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2010 Annual Report

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2010 Annual Report

A Message from the Director

Roger Wakimoto

With another year coming to a close, it is helpful to cast a look back to see where we have been, taking stock of both internal and community-wide scientific achievements. With preparation for the next Intergovernmental Panel on Climate Change (IPCC) well under way, it is worth noting that the Community Earth System Model (CESM) version 1.0 made its debut in June. This state-of-the-art model provides computer simulations of the Earth's past, present, and future climate states, with its outputs to be included in the IPCC Fifth Assessment Report expected to be released in 2013-2014. CESM, which builds on the Community Climate System Model, would not have been possible without funding from the National Science Foundation and the U.S. Department of Energy, as well as tireless efforts by the modeling community and our own National Center for Atmospheric Research scientists. Congratulations to all for a significant achievement, and to Jim Hurrell who chairs the scientific steering committee that developed the model.

Among other notable accomplishments, ground-breaking for the NCAR-Wyoming Supercomputing Center (NWSC), located in Cheyenne, Wyoming, occurred in early summer. With funding from NSF, and with our Wyoming partners, NCAR is in the process of building a world-class scientific computing facility that will serve scientists nationwide working on weather, climate, oceanography, solar physics, space weather, computational science, energy production, and carbon sequestration research. Opening in 2012, the NWSC will house one of the world's fastest supercomputers for scientific research, as well as a premier data archival facility that will preserve valuable research data including extensive climate history records. Congratulations to Krista Laursen, NWSC project lead, and to the project team as a whole, all of whom have worked diligently behind the scenes to ensure provision of these community computing capabilities.

In addition to CESM and the NWSC, NCAR and our community participated in many other notable scientific efforts. PPlease take time to read the suite of stories that comprise the 2010 NCAR Annual Report for details on these projects and many other exciting research efforts occurring in 2010.

In addition, I encourage you to see the annual reports created by each of our Laboratories, Programs and our Observatory. These provide a further variety and breadth of details on 2010 work.

With best wishes for 2011 and sincere thanks for your ongoing support, and the hard work of the past year,
Roger

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Science in the Field

Observations of natural phenomenon are critical to developing understanding of science. Obtaining such observations is the stuff of field programs and campaigns. Featured in the following pages are some of the projects that NCAR supported and ran in 2010. Highlights run the gamut from a pole-to-pole campaign to collect samples of atmospheric gases and particulates, to investigating the effects of pollution and ozone in one of China's megacities, Shanghai. Also featured is work being done to ensure safety of scientists and field technicians working in Antarctica, a program to better understand winter weather in the U.S. Midwest, the second and final phase of a field campaign studying tornado formation, and a field site providing data about the biosphere, hydrosphere, carbon and nitrogen cycles in the Rocky Mountains.

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HIPPO Takes to the Skies: Measuring Earth's Atmospheric Constituents

by Rachel Hauser

With efforts to mandate mitigation and management of greenhouse gas and black carbon emissions looming, estimating fluxes and transports of atmospheric constituents becomes critical. Effects of aerosols, and carbon dioxide, water vapor, ozone, and methane and other gases, vary across the global atmosphere in terms of distribution, emission rates, and residence time. Beyond meeting possible emissions-reduction mandates, establishing a better approximation of the global atmosphere's chemical distribution will improve understanding of many land-ocean-atmosphere interactions, feeding both basic scientific understanding and providing a vital source of data useful for informing policy. The 5-phase HIPPO (HIAPER Pole-to-Pole Observation) project provides the first detailed mapping of the globe's vertical and horizontal distribution of greenhouse gases, black carbon, and related species.

HIPPO, designed to collect detailed, high-accuracy measurements of atmospheric constituents, launched its proof of concept phase in partnership with the **START-08 mission in spring 2008** (note to John: link to Start-08 2008 NAR story – I think this is in 2009 NAR). The first series of global HIPPO flights ran in January 2009. The scheduled flight paths took the NSF/NCAR Gulfstream V (GV), HIPPO researchers and the variety of equipment responsible for measuring more than 150 gases and atmospheric constituents from pole to pole across the Pacific Ocean. Among the places visited on that first trip: Anchorage, Alaska, Christchurch, New Zealand, the Southern Ocean, Tahiti, Easter Island, and Central America. Since the initial campaign, two additional series of flights have occurred – the first in October to November 2009, the second in late March and April 2010 – with two more campaigns in the offing (May-June 2011 and August- September 2011). The precision instrumentation allows HIPPO scientists to take atmospheric measurements from the top of the troposphere to the Earth's surface.

Researchers have been using instruments on this adapted Gulfstream V jet to profile Earth's atmosphere. HIPPO/NCAR.

"We now have whole slices of the global atmosphere that, in many cases, appear differently than we expected," says Steven Wofsy, HIPPO principal investigator and atmospheric scientist at Harvard University.

Two things in particular stand out, Wofsy continues. One is that the distribution of black carbon and other dark-colored aerosols is more widespread and uniform than anticipated, with more than expected accumulation occurring at high latitudes. Additionally, nitrous oxide (N2O) concentrations are higher in the mid- and upper tropical troposphere than on the surface, which, lacking instrumentation and measuring capabilities prior to HIPPO, scientists could not have known pre-HIPPO. Readings from project instrumentation indicate that the biggest N2O sources are over land, but reasons for the N2O profile inversion currently elude understanding. What is known is that those models currently doing a good job of replicating near-surface-level atmospheric dynamics do not reproduce these phenomena. Model improvement is among the major HIPPO drivers; leveraging HIPPO observations will assist in model refinement. However, in some cases, observations alone cannot solve real-world replication processes, only model improvement will help.

The major model challenge from the perspective of carbon dioxide, says Britton Stephens, an NCAR atmospheric scientist and HIPPO Mission co-lead, is representations of atmospheric mixing. Often the models used have grid structures that are coarser than the fine-scale processes responsible for mixing.

"So, if mixing happens due to large convective cells or transport up and over a cold air mass, for example, the transport models used to track CO2 in the atmosphere do not represent these dynamics well," Stephens explains.

Increases in model resolution may improve these issues somewhat, however it does not get around the need for robust observations that capture the characteristics of broad swathes of atmosphere, from the ground well into the atmosphere. HIPPO profiles extend through the troposphere, expanding existing observational data sets – and knowledge – beyond that allowed by current ground-based capabilities. With these data, researchers will be able to test

the accuracy of existing atmospheric models to better discriminate among them to identify those that best represent observed processes. Moreover, these data will help with design of new models and data-assimilation systems able to take full advantage of such observations. In turn, improved models will push forward human understanding of the processes responsible for uptake of human-emitted CO2, during and between field campaigns – and beyond.

Sidebar: The big exhale

With three flights completed, Britton Stephens brings attention to what he calls the Northern Hemisphere's "exhale." HIPPO experimental design called for seasonal data collection to get a complete, year-round perspective on global atmospheric processes. In the first three missions, which occurred during the Northern Hemisphere's fall and winter, as the GV and its crew and payload flew between the high Arctic to the equator, significant changes in CO2 distribution and concentrations were detected on each mission.

"By lining the same slice of atmosphere up in seasonal order over the course of the three flights, it's possible to see build-up of carbon dioxide concentrations in the atmosphere over fall, winter and spring," says Stephens. "A plume of CO2 grows in the Northern Hemisphere as photosynthesis slows while fossil-fuel CO2 emissions continue."

The last two HIPPO missions will be run in early and late summer, at which point Stephens expects to see a massive inhalation of CO2 over the Northern Hemisphere beginning in May and June as plants and trees leaf out again, with carbon drawdown peaking in August and September.

The left photo, taken from the on-board GV camera, shows a clean segment of atmosphere seen over Alaska during a HIPPO-I flight in January 2009. The dark band in the atmosphere is an image of the shadow of the Earth hitting very fine ice crystals in a very cold atmosphere (photo credit NCAR). The second photo provides a glimpse of the air over the Arctic during a HIPPO-2 flight in November 2009. Atmospheric mixing and removal processes over the Arctic can be slow, as a result, many of the world's pollutants accumulate in this area, resulting in smog on par with that seen in major cities; pollutants are visible at heights up to six to eight kilometers in the atmosphere. (photo credit Eric Kort, Harvard University).

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Advancing Antarctic Science with AMPS

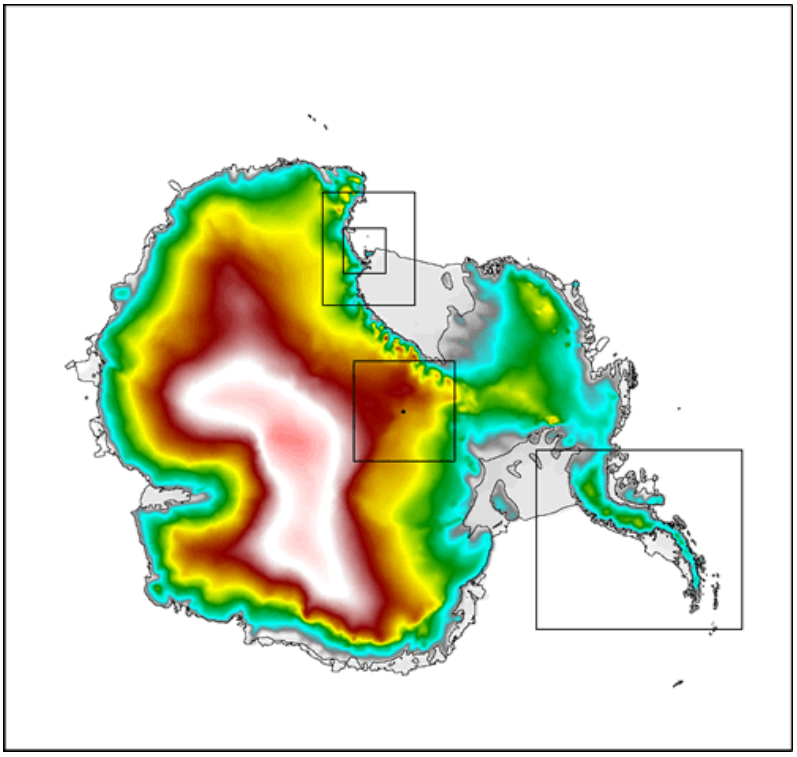
by Rachel Hauser

Having advance notice of poor weather is useful to anyone, but it is particularly critical for those working in remote polar regions where weather can quickly amplify existing hazardous conditions. To maximize its research mission safety and effectiveness, the National Science Foundation's Office of Polar Programs supports the Antarctic Mesoscale Prediction System (AMPS), which aids weather prediction in Antarctica. Working with The Ohio State University (OSU) and University of Colorado, members of NCAR's Mesoscale and Microscale Meteorology Division have developed a real-time, experimental Weather Research and Forecasting (WRF) model-based system that provides numerical weather prediction guidance for U.S. Antarctic Program (USAP) forecasters. While the system primarily serves the USAP, it also offers support to scientific field campaigns as well as a host of nations operating research stations and experiments in Antarctica. Using a polar-modified version of WRF, AMPS delivers the highest resolution model output available on the continent.

A need for a better, near-real-time weather forecasting capability came to the fore when Jerri Nielsen, a physician working at the U.S. research base at South Pole in 1999, was diagnosed with breast cancer during the austral winter, when weather conditions make flying to the pole impossible. The forecast challenge was to evacuate Nielsen as early as possible.

"At a subsequent National Science Foundation Antarctic weather forecasting workshop, stimulated in part by the Nielsen incident, it was noted that personnel safety and research would benefit from more tailored numerical weather prediction capabilities," recounts David Bromwich, a professor of atmospheric science at The Ohio State University.

Timing to create a near-real-time model was ideal as a polar-modified version of MM5, developed by OSU, had been shown to perform skillfully over Greenland. The Polar MM5 was the weather model used for AMPS weather prediction until 2008 when the MM5 reached the end of its lifespan, says Bromwich. The polar modifications developed for the MM5 had been ported to NCAR's Advanced Research WRF (ARW) model, which was then exclusively used in AMPS. Today, the ARW provides AMPS with numerical weather prediction capabilities that are used for a range of scientific and logistical activities in Antarctica. Since the original work began, many of the polar modifications that capture features unique to high latitudes and extensive ice sheets have been included in the officially-released versions of WRF. Among the modifications are provision of fractional sea ice coverage in grid cells and better representations of ice sheet conditions, both of which influence polar weather.



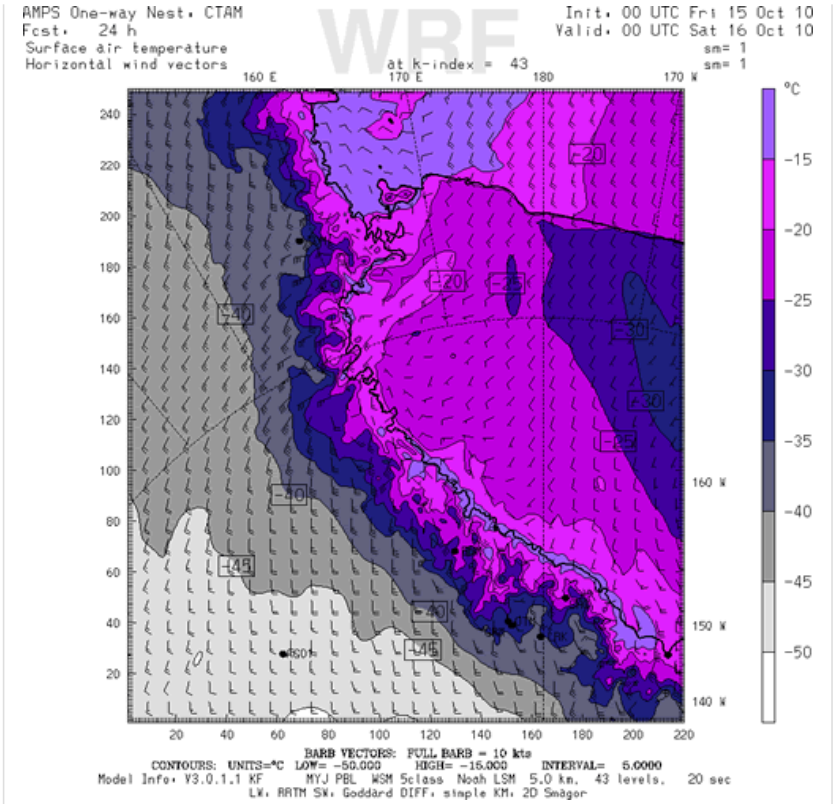
AMPS forecast domains. Outer frame: 15-km spacing. Inner frames: 5-km spacing. Innermost frame (Ross Island area): 1.67-km spacing.

ARW Antarctic weather forecasts are generated on grids with horizontal spacings that range from 1.7 to 15 km. The lower resolution coverage occurs in areas where USAP research and administrative requirements are limited; these areas lie over the ocean and around the continent, as far north as Australia and southern South America, while the highest resolution data are generated around McMurdo Station, the USAP's main area of operation. WRF, says Jordan Powers, an NCAR scientist and project lead for AMPS, is the highest resolution weather model covering the Antarctic, with resolution of the key continental regions provided at 5 km or better.

AMPS furnishes twice-daily, high-resolution numerical guidance for Antarctica and the sub-Antarctic. Assisting in assuring model performance, USAP forecasters provide regular feedback that allows the AMPS team to upgrade the system on an ongoing basis. Beyond AMPS's use for daily forecasting, special applications of it have figured prominently, including support for scientific field campaigns, medical and marine rescues, as well as assisting, as needed, with the activities of other nations operating in Antarctica. In addition, AMPS provides a capability for process and event studies, a platform to test model parameterizations in a polar region, and a database of high-resolution numerical output to researchers working on Antarctic meteorology and climatology. The latter is the AMPS archive, which contains model output since 2001. Notably, the archived short-term forecasts are being used to understand and predict possible regional weather conditions throughout the year. This information is also useful for exploring climatic conditions over the continent, says Bromwich.

Recent AMPS efforts include implementing a separate forecast domain of 2.5-km resolution over the Antarctic Peninsula in austral summer 2009-2010 for the LARISSA (Larsen Ice Shelf System, Antarctica) field campaign. Funded by NSF, LARISSA is an interdisciplinary program investigating the structure and possible changes to the Larsen Ice Shelf, on the western side of the Antarctic Peninsula. A better understanding of local small-scale processes will assist scientists in refining models that estimate how larger parts of the Antarctic cryosphere might respond to environmental change.

"Part of the AMPS effort includes providing tailored support for field campaigns, such as we did with LARISSA," Powers explains. "For the 2010-2011 field season we are providing a special, 5-km forecast grid to serve the large number of research efforts taking place along the Central Transantarctic Mountains." This is another example of AMPS's service toward NSF's Antarctic goals.



AMPS 24-h forecast of surface temperatures (deg C) for the CTAM (Central TransAntarctic Mtns.) forecast grid (5-km spacing) set up for the USAP for the 2010-2011 field season. Valid: 0000 UTC 16 October 2010.

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Growth of a Megacity: Looking to Shanghai's Skies to Understand Some Effects of Economic Boom

by Rachel Hauser

Located on China's east coast in the heart of China's coal mining region, Shanghai is that nation's largest city, surrounded by a nearby cluster of cities. A megacity, with a population of more than 20 million, the regional gross domestic product of Shanghai and surrounding areas grew 500% between 1996 and 2006, a reality reflected to some degree by the growth in number of cars, which increased 400%, expanding from just under ½ a million in 1996, to more than 2.5 million in 2006. Like many other large cities, Shanghai suffers from severe air pollution problems, including high particulate concentrations and poor visibility. With its rapid growth and economic expansion – and that of the surrounding cities – Shanghai offers fertile ground for studying the combined effects of economic boom and pollution increase in a megacity.

Ozone, which can negatively impact human respiratory systems, is created by photochemical reactions occurring between the sun and chemicals making up urban smog. Composed of compounds including volatile organic carbons (VOCs) and nitrogen (NOx), smog is generated by car and factory fuel combustion. Coal is used to meet a large proportion of Shanghai's industry and domestic energy demands, but growing use of petroleum to meet industrial and automotive fuel demands will likely enhance VOC presence in the atmosphere.

The amount of aerosols in the air can also enhance cloud formation, which increases urban cooling by reducing incoming solar radiation. In addition, aerosol-loaded skies scatter and absorb solar radiation, which affects photochemical activity and the amount of ozone formed – less sun means lower ozone production. Studying Shanghai's high aerosol concentrations offers an exciting opportunity for scientists to understand the interactions between pollution, climate change, and ozone concentrations. These efforts will provide scientists, urban planners and policy makers in Shanghai and surrounding cities with an improved means of predicting high ozone days.

Eastern China, where Shanghai is located, is in the heart of a heavy coal mining region, making it an ideal place to study the interactions of aerosol particles and photochemistry on the atmosphere, which have important effects on the formation of ozone, and human health.

In a 2009 field study, scientists from the Shanghai Meteorological Bureau, NCAR, and Chinese and U.S. universities studying Shanghai urban climate looked to on-the-ground observing sites, models, and measurements of atmospheric chemistry derived from satellites. Two satellites (MODIS and GOME) reveal that the columns of NO2 gas, one of the key components in ozone creation, have much faster growth rates along the east coast of China than in other regions on the globe. Because coal burning produces more NOx and fewer VOCs, Shanghai's NOx/VOC emission ratio is much higher than is true for other large cities, such as Los Angeles or Mexico City.

The high emission ratio of NOx/VOCs often results in a strongly VOC-limited regime for ozone chemical production. Thus, Shanghai presents a valuable opportunity to study ozone in different regimes (i.e., NOx-limited, VOC-limited, and NOx-inhibited regimes). Variation in these regimes may prove important because, like sunlight, the ratio of these constituents is important; more VOCs and moderate NOx tend to mean higher levels of ozone, whereas very high NOx results in less ozone production. Understanding the interactions between all of these processes, and which ones predominate under varying scenarios, as well as how the variety of effects play out geographically – in other words, within the city, near industrial zones or in more rural areas – is critical for development of effective pollution control strategies.

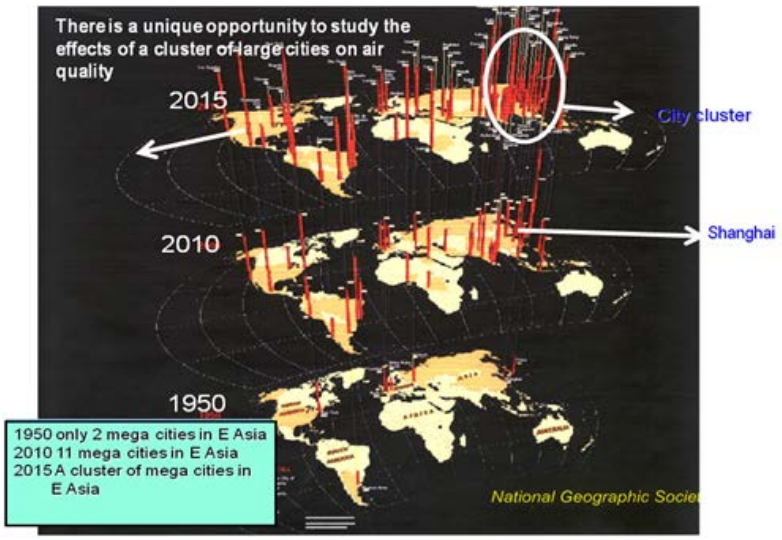
The 2009 field campaign is the first of a series of field projects that will occur in and around Shanghai to study the impact of air pollutants. In 2009, a network of nine observing stations was established. Located within the city, near industrial plants, and in remote areas, station observations will assist in studying oxidant and aerosol processes at the urban to regional transition. In addition, observations are being used to evaluate WRF-Chem, NCAR/NOAA's Weather Research and Forecasting model that is a coupled model of meteorology and chemistry. These evaluations are expected to aid development of a chemical weather forecasting system for Shanghai, explains NCAR's Shanghai-MIRAGE

scientific project lead, Xuexi Tie.

“Initial results showed that model-calculated ozone concentrations are fairly consistent with measurements at city sites, but are significantly underestimating observed maximum values in petroleum-intensive industrial regions,” says Tie. “Also notable, the simulated diurnal cycle of ozone is weaker than the observed values near the chemical industrial site, indicating that chemical industrial emissions play an important role in pollution and ozone characteristics in Shanghai and its surrounding area.”

Comparisons between modeled output and observations are critical to ensuring accurate projections. The modeling team is currently working on getting a better match between the NOx and VOC emissions in the morning, and ozone concentrations at noon in the industrial regions. At noon, when incoming solar radiation is peaking and presence of smog is significant, observed ozone concentration is higher than the values the models are predicting. Among other foci, these questions will be addressed and expanded upon in follow-on MIRAGE-Shanghai campaign.

Follow-up experiments will also see the researchers considering downwind dynamics and impacts of the ozone plume on forests and vegetation; vegetation also contributes VOCs to the atmosphere and scientists are interested in understanding the resulting effects on the short-lived (two weeks) plume. In addition, consideration of the effects of an increasing car population, and possible reductions in chemical emissions through pollution reduction efforts will be considered. The scientists will also collaborate on developing a chemical weather forecasting system for the Shanghai region, which will include data assimilation of satellite data, including key atmospheric components such as nitrogen dioxide, carbon monoxide, and formaldehyde. Together, the researchers hope these advances in understanding will feed development of pollution mitigation strategies from a scientific perspective.



In 1950, only two megacities – cities with population in excess of 10 million – existed in China. In 2010, China has 10 megacities; by 2015 projections indicate that East Asia, including China, will have clusters of merged megacities (United Nations State of the World's Cities 2008/2009).

Within the existing nine measurement stations established by Shanghai Meteorological Bureau during the 2009 Shanghai-MIRAGE field campaign, including three supersite measurement stations – one in the city (PD), one at a chemical industrial site (JS), and the third located outside Shanghai (DT); red dots indicate supersites, and the blue-dots show regular sites. The supersites will provide information regarding (a) ozone, (b) ozone precursors such as NO, NO2, NOx, CO and volatile organic carbons (VOCs), (c) aerosols, (d) chemical products created during ozone oxidations (HNO3, HONO), (e) biogenic VOC (isoprene, etc), and (f) impacts of aerosols on photochemical activities.

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Winter Storm Profiling to Improve Forecasting Capabilities

by Greg Guibert

The PLOWS (Profiling of Winter Storms) research program seeks to understand the dynamic and microphysical processes governing spatial and temporal variability of precipitation within extratropical cyclones in order to reduce injury and loss of life associated with winter storms and blizzards. PLOWS is a comprehensive field campaign designed to address outstanding scientific questions targeted at improving our understanding of precipitation substructures in the northwest and warm frontal quadrants of continental extratropical cyclones, where variability in the location, type, and intensity of precipitation is often determined by precipitation banding and/or embedded convection. Improvement of 0-48-hour, cool season quantitative precipitation forecasts, the period of greatest impact, depends on obtaining a greater understanding of the mesoscale structure and dynamics of cyclonic weather systems.

In the course of PLOWS, researchers will address the following questions: 1) What are the predominant spatial patterns of organized precipitation substructures, such as bands and generating cells, in these quadrants and how do they evolve? 2) How do frontal scale systems above and within the boundary layer such as warm fronts, cold fronts aloft, and occluded fronts relate to these precipitation substructures? 3) What are the thermodynamic and kinematic structures of these frontal systems including the distribution of moisture and vertical motion? 4) What instabilities and types of mesoscale forcing (e.g., moist CSI, moist frontogenesis, gravity waves, and elevated upright convection) control the generation and evolution of precipitation substructures? 5) How do microphysical processes vary between the different precipitation substructures and what are the consequences? 6) Is instability triggered in ice-saturated ascent critical in some of these instances and is it through the release of the latent heat of deposition that instabilities can persist?

The PLOWS field campaign is comprised of two field seasons. The first took place from 7 February to 31 March 2009 (PLOWS 2008-2009) and the second 1 November to 15 December 2009 and 15 January to 28 February 2010. The project focuses on the Midwestern United States (Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, and Wisconsin).

The 2010 field campaign provided new insight into remote sensing of winter weather systems that can be translated directly into better operational interpretation and observation strategies of winter weather mesoscale features. The study will provide a unique dataset, which can be used to interpret data from the next generation of operational polarization diversity Doppler radars to be deployed in the next decade. PLOWS utilizes high resolution observations of precipitation substructures using four mobile ground-based observing systems, the University of Alabama at Huntsville Mobile Integrated Profiling System, the Mobile Alabama X-band dual polarization radar, and the NCAR Mobile Integrated Sounding System, and the University of Missouri sounding system, along with the NCAR C-130 Aircraft equipped with microphysical probes and the Wyoming Cloud Doppler Radar and Cloud Lidar. The Weather Research and Forecasting (WRF) Model is also used to simulate the precipitation substructures using at high horizontal and vertical resolution.

PLOWS PI Bob Rauber from the University of Illinois Urbana-Champaign characterized the results from their second season this way, “Based on our initial analyses, the data quality appears to be excellent. Thus far we have encountered no systematic problems with any of the radar, profiler, or other ground based datasets… In our view the data we obtained are truly remarkable and will produce groundbreaking findings about mesoscale substructures within winter cyclones and the instabilities that cause them.”

Drivers make their way through a snow storm in Boulder, Colorado.

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Twister Tracking Across the Great Plains

by Greg Guibert

During two months this summer, VORTEX2 (Verification of the Origins of Rotation in Tornadoes Experiment 2), deployed 100 scientists and a flotilla of 40 research vehicles across the U.S. Great Plains. During this, its second and final phase, VORTEX2 (V2) scientists sought to better characterize the generation, structure, and performance of tornadoes in a research effort that will ultimately result in increased lead-time for providing tornado warnings, as well as more accurate forecasts.

Although the scientific understanding of the full tornadic lifecycle was greatly improved by results of VORTEX 1, which ran in 1994 and 1995, significant questions remained about factors that influence storm genesis, longevity, and intensity. Funded by the National Science Foundation and NOAA, V2 sought answers to a variety of research questions. These included a desire to gain better understanding of tornadogenesis (the physics driving tornado formation), and the relation between structural damage and near-ground winds, with wind characteristics such as speed, acceleration, and duration closely observed. Scientists also studied effects of supercells – storms with vortices of air spanning two to 10 miles in diameter – on the surrounding environment and tornado formation, as well as refining storm-scale weather prediction with V2 observations and modeling.

