31 mm yr^{-1}. Offsetting the precipitation increases, monthly ET is higher in nearly all months in the future climate scenario with ET increases most pronounced during late spring and early summer. ET actually decreases slightly in August and September in the future due to the reduction in future precipitation during this period and the depletion of soil moisture (note the differences between ET and PE). The annual increase in ET is 37 mm yr^{-1}, resulting in a net annual decrease in runoff of 6 mm yr^{-1}.

between the future and current conditions. Vertical bars on the dots are one standard deviation from the seven-year mean. (c) – (d) are for evapotranspiration (ET), (e) – (f) are for runoff (Q), and (g) – (h) are for potential evaporation (PE).



Caption: Model domain for the new 4-km North America WRF simulations. These simulations use 4-km horizontal resolution (1360x1016 horizontal grid points and 51 vertical levels), Thompson microphysics, YSU PBL, RRTMG radiation, and the Noah-MP LSM, with forcing data from ERA-Interim.

FY 2014 PLANS

These analyses have motivated a series of new modeling studies to investigate regional differences in the impact of climate change on seasonal cycles of snow accumulation and ablation, soil moisture, ET, and the overall partitioning of precipitation between ET and runoff. A key focus of these new studies is to evaluate the hypothesis that the hydrologic cycle in many regions will shift from a hydrologic regime where ET is primarily limited by availability of energy, to a regime where ET is limited by the availability of soil moisture as caused by earlier snow melt and increases in the amount of energy during the growing season. New runs are now underway using a modeling domain which covers the coterminous U.S. and parts of Canada and Mexico, so that we can begin to compare and contrast the change signals from the Colorado Headwaters regions to other regions such as the Pacific Northwest and the Canadian Rocky Mountains.

‹ Winter Weather | up | Climate Change and Water ›

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CLIMATE CHANGE AND WATER

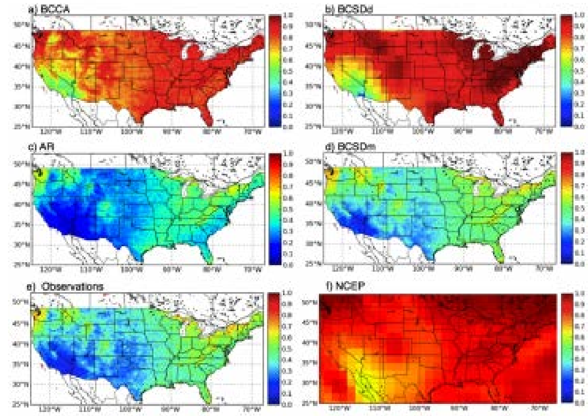
BACKGROUND

Water is a precious commodity underpinning not only the global economy, but also our quality of life. The U.S. federal agencies managing the availability and distribution of the nation's water resources face a variety of challenges every year in ensuring a high-quality, always-ready resource to meet public and private demands, as well as managing highly changeable flood risks and drought responses around the nation. Recognizing that climate change is exacerbating these challenges, and to help managers better plan for and respond to climate change effects on water resources, the Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers (USACE), and National Center for Atmospheric Research (NCAR) are collaborating to improve our understanding of water resource-related climate effects. In addition, they are testing and improving some of the important management tools that the water resources community relies on to fulfill their federal missions to manage water resources in the best national interest.

The first stage of the research being conducted at RAL addresses the question: "How does the portrayal of climate change impacts depend on the selection of downscaling methods and the selection and configuration of hydrologic models?" This comprehensive analysis of methodological shortcomings provides the user community with guidance on appropriate methods for climate impact assessments. The project helps identify limitations of the current generation of statistical downscaling methods and hydrologic modeling applications and articulate key research needs to improve assessments of climate change impacts on water resources. Ongoing research on developing new downscaling methods and new hydrologic modeling approaches will both improve the characterization of uncertainty in climate change assessments and reduce costs of individual basin studies.

FY2013 ACCOMPLISHMENTS

Reclamation, USACE, and other water management agencies have an interest in developing reliable, science-based methods for incorporating climate change information into longer-term water resources planning. Such planning assessments must quantify projections of future climate and hydrology. The common practice is to begin by developing relationships between current observed climate and climate projections over the assessment region. Because the spatial resolution of global climate projections is not adequate for local to regional hydrologic assessments, this step relies on some form of spatial downscaling and bias correction, which produces watershed scale weather information to



Caption: Historical fraction of wet-days from four statistical downscaling techniques (plots a-d), all of which have different wet day fractions compared to observations (plot e). The low resolution data they are downscaled from is provided for reference (plot f). Figure from Gutmann et al. (2013).

drive simulations of hydrologic and other water management conditions (e.g., water demands, water quality, environmental habitat.

Water agencies continue to face decisions about the selection of downscaling method(s) and the selection and configuration of hydrological models, and of observational datasets. There is a critical need to understand the ramification of these methodological decisions, as they affect the signal and uncertainties produced by climate change assessments, and, thus, the effectiveness of these results to support adaptation planning and decision making.

The project has found that there is indeed reason for concern over methodological choices. Initial results indicate that selection of downscaling methods and the selection and configuration of hydrologic models can substantially alter the portrayal of climate change impacts on hydrology. Specifically,

1. The choice of methods to produce gridded meteorological fields can have as large an impact on projected hydrologic outcomes as the climate change signal. Compounding the issue, hydrologic model calibration yields model parameter sets that inappropriately compensate for the biases in the model forcing data (different model parameter sets for different model forcing data), influencing climate change sensitivities in unappreciated ways.
2. Many statistical downscaling methods that are popular in the water management community produce hydroclimate representations with too much drizzle, too small extreme events, and improper representation of spatial scaling characteristics that are relevant to hydrology. These deficiencies vary by method, significantly impacting results.
3. The choice of statistical versus dynamical downscaling is important: the climate sensitivities obtained from 4-km dynamically downscaled simulations from the Weather Research and Forecasting (WRF) model differ from current statistically-based guidance being provided to water managers. WRF shows wintertime increases in precipitation in the Colorado Headwaters that are consistent with a warmer and moister atmosphere, and occur when topography is adequately resolved by the regional climate model.
4. The resolution used in dynamical downscaling matters. The 12-km and 36-km WRF simulations have poor correspondence to observations, and very different change signals compared to the 4-km WRF simulations. The impact of WRF resolution on hydrology is primarily due to differences in precipitation among WRF simulations, although differences in the spatial resolution of the hydrology model are still important.
5. The choice of hydrologic model also affects projection outcomes, though less so if a hydrology model is well calibrated. Popular calibration procedures only constrain the range of climate change impacts for metrics that are closely related to the objective function used in calibration. For example, minimizing errors in simulations of observed streamflow reduce inter-model differences for mean change in the future, but does not improve model agreement on the flashiness, seasonal timing, or low flow rates. The use of uncalibrated hydrology models, as is common in regional or larger scale assessments, is ill-advised, and there is a clear need to implement more comprehensive (multi-objective) calibration schemes that consider multiple attributes of model behavior.
6. Finally, outcomes depend significantly on subjective decisions made in calibrating hydrologic models, such as the choice of forcing data, the choice of calibration scheme, and the choice of objective function. Work is continuing to quantify the effect of calibration decisions in more detail.

Taken together, the methodological sensitivities found thus far reveal that the current practice of impact assessment unwittingly includes an array of unintended effects – artifacts resulting from the method, data and model choices – and suggest that the practice must seek a new path.

FY2014 PLANS

The project team is currently focused on efforts to develop and demonstrate improved methods for downscaling and hydrologic modeling. On downscaling, the effort considers advanced hybrid statistical-dynamical downscaling methods to provide a realistic depiction of physical processes at a low computational cost. These methods improve hydrologically relevant metrics, such as the spatial representation of extreme precipitation events, and can be applied to a large range of climate scenarios. On hydrologic assessment, the effort employs a multi-model approach with multiple advanced calibration strategies to reduce simulation errors and improve characterization of uncertainty in hydrologic models. Improved hydrologic models and more physically realistic downscaling implementation will lead to more dependable projections, and

ultimately improve decision support.

REFERENCES

Gutmann et al. (2013) An Intercomparison of Statistical Downscaling Methods over the Contiguous United States. Journal of Climate. In Review

Mizukami et al. (2013) Hydrologic implications of different large-scale meteorological model forcing datasets in mountainous regions. Journal of Hydrometeorology. In Press

Rasmussen et al (2013) Climate Change Impacts on the Water Balance of the Colorado Headwaters: High-Resolution Regional Climate Model Simulations. Journal of Hydrometeorology. In Review

‹ Western Water up Probabilistic Hydrologic Forecasting at Lead Times from Minutes to Seasons ›

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PROBABILISTIC HYDROLOGIC FORECASTING AT LEAD TIMES FROM MINUTES TO SEASONS

BACKGROUND

Every day, streamflow forecasts are used to support decisions by reservoir operators and water managers in the United States, who must balance a range of competing objectives. At local scales these might include preventing floods by capturing water, maintaining cool stream temperatures for fish by releasing water, or delivering water to irrigators through scheduled releases. At large regional scales, decisions to store or release water may affect the available supply and water markets for large US cities or growing regions situated hundreds of miles from the water's headwater source, or even have international treaty implications. The need for better short-term forecasts – from minutes to seasons – is perennially raised in studies related to water management. However, identifying the research necessary to improve hydrologic monitoring and prediction products requires identifying the overlap between (i) user needs, and (ii) opportunities to improve hydrologic monitoring and prediction products.

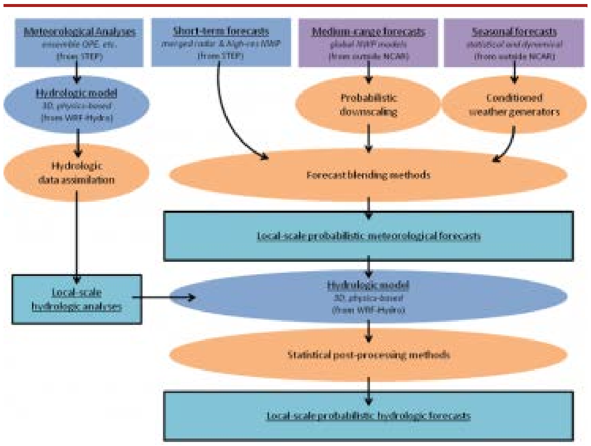

Figure 1. Components of a minutes-to-seasons hydrologic forecasting system, capitalizing on products developed within NCAR (blue shades) and outside NCAR (purple shades).

Meeting this demand requires integrating different types of quantitative meteorological analyses and forecasts with state-of-the-art models of environmental processes (e.g., hydrology, crop yield, ecosystems, etc. Essential technical capabilities include (1) ensemble methods for high-resolution meteorological analyses; (2) ensemble high-resolution meteorological forecasts from merged radar and NWP systems (lead time of 0-72 hours); (3) ensemble downscaling of global-scale numerical weather prediction forecasts (lead time of 1-14 days); (4) ensemble local-scale meteorological time series conditioned on seasonal climate outlooks (lead time of 0-12 months); (5) environmental models with advanced data assimilation capabilities; and (6) statistical post-processing methods to improve the probabilistic information content in environmental forecasts. The figure below provides an example of a minutes-seasons forecast system for hydrology (similar systems can be used for other environmental processes, e.g., using WRF-Crop for crop yield).

FY 2013 ACCOMPLISHMENTS

Hydrometeorological forecasting across time scales from minutes-to-

seasons is a key strategic direction for the Hydrometeorological Applications Program and is pursued across multiple fronts. A major effort in this area is a collaboration with the Bureau of Reclamation and the U.S. Army Corps of Engineers to undertake a comprehensive predictability assessment to quantify the major sources of skill and uncertainty in hydrologic predictions from minutes to seasons ahead. The first stage of the project addresses the question, “What are the sources of skill and uncertainty in watershed-scale streamflow predictions and how do these vary seasonally and geographically?” Focusing on different types of forecasts (e.g., daily to weekly flow forecasts, 3 month volume forecasts), at different forecast initialization dates (e.g., October 1st versus April 1st) and in different hydroclimate regions (e.g., regions with/without substantial snow storage), the project quantifies how varying levels of skill in the two capabilities influencing streamflow prediction – estimating watershed conditions and predicting future meteorology – propagate into skill and uncertainty in streamflow predictions. This work will establish a foundation for assessing the current state of the art and practice in streamflow forecasting, and define realistic expectations for near-term scientific and technical advances.

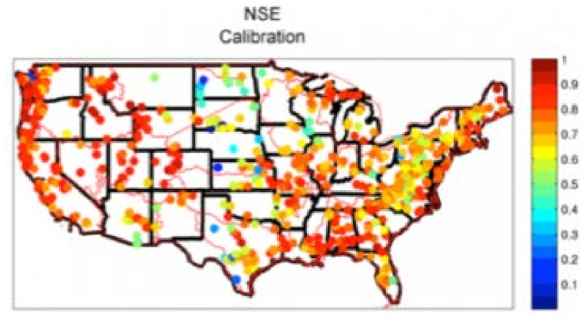

Figure 2. Nash-Sutcliff Efficiency (NSE) calibration skill score for testbed watersheds

In FY2013, the hydrologic predictability project progressed in three areas, each of which was applied on a CONUS-wide domain: (1) development of a modeling testbed, including watershed models and associated data and methods to support collaborative research in the university and agency community on streamflow forecasting methods; (2) comprehensive analysis of hydrologic predictability at monthly to seasonal scales; and (3) the development of the first large-scale probabilistic meteorological forcing dataset, which forms a key building block for uncertainty-based hydrologic prediction. The first of these efforts developed calibrated Sacramento/Snow17 simulation models for approximately 600 relatively unimpaired watersheds, of which over 400 were selected to gage the streamflow forecast skill dependence on the two major skill sources (watershed initial conditions and meteorological forecasts). Results from nearly 500 million retrospective simulations are illustrated (Figure 3) by the regional variations in *forecast skill elasticity* – the unit change in streamflow forecast skill per unit change in predictor skill – for a 3-month runoff prediction. In the western US, for instance, the benefits of watershed condition skill dominate those of meteorological forecast skill in the summer, in contrast to the eastern US, where meteorological forecast skill always yields the greatest benefit for streamflow forecasting.

FY 2014 PLANS

The idealized predictability assessment completed in FY 2013 lays the groundwork for the next steps: using state of the art weather and climate predictions and an assessment of actual forecast skill to untangle and quantify current actual levels of uncertainty in weather and climate forecasts and initial conditions, and to target the most beneficial areas for efforts to reduce uncertainty. A series of case studies will examine the potential impact of such efforts for water management decisions, and provide insights for strategic decisions on forecasting or monitoring research to operations transition efforts. Understanding variations in the skill and uncertainty of streamflow predictions will help water managers make more informed use of predictions, and guide strategic investments toward filling key information and prediction gaps.

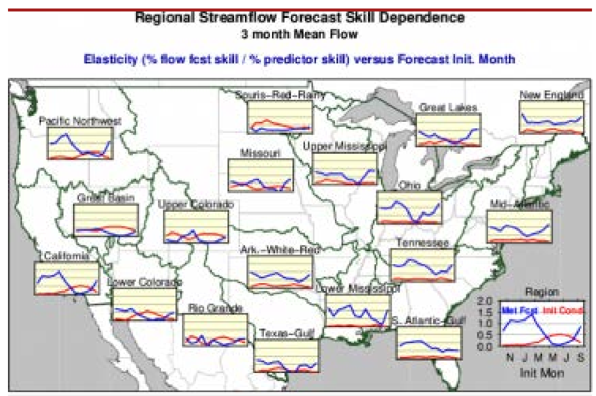

Figure 3. The seasonal variation in regional average *forecast skill elasticity* – the unit change in streamflow forecast skill per unit change in predictor skill – for a 3-month runoff prediction. Elasticities are shown for two predictors, watershed initial conditions and meteorological forecasts.