V2, fully nomadic, constituted a broad collaborative effort of scientists from diverse U.S. and international universities and organizations. The project used an unprecedented fleet of instruments to surround tornadoes and the supercell thunderstorms that form them. The vehicle fleet included 10 mobile radars, including the Doppler On Wheels (DOW) from the Center for Severe Weather Research (CSWR), SMART-Radars from the University of Oklahoma, the NOXP radar from the National Severe Storms Laboratory (NSSL), radars from the University of Massachusetts, the Office of Naval Research, and Texas Tech University (TTU), 12 mobile mesonet-instrumented vehicles from NSSL and CSWR, 38 deployable instruments including Sticknets (TTU), Tornado-Pods (CSWR), 4 disdrometers (University of Colorado (CU)), weather balloon launching vans (NSSL, NCAR and SUNY-Oswego), unmanned aircraft (CU), damage survey teams (CSWR, Lyndon State College, NCAR), and photogrammetry teams (Lyndon State University, CSWR and NCAR), and other instruments. The instruments allowed for a resolution as fine as 100 feet and time steps as small as 10 seconds. Ground-based instruments were also supported by a robotic 12-foot propeller aircraft tasked with probing the edges of severe storms.

The study area spanned more than 900 miles, stretching from West Texas to southwestern Minnesota. On each day of operations, V2 teams positioned equipment about an hour ahead of a potentially tornadic storm and remained in place until the storm passed. About half of the participants in the field were undergraduate and graduate students, which is an unusually high percentage for a major field campaign, and an effective way to provide young researchers with an opportunity to step away from the computer and step into the field for hands-on learning.

Among the researchers was University of Oklahoma PhD student, Ryan Sobash, who works on modeling and predicting convection. Sobash spent time working with the mobile mesonets, which collect surface weather observations in and near severe storms.

“My experience with V2 illuminated the many challenges associated with obtaining high-quality observations of severe storms and tornadoes,” says Sobash. “Working with the mesonets, we faced a variety of challenges such as inadequate road networks and violent weather conditions. Seeing the team execute our mission in spite of these obstacles was very satisfying.”

Also from University of Oklahoma, Chris Swartz, a University of Oklahoma Master's student and avid storm chaser had a chance to work with the NOAA/NSSL X-band Polarized mobile weather radar, collecting data on low-level mesocyclones.

"Being a part of VORTEX2 was certainly a fascinating experience. I have spent a lot of time visually watching thunderstorms evolve, but having high-resolution radar data at your fingertips and the visual aspect was an awesome experience. From an operational perspective, VORTEX2 provided a lot of insight for the students about decision making, team collaboration, and the forecasting involved on various weather setups," Swartz says.

Swartz expects that V2 data collected will shape the premise of his graduate work. He, with his adviser, Don Burgess, expects to begin analysis of wind field observations and precipitation distribution in and around the low-level mesocyclone before, during, and after tornadogenesis.

VORTEX2 vehicles stop by the side of the highway as they track the Goshen Country storm in Wyoming on June 5, 2009. Two vehicles are equipped with roof-mounted weather stations. VORTEX2 is designed to improve our understanding of tornado formation, which ultimately will better allow us to assess the likelihood of tornadoes in supercell thunderstorms and possibly tornado intensity, longevity, and cyclic behavior. .

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BEACHON

BEACHON is an NCAR cross-laboratory program with the goal of improving predictability of Earth system behavior based on better measurements and understanding of the coupling between water, energy, and biogeochemical cycles; and to expand the range of societal-environmental options available to policy and decision makers. To support this goal, BEACHON research focuses on the following

1. Understand and quantify the fundamental ecological, hydrological, and atmospheric processes associated with land ecosystem-atmosphere interactions including the response to disturbances (e.g., drying, warming, and insect outbreaks).
2. Advance world-leading numerical models of land ecosystem-atmosphere interactions, including atmospheric oxidation and aerosol/cloud processes, make them widely available, and support their use by the scientific community.
3. Develop and provide state of the art observational facilities and approaches required to quantify land ecosystem-atmosphere interactions, including atmospheric oxidation and aerosol/cloud processes, and make these approaches available to the scientific community.
4. Lead integrated regional studies (aircraft, satellite, and regional network observations and regional modeling) to develop a comprehensive knowledge system designed to analyze and predict bio-hydro-atmosphere interactions and feedbacks and the impacts of disturbances at the regional scale.

The NCAR-BEACHON Manitou Forest Observatory (MFO) is a key component of BEACHON efforts to develop and provide state-of-the-art observational facilities. The observatory is located on a US Forest Service experimental forest near Woodland Park, Colorado that is representative of the semi-arid Western U.S., where biosphere-atmosphere exchange processes are particularly sensitive to changes in water availability. The site is one of only a few in the world with continuous measurements of biosphere-atmosphere exchange processes of energy, water, carbon, reactive gases, and aerosols along the with the meteorological, hydrological, and ecological variables that control these exchanges. BEACHON hosts intensive field campaigns that bring from 20 to 60 university and international investigators to the site each year. An August 2010 field campaign at MFO brought participants from NCAR, US Forest Service, US EPA, University of Wisconsin, Stonybrook University, University of Colorado, Colorado State, Colorado College, U. Innsbruck (Austria), and Tokyo Metro. University (Japan) and successfully obtained a comprehensive suite of measurements of biogenic VOC (volatile organic compounds) emissions, oxidation products, and oxidants.

An example of BEACHON's success in integrating biological, chemical, and physical process understanding with multi-scale (leaf, canopy, regional/global) measurements and modeling is the investigation of efficient uptake of atmospheric organics by plants. VOCs fuel tropospheric chemistry and are a critical component for understanding radical cycling as well as ozone and organic aerosol formation. Biogenic sources are thought to dominate the global VOC budget (i.e. 80-90%). The fraction of low to moderately soluble VOC depositing back to vegetation currently remains practically unknown. This represents a significant uncertainty when constraining budgets of VOC (and subsequently organic aerosol), because these VOCs account for a large amount of carbon during the initial oxidation phase. BEACHON scientists analyzed a large number of canopy-scale micrometeorological field observations and have shown that the removal of oxygenated volatile organic compounds (oVOCs) via dry deposition is substantially larger than currently assumed for deciduous ecosystems (temperate, sub-tropical and tropical). Leaf-level laboratory

experiments were conducted to identify detoxification mechanisms that explain these observations. These laboratory experiments also suggest that chemical stresses (e.g. elevated ozone levels) can potentially increase the uptake of oVOC via short (0-2 hours) and long-term (>1day) genetic upregulation of enzymes controlling detoxification. Incorporation of a modified dry deposition scheme into the NCAR MOZART (model of ozone and related trace species) global chemistry model leads to appreciable regional increases of predicted dry deposition. These results were published in the Nov. 2010 issue of Science (Karl et al. DOI: 10.1126/science.1192534) and have important consequences for capturing the dynamic behavior and repartitioning of organic carbon (VOC+SVOC+SOA) in coupled Earth-system models.

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Community Service and Support

NCAR is charged with providing facilities and support to university groups that might not otherwise have access to needed expertise and infrastructure. Many exciting community-wide partnerships and collaborations have evolved from this directive. In 2010 some of the highlighted efforts in this area include a partnership between NCAR and Colorado State University, which provide researchers with an integrated weather radar facility, and a look at the Research Data Archive, which provides scientists with more than 600 datasets related to weather, climate and ocean-atmosphere interactions. NCAR and the community of scientists we serve are working to improved climate and other models. Part of this effort was establishing and guiding the Coupled Model Intercomparison Project, the details of formation and capabilities are available in the following pages.

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Data support for climate and weather research

by Brian Bevirt

Weather and climate research rely on accurate data describing the Earth System. NCAR's Research Data Archive (RDA) is a key resource for the global community studying climate, weather, and ocean-atmosphere interactions. Maintained by NCAR's Computational and Information Systems Laboratory (CISL), the 600+ terabyte RDA offers open access to more than 600 collections. Ease of access and data content are equally important to researchers, so RDA personnel focus improvement efforts on both of these areas. Maintaining this balance assures that the RDA will sustain its high value as a user-centered data resource.

Trained in atmospheric and oceanographic sciences, the RDA support staff is uniquely prepared to offer knowledgeable consulting on broad-ranging research data questions. The team is also expert in handling data. They use efficient methods to both import new data to NCAR and export data to users. These data professionals evaluate incoming data as part of their data curation job. Since they know how the data should "look," their evaluation process frequently identifies data content errors that can be eliminated before releasing the product to the public. RDA management by a team of data scientists is a recognized asset among data managers worldwide.

In addition to providing, curating, and quality-controlling data, the RDA staff – in collaboration with the user community – identifies useful new data sets to be added to the archive. RDA staff support the scientists and organizations that offer data to the archive by ensuring data integrity during transfer, long-term preservation, and complete data user metrics. RDA staff relieve data providers from most of the necessary data support tasks, and they also act as the first point of contact for users, offering answers to scientific data questions that arise, providing insights on effective data manipulation software tools, and creating documentation and metadata that are both meaningful to users and accurate from the provider's perspective. This proactive work to enhance the archive keeps the RDA relevant to a large user community and accelerates the pace of its enrichment.

Reanalysis Name	Time Period
NCEP/NCAR Global Atmospheric Reanalysis	1948-2010*
NCEP/DOE Global Atmospheric Reanalysis	1979-2008*
ECMWF Re-Analysis 40-year (ERA-40)	1957-2002
NCEP North America Regional Reanalysis**	1979-2010*
Japanese Reanalysis (JR-25/JCDAS)	1979-2009*
ECMWF Interim Reanalysis (ERA-I/ECDAS)	1989-2010*
NOAA-CIRES 20th Century Reanalysis	1891-2008
NCEP Climate Forecast System Reanalysis, Ocean	1979-2009*

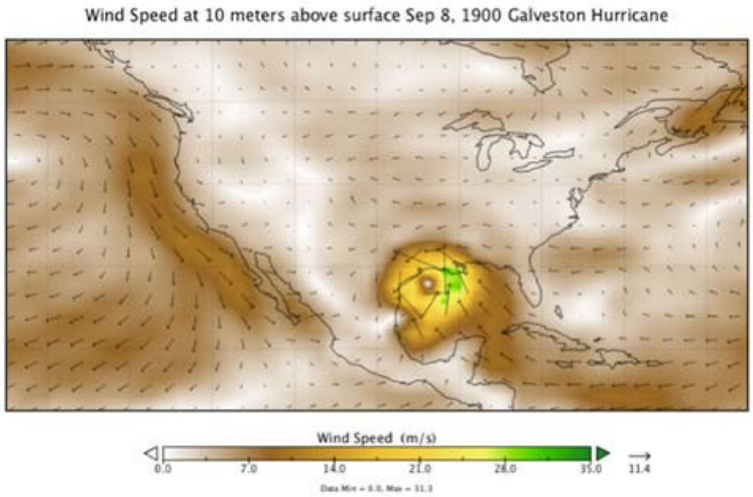
NCAR's RDA is known for having nearly all the low- and high-resolution products for each reanalysis, and it is the largest collection organized in one location. All reanalyses cover the entire globe except one, and they are listed here in the order they were produced.

** These reanalyses are continually being extended by the data providers.*

*** Geographic coverage is centered on North America.*

RDA data access has made substantial gains in the past five years. This growth and change will continue in the future, just as user expectations and data service challenges continue to evolve. Plans for the RDA in 2011 include expanding the existing online data archive to 250 terabytes, six times its current size. The RDA's online data service is supplemented by an easy-to-use request interface that stages data to disk for Internet download from tape archive storage. This system gives users access to the complete RDA. By coordinating with user-oriented workflow

improvements in NCAR's data storage architecture, the RDA now provides data users with more efficient and significantly faster online access to the major portions of the archive. These improvements will be scaled up again to complement supercomputing at NWSC.



This visualization of wind speeds for the extremely destructive Galveston hurricane of 1900 was generated using the global NOAA-CIRES 20th Century Reanalysis data. Reanalysis data products are useful in weather and climate studies because they provide a consistent, dynamically constrained mapping of point observations onto 3D atmosphere and ocean grids.

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Colorado Collaboration Brings Together Two NSF Research Facilities to Create Radar Testbed

by Rachel Hauser

Radars are the observational backbone of weather research and forecasting. Providing detailed information on precipitation patterns and movement, radar data can be fed into operational meteorological models in real-time to ensure up-to-the-minute weather reports. Such data are equally essential to verify output of research models, providing a means of comparing predictions with reality, and in research programs such as **VORTEX2**. This critical tool for weather research – which comes in a variety of shapes and sizes – is included amongst the other equipment and services provided by the National Science Foundation (NSF) to U.S. researchers and scientific programs.

Colorado's Front Range researchers have close access to two NSF-funded transportable, dual-polarimetric 10-cm wavelength (S-band) state-of-the-art weather radars that can be requested for remote or on-site experimental use. S-band radar is valuable for both long- and short-range weather observation, but to assure high-resolution radar images, these instruments require a large dish (about 25-feet in diameter) to maintain a narrow beamwidth (~1°), and considerable motorized power for scanning capability in all weather conditions. Because of this, leaving them in a single location is ideal, however many research projects that benefit from use of S-band radar are not necessarily located near the S-Pol or CHILL's home base. Supported by NCAR and Colorado State University (CSU), these well-traveled radars are ready for deployment to wherever in the world NSF researchers require them.

S-Pol was developed by NCAR through its Earth Observing Laboratory (EOL) in the early 1990s. S-Pol is an NSF national facility, and has served the NSF research community since 1995. CSU acquired the CHILL S-band radar from the University of Chicago and Illinois State Water Survey in 1985, becoming an NSF National Facility with its acquisition. Both EOL and CSU-CHILL provide radar expertise and support to the broader science community. Often cooperating, the two institutions recently integrated the two systems to streamline radar operations, data archival and distribution, related software development, and support, creating FRONT, the Front Range Observational Network Testbed. This radar research facility brings the skills of each organization to bear on understanding weather in the Front Range of Colorado, and weather-related tools – from radar and radar components to weather models, as well as a physical location to host educational programs.

An image of CHILL, Colorado State University's S-band radar.

Among the other benefits of FRONT creation is the ability by scientists to conduct "target of opportunity" scientific field experiments, to identify locations that best meet research-question requirements. Additionally, FRONT establishes a long-term mesocale meteorological test bed where data quality procedures, sensor integration, numerical models, networking capabilities, derived products and a wide variety of instruments other than radars can be assessed. By merging capabilities and expertise, FRONT has become a magnet for local field campaigns. Through a combination of multiple instruments, some potential research projects in the Front Range include orographic precipitation, mountain waves, summer thunderstorms, lightning, winter storms, short-period forecasting (nowcasting), microphysical studies, satellite cloud product validation and hydrological applications. Additionally FRONT has become a place in which hands-on learning can occur, which is critical for new researchers and those acquiring additional skills through continuing education.

Among the exciting advances that FRONT supports is set up of S-Pol for remote operation that will occur between deployments via VCHILL (virtual CHILL), effectively broadening radar accessibility for the science community. EOL summer intern, Fatoumata Dembele from Michigan State University, worked with Remote Sensing Facility staff to develop S-Pol remote monitoring capabilities to allow unattended radar operation. Dembele worked on integrating a power meter into a remote monitoring system, successfully establishing communication protocols with the power meter, web interfaces and control systems.

In other areas, FRONT continues development of the new S-Pol antenna, which began in 2009. The radar has now been hardened for remote web-based operation and the automated calibration subsystem has been integrated. Currently the radar is being prepared for the proposed DYNAmics of the Madden-Julian Oscillation (DYNAMO) deployment in the Maldives and will be moved to its new location when it returns from that project in May 2012.

“The FRONT network provides a unique NSF facility for the broader community to test pre-deployment feasibility as well as run on-site real-time experiments,” says Wen-Chau Lee, an NCAR senior scientist and interim manager of EOL’s Remote Sensing Facility.

NCAR's S-Pol radar gathers refractivity measurements as part of the REFRACTT (Refractivity Experiment For H2O Research And Collaborative operational Technology Transfer) project. Researchers measured changes in the speed of radar signals caused by refraction, which in turn reveal the presence or absence of atmospheric moisture. the aim of the project was to help forecasters predict where heavy rains might develop. University Corporation for Atmospheric Research.

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Scientific Collaboration and Cooperation Builds a Better Model

by Rachel Hauser

Output from different climate models will always vary to some degree. Under the same set of parameters, temperature data from one model might differ by several degrees when compared to data from another, or the effects of cloud cover might be seen to affect a particular area of the world in one set of outputs, while another model shows significantly different effects. To understand why these variations occur, to improve model capabilities, and to enhance scientific understanding related to both models and real-world dynamics, the World Climate Research Programme (WCRP) created the Coupled Model Intercomparison Project (CMIP). Such understanding is not only important for science, but the research feeds into expanding environmental policy and decision making to affect society and societal well being.

CMIP was designed to be similar to the late 1980s' Atmospheric Model Intercomparison Project (AMIP), which compared output from atmospheric models run with observed sea surface temperatures to improve model parameterization and understanding of basic scientific processes, explains Gerald Meehl, an NCAR climate scientist who headed up CMIP from its inception. Meehl is the current co-chair of the Working Group on Coupled Models (WGCM), the committee that oversees the CMIP Panel in coordinating this multi-national effort.

With a growing number of global climate models coming on line in the 1990s, all of which had notable variations from the others, scientists wanted a means of better identifying why such differences in response to increasing CO2 might be occurring. At a 1994 meeting at Scripps Institute of Oceanography, a group of scientists working under the auspices of the WCRP met and discussed the problem, coming up with the idea of having a number of models run the same experiment and comparing the results to identify where models diverged. In 1995, the WCRP's WGCM moved on this idea, identifying a single experiment to be run by four different global climate models at four research organizations, including NCAR, the Geophysical Fluid Dynamics Laboratory, the UK Met Office, and the Max Planck Institute. Each institute's coupled land-ocean-atmosphere-sea ice model performed a control run with CO2 held constant, and subsequently in 1997 for CMIP2, all the models performed a simple one-percent-per-year CO2 increase experiment with output from a limited number of fields (surface temperature, precipitation, and sea level pressure, among others) from these runs designated for comparison. Scientists from around the world also formulated analysis subprojects; numerous scientific papers documented model performance, limitations, and processes important for the climate system response to increasing CO2.

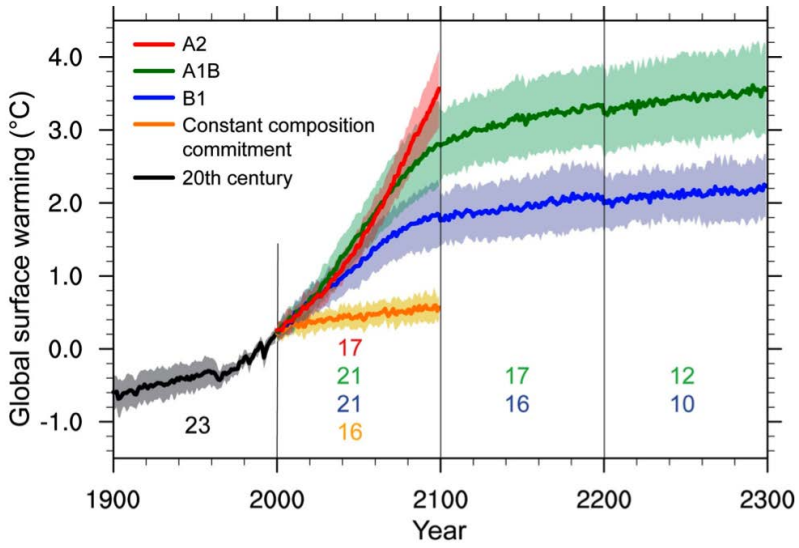
Around the same time, scientists included in the Intergovernmental Panel on Climate Change (IPCC) assessment process were analyzing data from this initial phase of CMIP, and those results were included as part of the IPCC Second Assessment Report on climate change. Subsequent phases of CMIP encompassed more and more models as the number of modeling groups increased, and CMIP intercomparisons were assessed as part of the IPCC Third Assessment Report. The largest and most comprehensive phase of the project, CMIP3, culminated with 21 models in total that were run in a coordinated set of 20th century and 21st century climate change experiments. This multi-model CMIP3 dataset was made openly available for analysis by scientists from around the world and was a central element of the IPCC Fourth Assessment Report. Among the intercomparison outcomes was identification of systematic errors present in almost all the models, such as the double inter-tropical convergence zone, which affects tropical precipitation patterns, affecting many of the tropical ocean-atmosphere feedbacks. Additionally, the range of model responses was documented to better quantify uncertainty of future climate change projections.

An outgrowth of these formative projects is that today modeling groups look to CMIP to provide a framework for coordinated experiments that can be performed by the international climate modeling community to improve understanding of climate variability and change. The additional benefit is that the model simulations can then be assessed as part of the IPCC process. Moreover, through such participation, modeling groups collaborate as part of an international community with a common goal of improving state-of-the-art of modeling and understanding derived from climate models. This helps groups to be considered more favorably for funding from their governments, says Meehl.

The number of intercomparison projects since early inception has grown greatly, with CMIP5 the most recent version of the climate model intercomparison. This has spawned scores of related efforts currently underway, including comparisons between modeled and observed aerosol concentrations, paleoclimate model experiment intercomparisons, and model-simulated tropical cyclone comparisons, among others (for a full list, see http://www.clivar.org/organization/wgcm/projects.php). Due to widespread recognition of the importance of doing

such intercomparisons, the WCRP/CLIVAR Working Group on Coupled Models provides a process for coordinating such comparisons where need is perceived by the community. An essential part of CMIP is open availability of model output. Investigators need only register on the CMIP web page. Once a model analysis project is initiated, participants must agree to make resulting comparison data accessible to interested researchers.

“Some people have the mistaken impression that CMIP is only for the IPCC assessments, but it’s much more than that,” explains Meehl. “The motivation for CMIP is to provide a framework for coordinated climate model experiments so we can collaborate as an international community of scientists to better understand how the climate system works. That’s what all of us find so interesting, and why so many scientists from around the world participate in CMIP.”



Multi-model means of surface warming (relative to 1980-1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulation. Values beyond 2100 are for the stabilization scenarios (see Section 10.7). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi model means, shading denotes the plus minus one standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the coloured numbers given for each phase and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure. (Source: Chapter 4, Intergovernmental Panel on Climate Change, 4th Assessment Report.)

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Advancing the geosciences through simulation

by Brian Bevirt

Simulation, an increasingly valuable complement to theory and experiment, has become one of the principal tools of modern science. Science demands a relentless advancement of computing technology because only the most powerful supercomputers can increase our skill in simulating and predicting the immensely complex physical processes in the Earth-Sun system. NCAR scientists and engineers improve the sophistication of computer models and provision some of the world's most capable computers. But the petascale systems of the near future require a facility that can support their massive power and cooling requirements. Therefore, NCAR and its Wyoming partners are building a world-class scientific computing facility that will adapt to future needs without compromising on efficiency or sustainability.

The NCAR-Wyoming Supercomputing Center (NWSC) will serve scientists nationwide who research weather, climate, oceanography, solar physics, space weather, computational science, energy production, and carbon sequestration. Opening in 2012, NWSC will house one of the world's fastest supercomputers for scientific research, as well as a premier data archival facility that will preserve valuable research data including extensive climate history records. NWSC will also deliver data analysis and visualization services to the scientific community, and its high-performance networks will provide full access to its world-class resources. Developed and managed by NCAR's Computational and Information Systems Laboratory (CISL), NWSC will advance the Earth-Sun system science.

Designed specifically for scientific supercomputing, NWSC integrates best practices for energy efficiency and sustainability in a computational data center. Numerous innovations make the facility approximately four times more efficient than NCAR's current Mesa Laboratory computing facility. When it begins operation, NWSC is projected to be nearly 90 percent more energy efficient than typical data centers, and significantly more energy efficient than today's top centers. Almost 92 percent of the energy consumed by NWSC will go directly to powering the supercomputers, and wind energy will supply at least 10 percent of the facility's electricity. Environmental stewardship is a core value of both CISL and NCAR.

Most researchers will interact with the center remotely via the Internet. NWSC's cyberinfrastructure – technology that connects people anywhere with computing centers – will stimulate high performance computing at universities across the nation, broaden participation in scientific discovery by people from any background, and build interdisciplinary collaborations. Because it leverages strong programs at both NCAR and the University of Wyoming (UW), NWSC will be a catalyst for education, outreach, and training (EOT). Educators across the country will use NWSC to develop computational science and computational geoscience curricula at colleges and universities. UW is now a prototype campus for identifying and testing successful ways to develop campus cyberinfrastructure and computational science curricula. These capabilities will be replicated or improved at other campuses – including NWSC – then used to invigorate education programs at still more institutions.

NWSC will also expand educational opportunities at two-year and tribal colleges in the region by building on existing programs and contacts within those communities. EOT efforts will leverage NCAR's current work with minority-serving institutions to attract more people to NWSC-related programs, and to increase workforce diversity within computational science and the geosciences. NWSC will also expand existing internship and mentoring programs at NCAR and UW. To stimulate early interest in scientific computing, project partners will initiate K-12 and community education programs. NWSC will also feature an unparalleled on-site learning and discovery experience for visitors. As a public resource dedicated to educational excellence, NWSC will strive to advance the scientific literacy of the nation.

This photo shows NWSC's highly reinforced computer room floor being built at end-FY2010. Numerous innovations and efficiencies were made possible by this design. NWSC will enable NCAR to support critical Earth System sciences research through high-performance computing for the next two to three decades.

This photo shows the NWSC building structure at end-FY2010. Construction progress has been very efficient and continues ahead of schedule. Fully enclosing the building before winter will allow interior constuction to continue at full speed even during storms. The NWSC will enable NCAR to support critical Earth System sciences research through high-performance computing for the next two to three decades.

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Science Serving Society

A driving National Science Foundation and NCAR mission is for society to benefit from the science community's research efforts. Among the featured stories for 2010 is a description of a device that notifies pilots of turbulent skies ahead, as well as an introduction to the Community Earth System Model, the latest version of the NCAR-housed and community-created climate model.

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Helping Navigate Turbulent Skies

by Rachel Hauser

Despite frequency and severity of turbulence effects on aircraft, understanding this phenomenon's complex nature and genesis remains limited. Accounting for more than 75% of all weather-related injuries on commercial aircraft, turbulence can also result in serious aircraft damage, posing significant safety and flight efficiency concerns for general and commercial aviation. Based on FAA surveys, costs to airlines due to turbulence related injuries and aircraft damage average about $200 million annually, says Robert Sharman, a project scientist in the Research Applications Laboratory's (RAL) Aviation Applications Program (AAP), making turbulence detection and forecasting a priority for federal agencies and industry alike.

Turbulence research suffers from a lack of reliable observational data, with the main source of information coming from pilot reports detailing flight-level turbulence location and severity; however these reports are often incomplete and highly subjective. Computer models, useful in forecasting other atmospheric hazards, are of limited value because of the short lifespan and limited spatial distribution of turbulent atmosphere. Improved detection and forecasting requires upgrading turbulence observation and reporting systems to provide reliable tuning and verification data and creation of empirical models to nowcast and forecast turbulence locations and severities.

Under Federal Aviation Administration (FAA) and NASA sponsorship, a group of scientists and engineers at NCAR's Research Application Laboratory has led the effort to address these needs during the past 15 years. Working in collaboration with NOAA, the National Severe Storm Laboratory, the Naval Research Laboratory, University of Colorado, University of New Hampshire, UCLA, and University of Wisconsin Madison, the team has created three products that are improving fundamental understanding of the nature and causes of turbulence.

Efforts focus on three areas: (1) Development and implementation of new techniques for obtaining automated in situ measurements and reports of turbulence encounters from commercial aircraft using the Eddy Dissipation Rate (EDR) Algorithm; (2) development of an automated detection system of in-cloud turbulence using the national NEXRAD radar network; and (3) development and implementation of an automated turbulence forecasting system called Graphical Turbulence Guidance (GTG). Even as research and development continues, products have reached a level of maturity that allows operational use by pilots and routing experts involved in tactical and strategic planning for avoiding turbulence.