‹ Climate Change and Water up
Fully-coupled Hydrometeorological Modeling with WRF-Hydro ›

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FULLY-COUPLED HYDROMETEOROLOGICAL MODELING WITH WRF-HYDRO

BACKGROUND

Accounting for fully-coupled, two-way interactions between the land surface and the atmosphere is a core challenge in the emerging Earth System modeling discipline. The chaotic and non-linear response of the atmosphere to land surface perturbations implies that relatively small heterogeneities in land surface states and fluxes have the potential to drive upscale responses in the atmosphere. Improper representation of land surface processes such as the spatial patterns of soil moisture and snowpack may significantly limit prediction skill for many meteorological events. Similarly, there are increasing needs to develop spatially-distributed, physics-based, conservative modeling approaches for a variety of applications such as regional hydroclimate impacts of climate change and flood forecasting from minutes to seasonal timescales.

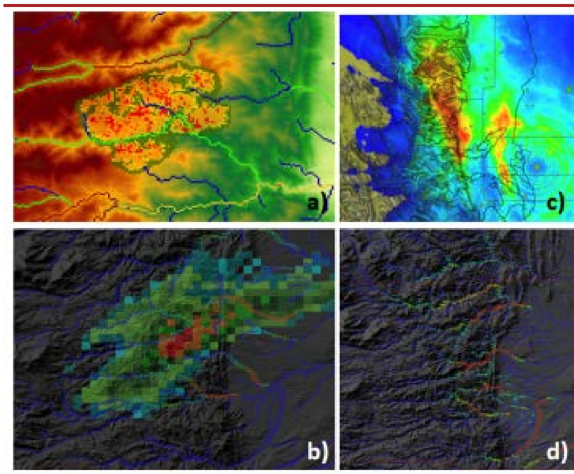

Figure 1: a) USGS burned severity indices for the 2010 Fourmile Canyon fire (red indicates ‘severe’ burned areas) b) simulated flash flood wave emanating from the Fourmile Canyon area, colors along stream networks indicate streamflow values on 14 Jul 2011 around 03UTC, gridded color shading is the accumulated rainfall on 13-14 July 2011, c) radar estimated accumulated rainfall for the Sep. 2013 flood event along the Colorado Front Range, d) simulated streamflow on 12 Sep. 2013 at 03UTC following a pulse of heavy rainfall.

The community WRF-Hydro modeling framework is addressing these needs by providing a flexible and extensible model structure for representing distributed hydrologic processes in a fully-coupled environmental prediction system such as the Weather Research and Forecasting (WRF) model or the Community Earth System Model (CESM). WRF-Hydro development follows the WRF modeling paradigm of relatively simple extensibility of model physics within the existing WRF modeling framework. Publically released in April 2013, the WRF-Hydro modeling system is finding rapid use in the U.S. and in countries around the world by research groups and operational prediction agencies. With a growing domestic and international network of model developers users and increasing record of improved model skill, it is becoming clear that WRF-Hydro is poised to become an essential community resource for hydrometeorological and hydroclimatological prediction.

Current activities include the modeling of seasonal water supply from the Colorado Headwater region, evaluating the impact of new radar technologies on streamflow forecasting, flash-flood predictions in recently burned landscapes, fully-coupled hydrometeorological prediction from extreme Mediterranean storm events in Italy, Turkey and Israel, land-atmosphere coupling controls in the North American Monsoon region, and regional climate change impacts on water supply in India. In

Figure 1 below we a) highlight the capabilities of the WRF-Hydro system in simulating a flash flood event in a recently burned landscape in the Colorado Front Range in July of 2011. This simulation-calibration exercise was the first implementation of the WRF-Hydro system in a burned landscape and those burned landscape parameters have since been regionalized to other recent burn areas in the western U.S. We then applied this new architecture to b) simulate the catastrophic flooding that occurred as a result of the extreme rainfall that fell during Sept. of 2013. In c) we show a map of the accumulated precipitation during that event while in d0 we see the simulated flow response from that rainfall. In general, the rapid increase in streamflow and the relative magnitudes of the flood wave peaks were reasonably captured in the foothill canyon systems which exhibited some of the most severe flooding.

Looking forward to 2014, the WRF-Hydro team will release v2 of WRF-Hydro to the community We are also expanding several other community-based efforts to expand the functionality and utility of the WRF-Hydro system through projects like the NSF EarthCube initiative and a joint NSF-EU program to improve cyberinfrastructure for hydrometeorological predictions between the U.S. and European countries.

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  - Advances in Land Surface Modeling
  - Aerosols and Precipitation
  - Winter Weather
  - Western Water
  - Climate Change and Water
  - Probabilistic Hydrologic Forecasting at Lead Times from Minutes to Seasons
  - Fully-coupled Hydrometeorological Modeling with WRF-Hydro
  - Water, Energy and Food Security
- Climate, Weather and Society

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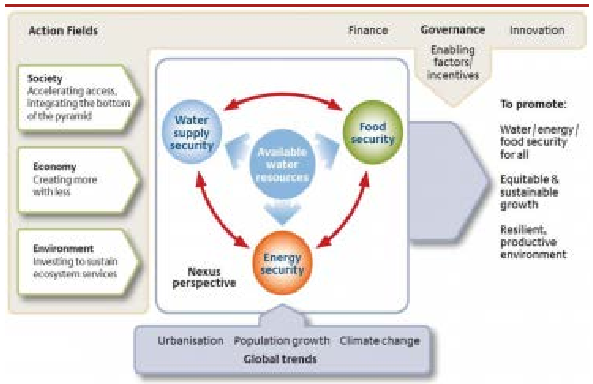
WATER, ENERGY AND FOOD SECURITY

BACKGROUND

Policy and management decisions regarding water and energy figure prominently in efforts to adapt to and mitigate anthropogenic climate change. To be effective, these decisions need to consider the interconnections between energy, water and food production and use–the *water–energy-food nexus*--and to assess the implications of a changing climate for the reliability of energy and water supplies. A number of important, quite complex research efforts are currently underway addressing each side of the nexus. Assessments of water use in generating hydroelectric power, are for example, studying freshwater use and consumption as a function of the generation type (combustion turbine, combined cycle, etc), fuel used (coal, natural gas, nuclear, etc.) and the cooling system technology (once–through, recirculating, dry, etc.). Analyses focusing on the consumption of energy by the water sector are also underway, examining energy use extraction, transport, delivery, pre– and post–use treatment, and user applications. Both sides of the *energy–water-food nexus* are being examined, but typically as loosely connected puzzle pieces rather than as integrated components of a coupled resource management system.

While the *water-energy–-food nexus* information–base has been growing, there remains a dearth of modeling tools to evaluate long–term interactions and feedbacks between these sectors in the context of a changing climate. In particular, a spatially-explicit coupled modeling system is needed to facilitate a more complete and accurate evaluation of the workability and consequences of alternative climate mitigation and adaptation strategies.



Both sides of the *energy–water-food nexus* are being examined, but typically as loosely connected puzzle pieces rather than as integrated components of a coupled resource management system.

To address these needs, RAL in collaboration with the Stockholm Environment Institute US-Center (SEI) and the Union of Concerned Scientists (UCS), has made exploration of the water-energy-food nexus in the Western United States a research frontier in its Strategic Plan. Efforts in FY2013 were supported from a NOAA SARP grant, the NSF, and a Norwegian research organization, Der Norske Veritas.

FY2013 ACCOMPLISHMENTS

The physical sciences in support of Integrated Water Resources Management (IWRM) is extremely useful, yet conventional approaches to natural resource management, based on physical sciences alone often fail to fully address the continual need

to negotiate tradeoffs between conflicting resource use and changing interests. A coupling is needed between the natural, social, and the ecological systems with interactions across spatial and temporal scales. Along with the Stockholm Environment Institute-US Center, we have successfully linked two planning-purposed models with a long legacy of successful use in decision support in their respective disciplines; the Water Evaluation and Planning (WEAP) and the Long-range Energy Alternatives Planning (LEAP) modeling systems. WEAP and LEAP have been recently coupled to better explore the *water-energy-food nexus.*

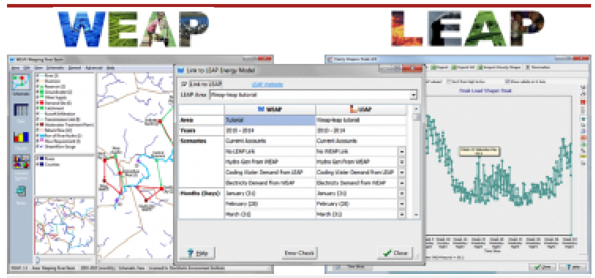


Figure 2. The Integrated WEAP and LEAP tools, showing the linking window (center), where common modeling areas, scenarios, periods of analysis, and timesteps are matched.

As part of this work, Yates and Miller (2013) have explored the implications of energy alternatives on water in the southwestern U.S.; their paper, "Integrated Decision Support for Energy/Water Planning in California and the Southwest", has been accepted for publication in the *International Journal of Climate Change: Impacts and Responses.*

In 2013, we completed a report with the UCS, *Water-Smart Power, Strengthening the U.S. Electricity system in a Warming World* (www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-smart-power.html) in which we addressed the following core research questions:

Energy-water baseline: What are the current impacts of electricity production on freshwater availability across technologies and U.S. regions?

Energy-water pathways: How will electricity choices over the next few decades affect water availability, quality, and energy costs across U.S. regions under unconstrained and constrained carbon budgets?

Regional vulnerability / risk: Which regions are at greatest risk of facing water (and/or water-related energy) shortages, and how does risk vary across scenarios and geography?

Solutions: For regions at risk, how does, e.g., the prioritization of low-water energy options alter risk within the system and the relative attractiveness or cost of different energy choices?

The outcome of this work was a series of papers in *Environmental Research Letters:*

Yates, D., J. Meldrum, and K. Averyt, 2013, The influence of future electricity mix alternatives on southwestern US water resources, *Environ. Res. Lett*. 8 045005.

Yates, D., K. Averyt, F. Flores-Lopez, J. Meldrum, S Sattler, J Sieber and C Young, 2013, A water resources model to explore the implications of energy alternatives in the southwestern US, *Environ. Res. Lett*. 8 045004.

Yates, D, J. Meldrum, F. Flores-Lopez and M. Davis, 2013, Integrated impacts of future electricity mix scenarios on select southeastern US water resources, *Environ. Res. Lett*. 8 035042

Flores-López, F. and D. Yates, 2013, A water system model for exploring electric energy alternatives in southeastern US basins, *Environ. Res. Lett*. 8 035041.

Linking electricity and water models to assess electricity choices at water-relevant scales

Sattler, S., J. Macknick, D. Yates, F. Flores-Lopez, A. Lopez and J. Rogers, 2012 Environ. Res. Lett. 7 045804

FY2014 PLANS

Research is needed to better understand the interactions, and possible collisions, between water-management and energy-management decision making. National-scale guidance is needed on energy policy and decision making that leads to reduced greenhouse gas emission, and avoids unintended consequences related to water management in the context of energy generation. Different energy management strategies will have different water management implications that extend from the local, to the regional, and ultimately to the national scale. Further, it is recognized that the local importance of these impacts will be defined by the characteristics of individual water systems within which energy management strategies are implemented.

Proposed areas of focus include:

- In collaboration with the Headwaters Program (part of NCAR's Water System research program), explore how improved scientific understanding of seasonal changes in precipitation, sublimation, snow water equivalent, snowmelt, soil moisture, and transpiration in the western USA impact the water-energy-food systems of the region. Explore the particular emphasis to changes associated with a shift to earlier snowmelt and the potential shift from energy-limited to water-limited systems.
- Using improved scientific understanding of the magnitude of the expected drought through the use of high-resolution climate models (in association with the Colorado Headwaters Project), explore water-energy-food relationships in the region.
- Work closely with the social science community, both at RAL and externally, to explore the impacts of climate change on the *water-energy nexus* from a societal perspective.

‹ Fully-coupled Hydrometeorological Modeling with WRF-Hydro up Climate, Weather and Society ›

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CLIMATE, WEATHER AND SOCIETY

Promote societal welfare by conducting interdisciplinary research on the interactions between society and weather and climate in order to increase societal resilience to the associated risks and to support decision making.

- Use and Value of Weather Information
- Socio-ecological Systems in a Changing Climate: Governance and Adaptation
- Urban Futures
- Weather, Climate and Health
- Geographic Information System (GIS) Program

‹ Water, Energy and Food Security up Use and Value of Weather Information ›

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USE AND VALUE OF WEATHER INFORMATION

BACKGROUND

Weather and climate affect all economic sectors, regions, individuals and communities. Improved weather forecasts – and better use of current forecasts – could save lives and millions of dollars annually. To realize the potential benefits associated with improved weather forecasts and stakeholder decision making, in 2004 NCAR established the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information (aka Societal Impacts Program or SIP) to create a dedicated focal point for assembling, coordinating, developing, and synthesizing research and information on the societal impacts and economic benefits of weather information. The SIP is a collaborative effort with researchers from the Mesoscale and Microscale Meteorology Division of NCAR's Earth System Laboratory and supported in part by the Integrated Science Program.

The SIP aims to improve the societal gains from weather information by infusing social science research, methods, and applications throughout the weather enterprise and to be the premiere focal point for integrating social science and societal impacts understanding into the weather enterprise through cutting-edge research and capacity building. The SIP endeavors to:

- Advance knowledge on the socio-economic impacts of weather and the communication, use, and value of current and improved weather information.
- Build a multi-disciplinary, multi-stakeholder community of researchers and practitioners engaged in developing and applying knowledge on societal aspects of weather information.
- Enhance social science aspects of policy-making, development, and use of related weather information

FY2013 ACCOMPLISHMENTS

Assessing Current Storm Surge Information

Using focus groups, in-depth interviews, literature reviews, and telephone and web-based surveys, work was completed exploring forecasters', media broadcasters', emergency managers' and the public's awareness and understanding, or lack thereof, concerning storm surge and currently available storm surge information. This research assessed whether new storm surge informational approaches should be developed to improve the communication and decision-making with respect to extratropical and tropical cyclone storm surge risk and began assessing different approaches to providing this information. Results suggest strong support for a storm surge information product separate from the current Saffir-Simpson Hurricane Wind Product.

Assessment of Hurricane and Flash Flood Warnings

Work continued examining decision processes employed by institutions, organizations, and individuals in analyzing, disseminating, and interpreting warnings of for hurricanes and flash floods. This effort represents a critical effort by balanced research teams representing the fields of meteorology, sociology, economics, public policy analysis, and decision sciences to evaluate warning processes and systems holistically. In-depth interviews and observational sessions with NWS forecasters, emergency managers, and the media from the Greater Miami area with respect to hurricanes and from the Boulder-Denver, Colorado area with respect to flash floods were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Results indicate that NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios.

Assessing the Economic Value of Improving Weather, Water, and Climate Information in Mozambique

Building on work supported by the World Bank, analysis continued on a survey of members of the public in Mozambique on the sources, perceptions, uses, preferences, and values for current and improved weather, water, and climate information. 576 responses were received from 13 Mozambican communities using in-depth in-person survey interviews. Three non-market valuation methods for eliciting economic values were implemented to determine the current value of weather information as well as the potential value of improved forecast information. Related work entailed the development and implementation of an expert elicitation of 26 stakeholders in specific public and private sectors of Mozambique assessing their perceptions of the value of current services and potentially improved hydrometeorological information. This effort may represent the first use of expert elicitation of the value of information in a developing country.

A Public-Private-Academic Partnership to Advance Solar Power Forecasting

For this DOE-funded project, primary research was initiated to develop a conceptual information process model of the creation, communication, use, and value of solar irradiance information. This model represents the full information process from observational systems to end-users such as solar energy utilities. Building on methods from expert elicitation, mental modeling, influence diagrams and decision analysis, and cognitive task analysis, an interview protocol was developed and a set of focus groups and in-person in-depth interviews undertaken to develop an initial graphical model.