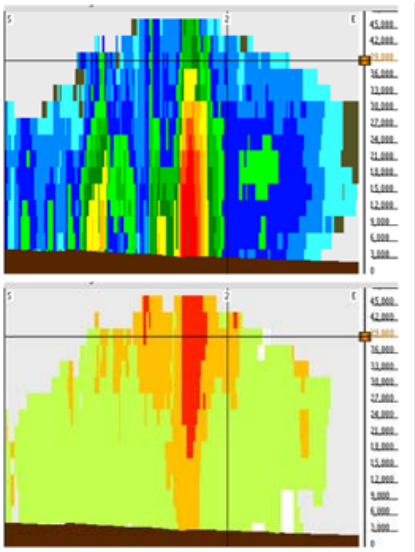
Installed on commercial aircraft to measure turbulence automatically, information about atmospheric turbulence levels is sent via downlinks to ground-based systems for input to turbulence diagnostic and forecasting software. With initial deployment on United Airlines and Delta Airlines complete, and Southwest Airlines in the process of installing this capability (called the Eddy Dissipation Rate or EDR), soon 520 aircraft will be able to generate automatic turbulence reports.

The figures below show the daily volume of automated reports from 100 United, 80 Delta, and 10 Southwest aircraft, providing a sense of the volume of turbulence reports now available to users. The number of Southwest aircraft will grow to 340 as EDR capability is deployed across their fleet. Of note: what appear to be lines of data actually represent hundreds of individual reports at closely spaced intervals, making them look like connected lines.

United Airlines Automated Turbulence Reports

Delta Airlines Automated Turbulence Reports

Southwest Airlines Automated Turbulence Reports (still in the deployment process)



Comparison of radar reflectivity (left) and NTDA-derived EDR (right) based on a vertical cross section through an actual cloud. Note high values of relectivity (red) associated with the rain shaft are not conicident with regions of elevated turbulence (red).

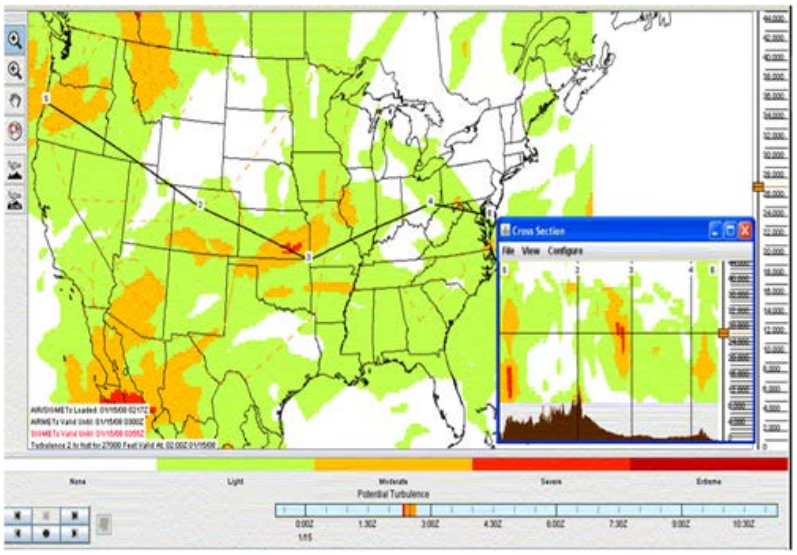
“Eliminating the lack of accuracy and precision associated with conventional turbulence reporting, the EDR automatic turbulence reporting metric is in the process of revolutionizing the way in which industry stakeholders conceive of and deal with atmospheric turbulence,” observes Bill Watts, Manager of Delta Airlines’ Turbulence Program.

The team has also developed the NCAR Turbulence Detection Algorithm (NTDA), which uses ground-based radars to detect and measure within-cloud turbulence (EDR), with algorithm output then mapped for chosen flight altitudes and displayed for users; the National Weather Service (NWS) has adopted and implemented NTDA on all of its radar systems.

The turbulence forecast product is termed the Graphical Turbulence Guidance (GTG) and provides a 4-dimensional capability to visualize turbulence along a given flight path. Users can observe a horizontal slice at any desired flight altitude, a vertical slice along any selected flight path, and can also select an arbitrary time in the future for either of these views, making it a useful flight planning tool.

Disseminated through the NCAR-developed and NWS-operated Aviation Digital Data Service web site, these products are reducing the number of turbulence encounters and the number of injuries incurred throughout the nation, says Bruce Carmichael, AAP director.

“This turbulence information will be used by automated decision support tools to help insure safe and efficient flight through our skies, making it an important component in the nation’s coming Next Generation Air Transportation System (NextGen),” Carmichael explains.



This graphic shows the result of a request to view a GTG 2-hr forecast of turbulence at Flight Level 270 over the CONUS at 2:30Z. The colors represent light (green), moderate (orange), and severe (red) areas of potential turbulence. The inset shows a vertical cross section along the flight path depicted from Portland, Oregon to Denver, Colorado, to Southeast Kansas, to Cincinnati, Ohio, to Washington, DC. Terrain is indicated at the bottom in brown. This diagram shows that the pilot could avoid the areas of predicted severe turbulence by flying a few thousand feet higher.

For more information please see: http://www.rap.ucar.edu/aap/themes/turbulence.php and http://weather.aero/turbulence and http://aviationweather.gov/adds/turbulence/turb_nav.php

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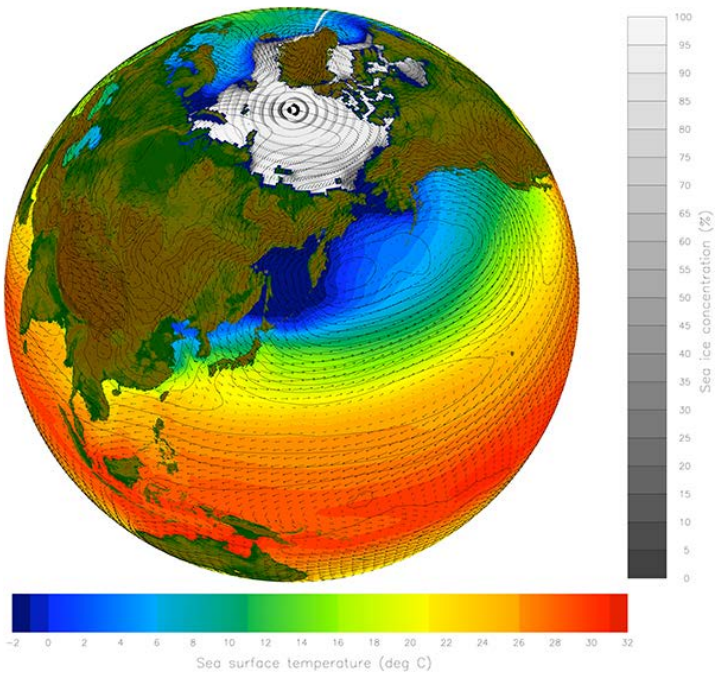
Community Earth System Model

by Nicole Gordon

In the early 1960s, NCAR scientists Warren Washington and Akira Kasahara began developing one of the world's first computer models of atmospheric circulation. They used a CDC 6600 computer in the basement of the Mesa Lab, before today's computing room was even built. The machine received input via punch cards and seven-channel digital magnetic tape, and generated output via two line printers, a card punch, a photographic plotter, and standard magnetic tape. In 1967, the pair published their first journal paper, "NCAR Global General Circulation Model of the Atmosphere."



This image, taken from a simulation of 20th century climate, depicts different aspects of Earth's climate system. The two color scales show sea surface temperatures and sea ice concentrations; sea level pressure and low-level winds are also illustrated, including warmer air moving north on the eastern side of low-pressure regions and colder air moving south on the western side of the lows. Scientists used the CCSM to produce this simulation. The newly released CESM, of which the CCSM is now a subset, will allow them to study the climate system in even greater complexity.

Climate modeling has come a long way since the days of punch cards. In August, NCAR released its latest and most advanced tool: the Community Earth System Model (**CESM**), a fully coupled, global model that provides state-of-the-art computer simulations of Earth's past, present, and future climates. CESM will be one of the primary models used to conduct simulations in support of the next assessment by the Intergovernmental Panel on Climate Change (IPCC), due in 2013–14.

Building on CCSM

CESM is the successor to the CCSM (Community Climate System Model), whose first version, the Community Climate Model, was created at NCAR in 1983. Scientists steadily improved and added capabilities to the model over the years, renaming it CCSM in 2001. A third version of CCSM was one of the main climate models used for the IPCC's 2007 assessment report, for which NCAR scientists shared a Nobel Peace Prize. The CCSM's fourth version, released last April, is now considered a subset of CESM.

CESM builds on CCSM, giving scientists a broader picture of Earth's climate system by incorporating more influences and feedbacks. With the new model, for instance, researchers can simulate the interaction of marine ecosystems with greenhouse gases; the climatic influence of ozone, dust, and other atmospheric constituents; the cycling of carbon through the atmosphere, oceans, and land surfaces; and the influence of greenhouse gases on the upper atmosphere. In addition, an entirely new representation of atmospheric processes in the CESM will allow researchers to pursue a much wider variety of applications, including studies of air quality and the role of aerosols in climate.

The improved realism of the model should also be helpful for studying and perhaps forecasting the evolution of ocean-atmosphere patterns (such as the El Niño/Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation), which dominate regional changes in weather and climate on interannual to decadal time scales.

"With CESM, we can pursue scientific questions that we could not address previously," says Jim Hurrell (NESL/CGD),

who is the current chair of the CESM Scientific Steering Committee. “Thanks to its improved physics and expanded capabilities, it gives us a better representation of the real world.”

Some specific questions that the model will be applied to include:

• What impact might warming temperatures have on the massive ice sheets of Greenland and Antarctica?

• How might patterns in the ocean and atmosphere affect regional climate in coming decades?

• How might climate change influence the severity and frequency of tropical cyclones, including hurricanes?

• What are the effects of tiny airborne particles, known as aerosols, on clouds and temperatures?

Akira Kasahara, pictured here, and Warren Washington relied on a CDC 6600 supercomputer to run the NCAR General Circulation Model that they developed in the 1960s and ‘70s. The model’s output was stored in the IBM 9-track magnetic tapes shown in this picture.

Preparing for the IPCC

CESM’s advanced capabilities will help scientists study climate change in greater detail, and they’ve already begun using the model for an extremely ambitious set of climate experiments to be featured in the next IPCC assessment. Although the publication of the assessment is still several years off, most of the simulations are scheduled for completion and public release beginning later this year, so that the broader research community can complete its analyses in time for inclusion in the report.

“We are working day and night to get all of the long-term climate change runs completed,” Jim says. “It takes the commitment of nearly everyone in the project, as well as strong collaboration with CISL.”

“It’s a big investment of time and takes a lot of effort from a lot of people,” concurs CGD/ACD scientist Jean-François Lamarque, who is working on the atmospheric chemistry component of the IPCC runs. One of the advantages of CESM for Jean-François is its ability to simulate interactive chemistry. “By having interactive chemistry, you can better capture feedbacks between chemistry and climate,” he says. “We can do this in CESM, but couldn't in CCSM4."

The long-term IPCC runs are being carried out mainly on CISL’s bluefire supercomputer. “Through a combination of careful planning both by the CGD and CESM teams and cooperation from CISL staff, the CESM team is able to carry out the IPCC runs on the necessary schedule while still allowing bluefire to support the computational needs of many users from the university and NCAR communities,” says Dave Hart, CISL’s user services manager.

CESM, which is supported by NSF and the Department of Energy, is freely available to researchers worldwide.

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Partnering

Strong partnerships are the keystone for all scientific endeavors, and are a focus for NCAR. The following stories draw attention to only a few of the collaborations that are NCAR's lifeblood. Among these is a first-time exchange between NCAR's Advanced Study Program and Howard University, a member of the Historically Black Colleges and Universities, and a new ASP-Integrated Science Progam-Centers for Disease Control and Prevention post-doc program. Also, with growing national focus on Climate Services, the Research Applications Laboratory has developed a new program with this broad topic as its focus. Details on all of these efforts are available in the following pages.

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Dr. Kang Goes to Washington

by Rachel Hauser

Recently returned from a semester-long stint at Howard University in Washington, D.C., Advanced Study Program (ASP) Fellow, Song-Lak Kang, gained first-hand – first-time – experience teaching graduate students. The inaugural visiting scholar in a pilot program partnering National Center for Atmospheric Research (NCAR) ASP post-doctoral Fellows with Howard University and other Historically Black Colleges and Universities, Kang also had an opportunity to meet and work closely with scientists at Howard, NASA's Goddard Space Flight Center, and the U.S. Department of Agriculture.

The teaching experience was invaluable, says Kang, who did not have the opportunity to teach classes while doing his PhD work at Pennsylvania State University. Teaching appealed to Kang as an untried challenge, but will also help with his future endeavors, as he is currently applying for university faculty positions. His classroom experience at Howard will be looked at positively by academic search committees when considering applicants for tenure-track positions.

"In addition to teaching, as a scientist at an early stage of my career, having a chance to speak at a variety of seminars and meetings at Howard and in the Washington, D.C. area were useful for gaining footholds for future research associations," explains Kang. "Already, the meetings between myself and researchers at Howard University and the USDA have led to scientific collaboration."

The exchange also proved to be a winning proposition for Howard University. Not only did the university gain a well-liked instructor, but both students and faculty had a chance to gain insights on many of the latest breaking ideas and results in meteorology as a result of Kang's classes and seminars.

"Dr. Kang's research expertise in turbulence, boundary layer processes, and mesoscale meteorology provided relevant and updated knowledge for both the classroom and ongoing research," says Gregory Jenkins, chairperson of Howard's Department of Physics and Astronomy.

Kang is an enthusiastic proponent of the effort, and as the initial program participant he gained valuable insights on both the benefits, as well as things future candidates might consider before taking part in the program. Among these latter: participate early on in the two-year ASP stint. Even though his four months at Howard was not included as part of his official 2-year ASP tenure, he left to teach at Howard near the end of his post-doctoral program and had only a short amount of time left after his return to NCAR to complete his ASP Fellow research requirements. Also, with a wife and school-aged daughter, family logistics proved challenging. Kang didn't want to relocate his family to Washington, D.C. for just four months. A visit back to Colorado over the Thanksgiving holiday eased the family separation, but it is an issue he urges future participants in similar situations to consider.

The positives of the experience, beyond those described above, include an unprecedented level of exposure to others working in similar fields. Many of the ties Kang now has to the wider university and science community might not otherwise have occurred. Among the benefits of working and living in the nation's capitol, was direct access to people working in the many national research institutions. Through Howard University, Kang developed a new cohort of colleagues in his field, having been introduced to researchers in other university departments including Physics and Astronomy, Mechanical Engineering, and Chemistry, and he now acts as an academic advisor to Mike Hicks, a Howard PhD candidate.

"I hope we can capitalize on this success and engage more Fellows in similar experiences, at Howard and other partner institutions," says Maura Hagan, director of the Advanced Study Program. "This bridge between ASP and historically black colleges and universities provides an invaluable teaching tool for post-doctoral Fellows, and strengthens links between NCAR and the university community."

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NCAR Creates Climate Science and Applications Program

by Rachel Hauser

NCAR has a long history of providing a home for science benefiting society. Recently NCAR's Research Applications Laboratory (RAL) created the Climate Science and Applications Program (CSAP) as a focal program, bringing together NCAR's social and physical sciences. Fostered by support from RAL, the Integrated Science Program (ISP) and NCAR management, social science, particularly as it relates to climate- and weather-effects on human society, is considered an important NCAR mandate and a natural addition to RAL's current applied research program. CSAP scientists engage in a variety of multidisciplinary scientific endeavors and develop applications to support decision makers needing to gain better traction on understanding the relevance and effects of changing weather and climate on coupled human and natural systems.

The physical climate and weather models that NCAR is well known for within the scientific community are important components in addressing research questions related to societal issues. However, used alone these physical models are not sufficient to answer societally relevant questions about now and future impacts of the changing environment. Social science approaches are essential to evaluating vulnerability and response capacities to, for example, warming temperatures, varying precipitation regimes, and carbon emissions mitigation.

Recognizing the need for such a capacity, real progress has occurred by immersing NCAR's social scientists with existing physical science programs. Many of these cross-cutting opportunities have been fostered by ISP, which facilitates collaboration within the organization and across the university community. Among CSAP's efforts to meet societal needs and bridge between the sciences:

- Governance and Adaptation – Water and Fisheries: The governance arrangements defining the role and scope for public involvement in natural resource management have important impacts on the vulnerability of coupled human-natural systems to climate-related disruption and their capacity to adapt to evolving risks posed by climate change. These arrangements determine who makes which decisions, how those decisions are made and enforced, decision efficacy, and mechanisms for resolving disputes. During the past year, CSAP research focused on analysis of governance and adaptive capacity in two types of natural resource systems (water resources and marine fisheries), as well as in Latin American cities (e.g., Mexico and Buenos Aires).
- Urban vulnerability to weather and climate variability, particularly in the emerging medium, large and megacities in Asia and South America, is already an issue and will be more so in the near future under warming climate. To reduce vulnerabilities, the Resilient and Sustainable Cities program was created to meet the challenge of emissions reductions and improve a city's capacity to cope with environmental impacts. ADAPTE, a key project from this program, brings together scholars from different countries and disciplinary backgrounds to investigate the independent and combined effects of exposure to weather related stresses, air pollution, and human-health vulnerability in Buenos Aires, Argentina, Bogotá, Colombia, Mexico City, Mexico, and Santiago, Chile.
- Weather, Climate and Health: Recent CSAP work also includes training community health practitioners – among these are traditional healers – in Uganda to recognize plague symptoms, and to use donated cell phones to contact clinics for patient assistance. A truly multidisciplinary focus, this work brings together predictive weather modeling expertise with anthropological and health and climate specialization.
- Co-funded by NSF's Dynamics of Coupled Natural and Humans Systems (CNH) and Ecology of Infectious Diseases (EID), work in Veracruz, Mexico couples natural-human system interactions to better understand and predict the spread of Aedes aegypti mosquitoes, vectors of dengue fever, along an altitude-gradient from Veracruz to Puebla ,Mexico, considering the combined effects of geography, weather and climate, and human and vector ecology.
  - This work features participatory epidemiology, in which high school-aged students in Veracruz are entrained to monitor mosquitoes and weather; these students will train other high school students living along the altitudinal-gradient under study.
- The GIS program integrates Earth system and social sciences through spatial analysis and interoperability of georeferenced information. The GIS program also ensures that global climate data are both easy to access and useful for on-the-ground decision makers, such as those managing cities, tribes or ecosystems. A growing clamor for information that can be quickly put to use in addressing the myriad environment-and-society questions has become a priority for leaders at all levels.
- A follow-on to the Phoenix heat stress study that aimed to better understand populations' adaptive capacity to

heat through integrating quantitative and qualitative data, CSAP's SIMMER project (System for Integrated Modeling of Metropolitan Extreme Heat Risk) is funded by NASA to explore effects of urban heat on human health. This highly interdisciplinary 3-year effort will focus on modeling extreme heat vulnerability in Houston, Texas and Toronto, Ontario.

The emerging area of Climate Science is bringing together basic research with operational provision of high quality data to enable policy makers to make significant, climate-informed decisions. NCAR's cutting edge research and data capabilities are shaping the new climate services efforts in the United States and internationally. NSF support funds these research efforts, as do funds from NASA, the Inter-American Institute for Global Change Research, Centers for Disease Control and Prevention, and the InterAmerican Development Bank.

A Ugandan healer holding his dream stick, an integral tool to traditional healing practices.

Under climate change, health impacts of air pollution and weather extremes may be aggravated, particularly in large cities and in nations whose economies are in transition. Panoramic view of Santiago, Chile ©iStockphoto.com/ralphoto

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New data service speeds the progress of research

by Brian Bevirt

Copying data between computers, filesystems, and tape archives can be time-consuming when handling enormous quantities of data, and this repetitive process impacts scientific productivity. To speed the pace of research, NCAR's Computational and Information Systems Laboratory (CISL) has initiated a paradigm shift in its high performance data infrastructure by creating a large, centralized pool of data storage shared by supercomputers, data servers, and analysis and visualization systems. In the past, disk space was fragmented because each computer had a dedicated disk system associated with it. CISL's new central data storage pool, called the GLobally Accessible Data Environment (GLADE), reduces copying of model output between computer systems and allows online access to data collections – such as NCAR's Research Data Archive – by both local and remote users. Reducing the number of times scientists have to copy their datasets also creates the benefits of using disk space more efficiently and reducing the amount of data written to tape archive. In the past, much of this intermediate data had to be written to tape before it could be used on the next system. GLADE's innovative design allows significantly faster and more efficient user workflows, the sequence of tasks they have to perform during scientific computation and analysis.

One breakthrough in GLADE's design is that it can mirror the needs of user workflows rather than requiring users to adapt to the system's design, which is typically inefficient. Another is that GLADE's 1.6 petabytes of centralized disk storage space provides system managers and scientists with a synoptic view of the available storage, thus enabling them to more effectively manage and allocate resources between modeling, analysis, and data management requirements. This results in a more effective overall system performance in service to science. Additional, consolidated services – like wide-area high-performance data transfer engines using grid middleware such as gridftp – enhance the bandwidth available to transfer data between other sites and NCAR. This capability facilitates collaboration and improves the ability of scientists to use national high performance computing infrastructure.

GLADE is supporting NCAR's participation in the Intergovernmental Panel on Climate Change Fifth Assessment Report campaign through the Earth System Grid science gateway with 400 TB of GLADE dedicated to this campaign. GLADE also enhances NCAR's Community Data Portal and Research Data Archive (RDA). In particular, GLADE's size is designed to support anticipated growth in certain critical data products over its lifetime. For example, the RDA datasets online are expected to grow to 250 TB in 2011, six times the size of the online RDA in 2010. For the first time, users of NCAR computing resources now have high-speed direct access to the RDA. Internet users will retain their current workflows, and all users will benefit from increased speed, dataset availability, and data services. CISL's data servers and GLADE central data storage infrastructure will also speed data access for a variety of other data-intensive projects, and these projects will be able to request dedicated space through an allocation process currently under development.

CISL engineers are studying GLADE's performance in the Mesa Lab production environment, and they will use the knowledge gained from this operational experience to adapt the design for the much larger (greater than 10 petabytes) successor system to be deployed at NWSC. Researchers also benefit from using GLADE now because they will be prepared for a smooth transition to NWSC's new resources. Continued enhancement of NCAR grid services and their usability sustains CISL's commitment to the future of supercomputing.

The new GLobally Accessible Data Environment (GLADE) system currently offers 1.6 petabytes of shared disk storage. NCAR's supercomputer users receive numerous benefits because GLADE provides computational, analysis, and visualization work spaces common to all CISL computing resources, and because storage can be allocated according to project needs. Immediately after deployment, GLADE significantly expanded online data available for the Research Data Archive, the Earth System Grid, climate model projections for the upcoming IPCC report, and the NCAR-UCAR Community Data Portal.

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Post-doctoral Fellowships Bridge Climate-Health and Climate-Ecology Studies

by Greg Guibert

In 2010, NCAR partnered with the National Ecological Observing Network (NEON) and the Centers for Disease Control and Prevention (CDC) to create several new transdisciplinary postdoctoral research opportunities. In both cases, the fellows will split time between the partner organizations and contribute to cutting-edge research across disciplines and institutions. The creation of the positions extends NCAR's commitment to pressing the boundaries of integrated research and science in service of society's needs. Their work is supported through the Integrated Science Program (ISP).

NEON

The postdoc fellows with NEON will seek to develop a fuller understanding of the interactions of climate change with terrestrial ecosystems and the carbon and water cycles and is currently seen as a grand challenge in environmental and Earth system science. Understanding these complex interactions requires expertise and integration across a broad spectrum of scientific domains and provides an opportunity for recent doctoral graduates to continue pursuing their research interests in an environment that fosters the development of transdisciplinary projects.

Uncertainty in the response of the coupled carbon-climate system to anthropogenic CO2 is now considered to be one of the largest uncertainties in scenarios of future climate. Countless local flux and process studies have been conducted, but scaling these up to continental scales and reconciling them with atmospheric inverse estimates to obtain an observationally-based understanding of the climate sensitivity of ecosystem carbon storage remains a grand challenge research question of great societal concern.

Such interactions will be an important factor in determining the evolution of ecosystems and the services they provide to human societies, the rate and magnitude of climate change, and the severity of climate change impacts during the next century. The complexity of such interactions, and their importance for environmental quality and human health and well-being, argues for a multidisciplinary approach and setting for training the next generation of climate and ecological scientists.

Bill Sacks, the 2010 NEON post-doc, received a Ph.D. in Environment and Resources from the University of Wisconsin-Madison in August. His dissertation research investigated interactions between agricultural management and climate, through climate and land surface modeling and data analysis. Over the next two years, he will be working with Dave Moore (NEON) and Andy Fox (NEON/NCAR) to develop a data assimilation system in NCAR's Community Land Model (CLM). This will allow more objective parameterization of CLM, and will also provide a tool that NEON can use to scale its data up in space.

CDC

The two-year postdoctoral training fellowship with CDC provides opportunities to address public health concerns related to climate variability and change. With 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, there is a clear and immediate need for a new generation of scientists who can work across disciplines. Fellows will acquire specific training in atmospheric and climate research following NCAR's established postdoctoral training program, as well as training in public health at CDC. The goal is to increase the number of scientists with the appropriate experience and training to conduct research in this newly emerging field.

The fellows will spend time at NCAR for research and training in weather/climate analysis and modeling, and at CDC for research and training in epidemiology and disease ecology at the National Center for Zoonotic, Vector-borne and Enteric Diseases (NCZVED)/Division of Vector-Borne Infectious Diseases (DVBID) located in Fort Collins, Colorado and the National Center for Environmental Health (NCEH), located in Atlanta, Georgia, (at NCZVED) or for research and training in environmental health (at NCEH).

Chris Uejio's work builds the evidence base to anticipate how global environmental changes may influence public health following the US Environmental Protection Agency endangerment ruling. His research portfolio examines a broad range of health problems including heat waves, mosquito transmitted diseases like dengue and West Nile Virus, and the safety

of drinking water. Accurately anticipating climate impacts requires reconciling knowledge from multiple disciplines including atmospheric sciences, public health, ecology, and the social sciences (e.g., geography).

Sean Moore's research addresses how climate variability and climate change can influence public health. He is currently investigating how both short-term weather events and longer-term climate variability affect infectious diseases such as plague, Lyme disease, and dengue that are transmitted by insects and ticks. Predicting how climate change will alter disease risk requires a better understanding of how transmission responds to climate variability both seasonally and at longer time scales. Sean's projects include an analysis of the association of inter-annual climate variability with plague outbreaks in Uganda, and an examination of the influence of meteorological variables on seasonal patterns of Lyme disease incidence in the United States.

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Getting Back to Basics: A look at NCAR core science efforts

In addition to serving our research community, performing basic research is another important focus for NCAR. With limited space, only a few of the noteworthy efforts in this area have been captured. Among these are research and modeling of carbon emissions from controlled burns and new modeling and observational results stemming from the High Altitude Observatory's coronal multichannel polarimeter.

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Where there’s smoke, there are carbon emissions

by Rachel Hauser

Prescribed burns could offer a one-two punch in terms of ecological system benefits. Not only do controlled burns seem to reduce wild fire severity, they may also reduce carbon emissions resulting from similar sized wild fires, according to a study by NCAR’s Christine Wiedinmyer and Northern Arizona University’s Matthew Hurteau. When atmospheric conditions are favorable, burning underbrush and surface fuels can result in lower fire intensity and less carbon escaping to the atmosphere during controlled burns. Moreover, by reducing underbrush and forest litter, larger, carbon-rich trees are less vulnerable to wild fire. Using the Fire INventory from NCAR (FINN), a fire emissions model created by Wiedinmyer, and satellite observations, the researchers estimate that carbon emissions due to fire can be reduced by 20 percent on average, and as much as 60 percent in some forest systems.

The western U.S. is experiencing increases in wild fire severity and size, which partially played into the choice of focusing research on this area. With climate expected to become warmer and drier in much of this part of the nation under changing climate scenarios, this reality is likely to continue. Another driving motivation: prior to this study, quantification of carbon emissions from controlled burns had not been done at this scale. In addition to assisting with land and forest management planning, the research results will assist in regional and national policy planning efforts.

As part of its emissions compliance efforts, the United States relies on a certain amount (do I need to specify; do you know what this is?) of carbon uptake by forests to satisfy part of its national climate mitigation strategy. Better understanding of and finding ways to minimize wild fires on public forest ecosystems will aid these efforts. In addition, having a sense of how much carbon is emitted from controlled burns will be important information for decision makers developing and studying carbon policy options, explains Wiedinmyer.