FY2014 PLANS

Work will continue on several projects on communication, understanding and use of hydrometeorological information particularly with respect to the creation, communication, and value of hurricane and flash flood forecasts and warnings.

Analysis of primary survey data and in-depth interviews will continue to further develop an integrated understanding of warning systems and processes with a focus on hurricanes in Miami, Florida, and flash floods in Boulder, Colorado by:

- Identifying more completely the suite of factors influencing organizational and public decision making and action during extreme weather events
- Characterizing public preferences for different attributes of forecast and warning information

Work will continue on the project assessing current storm surge information, including analysis of multiple surveys and focused research assessing emergency managers', broadcast meteorologists', and the publics' perspectives, uses, and needs for storm surge information in all coastal US surge-vulnerable areas.

Work will also support a collaborative effort between The World Bank, the World Meteorological Organization, and USAID to develop a guidance document for National Hydro-Meteorological Services on best practices for socio-economic benefit (SEB) assessment. This effort will involve document development and writing as well as several international workshops to evaluate the effectiveness of this approach.

Analysis will continue on the data from the public survey and expert elicitations as documentation in support of World Bank efforts in Mozambique and as a case study for the SEB guidance document.

In support of the DOE funded project "A Public-Private-Academic Partnership to Advance Solar Power Forecasting," primary research will develop a conceptual information process model of the creation, communication, use, and value of solar irradiance information to solar energy utilities. This conceptual model will form the basis of expert interviews and a utility survey to assess the economic value of forecasting improvements based on rigorously developed forecast metrics.

‹ Climate, Weather and Society   up   Socio-ecological Systems in a Changing Climate: Governance and Adaptation ›

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SOCIO-ECOLOGICAL SYSTEMS IN A CHANGING CLIMATE: GOVERNANCE AND ADAPTATION

WATER RESOURCES

In FY2013 Kathleen Miller initiated a collaboration with Dr. Robert Wilby, Loughborough University, UK, Dr. David Yates, RAL-HAP and staff at Denver Water on a project to develop a decision-centric scenario approach for long-term water resource planning in the context of climate-related uncertainties. This approach turns the usual adaptation assessment process upside down by starting with a detailed consideration of a decision problem. In this case, we have focused on Denver Water's need to understand the yield and reliability of a particular drought response option in a changing future climate. The analytical approach involves generating a large ensemble of plausible weather sequences using the Statistical DownScaling Model – Decision Centric (SDSM-DC) tool. These are then run through a WEAP model of the hydrology and management system to stress-test the management option under consideration. This approach facilitates an assessment of the resilience of a plan or strategy to uncertain future climate change and can be used to pinpoint specific sources of vulnerability. Thus far, the project team has developed the modeling system, generated spatially explicit scenarios in the complex Headwaters catchments from which Denver draws approximately 40 percent of its water supplies, and examined some of the impacts of an existing agreement pertaining to reservoir storage operations during drought years.

Dr. Miller also has led work on a book planned for publication in 2015 by Taylor and Francis entitled: *Western Water Policy and Planning in a Changing and Variable Climate.* This is an edited volume that will serve as a comprehensive resource for both students and practitioners in fields related to water policy and environmental management in the Western United States.Most of the chapter authors have now been confirmed and work on the volume is underway.

Drs. Miller, Wilhelmi and Sampson collaborated on an analysis of the legal, economic and geographic aspects of transbasin water diversions from the Colorado River Basin to Colorado's Front Range, as part of the NSF-WSC project: "Snowpack-ecosystem feedbacks and the sustainability of transbasin diversions under a changing climate." The project is making use of information from the state of Colorado's hydrobase data base, published literature and legal documents to characterize the rules and limits governing transbasin diversions. Work also is in progress on a related paper documenting drought-related changes in water use by Colorado water right holders as a function of the position of the right in the seniority hierarchy, as well as type and place of use and the nature of the water source from which the water is drawn.

Drs. Miller and Yates collaborated on a paper that describes the characteristics of the energy-water nexus in California and the Southwest, and the role of the region's climate in shaping the region's water and energy use as well as current policy challenges. The paper discusses the development and capabilities of the WEAP-LEAP integrated water-energy modeling tool, and the policy need for such integrated modeling capabilities as well as potential applications to policy and planning questions.

In addition, Dr. Miller collaborated with Dr. Valerie Belton, University of Strathclyde, UK to finalize work on a paper articulating a multi-criteria framework to be used for holistic and transparent consideration of water resource policies and climate adaptation plans. The paper also describes an experimental application of the framework in a developing country context.

Related Publications

Yates, D. and K. Miller, 2013. Integrated Decision Support for Energy/Water Planning in California and the Southwest. *The International Journal of Climate Change: Impacts and Responses* 4(1): 49-63. Open Access at: http://ijc.cgpublisher.com/product/pub.185/prod.179.

Miller, K.A., and V. Belton, *in review*. Water Resource Management and Climate Change Adaptation: A holistic and multiple criteria perspective. *Mitigation and Adaption Strategies for Global Change,* Special Issue: Climate Policy Planning and Development Impact Assessment. Revised draft submitted.

MARINE FISHERIES

It is notoriously difficult to maintain environmentally responsible and economically efficient management of commercially-exploited marine fisheries. The common-pool nature of fishery resources makes them vulnerable to competitive harvesting that can result in a race to "the tragedy of the commons." To be effective, marine resource governance arrangements must not only control that tendency, but also must be able to maintain ecologically sustainable harvesting levels for targeted species despite often complex, highly variable and difficult-to-observe biophysical processes driving the dynamics of those populations and their supporting ecosystems. In FY 2013 CSAP's Dr. Miller finalized revisions on two papers with teams of international collaborators. These papers focus on the role of strategic behavior in the exploitation of shared marine fishery resources and the design of governance arrangements to facilitate effective collaborative management of these resources. These efforts mark the completion of her work in this area for the time being.

Related Publications

Maury, O., K. Miller, L. Campling, H. Arrizabalaga, O. Aumont, Ö. Bodin, P. Guillotreau, A. J. Hobday, F. Marsac, Z. Suzuki & R. Murtuggude, 2013. A global science-policy partnership for progress towards sustainability of oceanic ecosystems and fisheries, *Current Opinion in Environmental Sustainability (COSUST)*, 5: 314-319.

Miller, K.A., G.R. Munro, U.R. Sumaila and W.W.L. Cheung, 2013. Governing Marine Fisheries in a Changing Climate: A Game Theoretic Perspective. Special Issue 2013: "Applied Economic Analysis of Marine Resource Management Issues in the 21st Century." *Canadian Journal of Agricultural Economics* 61: 309-334.

FY2014 PLANS

Work on the decision-centric scenario approach to Denver's Water adaptation assessment will continue and a related paper will be presented at the 2013 AGU meeting. It is anticipated that this project will lead to publication of at least one paper in an academic journal, and possible development of a research proposal to support a more complete analysis and elaboration of the approach.

The paper currently in progress related to water use in Colorado under drought conditions will be completed and submitted for publication. In addition, work will begin on a paper relating the institutional analysis of Colorado's transbasin diversions to the potential implications of anticipated changes in climate, hydrology and biophysical properties of the Colorado Headwaters region.

Dr. Miller also will collaborate with a research team based at Albany State University, GA and Auburn University, GA on an application of regional economic models to estimate the impacts of alternative drought response policies on Georgia's agricultural economy. Work will focus on irrigated cropland in Georgia's Flint River Basin, and will evaluate the pros and cons of existing drought management policies and proposed policy alternatives that could be used to more effectively manage drought in the basin. The project is primarily supported by the NOAA-SARP program, with NSF co-sponsorship of part of Dr. Miller's time.

As lead editor of the book project described above, Dr. Miller expects to devote major effort in FY14 to managing development of the volume and coordinating with the chapter authors and other members of the editorial team.