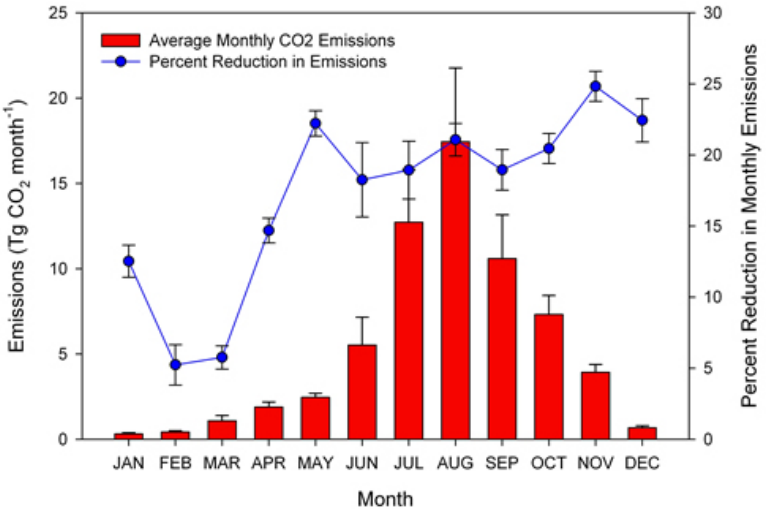
“Forest managers have long been convinced of the utility of managed fires in boosting overall forest health, as well as minimizing damage from wild fire,” says Hurteau.

Wiedinmyer and Hurteau used 1-km resolution satellite images from MODIS (Moderate Resolution Imaging Spectroradiometer), and FINN to estimate carbon emissions from fires in 11 western states occurring between 2001 and 2008. For the same time period, they also estimated the carbon emissions that would have resulted, had the wildfires been replaced with prescribed burns in forests that historically burned with high frequency. Depending on vegetation mix and forest location, results from their efforts show a reduction in carbon emissions from 37 to 63 percent for forests subjected to prescribed burns.

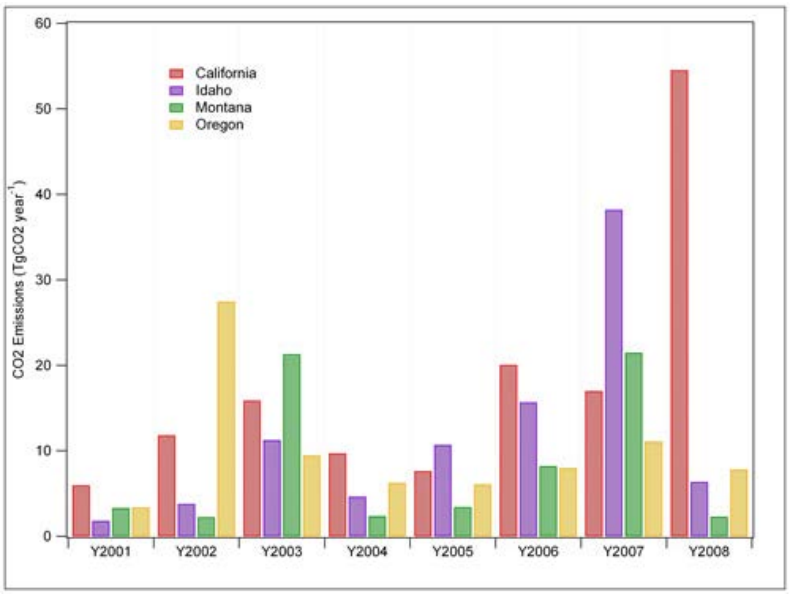
“Given the recognized need to restore fire to many dry forest types, such as ponderosa pine, we wanted to quantify the potential emissions reduction that prescribed burning may have as compared to emissions from wildfire,” Hurteau explains.

Actual carbon emissions reductions resulting from pursuing controlled burns will likely be lower than our results predict, cautions Hurteau, because the study assumes prescribed burns could occur in any suitable forest. Practically speaking, given the number of acres of public lands and limited resources, land resource managers are unlikely to be able to initiate prescribed burns in all of the areas that would benefit from such efforts.

“Our research shows that, in addition to reducing carbon dioxide emissions, prescribed burns could lead to additional air quality benefits such as a reduction in fine particulate matter and carbon monoxide,” says Wiedinmyer. “This is the focus of ongoing work.”



Annual CO2 emissions from fires in California, Idaho, Montana, and Oregon. CO2 emissions can vary as much as a factor of 10-20 from year to year



Monthly averaged (2001-2008) estimated CO2 fire emissions for all eleven western states (Red). Average percent reduction in CO2 emissions when prescribed burning is applied in applicable forest types (blue). Error bars represent the standard
error of the monthly estimates.

A U.S. Forest Service employee working on a prescribed burn in Oregon's in Ochoco National Forest.

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2010 Annual Report

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Taking STEPs to Improve Short-term Forecasting Capabilities

by Greg Guibert

STEP (Short-Term Explicit Prediction) is a NCAR cross-laboratory program with an overarching goal to improve short-term forecasts of high impact weather. STEP defines “short term” as forecast periods out to approximately 36 hours and focuses on high impact weather such as severe thunderstorms (heavy rain, tornados, downburst, flash flood, lightning and hail), winter storms (snow, freezing rain and drizzle), and hurricanes. One of the chief objectives of STEP is to coordinate and strengthen the disparate short-range forecasting efforts at NCAR, ranging from basic research to serving the operational community domestically and internationally.

The STEP basic research will focus on the following six areas because of their important role in improving the short range forecast of high impact weather and NCAR’s expertise in these areas:

- Dynamics and predictability of high impact weather systems
- Field campaign and prototype demonstration
- High-resolution data assimilation
- High-resolution NWP with WRF-ARW
- Nowcasting
- Verification

The ultimate goal is to transfer these forecast systems to universities, NWS, NCEP, FAA, and other mission agencies for research collaboration and operational prototype demonstration and evaluation. Feedbacks from the operational evaluation will provide clearer goals and directions for further research.

This NCAR/STEP grant to EOL has focused on improving our understanding of warm season precipitation and associated nowcasts through basic research and improved S-Pol products. This work has included analyses of data from the Convective and Orographically-induced Precipitation Study (COPS) and the development and verification of dual-wavelength radar (S- and Ka-band) retrievals of boundary layer humidity and cloud liquid water content (LWC).

A nine-year radar climatology was performed in preparation for COPS. It provided interesting results about the locations and timing of convective development in the low-mountain regions around the Black Forest in Germany. One somewhat surprising feature was a high frequency of convection initiation (CI) events in the Rhine River Valley and not just in the higher terrain. The frequency of storms in the mountains was two times greater than the valley but that still left a large number of CI events in the valley. Preliminary analyses of Doppler on Wheels (DOW) mobile radar data from COPS highlight the frequency of boundary layer convergence zones within the valleys and along the slopes of the Black Forest Mountains. These boundaries may be a cause of the frequency of CI events within the Rhine River Valley. COPS was the focus of three collaborative papers in press.

Progress has also been made on the development and verification of dual-wavelength radar retrievals of boundary layer humidity and cloud liquid water content (LWC). Colorado REFRACTT (Refractivity Experiment For H2O Research And Collaborative operational Technology Transfer) project humidity retrievals compared favorably with nearby soundings and GPS retrievals. The Barbuda RICO project LWC retrievals compared favorably to in-situ aircraft measurements. Two publications on the humidity and LWC algorithms are recently published and in press, led by Scott Ellis. These retrieval techniques are currently being automated to provide real-time moisture and LWC estimates for the upcoming DYNAMO (Dynamics of the Madden-Julian Oscillation) field campaign.

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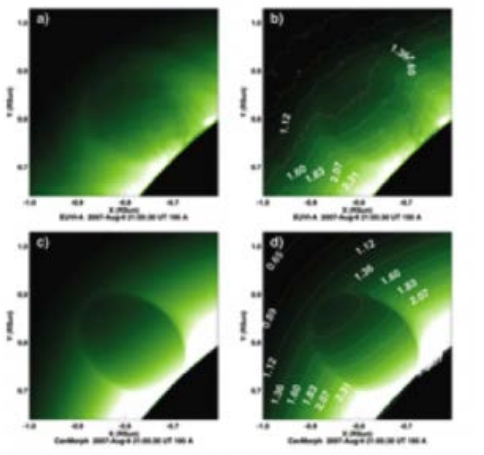
Forward-modeling of Polarization Signals: Gaining A New Perspective on the Solar Corona

by Rachel Hauser

Solar, climate, weather and similar models are designed to replicate natural phenomena. To check model accuracy, it is typical to compare real-world observations with modeled. When it comes to considering solar dynamics, modeling by its nature is more nuanced and complex than Earth-bound models not least because of our relatively remote link to the Sun – distance alone reduces immediacy of understanding. Assisting with this effort are polarimeters, instruments that measure the Sun's magnetic activity. Polarimeters estimate magnetic field by measuring several components of visible radiation; the brightness of the Sun's polarized light is proportional to the strength of the magnetic field along the line of sight. Developed in NCAR's High Altitude Observatory (HAO), the coronal multichannel polarimeter (CoMP) provides, for the first time, ongoing views of magnetism in regions of the solar atmosphere where coronal energy is stored. With CoMP, solar physicists at HAO and around the world are pushing understanding of coronal dynamics forward.

CoMP provides a full view on the solar corona and its magnetic fields, tracking magnetic activity around the edge of the Sun. With sensitive, low-noise infrared sensors, CoMP can measure the intensity, velocity, and polarization of the solar corona's magnetic field, with readings available every 15 minutes, if needed. Today, CoMP data are providing new insights on solar events such as coronal mass ejections (CMEs), among other stellar dynamics. For instance, CoMP's detailed observations can be compared to "forward models" that incorporate theoretical descriptions of the evolution of magnetic fields and other properties – such as variations in plasma density and temperature – to reproduce coronal structures and dynamics.



Forward modeling a coronal prominence cavity (Gibson et al., 2010). (a) STEREO EUVI-A image of the cavity with (b) intensity contours overlaid. (c) Forward modeled (line-of-sight integrated) EUV emission using model density and temperature with (d) intensity contours overlaid. Contours are in units of "Data Number"(DN) per second.

HAO's Sarah Gibson has led a concerted forward-modeling effort during the past two years. With support from the International Space Science Institute (ISSI), an international team of researchers is comparing CoMP and other data to models in order to better understand and predict coronal prominence cavity morphology and dynamics. Understanding prominence cavities will feed CME understanding that, in turn, influence space weather and the storms that can disrupt satellite communications and air transportation (particularly at high latitudes), as well as impact human space exploration. Prominence cavities are regions where magnetic energy is stored, the more energy stored, the stronger the CME and more serious the resulting weather and storm effects on regions of space surrounding the Earth. Coronal prominences consist of dense, relatively cool mass that collects along coronal magnetic energy lines. Such a prominence is often surrounded by a dark, circular-cross-section cavity that extends as a tunnel along its length. These structures can also frequently be seen erupting within coronal mass ejections.

Modeling coronal white light (e.g., as observed by HAO's Mk4 Coronameter) is simplest, explains Gibson, because white light generation depends on a single solar characteristic – plasma density. Other coronal observables that aid understanding of solar activity, like extreme ultraviolet (EUV) and soft X-ray (SXR), also depend on coronal temperature.

"But the concept is the same. A 3-dimensional distribution of density and temperature from a theoretical model is used to predict what the corona would look like in EUV or SXR," says Gibson.

Seen in the accompanying movie, forward modeling was used to predict morphology of a coronal prominence cavity. The animation shows EUV observations of a cavity from NASA's STEREO spacecraft on the top/left, as well as the forward-modeled predicted EUV for the coronal cavity on the bottom/right. As time goes by in the movie, it's possible to

see the 3-dimensional, tunnel-like cavity rotate past.

Because its observations include information on magnetic fields as well as density and temperature profiles, CoMP data are slightly more complex than that of STEREO, however, forward modeling can still be run. Jim Dove, an astrophysicist at Colorado's Metro State College and an HAO visitor in 2010, has worked with Gibson and other HAO scientists, including Laurel Rachmeler, Steve Tomczyk, and Phil Judge, to compare theoretical models of coronal magnetic fields and plasma density and temperature to CoMP coronal observables. In doing so, the scientists were able to establish that CoMP observations of a coronal cavity were well reproduced by a coronal magnetohydrodynamic model of twisted, slinky-like magnetic fields.

With the initial forward-modeling effort completed, the next step will be to compare CoMP observables side by side for a range of magnetic field models, including HAO models, and those from the community, says Laurel Rachmeler, a post-doctoral student working with Gibson in HAO.

"This work relies on CoMP observations and will reveal new coronal magnetic signatures that allow us to choose between theoretical models, assessing which one provides the most accurate representation of coronal activity," Rachemeler says. "It's exciting work because the observations provided by CoMP are unprecedented, and can greatly help advance current models."

Download Movie - http://www.hao.ucar.edu/Profiles%20In%20Science/Images/sgibsonMovie1.mov

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Metrics

These metrics are qualitative and quantitative measurements and assessments of the productivity, quality, and impacts of NCAR programs and activities.

Field Programs

Collecting field data has always been a scientist's stock in trade. Direct observations shed insights on weather, climate, and related Earth-system phenomena. Ranging from a few weeks to several months, field programs (field-based observing campaigns or experiments) ensure successful data collection.

NCAR led or participated in 49 field campaigns in seven countries and the United States. Locales ranged from as large as the eastern half of the United States to events as famous as the Vancouver 2010 Olympics, and included more than 1,100 participants.

Editorships

NCAR staff also 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.

Fifty-nine NCAR staff served in 84 different editorial roles on 66 different publications or journals. Publications included top-tier journals such as *Journal of Geophysical Research - Atmospheres and Atmospheric Environment* to targeted journals such as *Boundary-Layer Meteorology and Carbon Management*.

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, 136 NCAR staff served in a multitude of roles on 397 external committees for national and international scientific, education, and governmental organizations, including entities such as the Intergovernmental Panel on Climate Change (IPCC), the American Geophysical Union (AGU), and the American Meteorological Society (AMS). Positions ranged from Chair to Councilor. More than 66% served on more than one committee.

Presentations

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

More than 100,000 people were in the audience when 276 NCAR staff made more than 1,500 presentations across the country and around world, from Foz do Iguassu, Brazil to Melbourne, Australia. Examples range from Cindy Bruyere's (NESL-MMM) presentation on lessons learned from North American Regional Climate Model (NRCM) experiments in Tucson, Arizona to a presentation on the design of polychromatic modulators for spectro-polarimetry by Alfred deWijn (HAO) in Maui, Hawaii.

Colloquia & Symposia

Smaller, often unilateral events, colloquia, symposia and tutorials focus primarily on education or training. This metric measures entire events that NCAR hosted alone, or co-hosted with other institutions or agencies.

NCAR sponsored 65 colloquia in Boulder and abroad. Participants per session averaged out to more than 40, for a total audience of more than 2,600 peers and students. Some of the co-hosts include the Air Force Weather Agency and NOAA and the Inter-American Institute for Global Change Research.

Workshops

NCAR-hosted or -co-hosted workshops and conferences are generally larger, bilateral events convened for the purpose of discussion, consultation and exchange of views and information.

NCAR sponsored 66 workshops and conferences in four countries and six U.S. states and Puerto Rico. We partnered with sponsors from the university community, such as the University of California, Berkeley, the University of Colorado and the Seoul National University, with government agencies including the National Weather Service, the Department of Energy and NASA, as well as with non-profit partners like the International Astronomical Union and the Tyndall Centre for Climate Change Research. In total, these workshops and conferences reached just over 3,500 participants around the world.

Teaching Appointments

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 34. Twenty-one percent of these appointments occur in seven countries around the world; 79% took place in eigh U.S. states and the District of Columbia, including NCAR's Super Computing partner, the University of Wyoming. The longest term is 25 years and counting and the current cumulative commitment adds up to more than 150 years of service.

Graduate Advisors

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

Of the 103 graduate students that have NCAR staff serving as graduate advisors, 22% hail from Colorado institutions; 28% attend schools in 19 other states. The remaining 50% study at schools in 23 countries around the world, including five students from the University of Warsaw who are advised by Wojciech Grabowski.

Thesis committees

NCAR staff serve as dissertation or thesis committee members for internal and external graduate students.

Twenty Masters students and 87 PhD candidates work with 62 NCAR staff as they pursue their degrees from universities in 17 U.S. states; this includes 40 students from Colorado institutions. Twenty-one students come from 16 countries, with Taiwanese students leading the international count at four.

NCAR Student Appointments

Students also enjoy NCAR-based appointments.

In FY10, there were two Graduate Student, nine Graduate Research Assistant and 14 undergraduate Student Assistant appointments. There were also 21 student internships coordinated through the Summer Internships in Parallel Computational Science (SIParCS) program, (**www.cisl.ucar.edu/siparcs/index.jsp**) and the EOL Undergraduate Engineering Internship program (**www.eol.ucar.edu/about/work/eng-internship**). These students hail from home institutions ranging from Mesa State College to Tufts University. NCAR also awards postdoctoral fellowships to talented staff through the Advanced Study Program (**www.asp.ucar.edu**) and other laboratory visitor programs (**www.ucar.edu/opportunities/postdocs)**.

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 3-year terms. This appointment is particularly suitable for parties who desire an extended, close-working relationship on scientific problems of mutual interest. Currently 33 hold appointments including Dr. Mary Hudson of Dartmouth College. Along with her students and postdoctoral research staff, Dr. Hudson is modeling sudden changes in relativistic electron fluxes and solar cosmic rays at and inside the 24-hr orbital period of many communication and navigation satellites, and effects of global oscillations of the Earth's magnetic field, associated with changes in solar wind conditions, which have their origins at the Sun; Dr. Hudson collaborates with HAO.

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 12 with the recent appointment of eminent NESL/MMM scientist Margaret (Peggy) LeMone.

K-12 Outreach (top) 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-one NCAR Staff worked with K-12 students from 35 schools. Activities included mentoring, lectures, tours and field trips reaching 13 different communities. Examples range from serving on an exhibit advisory committee, to

providing and vetting science content in Web sites and modules, to supporting community outreach at local community events, including judging at a science fair and supporting Super Science Saturday.

Among the highlights: Jacob Fugal (ASP/EOL Postdoc) worked with students on measurement accuracy and water in our atmosphere at Creekside at Martin Park School in Boulder, Peggy Lemone (NESL/MMM Senior Scientist Emerita) worked with teachers and students on a film project at Horizons K-8 School and Sarah Tessendorf (RAL Project Scientist) mentored a student at Niles North High School in Skokie, Illinois.

Awards

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

Thirty-seven staff received special recognition for their work in FY10. Warren Washington (NESL/CGD) received the 2009 National Medal of Science, the highest honor bestowed by the U.S. government on a scientist, for Warren's "fundamental contributions to the understanding of Earth's coupled climate system through numerical simulation, leadership in U.S. science policy, and inspiring mentorship of young people of all backgrounds and origins."

George H. Bryan and Richard Rotunno received the AMS Banner I. Miller Award for their publication, "The Maximum Intensity of Tropical Cyclones in Axisymmetric Numerical Model Simulations," published in *Monthly Weather Review*. The award is presented for an outstanding contribution to the science of hurricane and tropical weather forecasting published in a journal with international circulation during the past 48 months.

Bill Mahoney (RAL) received the AMS Kenneth C. Spengler Award for his exemplary leadership in fostering economic growth of the weather and climate enterprise. The award is presented to an individual whose efforts have contributed to the growth of the weather and climate enterprise while materially fostering a sense of community and creating synergistic linkages between the public, private, and government sectors as well as the user community.

Peter Backlund (DIR) was selected as an American Association for the Advancement of Science Member. The AAAS awards this to four tenths of one percent of the membership in a given year. Rolando Garcia (NESL/ACD) and James Hurrell (NESL/CGD) were selected as AGU Fellows. This honor is awarded to only one tenth of one percent of the membership in a given year. William Randel (NESL/ACD) was selected as an AMS Fellow in 2010. This honor is awarded to two tenths of one percent of the AMS membership in a given year.

Fellowships

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

Four NCAR staff received fellowships in 2010. Natasha Flyer continued her fellowship at the Oxford Center for Collaborative Applied Mathematics (OCCAM), situated in the Mathematical Institute at the University of Oxford. The objectives of OCCAM are to develop innovative mathematical and computational methods for application to biology, engineering, geoscience, and industry. During her stay, Natasha's research has focused on the development of radial basis functions, a novel mesh-less computational method, for 3-dimensional modeling of geophysical phenomena.

Scientific and Technical Visitor Appointments

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.

FY2010 numbers had a 5% increase over 2009. This year, NCAR Visitors hailed from 345 institutions, located in 44 different U.S. states and 41 different countries.

Visit Length - Number of Scientific and Technical Visitors in FY10
1-7 Days - 230
8-14 Days - 93
15-30 Days - 83
1-2 Months - 103
3-6 Months - 187
6 Months - 1 Year - 103
Total 799

Scientific and Technical Visitor Types - Headcount in FY10
Visitors on Payroll - 55

NCAR funded Visitors - 328
Externally funded Visitors - 416
Total 799

Publications

This is NCAR's first year with our publication records 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 preserve and make freely accessible the scholarly record of UCAR, NCAR, and UCP, in support of 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. OpenSky services are provided in support of the UCAR Open Access Policy and institutional reporting requirements.

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, 2009 to September 30, 2010. Search for recent NCAR publications by author, date, keyword or status please go to the **UCAR Open Sky Institutional Repository**.

For excellent library resources please go the NCAR Library Web site at: **www.ucar.edu/library/**

NCAR Refereed Publications: 400 (download PDF Bibliography)

400 NCAR Publication(s) for the time period 2009-10-01 to 2010-09-30
Class: Refereed; Status: All; (most recent first, AMS format)
Author Collaborations Summary:

UCAR Only: 48
UCAR & University: 121
UCAR & Other: 69
UCAR, University, and Other: 162

The FY10 UCAR Outstanding Publication Award was awarded to Steve Tomczyk, Scott McIntosh and Phil Judge of HAO. This award is given for the published results in the past five years of original research, review papers, or pedagogically oriented books that contribute to the atmospheric sciences. Publications are judged on four criteria: (a) importance of the subject to atmospheric science broadly defined, including work connecting atmospheric science with other disciplines or matters of public policy; (b) importance of the paper's contribution to its specific subject area; (c) evidence of creativity and originality; and (d) clarity of exposition.

Tomczyk, S., S. McIntosh, S. Keil, P. Judge, T. Schad, D. Seeley, and J. Edmondson, 2007: Alfvén waves in the solar corona. Science, 317:1192-1196.

Steven Tomczyk (HAO), Scott McIntosh (HAO), Stephen Keil (National Solar Observatory), Philip Judge (HAO), Thomas Schad (University of Notre Dame), Dan Seeley (Framingham High School), and Justin Edmondson (University of Michigan) were honored for their publication, which has been hailed as a remarkable, ground-breaking paper that will certainly become a solar physics classic. It has been cited more than 80 times to date. The authors report the detection of Alfvén waves in the corona. Tomcyzyk et al.'s novel observations reveal that these waves are ubiquitous in the Sun's hot outer atmosphere and provide theoretical interpretation that shows the energy flux carried by these waves is incapable of heating the corona, an important finding in the quest to solve the long-standing coronal heating problem. The detection of these waves will also prove invaluable to the emerging field of coronal seismology in inferring many physical properties of the corona.

For a full list of each metrics topic, contact Helen Moshak, **moshak@ucar.edu**.

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Advanced Study Program | ASP
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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) and Faculty Fellowship Program (FFP), 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 7 new postdoctoral fellowships in spring 2010. 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 69 months of long-term visits to NCAR in FY10. Four faculty members came to NCAR as part of the 2010 Faculty Fellowship Program while 11 GVP awards were given as a result of the 2010 GVP search. Most of the GVP awards also include an advisor visit.

The ASP continued its ongoing efforts to better serve diverse communities in FY2010 through two initiatives: a teaching partnership with Howard University, and a new collaboration with North Carolina Agricultural and Technical University.

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

FY2011 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. Bjorn Stevens, former ASP Postdoc and current Director of the Max Planck Institut fur Meteorologie will be visiting December.

The annual ASP Colloquium series will focus on the topic of Statistical Assessment of Extreme Weather Phenomena under Climate Change. New in 2011, the colloquium will expand to three weeks from two to accommodate a revival of an NCAR tradition: the ASP Research Colloquium. The new format will include 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 also provide organizational support for the NCAR Software Engineering Assembly and the newly established Technology Innovation Forum, along with 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 historically black colleges and universities (HBCUs), supporting teaching opportunities of NCAR postdocs at HBCUs and encouraging participation in ASP programs of individuals from underrepresented groups.

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

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ASP 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-four years and has sponsored over 435 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 FY10, the ASP appointed 7 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 FY2010, the ASP held monthly 'socials' that often included an education or career development aspect. Socials during the past year included a panel discussion on tenured and permanent positions with early career scientists and professors, an interactive presentation on communicating science, and an opportunity to interact with journalists. These socials not only brought members of ASP together, but also included any postdoctoral fellow or graduate student within the organization who wished to attend. 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 FY2011, ASP plans to continue the core elements of the program, including monthly seminars, bi-weekly research reviews, monthly socials, and the Thompson Lecture Series along with the annual research planning sessions and on-going mentoring that ASP postdocs receive.

The ASP postdoctoral program receives its funding from the National Science Foundation.

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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 FY10, applicants submitted proposals and budgets for 3- to 12-month visits that occurred between 1 June 2010 and 31 May 2012. ASP received fourteen viable applications. Four applicants were extended offers for visits that either occurred in FY10 or will take place in FY11. Two of those faculty visitors will bring a total of three graduate students with them.

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. The ASP hopes to augment this program slightly in FY11.

Adrian Sandu

Varavut Limpasuvan

"Through participation of this fellowship, we gained new insights on (1) how the effects of Gravity Waves (GW) can potentially be better incorporated in future version of the NCAR Whole Atmospheric Community Climate Model (WACCM), and (2) the dynamics involved in stratospheric sudden warming (SSW) from the troposphere up through the mesosphere. These new insights have paved ways for new proposal ideas that will be submitted to NSF. Furthermore, as the result of this participation, we got to meet and work with new collaborators (from Norway) who were also visiting NCAR and shared similar interests in WACCM and SSW. We also got to interact with other NCAR scientists and local GW experts who closely with NCAR."

Three publications have been submitted as a result of this visit and collaboration.

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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 fifth 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.

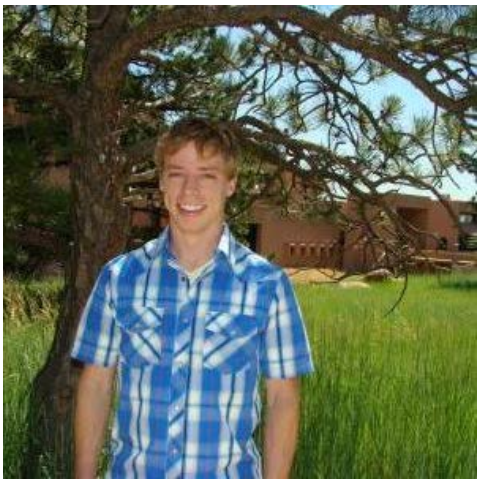
As a result of the 2010 GVP search, 11 GVP awards were given to students and most of those included a visit by the student's advisor.

The Graduate Visitor Program is still too new to measure or understand its full impacts. Yet, 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.

My ASP visit exceeded my expectations. My research goals for the 3-month stay were achieved and new projects/collaborations were initiated. I am gratified that there seems to be interest in the work I am doing. I met a lot of interesting and helpful people during my stay and was able to explore beautiful Colorado as well. I hope that this program will continue to benefit graduate students and postdocs for many years to come!

-Charlotte Kendra G. Castillo, Purdue University



The underlying personal goals of meeting professionals in my field and seeking their expertise as learning opportunities were satisfactorily accomplished during my visit. These professional relationships will certainly outlive my visit indefinitely. Meeting the "experts" will undoubtedly prove to be advantageous throughout my career in atmospheric science, both as invaluable resources in my research and as potential "ins" toward a long-term career with NCAR.

A highlight of my visit was the advisor visit. It was most helpful that my advisor's visit was set near the middle of my visit. This allowed time for my advisor, mentor, and I to touch base and decide if any changes to the visit plan need to be made.

My visit was an overall positive experience. It provided a unique and rewarding opportunity to, not only work amongst, but collaborate with professionals in my field, any of whom may hold the key to a possible long-term career with NCAR in the future. I would recommend this program to any graduate student in atmospheric science.

-Alex Bryan, University of Michigan

.....my participation in the NCAR GVP program allowed me to pursue a PhD project beyond the realm of my advisor's expertise and successfully accomplish my goals of running the CLM and successfully incorporating ozone oxidation damage to plants. Without participating in this program, my PhD research would have been strictly experimental in scope. I firmly believe that the skills I acquired while participating in this program will open more job opportunities to me upon completion of my PhD program.

-Danica Lombardozzi, Cornell University

From a personal perspective, the visit was a resounding success. I interacted with other scientists in the field in a manner that was constructive to my understanding of, not only the subject of data assimilation, but also other relevant topics in Atmospheric Science. In terms of data assimilation, my host, Dr Huang, and others in his research group were more than helpful in explaining the details of WRFDA [Weather Research and Forecasting Data Assimilation model]. Additionally, I attended the Data Assimilation Tutorial and this again helped to clarify many aspects of the subject for me. I also attended and presented at the 11th WRF User's Workshop during my visit and this afforded me the opportunity to learn much more about what others are doing in the field and also enhanced my confidence in presenting my work. In terms of computing resources, the CISL staff was very accommodating and thanks to their generosity, I was able to run all my planned simulations. Finally, the ASP staff and coordinators were extremely helpful and welcoming which served to make my visit a very unique and pleasant one. I will close off by saying thank you to all involved in making my experience at NCAR both a productive and memorable one.

-Ronald Gordon, University of Miami

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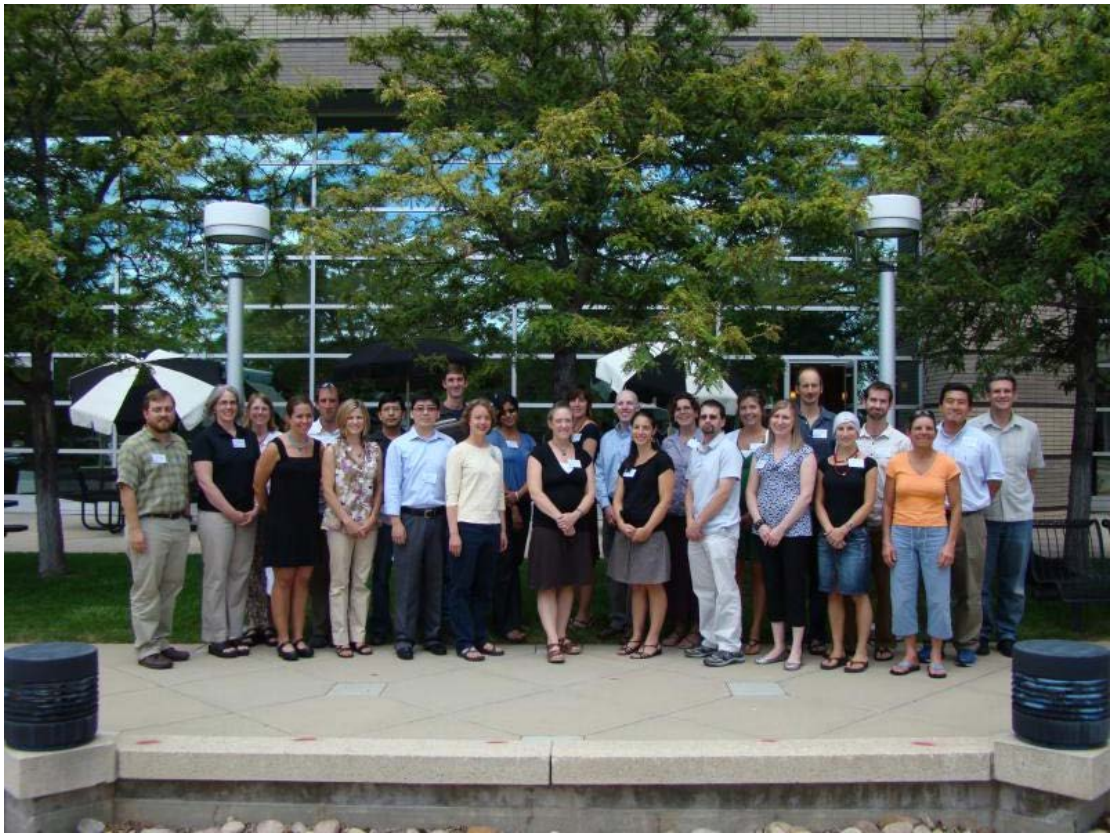
Bringing Early Career Faculty and NCAR Scientific Staff together

In 2003, the Advanced Study Program and the Early Career Scientist Assembly (ECSA) began hosting an annual forum at NCAR on future scientific directions. The objective of this forum is to bring together early career faculty and NCAR scientific staff to discuss selected topics in the Geosciences. This forum is open to non-tenured faculty at universities who are within five years of their first professorial academic appointment and to Level I and Level II NCAR scientific staff. In addition to promoting scientific discussion, an intended goal of the forum is to encourage development of professional relationships between members of the ECSA and UCAR institutions.

The Forum targets specific topics of interest based on feedback from early career staff from NCAR and the university community. In FY2010, the themes were Climate and Water, and Biomass Burning. A total of 34 external and 7 internals participants from across the nation, as well as a few international participants, attended the 2010 Forum. The organizers plan to submit a summary of the Forum to the Bulletin of the American Meteorological Society and as part of the paper, there will be an interactive website created and maintained by NCAR to facilitate future collaboration on the topic.

The Junior Faculty Forum on Future Scientific Directions is funded by the NSF.



Climate and Water group photo

Biomass Burning group photo

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ASP Summer Colloquia

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 FY10, the ASP hosted two colloquia:

1. Forecast Verification in the Atmospheric Sciences and Beyond, and
2. Asia in the 21st Century.

The first colloquium, **Forecast Verification in the Atmospheric Sciences and Beyond** was developed by scientists in **RAL**, **Purdue University**, and **NOAA's National Severe Storms Laboratory**. The colloquium included 25 students and 13 lecturers.

Forecast verification is a dynamic and rapidly evolving field. As computing power grows, more forecast models are available with increased complexity and greater resolution, and are updated more frequently. New observations to verify forecasts are available from satellites, aircraft, and automobiles, and an increasing array of surface based instruments. New information technology is available to directly use forecasts in decision making processes.

In addition, new types of forecasts have been created, including seasonal forecasts, climate forecasts, forecasts with probabilistic information and forecasts created for specific users such as the aviation and transportation communities.

The Colloquium addressed the many facets of forecast verification and evaluation. Invited lecturers discussed verification from the perspective of the meteorologist and climatologist, the statistician, the scientist and the decision maker. Speakers from the fields of meteorology, statistics, economics and health sciences were on hand to share a wide range of perspectives. Students worked in groups on small, well-defined research projects in order to implement ideas from the lectures. Projects were motivated by real users of forecast verification information and results from each project were presented at the end of the second week of the colloquium .

The second colloquium, Asia in the 21st Century was organized by scientists in the **Atmospheric Chemistry Divison** at NCAR and at **The University of Texas, Austin**. The colloquium included 19 students and 30 lecturers.

This colloquium focused upon a region of the world whose influence, both in economic and environmental terms, is increasing in importance. How the global community lessens the degree of global warming this century is dependent upon unfolding stories of individual nations' population, industrialization effluent emission, and land-use trends.

The colloquium lecturers and participants discussed population, economic, industrialization, transportation, and atmospheric emission trends. The use of Integrative Assessment Models, applied as a tool to integrate physical, economic, and social influences, was included. The physics and interconnections of global warming, biogeochemical, and hydrological cycles were discussed in addition to energy themes such as coal consumption, CO2 sequestration, the costs of technological change, and alternative energy sources. Speakers from various fields and nations were able to share a wide range of perspectives. As with the first colloquium, students worked in groups on small, well-defined research projects to help implement the knowledge gained during lectures and discussions.

Group photo of Asia in the 21st Century

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Natalia Calvo-Fernandez - ASP/NESL/CGD Postdoctoral Fellow

I did my PhD at Universidad Complutense in Madrid on the ENSO (El Nino-Southern Oscillation) signal in the stratosphere, using both general circulation models (WACCM and MAECHAM) and reanalysis data. Since then, I have been working on different aspects of the stratosphere dynamics, such as the Quasi Biennial Oscillation (QBO), 11-year solar variability, stratospheric sudden warmings (SSW) and the Brewer Dobson circulation. In particular, I have become interested in understanding the combined effects of this ENSO signal with those from other sources of variability in the stratosphere such as the QBO or solar variability. Since October 2009 these are the main topics I have been working on:

a) Changes in the Brewer Dobson circulation: focus on tropical upwelling.

a.1) Several studies have pointed out the **effects of climate change** induced by greenhouse gases **on the stratospheric mean meridional or Brewer Dobson circulation.** Garcia and Randel (JAS, 2008) used the Whole Atmosphere Community Climate Model (WACCM) to show that in this model the tropical upwelling increases in response to growing greenhouse gas concentrations as a result of enhanced propagation of wave activity from the troposphere which dissipates in the stratosphere. In a follow up study, Calvo and Garcia (JAS, 2009) revealed that dissipation of stationary planetary waves is the main driver of trends in the tropical upwelling in the lower atmosphere and discuss the role of both changes in wave transmissivity and wave excitation as possible mechanisms to understand the trends in the stratospheric circulation.

a.2) The tropical upwelling in the lowermost part of the stratosphere is also **intensified during warm ENSO events.** Calvo et al. (2010) investigated the nature of this signature in WACCM simulations, and showed that this is mainly due to anomalous forcing by orographic gravity waves during the strongest warm ENSO episodes; as a result of anomalies in the location and intensity of the subtropical jets and in the meridional gradient of temperature observed during ENSO episodes. This paper also showed the distinct signatures of ENSO in ozone and water vapor in this region.

b) Combined forcing responses.

b.1) The combined effect of **ENSO and the 11-year solar cycle variability** in the NH polar stratosphere is analyzed using the Whole Atmosphere Community Climate Model in a recent paper, which has been submitted to Journal of Geophysical Research (Calvo and Marsh, 2010, under review).

b.2) In the tropics, ENSO is known to cause large displacement of convection in the equatorial atmosphere, and therefore can modify the excitation of waves that drive the QBO. I have performed some experiments with the Middle Atmosphere ECHAM model (MAECHAM5) from the Max Planck Institute in Hamburg to analyze possible ENSO-QBO interactions in the tropics during extreme QBO phases and warm ENSO events. (Presentation at EGU 2010; paper in preparation).

b.3) Stratospheric sudden warmings (SSWs) dominate the interannual variability of the polar stratosphere during NH winter and might be affected by different phases of ENSO, QBO and solar variability. Different sensitivity simulations are being performed using WACCM to understand the influence of these forcings on the frequency and intensity of SSWs. Richter et al (in preparation).

References

Calvo, N., R.R. Garcia, W.J. Randel and D. R. Marsh: Dynamical Mechanism for the Increase in Tropical Upwelling in the Lowermost Tropical Stratosphere during warm ENSO events. Journal of the Atmospheric Sciences. DOI: 10.1175/2010JAS3433.1. (2010)

Calvo, N. and R.R. Garcia: Wave forcing of the Tropical Upwelling in the Lower Stratosphere under Increasing Concentrations of Greenhouse Gases. Journal of the Atmospheric Sciences, doi: 10.1175/2009JAS2085.1 (2009).

Calvo, N. and D.R.Marsh. The combined effect of ENSO and the 11 year solar cycle on the Northern Hemisphere polar stratosphere. Submitted to Journal of Geophysical Research (2010).

Garcia R.R. and Randel W.J. : Acceleration of the Brewer-Dobson circulation due to increases in greenhouse gases. Journal of the Atmospheric Sciences, 65, 2731-2739, (2008).

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Clark Evans - ASP/NESL/MMM Postdoctoral Fellow

Statement of Research Interests

Clark's research interests encompass problems and phenomena over a broad spectrum of topics and scales within synoptic and dynamic meteorology. Specifically, he is interested in linking observations and theory with numerical simulation output to study phenomena in both the tropics and mid-latitudes. Vortex development mechanisms, the interplay between dynamics and thermodynamics, problems on the interface(s) between multiple scales, and convective system dynamics are of particular interest to him. Clark's research exemplifies these interests, focusing upon the study of several unique phenomena within these topics. Specific details behind these projects are discussed in detail below in conjunction with a brief discussion of some of his other related research areas of interest.

Current Projects

The Overland Reintensification of Tropical Storm Erin (2007)

Primary Collaborators: Russ Schumacher (Texas A&M University), Tom Galarneau (NOAA/CIRES)

Meteorological Foci: mesoscale vortex dynamics; numerical modeling; land-surface interactions

Discussion: This study sought to determine the factors responsible for the unique overland reintensification of Tropical Storm Erin over Oklahoma in August 2007. Work currently in the peer-review process for eventual publication in Monthly Weather Review highlights the environmental conditions surrounding the reintensification and relates them to those seen with tropical cyclones over both water and land. Current work attempts to diagnose the multiscale dynamics of the reintensification process. Submission of these results for publication in Monthly Weather Review is anticipated in early 2011.

The Thermodynamic Evolution of an Extratropically Transitioning Tropical Cyclone

Primary Collaborator: Bob Hart (Florida State University)

Meteorological Foci: NWP; thermodynamics; heat transport; extratropical transition

Discussion: During the extratropical transition process, the inner core of a tropical cyclone cools and its thermal structure transitions (in most cases) from warm-core to cold-core, resulting in significant impacts upon the structure and intensity of a transitioning cyclone. Ongoing research attempts to quantify the factors responsible for this evolution using thermodynamic budgets from a high-resolution simulation of a representative transition event. Submission of these results for publication in the Journal of the Atmospheric Sciences is anticipated in late 2010. For further details, please see the Summer 2010 ASP Spotlight article available at http://www.asp.ucar.edu/spotlight/clark_evans.php.

Surface Vortex Development Associated with the 8 May 2009 "Super Derecho"

Primary Collaborators: Morris Weisman (NCAR), Lance Bosart (Univ. at Albany, SUNY)

Meteorological Foci: mesoscale vortex dynamics; convective systems; numerical modeling

Discussion: During the early morning hours of 8 May 2009, an intense derecho developed across the central United States. Accompanying this event was the development of an intense tropical cyclone-like warm-core vortex with an eye-like feature on the derecho's northern flank. Current work uses output from a high-resolution simulation of the event to better understand the dynamics of the development of both the vortex itself and its accompanying eye-like feature. Submission of two manuscripts to Monthly Weather Review, one detailing the evolution of the derecho within the aforementioned high-resolution simulation and another describing the results relating to the vortex's development mechanisms, is anticipated in early 2011.

Early-Stage Projects

Tropical Cyclogenesis in the Tropics from Non-Easterly Wave Predecessor Disturbances

Primary Collaborators: Chris Davis and Brian Tang (NCAR), Lance Bosart (Univ. at Albany, SUNY)

Meteorological Foci: tropical cyclogenesis; application of observations to models and theory

Discussion: The pre-development periods of Atlantic tropical cyclones Karl and Matthew, both of which developed in the tropics from non-easterly wave disturbances, were sampled extensively during the summer of 2010 by the PREDICT (http://www.eol.ucar.edu/projects/predict/) field campaign. With his collaborators, Clark aims to use data collected from each disturbance alongside mesoscale model simulations to better understand the dynamics behind the development of each cyclone's predecessor disturbance.

Meso- to Synoptic-Scale Heat Transport Associated with Tropical Cyclones

Primary Collaborator: Heather Archambault (Univ. at Albany, SUNY)

Meteorological Foci: NWP; thermodynamic budgets; heat transport; extratropical transition

Discussion: Using output from multiple high-resolution numerical model simulations, we seek to understand the dynamics of how heat transport and diabatic heating result in the observed large-scale flow reconfigurations and resultant model forecast skill degradation associated with extratropically transitioning tropical cyclones.

The Interaction of Pre-Existing Convectively-Generated Vortices with Low Level Jets

Primary Collaborators: George Bryan (NCAR), Russ Schumacher (Texas A&M University)

Meteorological Foci: mesoscale vortex dynamics; low level jets; numerical modeling

Discussion: As Tropical Storm Erin reintensified, it moved across the axis of a well-defined low level jet. To date, little is known about how a low level jet influences a pre-existing vortex. Using a multi-faceted modeling approach, we aim to better understand how low level jets influence the structure and evolution of pre-existing vortices.

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Shannon McNeeley - ASP/RAL/ISP Postdoctoral Fellow

Yampa/White River Basins Vulnerability and Adaptation Assessment

The Yampa/White Basins region is an important piece of the Upper Colorado River Basin as it drains into the Colorado River system, and it delivers part of Colorado's obligation to the lower basin states. It is a particularly interesting region and river system for several reasons:

1. The Yampa and White Rivers are relatively unaltered with only a few small- to medium-sized reservoirs on the system and no major dam structures resulting in a near natural hydrograph;
2. As a result, the region lacks a large amount of water storage, which could make the system more vulnerable to long-term drought;
3. Most of the Yampa/White region is not fully allocated, which means there is still water left to develop;
4. Because there is still water to develop in the system it is looked upon as an area for a possible transbasin diversion to the Front Range of Colorado; and
5. The possibility for oil shale development in the Piceance Basin brings a lot of "what if" scenarios in terms of future water needs, population growth, and overall development of the region.

Initial broad research questions:

- What characterizes the seasonality of natural cycles and livelihoods in the region?
- What weather and climate conditions result in vulnerability of the social-ecological system?
- As climate change shifts seasonality (e.g., earlier snowmelt and runoff, extended drought, warmer temperatures) how are some sectors, stakeholders and ecosystem services more vulnerable than others? What are their adaptive capacities? What are the barriers or constraints on either near-term coping responses or longer-term adaptations?
- How do decision makers understand climate and climate change, and what types of weather/climate information do they use and how?

This research utilizes a stakeholder participatory vulnerability and adaptive capacity assessment approach (Smit and Wandel 2006). This means that with input from local experts living in the region, research questions and focus will evolve and be refined over time. This type of approach does not assume key aspects of vulnerability and adaptive capacity, a priori, but rather discovers them through participation with stakeholders.

Collaborators: Yampa/White River Basin Roundtable, Kathy Miller, other scientists at NCAR and elsewhere, tbd.

Research Timeline:

Extensive literature review March through mid-April, 2010

April 21, 2010 - first presentation to the Yampa/White Basin Roundtable (where they formed a sub-committee on the spot to help guide the research)

August-October 2010 - field work (observations and interviews, details below)

Winter 2010 - Analysis and begin write up of initial results for publication

Summer 2010 - Continue refining analysis and writing; working with stakeholders to determine next steps

Completed work to date:

1. Literature review (ongoing)
2. Observed and spoke at three Yampa/White Basins Round Table meetings in 2010
3. Observed two and spoke at the third of the Community Agricultural Alliance water forum series in 2010
4. Field work: August 14, 2010-October 22, 2010 lived in Steamboat Springs and conducted 37 interviews throughout the entire region and across all sectors = 3,076 minutes audio recordings/1,437 pages of transcripts for analysis
5. Review of some transcripts for transcription accuracy

Next Steps:

1. Continue reviewing transcripts for transcription accuracy
2. Analysis of transcripts in Atlas.ti (i.e., coding, memoing, link/network analyses, conceptual and theoretical model development, identification of key vulnerabilities and adaptive strategies)
3. Depending on results of transcript analysis, identification of additional necessary weather/climate/water and social data analyses

Reference:
Smit, B. & J. Wandel (2006) Adaptation, adaptive capacity, and vulnerability. Global Environmental Change, 16, 282-292.

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Michael D. Toy - ASP/NESL/MMM Postdoctoral Fellow

Nonhydrostatic atmospheric modeling using a hybrid isentropic-sigma vertical coordinate

We are developing a nonhydrostatic model that solves the compressible, nonhydrostatic Euler equations in a generalized vertical coordinate. The dry dynamical core, described in Toy and Randall (2009), uses a hybrid coordinate that is a height-based, terrain-following σ coordinate near the surface with a smooth transition to potential temperature (θ) in the free atmosphere. Potential temperature is a quasi-Lagrangian vertical coordinate since the vertical velocity is zero under adiabatic conditions. Therefore, the error associated with numerical vertical transport is greatly reduced. Where the flow is turbulent, or where the static stability is negative, the model vertically advects mass across coordinate surfaces in such a way as to prevent the grid from becoming too irregular or closely spaced in the vertical.

In 2010 we incorporated moist processes into the model and have successfully performed cloud simulations. Figure 1 shows a 2D simulation of a moist thermal rising in a conditionally unstable environment. The horizontal grid spacing is 100 m and the average vertical spacing is also 100 m. Note that the cloudy updraft penetrates coordinate surfaces, and that the isentropes are separated from these surfaces because the model automatically behaves in an Eulerian manner in the turbulent region. In the clear, environmental air to the sides of the cloud, the model levels coincide with the isentropes in a quasi-Lagrangian manner. These results are currently being reviewed in a manuscript submitted to the Monthly Weather Review.

References

Toy, M. D., and D. A. Randall, 2009: Design of a nonhydrostatic atmospheric model based on a generalized vertical coordinate, Mon. Wea. Rev., 137, 2305–2330.
Toy, M. D., 2010: Incorporating condensational heating into a nonhydrostatic atmospheric model based on a hybrid isentropic-sigma vertical coordinate, Mon. Wea. Rev., under review.

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Lulin Xue - ASP/RAL Postdoctoral Fellow

Numerical studies of the effects of aerosol solubility and regeneration on orographic clouds and precipitation:

A warm-phase and a mixed-phase numerical sensitivity studies have been conducted using a detailed bin microphysical scheme coupled with WRF model. It is found that: 1) Cloud properties and precipitation features are very sensitive to aerosol chemical compositions or solubility (Figure 1) and this effect is more prominent for polluted clouds than clean clouds. 2) Aerosol regeneration decreases the precipitation by 2%-80% under various conditions and regenerated aerosols replenish 1/3 to 2/3 of the missing particles when regeneration is not considered. 3) Cloud processed aerosols affect cloud and precipitation properties. 4) Riming of snow is not sensitive to aerosol concentration and chemical compositions but riming of graupel is very sensitive to both properties. 5) The sensitivity of mixed-phase clouds and precipitation to aerosol solubility and regeneration is lower than that of warm-phase clouds. 6) The quantitative sensitivity of mixed-phase clouds to aerosol is not changed by ice initialization parameterizations.

FY2011 Plans:

The theoretical studies on aerosol solubility and regeneration effects on orographic clouds and precipitation in 2010 confirmed that incorporation of aerosol regeneration process into the numerical model is necessary. Sensitivity studies of aerosol hygroscopic effects on strong convective clouds and maritime stratocumulus are planned for this coming year.

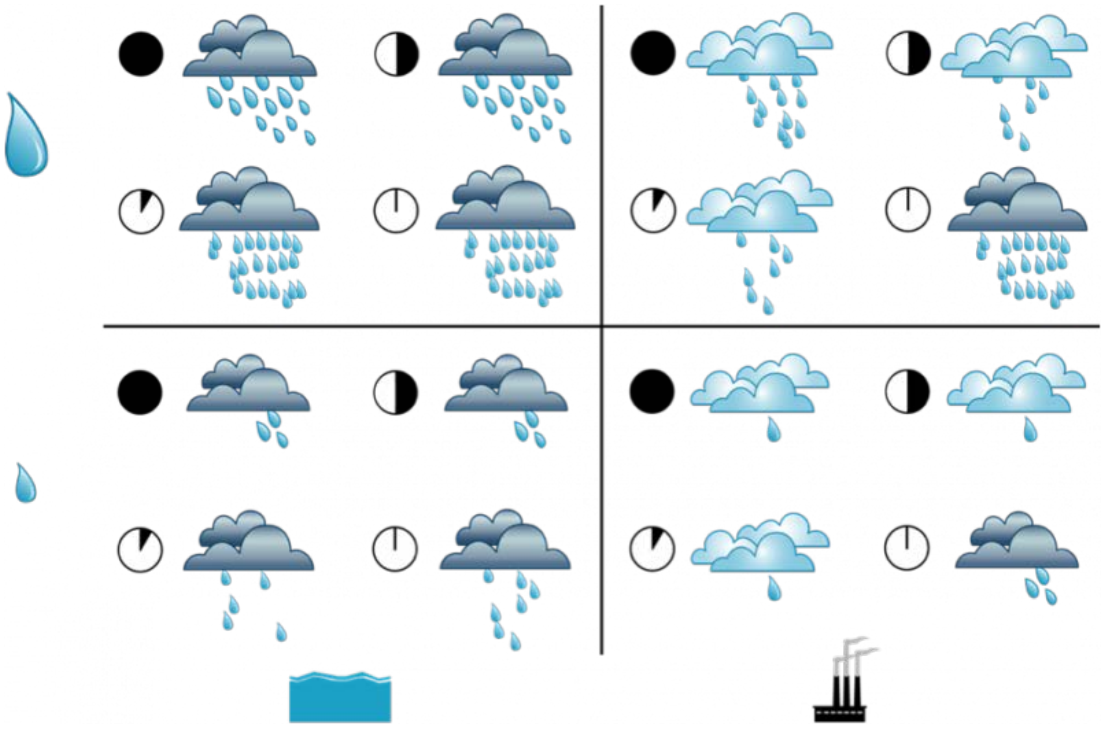

Figure 1: Schematics of aerosol solubility effects on clouds and precipitation. Top and bottom quadrants indicate wet and dry conditions, respectively, left and right quadrants respectively indicate the clean and polluted backgrounds. Circles represent aerosol solubility of 100%, 50%, 10%, and 1%, with the

black area indicating the soluble portion of the aerosol. Clean clouds are indicated by dark clouds and polluted clouds by light ones.

Cloud processing of internally mixed aerosol:

The studies of the effects of aerosol solubility and regeneration on orographic clouds and precipitation presented a scenario of aerosol-cloud-precipitation interactions as illustrated in figure 1. The initial aerosol population will be processed by clouds and their size distributions and chemical compositions will be modified. The new processed aerosols can activated new clouds and will be processed again. Enlightened by the question of how aerosols processed by clouds in details and how they impact clouds and precipitation, some preliminary theoretical studies using a new aerosol-microphysics scheme have been carried out. The mechanism of cloud processing of aerosol is illustrated in figure 2.

The preliminary results showed that 1) the solubility of large aerosols decides the aerosol bulk solubility after cloud processing; 2) cloud processing generates larger aerosols, equilibrates the aerosol size distribution and smoothes the aerosol solubility distribution; 3) cloud-processed aerosols have complicated effects on clouds and precipitation. Please see http://ams.confex.com/ams/13CldPhy13AtRad/techprogram/paper_170624.htm for details.

FY2011 Plans:

The problem of how the freshly emitted externally mixed aerosol particles become internally mixed by cloud processing will be investigated in this coming year.