‹ Use and Value of Weather Information up Urban Futures ›

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URBAN FUTURES

BACKGROUND

Urban areas play crucial roles in the arena of climate and environmental change, not only as key sources of carbon and other air pollutants, but also as hotspots of vulnerability to water scarcity, floods, heat waves, and other hazards that climate change is expected to aggravate. These roles create a unique opportunity for urban centers to prove their talents as sources of innovations, and laboratories for responses that help transition to more sustainable and more resilient pathways of urban development. The main goal of ***Urban Futures*** is to integrate different disciplinary domains within NCAR and with other national and international organizations to:

- Explore the dynamics of urbanization and urban systems that shape urban emissions, vulnerabilities and risks
- Investigate urban populations' and decision makers' capacity to respond to climatic and non-climatic hazards and stresses
- Research how particular cities attempt to meet the challenges of reducing emissions (sustainability) while improving their response capacity (resilience) to environmental impacts
- Build capacity to foster urban sustainability and resilience through educational, mentoring and outreach activities at the science-policy interface

2013 ACCOMPLISHMENTS

Dynamics of urbanization that shape urban emissions, vulnerability and risk

Few empirical studies have examined the interaction between urbanization and key dimensions of risk and response capacity, globally and in Latin America.

a) Existing scholarship has largely focused on exposure resulting from urbanization, while other dimensions of urban vulnerability such as sensitivity or capacity to cope and adapt have been insufficiently represented or understood. Furthermore, most attention has been given to the negative effects of urbanization, while opportunities for vulnerability reduction have been underemphasized. The paper "Exploring the relationships between urbanization trends and climate change vulnerability" explores key relationships between urbanization, economic development and socio-economic vulnerability on a global scale. Using data with national resolution, we applied a clustering approach to identify ten country groups sharing similar patterns of urbanization and socio-economic development. We then explored associations between these country groups and selected indicators for exposure, sensitivity, coping capacity, and adaptive capacity drawing upon data from the World Risk Index. Our findings suggest that countries with rapid urbanization and economic transformation face significant challenges with respect to sensitivity and the lack of capacities.

b) The paper "Urban Risk and Response Capacities in Neighborhoods of Latin American Cities" presents a framework for exploring key dimensions of risk in urban neighborhoods, and some of the fundamental causal pathways explaining differences in response capacities at the neighborhood scale. Because we conducted surveys using a non-random sample of neighborhoods that represent a variety of environmental hazards and socioeconomic profiles, we illustrate the diversity and complexity of causal mechanisms involved in producing urban risk. We found that: (i) Socioeconomic differences between neighborhoods differentiate urban risks in intricate and nuanced ways (e.g., responses to temperature changes depend on a context specific articulation of availability of assets, the latitude of the city and how much temperature variability people are exposed to). (ii) The use of census-based indicators of household access to electricity, water, housing and other assets is not enough to understand the dynamics of people's capacity to reduce risk and adapt to climate change. These indicators can mask factors such as the "informal" status of a settlement, which is a source of human insecurity. (iii) Common patterns of response capacity exist across neighborhood (e.g., low levels of education, insufficient incomes, some sort of

social support, and unstable employment conditions are prevalent); on the other hand, the level of household assets and options varied among neighborhoods and across cities, differently affecting the populations' capacity to respond.

Related Publications

Abrutzky, R., Ibarra, S., Matus, P., Romero-Lankao P., Pereyra, V., Dawidowski, L. (2013) "Atmospheric pollution and mortality. A comparative study between two Latin American cities: Buenos Aires (Argentina) and Santiago (Chile)", *Int. J. Environment and Health, 6(4), , 363 - 380*

Garschagen, M. and P. Romero-Lankao (2013). "Exploring the relationships between urbanization trends and climate change vulnerability." Climatic Change: 1-16,

Romero Lankao, P., Borbor-Cordova,M., Abrutsky, R., Günther,G., Behrentz, E. 2013: ADAPTE: a tale of four teams seeking to do integrated research, Environmental Science and Policy (Available on line).

Romero-Lankao, P., Hughes, S., Rosas-Huerta, Qin, H., A., Borquez, R., Lampis, A., (2013) "Urban Risk and Response Capacities in Neighborhoods of Latin American Cities" (under review)

Urban Response Capacity, Risks and Transformation Potentials and Limits

Summer of 2013: Field work with slum communities in Agra India

There is increasing interest in understanding the motivations behind cities' efforts to govern climate change, the strategies they employ, and their institutional capacity to enact the necessary policies and programs. Furthermore, the question of how to transform behaviors, systems, cultures and institutions to move to more sustainable and resilient cities has received increased attention among scholars and decision makers.

a) The paper "Institutional Capacity for Climate Change Responses"develops a framework to understand the political-economic determinants of institutional response capacity through an examination of climate change governance in Mexico City and Santiago, Chile. We ask whether being a frontrunner (Mexico City) is an indicator of greater institutional response capacity. Although Mexico City has slightly higher levels of institutional capacity than Santiago, both are faced with similar challenges, such as fragmented governance arrangements, asymmetries in access to information, and top-down decision making. However, both also have similar opportunities, such as leadership, participation in transnational networks and potential to integrate climate change goals into existing policy agendas. Examining urban climate change planning in isolation from other institutions is therefore likely to provide a false sense of a city's response capacity.

b) We use a combination of elements from socio-technical transition theory and political ecology and two Latin American cities (Mexico City and Manizales, Colombia) to suggest a framework for an analysis of urban transitions in Latin America. The two cities were faced with similar triggers and pressures to create sustainability and resilience and each acted within a time of sweeping international movements. Networks of actors introduced innovative responses to their own particular set of constraints and opportunities. Yet the innovations that took place in the two cities presented very different results with regard to regime transition. Mexico City's success at creating an urban regime change seems to have been based on the use of a top-down approach as it was driven mainly by actors within the existing power structure with access to the power and the resources of an authoritarian state. In contrast, actors in Manizales have been largely outside the power structure and had less success in creating a city-wide transformation. This highlights the importance of power structure dynamics that can promote or prevent transformations from within or impede transformations from without.

Related publications

Romero-Lankao, P., Hughes, S., Rosas-Huerta, A., Borquez, R., Gnatz, D., (2013) "Urban Institutional Response Capacity for Climate Change: An examination of construction and pathways in Mexico City and Santiago", *Environment and Planning C* (forthcoming).

Romero-Lankao, P. and D. M. Gnatz (2013). "Exploring urban transformations in Latin America." *Current Opinion in Environmental Sustainability* **5**(3–4): 358-367.

Rothman, D., P. Romero-Lankao, et al. (2013). "Challenges to adaptation: a fundamental concept for the shared socio-

economic pathways and beyond." Climatic Change: 1-13.

Romero-Lankao, P., Gnatz, D., (2013) “Mexico City, a tale of water development, its values and challenges” Terje Tvedt and Terje Oestigaard A History of Water, Series 3, Vol. 1. From Jericho to Cities in the Seas: A History of Urbanization and Water Systems, I.B.Tauris, Oslo Norway (forthcoming)

Hughes, S. and P. Romero-Lankao Institutionalization and the Science-Policy Interface in Urban Climate Change Planning: The cases of Delhi and Mexico City. (under review).

Building capacity to foster urban sustainability and resilience

Work began on an NSF Partnerships in International Research And Education (PIRE) grant led by Anu Ramaswami (University of Minnesota), Marian Chertow (Yale), Ted Russell (Georgia-Tech), Paty Romero- Lankao (RS-Cities, NCAR), Chris Weible (University of Colorado Denver) and Rachelle Hollander (The National Academy of Engineering, NAE). We held:

a) A Sustainable Cities Workshop at the Center for Engineering, Ethics, and Society
National Academy of Engineering DC (April 24-26 2013)
(http://www.nae.edu/Projects/CEES/70779/PIREworkshop/72042.aspx

b) The first PIRE International Summer School and Field Work in India (June – July 2013)

Paty Romero-Lankao co-coordinated the Colloquium Governance and Knowledge Integration at the Science-Policy Interface 8-12 April, 2013 - Quito, Ecuador. This colloquium provided the approaches, tools and techniques to understanding governance issues shaping knowledge integration at the science-policy interface (e.g., models of policy-science links, use of information, institutional capacity, and equity and justice). http://iaisrv1.iai.int/twiki/bin/view/Coloquia2013.

Dr. Romero-Lankao also mentored two postdoctoral fellows and one graduate student. In collaboration with Roberto Sanchez (COLFEN, Mexico) Ricardo Jordan (CEPAL) and Marcella Ohira (IAI), she drafted a practical and useful guide to adaptation and mitigation experiences in Latin American cities. She is currently the convening author of the IPCC-AR5 North American chapter and author of its Technical Summary and Summary for Policy Makers.

PLANS FOR 2014

In 2014 Dr. Romero-Lankao will conduct further research in the three areas described above both at the city and global level. With NCAR and external collaborators she submitted the proposal SWAM: Sustainable Water Access for the Megacities of Los Angeles and Mexico City during Drought. SWAM seeks to understand how urban actors, institutions and infrastructures interact across scales with dynamic hydrologic-climatic conditions to produce differential access to water resources during droughts. She will wrap up her role as co-leading author to Working Group II of IPCC Fifth Assessment Report (AR5) North American chapter and as lead author of the AR5 Summary for Policy Makers and Technical Summary.

‹ Socio-ecological Systems in a Changing Climate: Governance and Adaptation | up | Weather, Climate and Health ›

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RAL Strategic Plan
NCAR Strategic Plan

PREVIOUS RAL REPORTS

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WEATHER, CLIMATE AND HEALTH

BACKGROUND

There is widespread scientific consensus that the world's climate is changing and that there will be a broad range of impacts on health through a variety of factors, including greater heat stress, air pollution, respiratory disease exacerbation, and changes in the geographic distribution of vector-, food- and water-borne disease. The complexity of such influences requires a multi-disciplinary approach to address climate-related public health challenges. The overall goal of this work is to research the complex interactions among weather and climate processes, ecosystems, and human health in order to improve our knowledge of climate impacts on human health and the health of the planet. Through collaboration within RAL (Barlage, Bieringer, Delle Monache, Hopson, Wilhelmi), with other laboratories in NCAR (Morss - MMM, Oleson – CGD, Sain - IMAGe), UCAR (Pandya), ACD (Wiedinmyer) with university partners (CSU, CU, KU, U of Veracruz, U of AZ), federal agencies (CDC, NASA, NIH, Environment Canada), and state and local agencies (AZ Department of Health Services, Maricopa County Health Department, Office of Border Health (AZ),Toronto Public Health (Canada), Monroe County Health Dept. (Key West, FL) and Houston Department of Health), research will focus on:

- Investigating the complex relationships among weather, climate, human health and ecosystems
- Researching population vulnerability to human health threats
- Focusing on solutions-oriented scalable research with appropriate adaptation and mitigation strategies to tackle critical health issues
- Educating the next generation of scientists in these complex, yet interconnected areas

FY2013 ACCOMPLISHMENTS

Health Risks from Extreme Heat

Our changing climate is predicted to increase the intensity and impacts of heat waves prompting the need to develop preparedness and adaptation strategies that reduce societal vulnerability. Work continues on our NASA-funded project to develop a System for Integrated Modeling of Metropolitan heat Risk (SIMMER). The project focuses on understanding population vulnerability to extreme heat in Houston, TX, and, from the social science side, we are adopting a two-tiered approach to this. Results from the SIMMER project were presented in August 2013 to our Houston stakeholders, engaging participants from all sectors of heat-related preparedness and response. A workshop will be held in October 2013 in Toronto, Canada with our Canadian colleagues to present our SIMMER results and determine new ways forward in reducing population vulnerability to extreme heat.

Human–Environmental Interaction and Risk for Dengue Fever

Dengue is an emerging arboviral disease with worldwide impact. Increasing numbers of cases of this disease in both the Americas and Asia necessitate an examination of changing human and vector ecology in order to better understand the dynamics of dengue transmission.

We successfully completed our third year of this NSF-funded project to address the world-wide human health threat of dengue virus. The program, "The vector mosquito *Aedes aegypti* at the margins: sensitivity of a coupled natural and human system to climate change", is designed to investigate and model dengue fever risk along an altitudinal gradient from Veracruz to Puebla, Mexico, in FY2011-13. We have established a highly successful working relationship not only with our collaborators at the University of Veracruz, but also with four high schools along the transect where mosquito and weather data are being collected. Results for the first year have been published, results for the second year have been drafted for publication, a new model, "WHATCH'EM" has been developed (see below), and new analyses of the data will be presented

in a special session at the annual meeting of the American Public Health Association (APHA) and at the American Society of Tropical Medicine and Hygiene (ASTMH) in 2013.

The mosquito arbovirus vectors *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse) exploit a wide range of artificial containers as sites for oviposition and development of the immature stages, yet approaches for modeling container water dynamics have been limited. We developed WHATCH'EM, a state-of-the-science, physically-based energy balance model of water height and temperature in containers that may serve as development sites for mosquitoes or other container-inhabiting arthropods. WHATCH'EM is designed to be driven with field-derived meteorological data and can be used on an unlimited amount of user-specified container types. WHATCH'EM simulates the highly non-linear manner in which atmospheric conditions and container characteristics determine water temperature and height, leading to results that are not always intuitive and likely not simulated by simpler empirical models. WHATCH'EM simulations will be helpful in understanding the limiting climatic and container-related factors for proliferation of *Ae. aegypti* and *Ae. albopictus*.

WHATCH'EM is also being employed in a newly funded project by the Defense Threat Reduction Agency (DTRA) in which we aim to develop an early warning system for dengue risk. A unique aspect of the work is the formulation of an automated algorithm that employs high-resolution (sub-meter) satellite imagery to detect the types of containers that exist on premises in areas thought to be of risk for dengue. Once these containers are identified, they are then specified as input to WHATCH'EM (described above), which simulates the temperatures and water levels in the containers. Finally, WHATCH'EM results will be used to determine the suitability of the containers for harboring the dengue virus vector mosquito *Aedes aegypti*, and ultimately to estimate dengue risk at the neighborhood level within cities. In summer 2013 we completed field work in Mexico in which 300 premises were surveyed in order to characterize the container characteristics in various locations, to guide development of the container detection algorithm.

We have also completed a one-year pilot that was funded by the National Institutes of Health (NIH) to conduct work on *Ae. aegypti* in Arizona and Florida to better understand newly emergent areas for dengue virus transmission. Work began on this project in early 2012 and was completed in late 2012. Manuscripts have been submitted, and results will be presented at the annual ASTMH meeting. Additional funding has been procured from NIH to undertake a larger 4 year study along a transect from Tucson, AZ to Hermosillo, Sonora to determine factors that account for a lack of dengue transmission in areas where the mosquito vector is abundant.

A prototype Earth–gauging System Integrating Weather and Health Data to Manage Meningitis

This project was supported by the Google Foundation to build and implement a prototype decision–support system that integrated two–to 14–day weather forecasts and epidemiological data to provide actionable information that could be used to contain the spread of meningitis epidemics. In 2013, we published 2 manuscripts from the study; one on knowledge, attitudes and practices (KAP) and the other on the cost of illness (COI) regarding meningitis in the Navrongo region of Ghana. Work is ongoing to demonstrate weather–meningitis links, with a NSF funded grant to examine the health and local/regional air quality impacts of the introduction and adoption of clean cook-stoves in the northern region of Ghana.

Figure 1. Conducting a survey in Navrongo, Ghana

Integrating the Social and Physical Sciences to Reduce the Incidence of Plague in Rural Uganda

This project, sponsored by the Centers for Disease Control and Prevention and the U.S. Agency for International Development focuses on building links between weather variables and plague cases in order to develop an early warning system to allow limited resources for control of plague to be directed to the region. Additionally, we are working on enhancing surveillance for plague and assuring better access to health care for the residents of the West Nile region of Uganda by training traditional healers and village health workers to recognize plague symptoms and by providing them with cell phones so that they can call into the health clinics when cases are recognized. An evaluation of the program, which was begun in 2010, was conducted in 2011, and based on positive feedback, further training to an expanded traditional healer network was conducted in 2012. We continued to build a strong network of trained healers by conducting a refresher course in plague recognition in fall of 2013. This program has received recognition not only from the U.S. ambassador to Uganda, but also from Tom Frieden, director of the CDC, as well as coverage in the Washington Post. We hope to expand the program by incorporating a behavioral science component into the ongoing environmental/ecological studies focused on reducing rat populations.