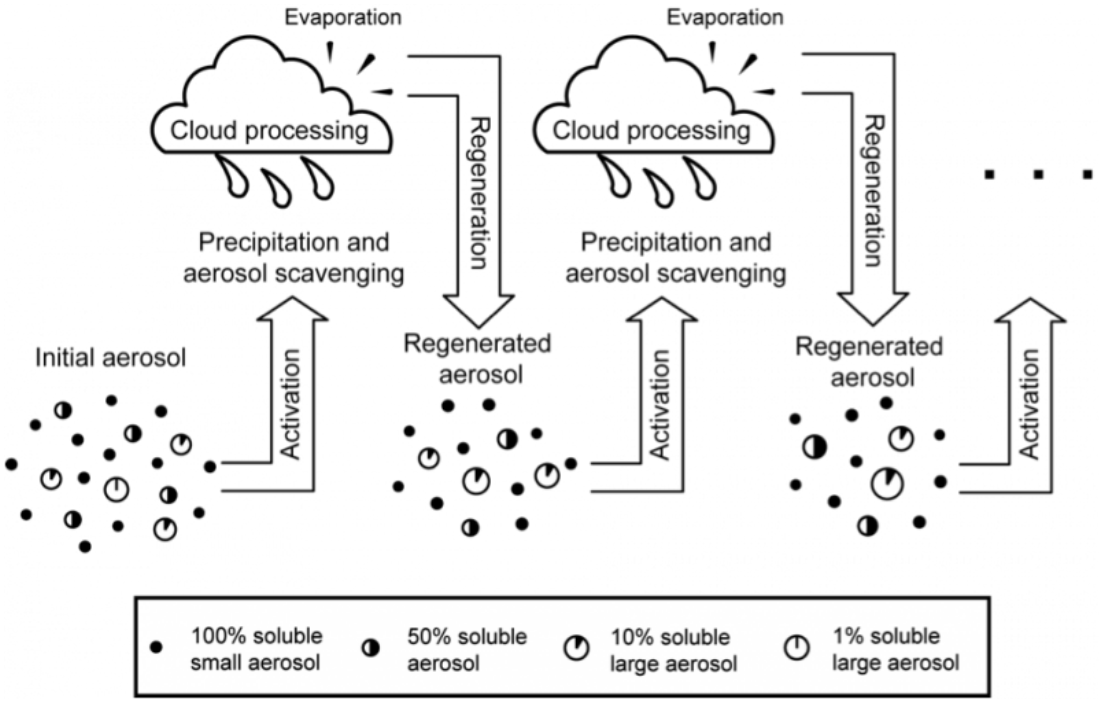

Figure 1: Schematics of aerosol-cloud-precipitation interactions.

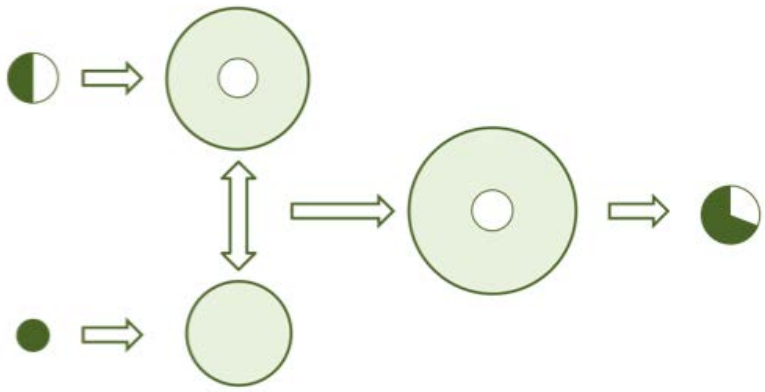

Figure 2: Schematics of cloud processing of internally mixed aerosol particles. Small circles represent aerosol particles with dark area indicating soluble portion. Light green large circles indicate cloud droplets with white area indicating insoluble aerosol core inside.

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Jia Yue - ASP/HAO Postdoctoral Fellow

Fast meridional transport of Columbia Space Shuttle engine plume in the lower thermosphere by planetary-scale waves

The shuttle main engine exhaust plume of water vapor and abladed iron was released at ~ 110 km height when the Columbia space shuttle was launched in January 2003 in its last mission. The plume was further transported from Kennedy Space Center, Florida, quickly to Antarctica within 3 days [Stevens et al., 2005]. This fast transport mechanism remains a mystery in the upper atmosphere dynamics because the mean meridional circulation at that height is much slower. Diagnostic calculations are performed to trace the particles with the adjusted quasi-two-day planetary wave and atmospheric thermal tides generated by the NCAR Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model TIME-GCM. The results show that we can simulate this fast meridional transport: after three days of releasing over Florida at 30N, the tracer reaches Antarctica (latitude 65S) in three days. For the first time, the combined effect of Rossby waves and tides driving the fast southward wind is proposed and demonstrated with the NCAR GCM model.

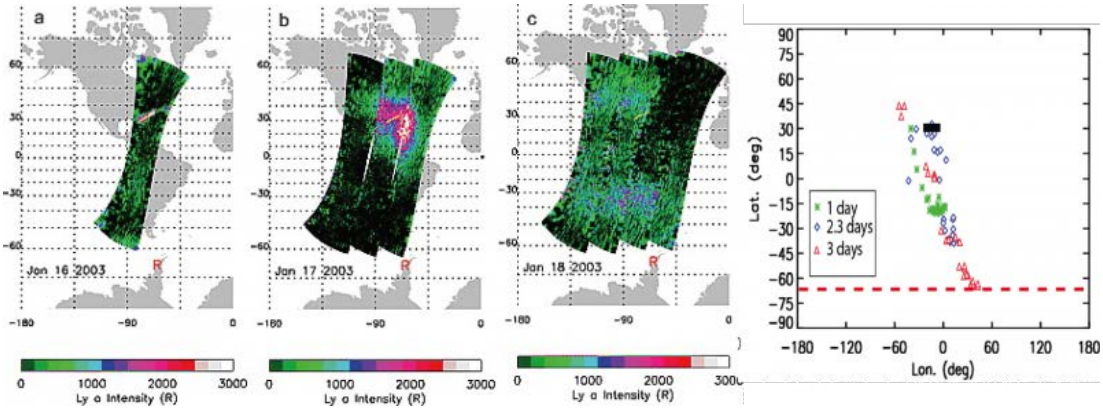

Figure 1. The left three figures show the GUVI satellite observations of hydrogen photodissociated from the plume water vapor, right after launch, 1 day and 2 days after, respectively, in red and while color. The right panel indicates the location of plumes in our off-line numerical calculation 1 day (green), 2.2 days (blue) and 3 days (red) after release. The location to release the tracer is denoted by the black strip near 30N. The red line marks the latitude of the Antarctica station at 67S.

Large wind shears in the lower thermosphere and tide-gravity wave interactions

Unexpected large horizontal winds (150 m/s) and wind shears (~ 100 m/s/km) in the lower thermosphere have been observed by rocket soundings and lidars for decades. In theory, large wind shears can be sustained in the region of high static stability, e.g., in the lower thermosphere, The full-diurnal-cycle lidar data enables the extraction of tidal wave components with periods of 24 h, 12 h, 8 h and 6 h, therefore allowing us to reveal the strong correlation of 60%, between large wind shears (>50 m/s/km) and tidal waves. The lidar measured seasonal variation of N^2 and tidal amplitudes in the mesosphere and lower thermosphere (MLT) are found to be consistent with the difference in altitude distribution of strong wind shears between winter and summer. A high resolution two-dimensional parallel numerical model is performed by Liu et al. [2010] to study the large wind shears and instabilities induced by the nonlinear propagation of gravity waves in the tidal background with different initial tidal phases. The result suggests that there is a strong correlation between the initial tidal phase and large wind shears that are induced by the nonlinear interactions between gravity wave, tide and mean flow. Therefore, the occurrence of large wind shears in the height range of 95-100 km is correlated with the local time and supports the sodium lidar observation result.

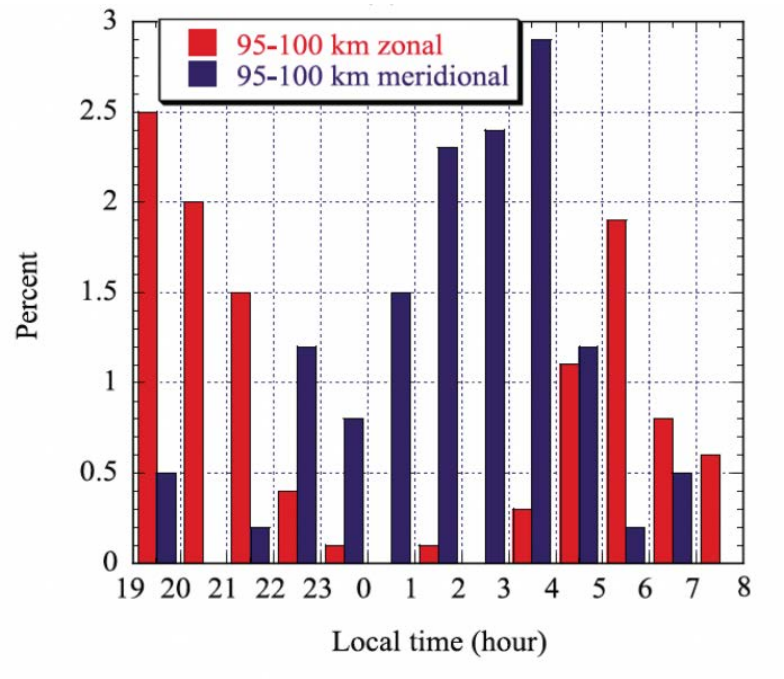

Figure 2. Local time dependent occurrence frequency of large amplitude zonal and meridional wind shears (>30 m/s/km), both at 95–100 km in winter.

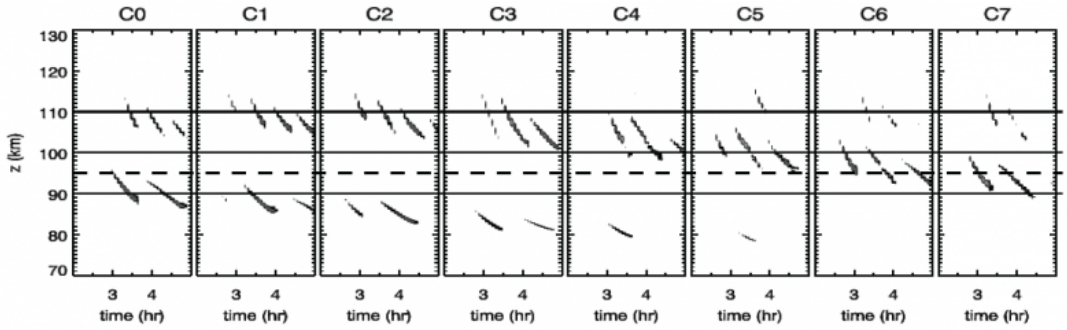

Figure 3. Contour plots of large wind shears (≥40 m/s/km) from gravity wave-tidal interactions in eight different solar tidal phases and local times.

Related publications:

J. Yue, C.-Y. She and H.-L. Liu, Large wind shears and stabilities in the mesopause region observed by Na lidar at midlatitude (2010), J. Geophys. Res., 115, A10307, doi:10.1029/2009JA014864.

Yue J. and H.-L. Liu (2010), Fast meridional transport in the lower thermosphere by planetary-scale waves, JASTP, in press.

Liu X., Xu J., J. Yue, H.-L. Liu, W. Yuan (2010), Large wind shears and instabilities due to gravity wave-tidal interactions, to be submitted to JGR.

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Supporting Diversity in the Atmospheric Sciences

The ASP continued its ongoing efforts to better serve diverse communities in FY2010 through two initiatives:

1. Cultivating a new collaboration between North Carolina Agricultural & Technical University (NCA&T), and
2. The new ASP Historically Black College and University (HBCU) postdoc exchange.

In Support of North Carolina Agricultural & Technical University

In FY2008, a Memorandum of Agreement (MOA) was signed between NCAR and four 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

In June 2009, NCAR's Maura Hagan traveled to NCA&T to meet with high-ranking officials about their current programs in Atmospheric Sciences and where possible collaborations might occur. As a result of that meeting, NCA&T faculty requested that five NCAR scientists come to NCA&T to give seminars. All five scientists (Tom Warner, Geoff Tyndale, Christine Wiedinmyer, Frank Flocke, and Jothiram Vivekanandan) agreed. Last spring, each of these scientists spent several days at NCA&T giving seminars and meeting with faculty and students to help build capacity. The main challenge for NCA&T is that it lacks enough faculty expertise to be able to teach several courses in support of its new Bachelor of Science program in Atmospheric Sciences and Meteorology. These lectures and seminars provided by NCAR staff have the potential to fill those holes. ASP plans to support additional NCAR staff to travel to NCA&T in FY11 to provide additional courses and seminars.

Initiating a new postodoc exchange with HBCU partners

In support of the Memorandum of Agreement referenced above, the ASP supported one of its postdoctoral fellows to spend four months teaching, conducting research, and collaborating with faculty and students at Howard University. Song-Lak Kang spent the fall semester, 2009 at Howard where he taught a course, participated in the ongoing research activities of the Physics Department, gave seminars, advised students, and initiated a new collaboration with Michael Hicks, a student in the department.

There is no doubt that his visit elevated NCAR's visibility at Howard among the students and faculty members and provided opportunities for recruiting more students for ASP's visitor and fellowship Programs. For the ASP Postdocotral Fellow, participating in the HBCU exchange provides an opportunity to gain valuable teaching experience and to increase their visibility in the university community, both of which can only help when it's time to find a position after their fellowship.

From Dr. Gregory Jenkins, chair of the Physics Department about Song-Lak Kang' semester at Howard:

He was an excellent role model, with great interactions with

the students and he provided guidance for some of the dissertation research that our students are undertaking. We expect to continue to collaborate with Dr. Kang in the coming years and hope that he will serve as a dissertation committee member for students in the HUPAS program. We also hope that if such opportunities present themselves in the future, that you will consider having another ASP postdoctoral fellow come to Howard University for a semester. ...Once again, thank you for helping us to build capacity and technical expertise in our atmospheric science program at Howard University.

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Director's Message

Message from CISL Director Al Kellie

Welcome to the FY2010 CISL Annual Report. We have documented a generous collection of highlights this year. I particularly want to call your attention to their balance with respect to CISL's three fundamental roles of service, science, and education.

Al Kellie described the promise of the NCAR-Wyoming Supercomputing Center at the ground breaking ceremony on June 15, 2010: "CISL is enjoying the moment of this first step along the way, but we won't really be celebrating until we are serving the community by facilitating their science production from this new building in Wyoming."

Perhaps the most important CISL activity highlighted this year, one with far-reaching implications, is the construction of the NCAR-Wyoming Supercomputing Center (NWSC). It is indeed gratifying to see this dream becoming a real image after six years of planning. Much work remains to be done: 60 weeks of construction activity, stocking the facility with infrastructure for supercomputing, storage, and networking; integrating and testing new systems; cultivating new research collaborations; expanding educational opportunities; allocating resources; and transitioning to operations at the Wyoming Campus.

NWSC will enable a significant increase in the scale of our computing and data infrastructure. In anticipation of this expansion, we are broadening our expertise by acquiring new computing and data management technologies and designing new systems. For instance, we are developing new and more efficient ways to manage data used in scientific workflows for the atmospheric and related sciences. To this end, we designed and launched the Globally Accessible Data Environment (GLADE), a new network-attached, centralized data management system to reduce unnecessary file copying, increase the efficiency of data analysis tasks, and speed up the rate of science production. We also rapidly expanded NCAR's online data capacity for both the Research Data Archive and NCAR's Earth System Grid in support of the IPCC AR5 campaign. These efforts are detailed in the GLADE and RDA sections of our annual report as well as in NCAR's Annual Report.

We also installed a test and development 8-TFLOPS Cray XT5 system at the Mesa Lab site, and we assisted in the design and deployment of a 183.9-TFLOPS Dell PowerEdge system at a partner university. Through these activities we have gained valuable experience exploring ways to configure and operate cyberinfrastructure relevant to NWSC. This knowledge will now be applied directly to our acquisition and deployment of the petascale cyberinfrastructure we plan for the NWSC facility.

New algorithms are needed for the massively parallel systems required to achieve petascale and ultimately exascale computing. CISL's Technology Development Division and IMAGe math institute have been making significant progress in this realm for years, and we achieved several major milestones in FY2010. In particular, the highly scalable HOMME dynamical core is now included in the latest production version of the Community Climate System Model (CCSM) and the Community Earth System Model (CESM). Other advancements in CISL science include progress in data assimilation for climate modules, developing ultra-high-resolution climate modeling capabilities, applying graphics hardware acceleration to climate applications, and using adaptive grids for multiscale simulation of the atmosphere and oceans. We are also preparing to handle exascale datasets by developing techniques such as high-fidelity data compression, defining methods for handling climate simulation metadata, and implementing new user interfaces.

CISL began hosting new scientific capabilities in FY2010 by incorporating the Regional Integrated Science Collective (RISC) in CISL's Institute for Mathematics Applied to Geosciences (IMAGe). RISC brings CISL into the societal

impacts realm, and adds a new service to our portfolio: providing decision makers with tools, methods, and unique data sets for analyzing climate change impacts, vulnerability, and adaptation options. RISC reaches out to the broader decision-making and policy communities by integrating geostatistics and mathematical analyses into more immediate and pragmatic products. CISL leverages all of its scientific efforts through far-reaching collaborations with public and private laboratories, universities, and other institutions.

CISL's education accomplishments this year have been equally significant. Both of our flagship education programs enjoyed record support and participation. IMAGe's Theme of the Year program hosted five meetings, culminating in the two-week summer school that trained 42 U.S. graduate students in applying mathematics to climate change. In SIParCS, a record number of 20 interns was made possible by funding from three partner organizations, grants, and NCAR diversity funds. This external support shows the strength of these programs that aim to develop skilled scientists and engineers for the future. In data analysis training over the last 10 years, we provided 49 four-day workshops to 683 students, and in FY2010 these NCL workshops began supporting participants from Minority Serving Institutions and EPSCoR states. All of our educational programs promote careers in science and engineering while reaching out to our historically underserved neighbors. We continue to expand our education, outreach, and training efforts to broaden participation in the Earth System science workforce.

Our plans for the future are organized by three pathways to petascale science: 1) facilities and infrastructure, 2) scientific tools and and research that are tightly integrated with other NCAR programs at the crossroads of petascale applications and massively parallel computing, and 3) critical and innovative workforce education and training. We will continue to provide balanced and greatly expanded computing and data environments that will support our traditional science community while sharing our resources via distributed facilities and new partnerships. Thus, CISL will support the Earth System sciences with increasing vigor and skill. As we look to the future, we continually adapt ourselves and our organization to maximize our contribution to understanding the complexities of the Earth System. As you read this report, I hope you share our sense of expectation and excitement for the significant progress coming in the future.

With this in mind, it is my pleasure to invite you to review our accomplishments and plans in this FY2010 CISL Annual Report.

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CISL Computing Services

CISL is a computing laboratory.

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 underlying technologies and scientific demands. For example, CISL foresees providing fewer standalone services: over time, services will increasingly be virtualized and federated with other resource and service providers. Another macro-trend will be to provide more flexible and customized services, e.g., through sophisticated science gateways tied to data repositories or computational resources, rather than the current paradigm of “batch” access.

CISL sees the following Imperatives for its role as a computing laboratory:

- CISL must deploy and operate the physical and virtual computational facilities needed to support the science community. CISL must provision mid-range, Track-2-scale computing, storage, data analysis, visualization, networking, and archival systems, customized to support the atmospheric and related sciences.
- CISL must develop and support software infrastructure and tools specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences.
- CISL must maintain online access to research data sets and the tools needed to access that data in a variety of user-specified ways.

As a computing laboratory, CISL faces one critical Frontier:

- CISL must exploit supercomputing center virtualization technologies to support and enhance the development of virtual organizations around its core services.

This section of the FY2010 CISL Annual Report reports on the topics shown in the navigation tool at left.

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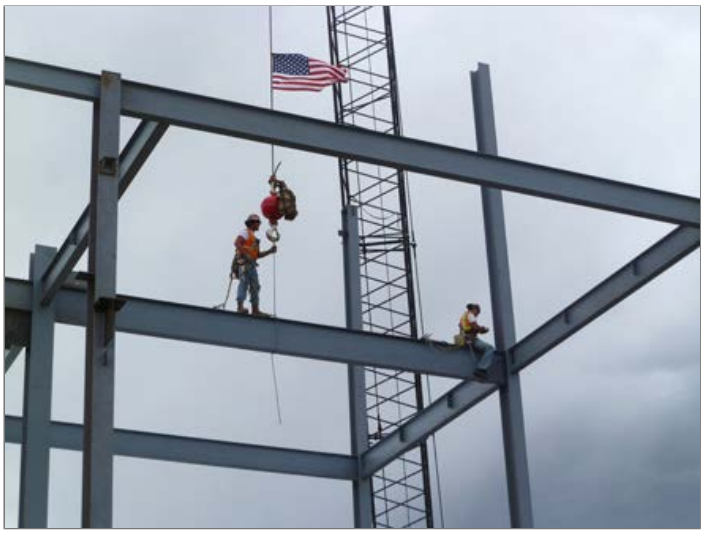
Computing Imperative: Facilities

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 continually enhances the capability and capacity of NCAR's supercomputing facilities while maximizing their efficiency. Our focus shifted from planning for the NWSC with the June 2010 start of construction in Cheyenne. The NWSC will be home to future generations of supercomputing systems for Earth System sciences.



Steel workers placing the second floor steel beams for the NCAR Wyoming Supercomputing Center (NWSC). Upon completion, the steel structure will house the mechanical and electrical equipment that will cool and power the supercomputing systems to be installed. This area of the building will be the heartbeat of the new facility.

FY2010 was eventful for NWSC design and construction efforts. The facility design was approved with both the Preliminary Design Review and the Final Design Review being completed in FY2010. With NSF's approval to proceed, construction started in earnest in June. At end-FY2010, the majority of concrete and utilities work is complete. The steel structure is well underway, and precast wall panels are being placed. Energy modeling of the designed facility indicates that the target efficiencies for the Wyoming facility will be met and will demonstrate maximum efficiency for a supercomputing center. The design documents were submitted for LEED certification and are under review by the U.S. Green Building Council.

The Mesa Lab computing facility continued operating throughout FY2010 with only modest changes. Several older systems were decommissioned, including the five "Powderhorn" libraries. CISL continues to improve and tune the operation of the facility to recover some electrical and mechanical capacity that could be used for continued upgrades to computing and data services equipment.

For FY2011 the majority of facilities effort will be focused on completing construction and commissioning for the NWSC. CISL will continue to maintain the Mesa Lab facility in FY2011, using it to both mock up and deploy new rack systems and to study hot aisle containment, all to gain experience for system deployments in Cheyenne. Work will proceed at the Mesa Lab to prepare it for its new role as a collocation facility to house both CISL systems and equipment for the rest of the organization.

This work is supported by NSF Core funding and other funds as described in the next section.

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The NCAR-Wyoming Supercomputing Center

This photo shows the NWSC building structure at end-FY2010. Construction progress has been very efficient and continues ahead of schedule. Fully enclosing the building before winter will allow interior constuction to continue at full speed even during storms. The NWSC will enable NCAR to support critical Earth System sciences research through high-performance computing for decades.

In partnership with the University of Wyoming (UW), the State of Wyoming, Cheyenne LEADS, the Wyoming Business Council, and NSF, NCAR has begun construction of the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming. The 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. In support of both NCAR's and the UW's strong commitment to environmental stewardship, the NWSC will be energy efficient and as green to build and operate as practicable.

The vision for the project is well aligned with the NSF Strategic Plan and the NSF vision for cyberinfrastructure (CI). The project is motivated by the scientific needs of the Earth System sciences community and is being proposed in direct response to geosciences researchers' increasing needs for both capability and capacity HPC resources. Whether because of a need for greater model resolution, increased model complexity, better statistics, more predictive power, longer simulation times, or a combination of these factors, Earth System scientists are calling for petascale computing, data analysis, and visualization resources combined with exascale data management capabilities.

The provisioning of such capabilities requires the availability of a large-scale computing center capable of handling the multi-megawatt heat loads of future systems. The basic size and infrastructure requirements for the NWSC have been established in accordance with these power demands.

Plans for developing the NWSC are fully aligned with NSF's larger CI vision and will directly contribute to the creation of a national petascale cyberinfrastructure. The facility will be a peer with other NSF Track-2 facilities and will serve as a "stepping stone" for Earth System science investigators to fully utilize NSF's multidisciplinary, one-petaflop-sustained Track-1 facility.

At the beginning of FY2010, NCAR staff provided support for this project's NSF Preliminary Design Review (PDR). During this review, a panel of community experts seated by NSF reviewed NCAR's Project Summary, NWSC Science Justification document, and Project Execution Plan (PEP). The panel performed an assessment to determine whether the project was sufficiently well-developed to proceed to the final design phase. The outcome of the PDR was a recommendation for the NWSC project to proceed to final design, and the latter effort began in November 2009. During the period of November 2009 to February 2010, NCAR personnel and the project design team collaborated on the iterative preparation of 75% and 95% design documents for the facility. In early March 2010, copies of 95% design documents, a new NWSC Education, Outreach, and Training (EOT) Strategic Plan, and a revised PEP were submitted to NSF in preparation for the project Final Design Review (FDR). The FDR was conducted in early March 2010, and the panel seated by NSF recommended without reservation that the project proceed to construction and be awarded funding by NSF.

Following satisfactory completion of the FDR, NCAR and design team personnel completed design of the NWSC and delivered 100% design (construction) documents in mid-April 2010. While the facility design effort was being completed, NSF personnel prepared and submitted the package of project materials required for National Science Board (NSB) review of the project. During their early May 2010 meeting, the NSB reviewed how the NWSC project had been conducted as well as the outcomes from the two project design reviews. Immediately following their review of the project, the NSB issued a formal resolution authorizing NSF to fund construction of the NWSC. NSF awarded the first (FY2010) increment of construction funding for the facility in June 2010, and this cleared the way for construction of the NWSC to begin on 3 June 2010.

From June to September 2010, significant progress was made on constructing the facility. Major construction

activities during this time period included: earth moving and excavation, concrete work (foundations, walls, and concrete pours of slab on grade and slab on deck), water and sewer line installation, steel erection, electrical conduit and vaults installation, and backfill. Good weather during June-September 2010 enabled the general contractor/construction manager and construction subcontractors to make significant progress, and the NWSC construction effort proceeded throughout the remainder of FY2010.

During FY2011, an aggressive schedule for completion of NWSC construction will be maintained, with facility construction scheduled for completion in August 2011. Commissioning of the facility will begin in early September, will continue throughout FY2011, and will end in early FY2012 (December 2011). This schedule for construction completion and commissioning will enable the installation of the first high-performance computing (HPC) system and affiliated data storage and network equipment in the NWSC beginning in January 2012. The NWSC will begin providing supercomputing support to Earth System scientists by mid-2012.

The first strategic imperative in CISL's Strategic Plan is the computing imperative for providing 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."

NWSC design and pre-construction services work during FY2010 was funded by the University of Wyoming. NWSC Project Office (NPO) costs in FY2010 were met using American Recovery and Reinvestment Act (ARRA) funds awarded by NSF in FY2009. Costs associated with NWSC construction in FY2010 (building construction, required Board of Public Utilities construction fees, construction administration, and commissioning expenses) were met using NSF Special and Wyoming Business Council (WBC) funds.

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Computing Frontier: Center Virtualization

To support CISL's computing frontier in cyberinfrastructure virtualization, we develop science gateways and other Grid-based technologies for virtual organizations. Higher wide-area network bandwidth, more powerful computers, and specialized software are creating a Grid that promises to provide simplified access to distributed HPC resources. Such a strategy offers several potential benefits. First, by teaming their computational resources with other powerful computing assets on the Grid, geographically dispersed partners can scale up processing cycles to meet increasingly large scientific challenges. Second, complementary expertise and resources can be combined across centers to tackle the complex and interdisciplinary challenges in computational science that are difficult or impossible for one center to tackle in isolation. This includes many computational geosciences problems, such as climate and earthquake modeling, for example.

Our portfolio of projects and initiatives described in this section span climate science, regional climate change, Arctic science, solar science, digital preservation, and international efforts to develop metadata and knowledge infrastructure for a range of problems. For example, the Asteroseismic Modeling Portal (AMP) provides an environment where community members can derive the properties of Sun-like stars from observations of their pulsation frequencies, a computationally intensive process. The Chronopolis project provides a digital preservation network, portal, and services for almost any sort of data or information. In addition, we have a substantial collection of coordinated efforts that are all contributing to the development of globally federated Earth System Science Gateways and the underlying Science Gateway Framework (SGF):

- The Earth System Grid Center for Enabling Technologies (ESG-CET) is developing a globally distributed data management environment for CMIP5/IPCC-AR5, and U.S. climate science.
- The Global Organization for Earth System Science Portals (GO-ESSP) and the Earth System Grid Federation (ESGF) are international collaborations building federated data systems for CMIP5/IPCC-AR5.
- The Cooperative Arctic Data and Information Service (CADIS) is developing cyberinfrastructure for data and knowledge management for the Arctic Observing Network (AON), IPY (International Polar Year), and related science.
- The Earth System Curator (ESC) is extending the SGF and ESG gateways to integrate modeling, data, and knowledge.
- The Community Data Portal (CDP) is the NCAR community's cyberinfrastructure for scientific data hosting and management.
- The WMO Information System (WMO-WIS) is an effort of the World Meteorological Organization to design and deploy the next-generation globally interconnected data system for weather, climate, hydrology, and more.
- The North American Regional Climate Change Assessment Program (NARCCAP) shares regional climate simulation data via the SGF and the ESG network.
- The TeraGrid Science Gateways project titled "Prototyping an Environmental Science Gateway" extends the SGF and ESG to prototype an end-to-end modeling and data management capability that includes distributed workflows.
- Chronopolis: Federated Digital Preservation over Space and Time is developing a distributed data preservation service.