Modeling Plague in Uganda

The West Nile region in northwest Uganda is a focal point for human plague which peaks in boreal autumn and is spread by fleas that travel on rodent hosts. The U.S. Centers for Disease Control and Prevention is collaborating with the National Center for Atmospheric Research to quantitatively address the linkages between climate and human plague in this region. We hope to advance our knowledge of the climatic conditions required to maintain enzootic cycles and to trigger epizootic cycles, as well as how to use limited surveillance, prevention and control resources most effectively. A hybrid statistical-dynamical downscaling technique was used by NCAR to generate a 2-km WRF-based climate dataset for 1996-2009 for modeling human plague dynamics (Monaghan et al. 2012, MacMillan et al. 2012). These results were reported in previous LARs. This dataset is now being employed to model the seasonality of rodent and tick dynamics, both of which play an important role in spreading human plague. In particular, we are finding that small rodent populations in in the region are driven especially by rainfall fluctuations, with plague-bearing rodents being more abundant near dwellings during the plague season when rain is abundant and crops are being harvested and stored. We expect to publish this work in 2014.

Figure 2a. Traditional Healer in Rural Uganda (photo courtesy of Andy Monaghan)

Mary Hayden (NCAR), Robert Okello (Zeu Health Clinic), and Andew Monaghan (NCAR) in Zeu, Uganda. (photo courtesy of Andy Monaghan)

CDC-NCAR Postdoctoral Fellowship

Two new postdoctoral fellows began work at NCAR in the fall of 2013 after a successful inaugural postdoc program. The goal of this program is to train the next generation of researchers in a multidisciplinary setting so that they are qualified to address the challenges of integrating health and weather/climate data. CDC has renewed funding for this joint program.

Climate and Health Workshop

The fifth bi-annual Climate and Health workshop was held at NCAR in collaboration with the CDC in July 2013 with a focus on two related atmospheric hazards – the individual and combined effects of extreme heat and air quality. The purpose of the workshop was to train researchers (graduate students, post-docs and early career scientists and faculty) on how to develop robust interdisciplinary research projects in the complex area of climate and health.

Community Outreach

We hosted a variety of visitors this past year. Auwal Abdussalam, a Nigerian PhD student at the University of Birmingham, UK, came for a second visit, during which we completed revisions on a paper in which a meningitis transmission model for northwest Nigeria was developed, and we drafted and submitted a new paper in which the model was used to explore the impacts of climate change on meningitis transmission in the same region. Additionally, Leiqiu Hu, a PhD student at the University of Kansas, also visited and we completed two papers (one submitted, one still being being circulated among co-authors) in which we investigated how to employ satellite imagery to evaluate high-resolution urban model simulations. Finally, we hosted a high school student from Puerto Rico, Gabriela Talavara Santos, as part of the UCAR Spark program, to conduct a set of experiments to assess water temperatures in various types and configurations of containers that the dengue vector mosquito *Aedes aegypti* exploits as habitat. This data is being used to validate a climate-based model developed at NCAR to simulate water temperature in containers that may serve as habitat for mosquitoes. Kacey Ernst, an assistant professor at the University of Arizona, came for her second visit to NCAR during which time we undertook collaborative work on a NIH funded project, outlined strategies for data collection in Mexico on dengue and in Kenya on malaria. We have submitted a paper to *PLOS NTD* entitled “Community views on the controversial release of OX513A *Ae. aegypti* in Key West, FL”, and we have drafted 2 more papers from our 2012 field work in Key West and Tucson.

PUBLICATIONS

Hayden MH,Dalaba M, Akweongo P, Awine T, Nyaaba G, Anaseba D, Pelzman J, Hodgson A, and Pandya R., 2013: Knowledege, Attitudes and Practices Related to Meningits in Northern Ghana. *American Journal of Tropical Medicine and Hygiene* 89, 265-270.

Akweongo P, Dalaba MA, Hayden MH,Awine T, Nyaaba GN, Anaseba D, Hodgson A and Pandya, R., 2013: The economic burden of Meningitis to households in the Kassena-Nankana District of Northern Ghana. *PLOS ONE*, in press.

Monaghan, A.J., M. Barlage, J. Boehnert, C.L. Phillips, and O.V. Wilhelmi, 2013: Overlapping interests: The impact of geographic coordinate assumptions on limited-area atmospheric model simulations. *Mon. Wea. Rev.*, 141, 2120-2127. DOI:10.1175/MWR-D-12-00351.1

Abdussalam, A.F., A.J. Monaghan, V.M. Dukic, M.H. Hayden, T.M. Hopson, G.C. Leckebusch, and J. Thornes, 2013: Climate influences on interannual variability of meningitis incidence in northwest Nigeria. *Wea. Clim. Soc.*, in press.

Abdussalam, A.F., A.J. Monaghan, D.H. Steinhoff, V.M. Dukic, M.H. Hayden, T.M. Hopson, J. Thornes and G.C. Leckebusch, 2013: The impact of climate change on meningitis in northwest Nigeria: an assessment using CMIP5 climate model simulations.. *Wea. Clim. Soc.*, submitted.

Ernst KC, Haenchen S, Dickinson K, Doyle M, Walker K, and Hayden MH. 2013. Community views on the controversial release of OX513A *Ae. aegypti* in Key West, FL. *PLOS Neglected Tropical Diseases.* Under review.

Heaton, M.J., S.R. Sain, T.A. Greasby, C.K. Uejio, M.H. Hayden, A.J. Monaghan, J. Boehnert, K. Sampson, D. Banerjee, V. Nepal, and O.V. Wilhelmi, 2013: Identifying Vulnerability to Heat-Related Mortality using a Spatially Varying Coefficient Model *Spatial and Spatio-temporal Epidemiology*, submitted.

Oleson, K.W., A. Monaghan, O. Wilhelmi, M. Barlage, N. Brunsell, J. Feddema, L. Hu, and D.F. Steinhoff, 2013: Interactions between urbanization, heat stress, and climate change. *Climatic Change*, doi: 10.1007/s10584-013-0936-8.

Moore, S.M., R.J. Eisen, A.J. Monaghan, and P.S. Mead, 2013: Meteorological influences on the seasonality of Lyme Disease in the United States. *Am. J. Trop. Med. Hyg.*, in press.

Hu, L., N.A. Brunsell, A.J. Monaghan, M. Barlage, and O.V. Wilhelmi, 2013: How can we use MODIS land surface temperature to validate long-term urban model simulations? J. Geophys. Res., submitted.

FY 2014 PLANS

Work will continue on the dengue and plague projects with funding through FY 2014 from NIH, DTRA and the CDC respectively. Funding has been received from the NSF to introduce clean cook stoves into the Upper East Region of northern Ghana in an effort to reduce negative health impacts of indoor open fire cooking and improve air quality. Additional funding has been procured from the CDC to model weather and climate impacts on Lyme disease and formulate risk communication.

A meeting was held in Xalapa, MX with all our collaborators in May 2013 to disseminate results of our NSF dengue study. Funding from DTRA will allow us to expand this study into FY14.

Figure 3. Demonstration of a clean cook stove in the UER of northern Ghana.

Funding has been procured for continuation of the CDC post-doctoral program, and we have hired 2 new postdoctoral fellows who began in late FY 2013

Work was completed on a small NIH funded dengue project focused on Key West, FL and Tucson, AZ in the summer of 2012. A larger, newly funded NIH study, also in collaboration with the U of AZ, began in the summer of 2013 along a transect from Tucson, AZ to Hermosillo, MX to investigate environmental determinants of dengue transmission.

‹ Urban Futures up

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