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 National Digital Information and Infrastructure Preservation Program (NDIIPP).

We have deprecated the Earth System Knowledge Environment (ESKE) designation that was used in previous years. All of the projects involved are still reported here. Also, the Cyberinfrastructure Strategic Initiative (CSI) has been transitioned from a successful initiative to part of our core CISL/TDD/VETS program, and we no longer report on it separately. The efforts described in this section support CISL's computing imperative for software cyberinfrastructure by developing 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 developing science gateways and other Grid-based technologies. Specifically, this work fulfills CISL's strategic action item to refactor existing Earth System Grid and Community Data Portal infrastructure into a Science Gateway Framework.

Support for these activities comes from a number of agencies and programs, as detailed in each of the following

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The Earth System Grid Center for Enabling Technologies

This image is a snapshot of the new ESG-CET gateway built on the Science Gateway Framework (SGF). It provides access to climate-related data, tools, models, and other federated gateways and their data holdings. ESG has delivered well over a petabyte of climate science data to the global community, and a network of these gateways will manage and deliver several more petabytes of CMIP5/IPCC-AR5 to researchers around the world.

The Earth System Grid Center for Enabling Technologies (ESG-CET) is a five-year project funded by the U.S. Department of Energy (DOE) SciDAC-2 program to develop and deploy an international data facility for WCRP/CMIP/IPCC, U.S. climate science, and related impacts research. The effort has grown into a large-scale collaboration among NCAR (CISL and the Climate and Global Dynamics Division), Argonne National Laboratory (ANL), Oak Ridge National Laboratory (ORNL), Lawrence Livermore National Laboratory Program for Climate Model Diagnosis and Interpretation (LLNL/PCMDI), NOAA's Pacific Marine Environmental Laboratory (NOAA/PMEL), the University of Southern California Information Sciences Institute (USC/ISI), Lawrence Berkeley National Laboratory (LBNL), Los Alamos National Laboratory (LANL), and Rensselaer Polytechnic Institute. In addition to these formal, funded collaborations, ESG-CET is now aggressively collaborating with NOAA's Earth System Curator (ESC) project, the EU METAFOR effort, the British Atmospheric Data Center (BADC), the Max Planck Institute for Meteorology in Germany, and the WCRP program.

The ESG federation currently provides a production service for most of the joint NSF/DOE climate change simulations conducted over the last decade as well as the IPCC Fourth Assessment Report data holdings. Access is provided through a combination of web portal access as well as desktop applications that mediate large-scale transfers to the user. The ESG federation currently has approximately 20,000 registered users worldwide, manages over 450 TB of data in archives distributed around the nation, and has delivered over a petabyte of data to its constituents. Over the past several years, more than 700 scientific journal articles have been published from analyses of data delivered by the ESG. ESG thus plays an important role in advancing NCAR's strategic plan and supporting cross-agency and international climate change science. It's an important component in our strategic thrust for center virtualization and data management and access.

Our contributions to ESG-CET support CISL's computing imperative for software cyberinfrastructure by developing 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 developing science gateways and other Grid-based technologies. Finally, ESG-CET fulfills CISL's strategic action item to establish metadata standards for diverse collections of data and models.

In FY2010, we released two beta versions followed by six release candidates of the SGF for the ESG Gateway, finally reaching a major milestone in May 2010: Version 1.0.0 of the ESG Gateway. Version 1.0.0 included many additional features, improvements, and fixes including versioned datasets, access-controlled file downloads and deep storage transfers, data publishing performance improvements, and user interface refinements. We cut over all of our ESG production services that month as well, migrating over 16,400 users and publishing over 250 TB of climate data holdings in over 1.3 million files. The transition went very smoothly, including the parallel migration to our new modular Linux cluster for gateways. In July we released Version 1.1.0 which addressed OpenID logins, dataset replication, Gateway OAI RDF-based metadata exchange, application build system upgrades, and a range of security improvements. This was followed by the Version 1.1.1 minor release. Progress toward the critical Version 1.2.0 CMIP5

Baseline release early in FY2011 further addressed federation capabilities and security infrastructure, plus enhanced support for CMIP5 data specifics. Collaboration continues between ESG, Curator, and METAFOR. To manage this complex enterprise, we invested very heavily this year in project management infrastructure and process, utilizing BaseCamp, Atlassian (for release control and issues), and Confluence (for requirements and documentation). We made substantial progress toward a community development process, including developing a Contributor License Agreement (CLA) and working toward applying an Open Source license to the SGF. The SGF is currently running at NCAR, LLNL/PCMDI, ORNL, NASA/JPL, BADC, and DKRZ for evaluation and feedback purposes.

Full production operation in support of WCRP-CMIP5 and CCSM will begin in the first half of FY2011. A substantial portion of the upcoming year will be spent responding to user needs for new and better capabilities, as the new system becomes increasingly exercised. We will have to address scalability relative to data volume, as well as metadata volume and complexity. We will deliver enhanced security, federation, versioning, and replication capabilities, along with more advanced data product services development and integration.

ESG-CET's primary sponsor is DOE's Scientific Discovery Through Advanced Computing program contract DE-FC02-06ER25772 with additional support via cosponsorship of NSF Core funds.

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The Global Organization for Earth System Science Portals and the Earth System Grid Federation

NCAR is a founding member of the Global Organization for Earth System Science Portals (GO-ESSP), which began about a decade ago as a grassroots international group sharing experiences on building environmental science data systems. It has grown into an annual international conference that has now mobilized to form the ESG Federation (ESGF), which is an international collaborative effort to develop the globally federated data system that will serve the WCRP/CMIP5 effort and the IPCC/AR5 process.

GO-ESSP is an international organization that has given rise to the ESG Federation. The ESG Federation is building a global data and knowledge environment through international collaboration across several countries and major projects. ESGF will jointly deliver the federated data environment that will manage and share several petabytes of climate science data for WCRP-CMIP5 and IPCC-AR5.

After ten years of annual community workshops (60-80 in attendance), we elected to focus intensely on developing the data systems for CMIP5 and IPCC-AR5 this year. Semi-weekly meetings of contributors from multiple U.S. agencies, BADC in the UK, DKRZ in the EU, ANU in Australia, and more have led to broad deployment and extension of technology. In FY2011 we will collectively deliver the CMIP5/IPCC-AR5 data system and resume our annual workshop with a meeting at NCDC in Asheville, North Carolina. This event will be adjoined by meetings focused on ESGF planning, and the further development of the netCDF Climate and Forecast Conventions (CF) for metadata.

GO-ESSP is supported primarily via core contributions from each contributing organization and agency, and NCAR's participation is supported via a combination of NSF Core funds and ESG-CET support.

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The Cooperative Arctic Data and Information Service

Arctic science in the U.S. lacks a single coordinated force setting a data management direction. To address the challenges of data management for Arctic-wide observing systems, this needs to change for several reasons: to meet scientists' growing expectations for sharing and working with data across diverse disciplines and in the broad Pan-Arctic geographic domain, to encourage the international exchange of data, and to reduce overlap and wasted effort spent developing data management solutions for small numbers of users.

This figure shows the newly released CADIS Science Gateway, which is now based on CISL's Science Gateway Framework (SGF). The CADIS portal provides a sophisticated data publication capability, where individual NSF projects can publish their data products into the system simply and easily. It also provides a central location where community members can search for Arctic Observing Network (AON) data by variable, principal investigator, discipline, and several other qualities. This work provides a sustainable, community-focused approach to achieving an integrated and collaborative view and usage of Arctic data.

The Arctic Observing Network (AON) is supported by the NSF and consists of more than 30 land, atmosphere, and ocean observation programs, some with new observing capabilities. This International Polar Year (IPY) initiative will succeed in supporting the science envisioned by its planners only if it functions as a system and not as a collection of independent observation programs. CADIS is working to create a data management system through which scientists can find all data relevant to a location or process: all data have browse imagery and complete documentation, time series or fields can be plotted online, and all metadata are in a relational database so that multiple data sets and sources can be queried.

CADIS is a joint effort of the University Corporation for Atmospheric Research (UCAR), the National Snow and Ice Data Center (NSIDC), and NCAR, all in Boulder, Colorado. Working with NCAR's Earth Observing Laboratory, NSIDC, and Unidata partners, CISL's contributions to CADIS include the application, integration, and enhancement of Community Data Portal (CDP) and Science Gateway Framework (SGF) infrastructure to support the needs of the Arctic research community.

Our contributions to CADIS support CISL's computing imperative for software cyberinfrastructure by developing 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 developing science gateways and other Grid-based technologies, and they fulfill CISL's strategic action item to establish metadata standards for diverse collections of data and models.

During FY2010 we continued to operate the prototype CADIS system that allows PIs to publish their data sets along with detailed metadata into the CDP environment. Early in the reporting period we released Version 1.0.0 of the new CADIS Gateway, which is now based on the new Science Gateway Framework (SGF), and migrated all collections and people to it. We announced the new community resource at the AON PI meeting, held in Boulder, and vigorously sought community feedback and answered questions on it. Based on feedback from this meeting as well as input from the AON data management advisory group, we invested a lot of effort in improving CADIS' user interface. We enhanced the search experience substantially, and improved the handling of metadata and UI provisions for navigating through collections. We also advanced our capabilities for OAI-PMH-based metadata exchange, and demonstrated end-to-end functionality with Norway/DAMOCLES and NASA GCMD. We added Google Analytics, improved gateway-based metrics

reporting, and investigated search engine optimization (SEO) strategies. We continued our Google Earth-based visualization efforts, developing and demonstrating the visualization of station data and NSIDC layers, KML upload, and custom animation capabilities. Lastly, we improved our software engineering practices and project management approach substantially, which helped us accomplish all of this. We escalated our use of the Atlassian environment for software engineering and issue tracking/resolution, including opening it up to the entire collaboration.

Our CADIS contract runs through February 2011, and NSF has provided an extension grant to accomplish some of future objectives. We will continue to improve our search and discovery capabilities as well as the user interface for publishing data collections into the system. Our metadata federation capabilities will be brought to production-quality status, and the Google Earth capabilities will be integrated into the production CADIS Gateway. Leveraging our work in the Chronopolis Project, we will establish digital preservation processes for all of the collections managed directly under CADIS. The CADIS Gateway and the formal AON CADIS project website will be totally integrated as “aoncadis.org” as well. The CADIS team has submitted a proposal to NSF to carry on this work in the future under the auspices of the OPERA program.

CADIS is supported via a combination of NSF Special funds and cosponsorship of NSF Core funding.

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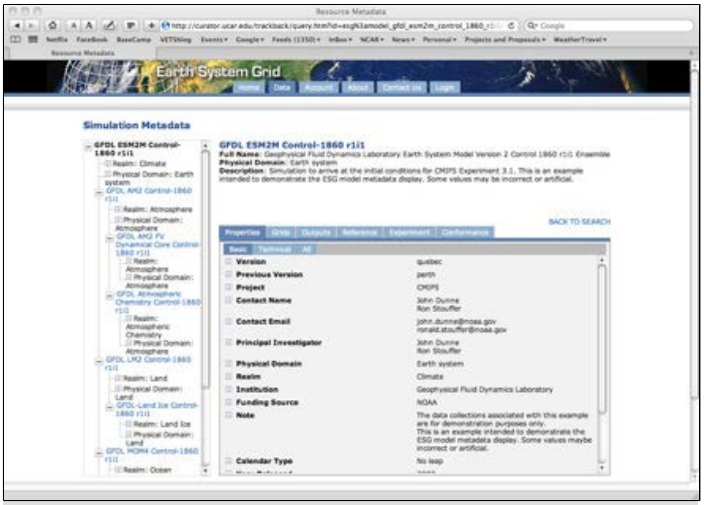
The Earth System Curator project

One of the lessons learned from the last CMIP3/AR4 process was that the community needed much more extensive – and machine readable – metadata about the experiments contained within the archive. There needed to be a much tighter integration across the modeling and data management enterprise to support multi-model analyses. The Earth System Curator (ESC) project, or Curator for short, is focused on this challenging problem. Curator began as an NSF-supported project, attracted NASA support, and is now currently sponsored by NOAA's Global Interoperability Program (GIP).



This is a snapshot of the Curator-developed "model trackback" interface in the Earth System Grid (ESG). It provides an interface for interacting with Common Information Model (CIM) metadata that will be produced as part of the WCRP/CMIP5 process. Users worldwide will have access to an unprecedented, rich supply of detailed information about the experiments undertaken as part of CMIP5.

Our contributions to Curator support CISL's computing imperative for software cyberinfrastructure by developing 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 developing science gateways and other Grid-based technologies, and they fulfill CISL's strategic action item to establish metadata standards for diverse collections of data and models.

In FY2010, Curator collaborated very closely with ESG on gateway development, and with the European Union-based METAFOR effort on metadata development and integration. METAFOR is developing a Common Information Model (CIM) specification aimed at capturing the extremely diverse volume of information needed to support the WCRP/CMIP5 and IPCC/AR5 studies. We collaborated closely with the METAFOR effort to develop components that could provide ESG ingest of CIM documents that would be delivered by the METAFOR CMIP5 Questionnaire. We also developed "model trackback" interfaces such that ESG gateway interfaces could provide the user community with the ability to interrogate and navigate the new knowledge holdings.

In FY2011, we will demonstrate a full end-to-end capability, wherein a METAFOR Questionnaire-based ATOM feed will deliver CIM and possibly CMIP5 quality control documents from each modeling center into the ESG federation. The information contained therein will become integrated with the rest of the ESG metadata, such that community members will be able to navigate and utilize the information. Curator capabilities will be integrated as part of the production ESG network for CMIP5. Working in concert with our TeraGrid-sponsored work, we will prototype and begin integrating model submission and integration capabilities into the core Science Gateway Framework (SGF), work which we expect to require a significant extension of the SGF domain model, among other things. Investigation and prototyping of collaboration capabilities into the SGF will begin in FY2011 as well.

Curator is supported by special funding from NOAA's GIP program, with co-sponsorship via NCAR's NSF Core funds.

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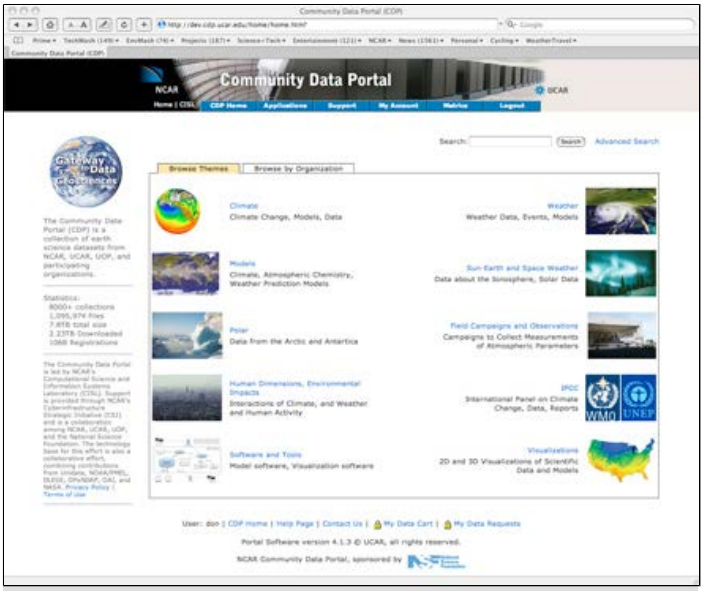
The Community Data Portal

The development of cyberinfrastructure that supports community data management has been a long-term priority of CISL's. The Community Data Portal (CDP) was the foundation for our science gateway development efforts, including the ESG and CADIS gateways. The CDP provides access to a broad range of scientific data collections that span climate, atmospheric chemistry, space weather, observational and field programs, models, analyses, and more.



This image is a snapshot of the Community Data Portal (CDP) home page. The CDP provides cyberinfrastructure for sharing a wide range of environmental data collections with the broad community. In a transition process to the new SGF, the CDP provides a low-cost, sustainable approach to providing researchers with a means of managing and sharing their data.

This effort supports CISL's computing imperative for software cyberinfrastructure by developing software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. It also addresses CISL's computing frontier for center virtualization through developing science gateways and other Grid-based technologies, and it fulfills CISL's strategic action item to establish metadata standards for diverse collections of data and models.

During FY2010, we migrated the CDP from its aging Solaris-based host to the new, modular Linux-based gateways cluster. We also published several new data collections, including ones related to magnetohydrodynamics (TIE-GCM) and Arctic and South Pole research endeavors. Prior to the release of the new SGF-based CADIS gateway, the CDP continued to serve as a hosting engine for PI-published Arctic data collections. We also continued to use the CDP as a service provider for the WMO WIS development and testing activity. As a technology foundation, the CDP was held largely in stasis as we developed the next-generation Science Gateway Framework (SGF).

In FY2011, we will migrate all of the CDP-hosted data collections and users to the SGF infrastructure. To the degree possible, we plan to co-locate current CDP local and federated collections alongside all of the ESG collections related to global and regional climate science. Given the diversity of data resident on it, we plan to use CDP-generated requirements to drive the evolution of SGF metadata handling capabilities. The CDP will also be migrated to CISL's new GLADE storage system.

The CDP is supported by NCAR's NSF Core funding.

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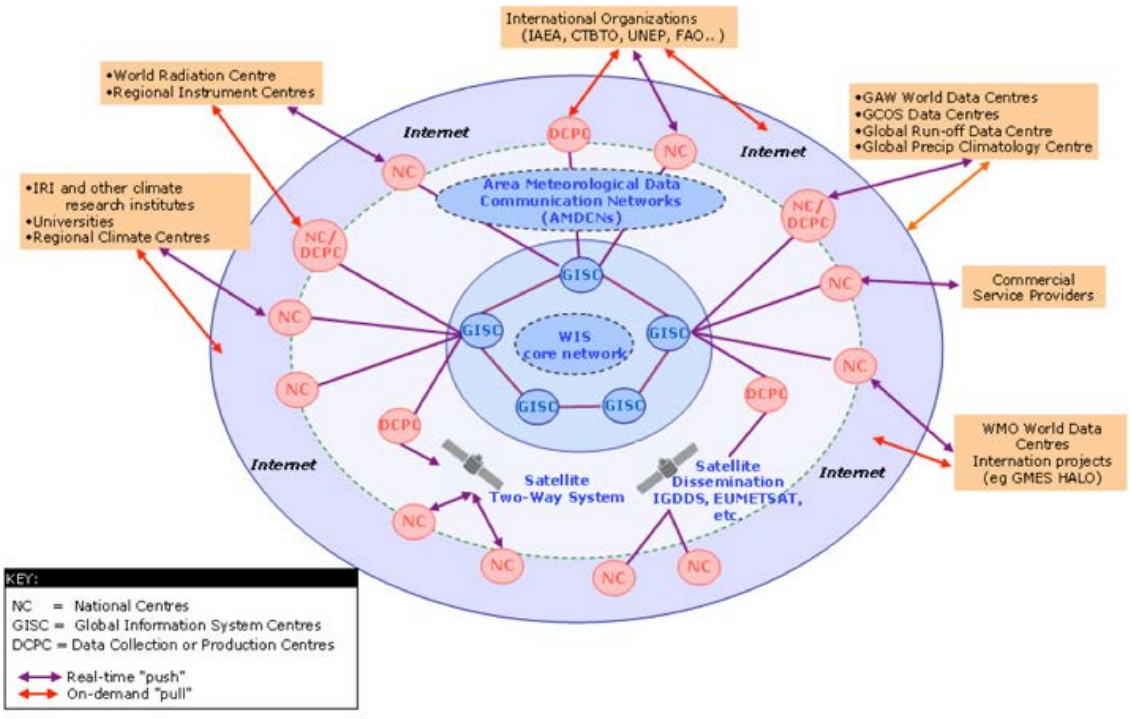
The World Meteorological Agency Information System

Under the auspices of the United Nations, the World Meteorological Organization (WMO) is in the process of designing, developing, and deploying the next generation of globally connected information systems for weather, climate, hydrology, oceanography, and many other disciplines. CISL plays a strong role in the management and technical direction of WMO-WIS and has contributed ideas, strategies, and services developed in our work with CDP, ESG, CADIS, and other efforts.

This effort supports CISL's computing imperative for software cyberinfrastructure by developing software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. It also addresses CISL's computing frontier for center virtualization through developing science gateways and other Grid-based technologies, and it fulfills CISL's strategic action item to establish metadata standards for diverse collections of data and models.



This diagram depicts the high-level architecture of the WMO WIS system. WIS will serve as WMO's next-generation substrate for globally federated data and knowledge integration. CISL is contributing to the design, development, and deployment of this global network, which will serve as a cornerstone for the Global Earth Observing System of Systems (GEOSS).

In FY2010, CISL continued to contribute to several groups across the realms of WMO-WIS management, strategic planning, project management, metadata development, gateway federation, and assessment of technology deployments. CISL led the effort to develop an environment for managing technical design, requirements specification, and software engineering processes. We continued to contribute to the WIS management functions, the testing and validation committee, and the metadata development committee.

In FY2011, we will supply core information services via SGF-hosted data management systems in support of validating new WMO-WIS systems that become subject to assessment. NCAR will also begin to function as a WIS Data Collection and Production Center (DCPC), contributing ESG, TIGGE, RDA, EOL, CDP, CADIS, and other collections to the global system.

CISL's contributions to this effort are supported via core NSF NCAR support.

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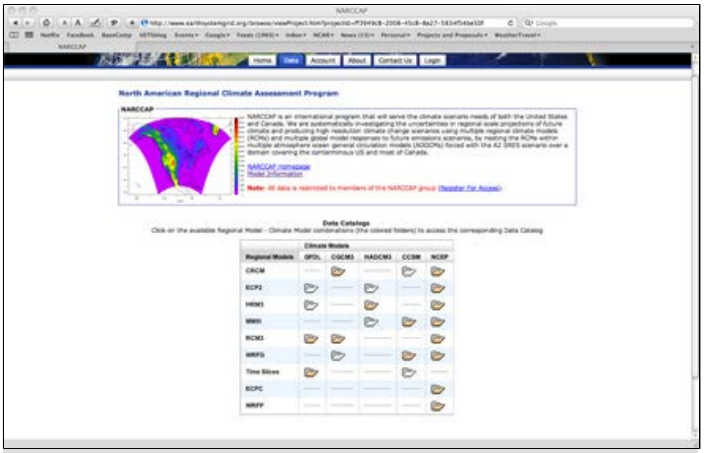
The North American Regional Climate Change Assessment Program

NARCCAP is an international program that serves the climate scenario needs of both the United States and Canada. We are systematically investigating the uncertainties in regional-scale projections of future climate and producing high-resolution climate change scenarios using multiple regional climate models (RCMs) and multiple global model responses to future emissions scenarios. This is done by nesting the RCMs within multiple atmosphere-ocean general circulation models (AOGCMs) over a domain covering the conterminous U.S. and most of Canada. The plan also includes a validation aspect through nesting the participating RCMs within reanalyses.



This image depicts the NARCCAP portal which is now hosted via the SGF and made available on the ESG network. The matrix-based user interface shows availability and provides access to a range of combinations of global and regional climate models. NARCCAP provides its user community with access to a unique and growing collection of regional climate scenarios for the U.S. and Canada.

CISL's contribution to this project is primarily in providing data management cyberinfrastructure and community access for NARCCAP-produced datasets. This aspect of the work is a collaborative effort with NCAR/SERE, Lawrence Livermore National Laboratory (LLNL), and Iowa State University. NARCCAP heavily leverages existing Earth System Grid (ESG) infrastructure as well as established data management practices developed for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4).

This effort supports CISL's computing imperative for software cyberinfrastructure by developing software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. It also addresses CISL's computing frontier for center virtualization through developing science gateways and other Grid-based technologies, and it fulfills CISL's strategic action item to establish metadata standards for diverse collections of data and models.

In FY2010 we transitioned the existing NARCCAP data environment into the new Science Gateway Framework (SGF) environment and began serving data through the ESG network. We are continuing to publish data collections from regional climate modeling experiments that are currently underway. At this point, we have completed the core NARCCAP development work and continue to engage with the operational team that manages existing and emerging NARCCAP data collection for the broad community.

Funding for this project has been provided by NSF special support, DOE, NOAA, OURANOS, and NCAR's NSF Core resources.

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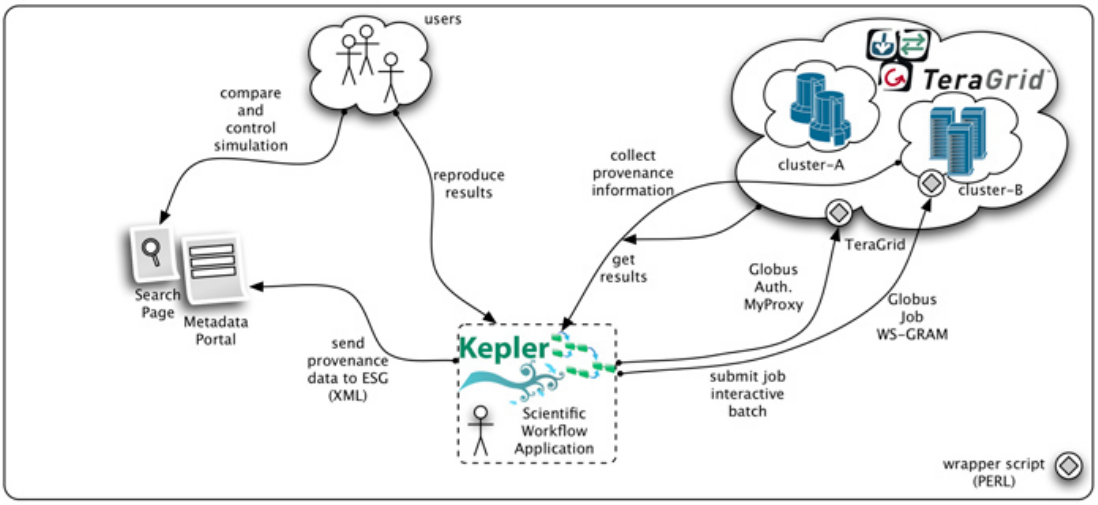
TeraGrid Science Gateways: Prototyping an Environmental Science Gateway

Science gateways represent an important emerging paradigm for providing integrated cyberinfrastructure for a range of communities. NSF's TeraGrid program has invested heavily in promoting and supporting a number of exploratory and production efforts in this area. This particular effort is a collaboration of Purdue University, NCAR, and NOAA aimed at building a prototype Environmental Science Gateway with an initial focus on CCSM modeling and data publication into the ESG infrastructure.

This effort supports CISL's computing imperative for software cyberinfrastructure by developing software specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. It also addresses CISL's computing frontier for center virtualization through developing science gateways and other Grid-based technologies, and it fulfills CISL's strategic action item to establish metadata standards for diverse collections of data and models.



This image shows the concept and information flow for a prototype of an integrated next-generation modeling, data, and knowledge environment. The environment allows a user to request a simulation scenario while a workflow engine manages the computation, data management, and publication processes behind the scenes. Sophisticated approaches such as this will be required to manage the inherent complexity of future computational research campaigns.

In FY2010, the collaboration continued to advance the development of the CCSM portal at Purdue, worked to instrument the CCSM model for Conceptual Information Model (CIM) metadata production via ESMF, established basic ESG data-publishing capability from Purdue to NCAR, prototyped Kepler-based workflow capabilities, and investigated iRODS-based data publication. Work also began on developing an ATOM-based CIM feed and ingest subsystem, which will ultimately allow a CCSM workflow to publish its data collections into ESG.

In FY2011 we will complete the development of CIM publishing capability into ESG and integrate the Purdue modeling portal with ESG. We plan to demonstrate an end-to-end capability in summer 2011: a user portal that will allow the submission of a job, then using a workflow engine, the publication of data and metadata into ESG.

This effort is supported by NSF TeraGrid funding.

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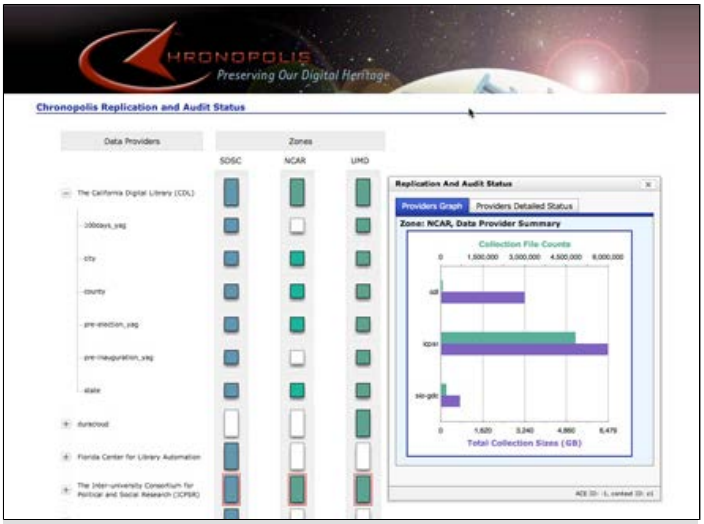
Chronopolis: Federated digital preservation across space and time

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 – science, engineering, humanities, and more. This new effort encompasses studying viable models and effective systems that facilitate establishing standard reference datasets, preserving collections that evolve over time, and establishing preservation resources "of last resort" for digital assets that might become lost. Digital collections that must persist for 100 or more years are one important focus of this activity. To solve this problem, a special synthesis of relationships and capabilities is required from scientists, librarians, curators, computer scientists, and long-term distributed cyberinfrastructure.



This image shows the Chronopolis operational status page, which displays the integrated real-time state of the Chronopolis system. Chronopolis software consists of a suite of replication, control, and validation packages running at the NCAR, SDSC, and UMD sites. This page allows the status of this distributed system to be assessed at a glance, and it provides tools to drill into the information as required.

The problem spans the gamut of academic scientific disciplines, historical collections, and digital library content. Though broadly useful, new capabilities developed in Chronopolis are expected to be powerful services that we can potentially offer to the Earth System sciences community through, for example, NCAR's **Community Data Portal**. This activity supports CISL's computing frontier for center virtualization by advancing grid-based data preservation technologies, and the growing CISL and community imperative to preserve scientific data.

In FY2010 Chronopolis moved toward being a more robust operational system. Chronopolis began the process of TRAC certification, an independent and lengthy audit of all aspects of technical, management, data life cycle management, business models, and governance structures that will be needed to certify the soundness of all important aspects of the project to potential clients. Technical development has continued in the infrastructural and usability realms, and was focused on the needs of clients to protect information about their collections and to personalize the display of status. The project is moving toward many new partnerships with potential data archiving clients, peer archiving projects, and cloud service providers. An alliance with the MetaArchive organization is being explored and shows promise for increasing the technical robustness of Chronopolis by bringing technical heterogeneity to techniques used to store and retrieve data. Potential alliances with cloud service providers is being pursued as well. Chronopolis would serve as a high-reliability dark archive service provider for cloud storage clients who need higher levels of reliability and, in some cases, larger data capacity than is typically provided to current clients. Chronopolis is currently acquiring a new generation of hardware to upgrade and consolidate server systems and expand storage capacity to about 110 TB of usable space.

In 2011 the new hardware will be brought online and data will be moved from the current storage to the new space. A key Chronopolis component, the SRB subsystem, will be replaced with iRODS on the new hardware. It is expected that TRAC certification will be completed, and Chronopolis will begin to move toward a client-funded service model. Technical interfaces to cloud providers, begun in 2010, will be brought to an operational level. The next generation of

status monitoring tools will be developed. CISL will begin pilot projects that investigate using Chronopolis services for the preservation of NCAR Library, CADIS, and other holdings.

CISL is engaging in Chronopolis as an important strategic thrust, supporting it through a combination of funding from the National Library of Congress with additional support via cosponsorship of NSF Core funds.

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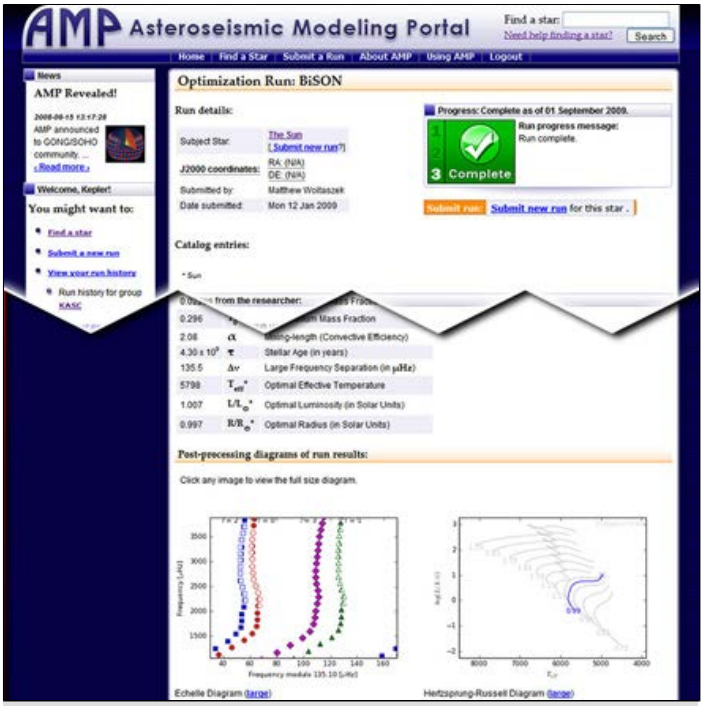
Computationally intensive science gateway development

Setting up and running modern computational models is often an involved process for scientists. A complete experiment may require the orchestration of multiple steps on computational resources at different institutions, generally referred to as a workflow. Typical workflow steps involve gathering the required data from online and archival storage systems, running preprocessing software to prepare data for the model, executing the simulation model itself, gathering and post-processing output data, and running separate programs to analyze and visualize the results. Often, the workflow must be repeated for multiple experiments, and the mechanism employed to perform each step may vary between different computer systems. The overhead of simply running a computational experiment is thus quite high as scientists are often required to perform many mechanical tasks just to coordinate the work on the computers.



This screenshot of the Asteroseismic Modeling Portal (AMP) shows the results of a test run for the Sun used to validate the operation of the computational model and AMP's grid-based workflow processing engine. AMP provides a web-based interface for astronomers to run and view simulations that derive the properties of Sun-like stars from observations of their pulsation frequencies. AMP's web-based user interface automates the execution of the asteroseismology software pipeline, allowing astronomers to easily execute the model on the NCAR Frost and NICS Kraken supercomputers.

Science gateways, also called "portals," are intended to simplify the use of complex software models by providing an intuitive web-based user interface and automating the workflow required to perform the experiment. In a typical gateway, scientists can choose to upload original input data or select from popular community datasets, configure the experimental run parameters, run the job, and view raw or processed results. All of this can be done in an intuitive web-based environment without knowledge of the specific configuration on each computer that was used to run the simulation. By reducing the amount of platform-specific computer expertise required to execute models, gateways allow scientists to focus on science, increasing the efficiency of scientific inquiry for mature computational models.

In FY2010, CISL's Computer Science Section (CSS) continued work on two science gateways. The first gateway, Grid-BGC, was originally developed from FY2003 to FY2006 with funding from NASA. As several years have passed since its development, CSS has committed to maintain the gateway's base functionality, allowing the principal investigator and close collaborators to continue to use the gateway to run an updated version of the Daymet surface observation interpolation engine. This year, the Grid-BGC gateway's back-end job execution software was decoupled from the IBM Blue Gene/L supercomputer Frost and reconfigured to use more common commodity Linux clusters to run its simulations. This facilitated more rapid software development update cycles with the investigator, and the use of current-generation processors substantially decreased the wall-clock time for processing.

NCAR also continued to maintain the Asteroseismic Modeling Portal (AMP), a web-based interface and automated processing pipeline that presents an asteroseismology model to an international community of researchers. The astronomy investigator and his colleagues have been using AMP to routinely benchmark and validate the modeling code, and about 30 astronomers from the Kepler Asteroseismic Science Consortium have obtained AMP accounts so

they can use the gateway as soon as the Kepler data becomes available. Designed as a TeraGrid science gateway, AMP is currently capable of running simulations on the NCAR Frost and NICS Kraken TeraGrid resources. In FY2010, NCAR worked closely with system engineers at NICS to bring the AMP automation system ("GridAMP") under the control of a new TeraGrid-recommended community account security model.

The Grid-BGC and AMP science gateways play an important role in supporting the CISL computing frontier of center virtualization. In particular, these gateways leverage the combination of NCAR's local and multi-agency Grid-enabled cyberinfrastructure to support geoscience research. In FY2011, NCAR plans to continue supporting the Grid-BGC and AMP gateways while investigating additional applications and technologies useful for this type of collaborative research and development. For example, one model under consideration for automation and presentation as a science gateway is the Population-Environment-Technology (PET) model developed by researchers in NCAR's Climate and Global Dynamics (CGD) division.

The development and maintenance of the Grid-BGC and AMP science gateways is supported by NSF Core funds. Supplemental funding to integrate AMP with TeraGrid resources was provided by NSF through the TeraGrid's Grid Integration Group (GIG) Science Gateways program.

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Computing Imperative: 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 1,300 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:

- TeraGrid integration
- Earth System Knowledge Environment
- Experimental computing systems

The most notable events for CISL during FY2010 included the completion of the final design for, and the approval to begin construction of, the NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming. Official groundbreaking took place on June 15, 2010, with a ceremony highlighted by statements from Wyoming Governor Dave Freudenthal, UCAR Director Rick Anthes, NCAR Director Roger Wakimoto, CISL Director Al Kellie, and officials from the University of Wyoming and the National Science Foundation. Through the summer, construction proceeded a rapid pace, with concrete foundations laid and steel superstructure assembled. At the end of FY2010, construction was ahead of schedule.

The NWSC facility construction progressed rapidly from groundbreaking in June to the installation of exterior precast walls in late September 2010. Shown in this photo from the construction site webcam on 28 September 2010, the steel joists in the foreground will be used in the data center area of the building.

Planning continued during the year for the RFP specifications and processes that will lead to the acquisition of the HPC computing, data storage, and archival equipment to be installed within the NWSC during FY2012.

CISL added four important technologies to the NCAR computational environment in FY2010:

- Acquisition of equipment for and the deployment of the GLobally Addressable Data Environment (**GLADE**).
- Augmentation of the NCAR Mass Storage System (**MSS**) with additional storage capacity and capability.
- Deployment of the High-Performance Storage System (**HPSS**) into a semi-production state and preparation for the transition of over 10 petabytes of data from the NCAR MSS into HPSS planned for FY2011.
- Acquisition and deployment of an 8-TFLOPS **Cray XT5** supercomputer system for testing and to augment existing computational resources.

CISL's main supercomputer, Bluefire, remained the primary production system for the Climate Simulation Laboratory

(CSL) and the NCAR/UCAR user community. It has proven to be a reliable and efficient computational platform. During the year, several projects were provided the opportunity to study challenging problems through **special computational campaigns** on Bluefire.

CISL is committed to deploying and maintaining a highly productive, end-to-end computational environment, and during FY2011 CISL will again enhance the data analysis and visualization environment by deploying a centralized home file system capability. CISL will fully deploy HPSS in production, ingest all MSS data into HPSS, and decommission the NCAR MSS system after 25 years of service. In addition, CISL will complete the development of, release, evaluate, and award procurements for the acquisition of HPC, high-speed file systems, disk storage, and data archival equipment for the NWSC. Finally, and most importantly, CISL will complete the NWSC construction and begin facility commissioning.

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

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Cyberinfrastructure procurement, deployment, and operations

NCAR maintains a comprehensive computational environment to satisfy CISL's strategic imperative for hardware cyberinfrastructure by provisioning robust, reliable, high-performance computing resources to enable world-class analysis and simulation of the Earth-Sun System. Tailored for efficient usage by the numerical simulation community, these resources offer an optimal combination of scientific data services with computational capability and capacity. To fulfill its responsibility to support science, CISL provides computational hardware and scientific data services including:

- 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. CISL also invests in developing Grid technology projects that allow NCAR's cyberinfrastructure and the science it supports to be better integrated with other centers, scientists, and research programs throughout the country and around the world, including:

- TeraGrid integration
- Globally Federated Earth System Science Gateways
- Experimental computing systems

The most noteworthy FY2010 event was beginning construction of the NCAR-Wyoming Supercomputing Center in June. Final design was completed and approval to go to construction was granted by the NSF in the spring. Official groundbreaking took place on June 15, and construction is ahead of schedule at the end of the fiscal year.

CISL's newest supercomputer is the Cray XT5m named Lynx. This 8-teraflop, 912-processor system was acquired to test file system and job scheduler technologies, and to augment NCAR's computational capacity.

During FY2010 CISL continued to operate and maintain the IBM Power575 system, Bluefire, the NCAR Mass Storage System, and other smaller systems and services to sustain a stable production computational environment for the CSL and NCAR/UCAR communities. CISL enhanced the data analysis and visualization environment by significantly increasing the amount of online disk storage available to scientists through the deployment of the GLobally Addressable Data Environment (GLADE). A portion of this effort was supported via NSF Special funds used specifically to further enhance data storage for the Research Data Archive (RDA) and for analysis and scientific visualization.

CISL augmented the capacity and capability of the NCAR MSS and continued the deployment of HPSS. At the end of FY2010, HPSS was being used by CISL and a friendly-user community in preparation for its production deployment and replacement of the NCAR MSS system in FY2011.

During FY2010, CISL acquired a single-frame, 912-processor Cray XT5 system

named Lynx. The system is being used as a test platform by CISL to evaluate key scheduler and file system technologies. In addition, the system has been made available to friendly users when it is not dedicated to testing.

In FY2010, CISL continued to measure the performance of selected applications on new platforms, both at NCAR and at other computing centers. To maintain a high level of performance on the NCAR system, CISL also routinely measured the performance of vendor systems on a representative workload selected with the input of NCAR scientists.

Periodic capacity increases built into the Augmentation of the Mass Storage Tape Archive Resources (AMSTAR) procurement are part of the smooth transition from the NCAR MSS to HPSS during FY2011.

CISL has begun drafting specifications and the internal procurement process for a Track-2-scale supercomputer with a peak performance in excess of 1 petaflops, along with equipment for data archival, data analysis, and visualization. This equipment will be installed in the NCAR-Wyoming Supercomputing Center during FY2012.

In FY2010 Grid cyberinfrastructure enhancement at NCAR continued to provide user access to substantial resources and collaborations needed to perform the most challenging research. Just before the start of FY2010, three IBM BlueGene/L frames quadrupled computational capacity of NCAR's TeraGrid resource by expanding it to an 8,192-processor system. CISL continued to operate as a TeraGrid Resource Provider through FY2010, and will continue until directed otherwise by the NSF. Investments will then be determined by CISL's role in the TeraGrid follow-on program, TeraGrid eXtreme Digital.

A key to making these cyberinfrastructure elements successful is to facilitate easy access to CISL systems by authorized researchers. For example, remote visualization or GridFTP sessions require ports to be opened through our security perimeter, particularly for trusted centers. During FY2010 CISL developed and implemented a plan that provides openness for collaborative purposes balanced with appropriate security. CISL will continue to track ease-of-access issues via user problem reports and user experiences expressed as responses to periodic surveys. User feedback via the TeraGrid system will also continue to be solicited.

During FY2011, CISL will focus on completing the NWSC and procuring the HPC, data archival, and data analysis and visualization resources. Attendant with those efforts will be the planning and execution of the initial phases those plans, for staffing and operating the new center, and for supporting the user communities to be served by the NWSC. CISL also plans to deploy, as part of GLADE, a new centralized home file system resource in preparation for a full NWSC deployment of shared data storage resources.

NCAR's supercomputers are managed by CISL under the UCAR/NSF Cooperative Agreement and are supported by NSF Core funds including CSL funding. GLADE development was partially supported by NSF Special funds in FY2010.

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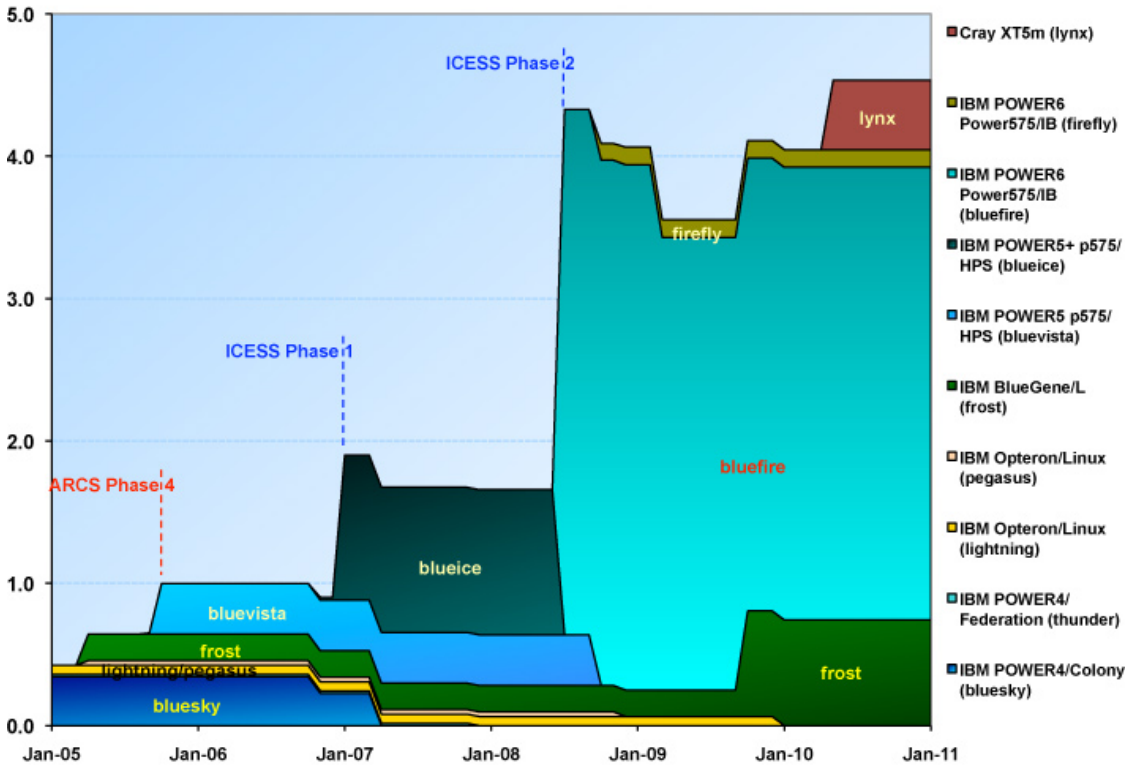
Production supercomputing status

Integral to its computing imperative for hardware cyberinfrastructure, CISL provisions robust, reliable, secure high-performance computing resources to provide a production research environment for a wide variety of disciplines related to the atmospheric sciences. Computational resources are balanced for the needs of the numerical simulation communities served by CISL to provide the most useful combination of computational capability and capacity with scientific data analysis, visualization, and archival services.



Estimated sustained computing capacity (in teraflops) available to the NCAR community over the past six years. CISL strives to provide regular substantial increases in computational capacity to meet the growing demands of the scientific research community.

CISL works to provide equitable access to reliable computing resources while minimizing user wait times and maximizing resource utilization. These are key elements in production supercomputing services. Providing such equitable access while maintaining high utilization requires that CISL monitors and maintains a proper balance of resource allocation, priority-based intelligent job scheduling, a well-tuned job queue structure, and single-job resource limits. When possible, CISL increases production computational capacity on a regular basis.

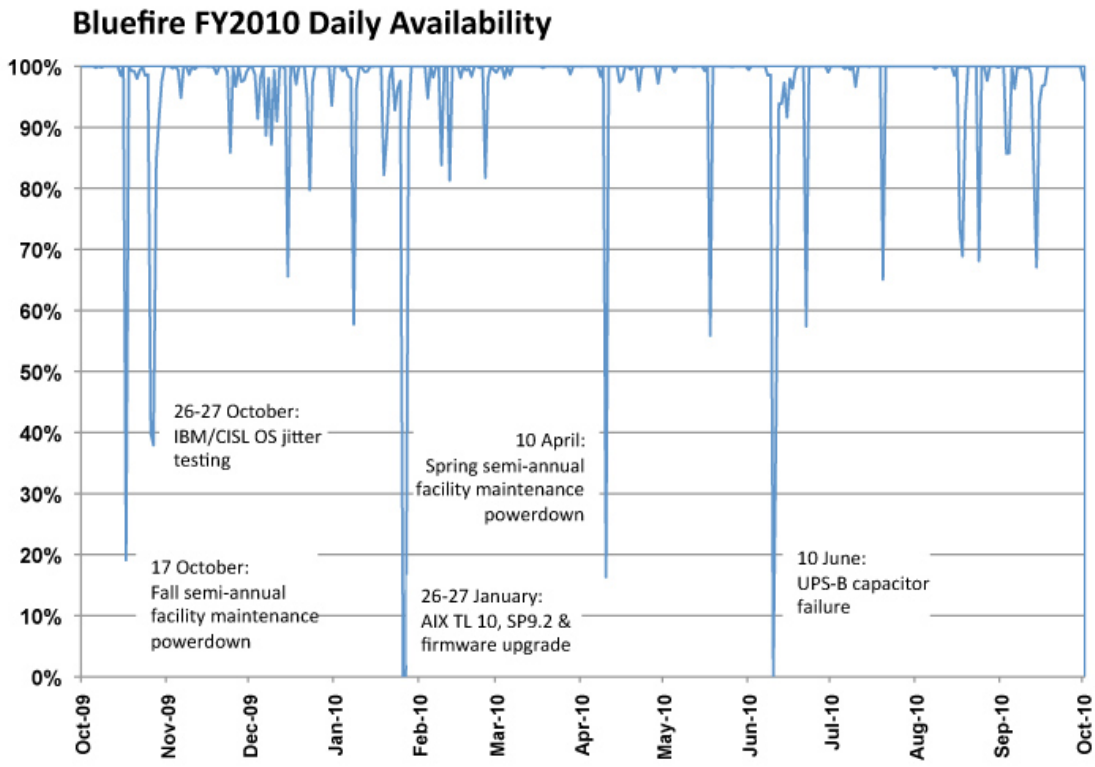
Further, CISL also provides the organizational focus, capabilities, and skill sets required to support important field and computational campaigns – including those driven by unfolding natural disasters – with on-demand resources. Bluefire supports the CISL-

developed on-demand capability computing model that enables the entire cluster or portions of it to support dedicated or shared special computing campaigns.

Supercomputer status

Bluefire and Firefly are the IBM Power 575 production and test supercomputers. Firefly may provide production services if needed to support operational forecasts for the NSF's Office of Polar Programs' Antarctic Mesoscale Prediction System (AMPS).

The IBM Power 575 system Bluefire is the primary computational workhorse at NCAR. It was placed into service at the end of June 2008 and CISL plans to keep it running until after new supercomputing resources are operational within the **NWSC** in 2012. During FY2010, CISL performed a number of software upgrades on Bluefire and its Power575 test cluster (Firefly). CISL continued to provide three Bluefire nodes, with Firefly as a backup, for the twice-daily operational forecasts in support of the NSF's Office of Polar Programs' Antarctic Mesoscale Prediction System (AMPS). Bluefire remained highly utilized throughout the year, averaging 93% utilization for the fiscal year with an average queue-wait time of less than an hour. Part of Bluefire's resources were used for **special computational campaigns** and important science projects such as the IPCC AR5 simulations.



Average user utilization of Bluefire during FY2010. Keeping scientific production at a high level meets NCAR's goal of providing reliable and robust computational services to the community.

In April, CISL acquired Lynx, an 8-teraflop, 912-processor Cray XT5m supercomputer. A strategic investment, the Cray XT5 system is being used to test filesystem technologies, alternate batch and resource management subsystems, as well as provide a local development platform for UCAR community users who have access to larger Cray XT systems at other computational facilities, such as Jaguar at the National Center for Computational Science.

During FY2010, the Computation Analysis Visualization Enabled Storage (CAVES) was redesigned and renamed the GLobally Addressable Data Environment (**GLADE**). GLADE now provides a common set of high-speed filesystems to complement and supplement the high-end computing environment. GLADE significantly increased the amount of online data storage for analysis and visualization to meet community demands. A portion of the system is commissioned to enhance data storage for NCAR's Research Data Archive (**RDA**). GLADE also serves as a prototype architecture for the deployment of high-performance computing, data analysis and visualization and data management resources within the NWSC.

The Globally Addressable Data Environment (GLADE) disk subsystem is checked by Pamela Gillman shortly after its deployment. NCAR's supercomputer users benefit from this new architecture because GLADE provides computational, analysis, and visualization work spaces common to all CISL HPC resources, and because storage can be allocated according to project needs. Immediately after deployment, GLADE rapidly expanded NCAR's online data for the Research Data Archive (RDA), NCAR's climate model projections for the upcoming IPCC report (AR5), the NCAR-UCAR Community Data Portal, and the Earth System Grid (ESG).

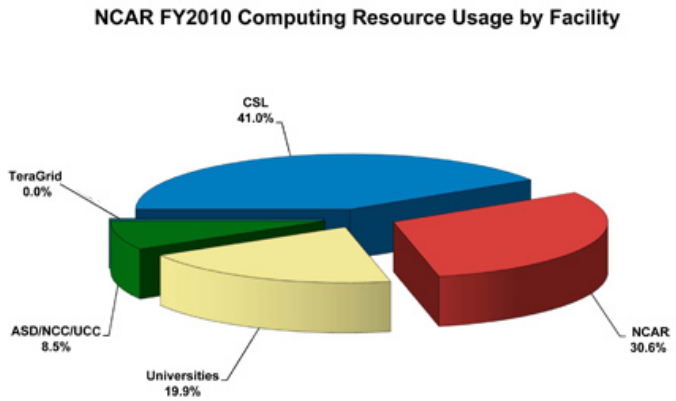
Plans for FY2011 include completing the construction phase of the NWSC and procuring its high-performance computing, data analysis, visualization, data storage and data archival resources, including a wide-area shared filesystems.

CISL operated, performed major software upgrades, and maintained its IBM Power 575 hydro-cluster system (Bluefire) through FY2010, providing 77 teraflops of peak production supercomputing resources to the Climate Simulation Laboratory (CSL), the NCAR and University communities, and special computational campaigns (Accelerated Scientific Discovery, NCAR Capability Computing, and University Capability Computing). Bluefire exhibited 96.2% availability and 92.9% system-wide user utilization for FY2010. CISL decommissioned two systems during the fiscal year: Lightning on 4 December 2009 (it was placed into service in September 2004) and Coral at the end of September 2010 (it began serving IMAGe in September 2005).

Various needs for special computational campaigns and on-demand computing were satisfied by either dedicating resources or using high-priority queues and advanced reservation features of the Bluefire job scheduler. For example, during FY2010 CISL supported special "near-real-time" computational campaigns (such as IPCC AR5 simulations and forecasts for the VORTEX2 and Hurricane Simulation projects) while maintaining high levels of system utilization and throughput for all other users. The average queue-wait time for jobs in the regular queue was 56 minutes.

Impact on science

Scientists at NCAR and across the country used Bluefire to accelerate research into climate change, including future patterns of precipitation and drought around the world, changes to agriculture and growing seasons, and the complex influence of global warming on hurricanes. Researchers also used it to improve weather forecasting models to more accurately predict where and when extreme storms may develop or hurricanes may strike. The system also allowed scientists to study in unprecedented detail the relationship between solar processes and weather on Earth, gain a deeper understanding of turbulence, and develop and refine models that simulate many of the processes responsible for elements of the Earth climate system.



This chart shows how the Bluefire supercomputer was shared during FY2010 by Climate Simulation Laboratory projects, NCAR users, University Community users, and special computational campaigns. Allocation committees balance scientific demands with available resources.

Looking ahead

During FY2011, CISL anticipates a continuing increase in demand for computational resources that will stress the existing systems and likely contribute to higher queue-wait times. CISL does not expect to augment computing capacity until new equipment is deployed within the NWSC.

Funding sources

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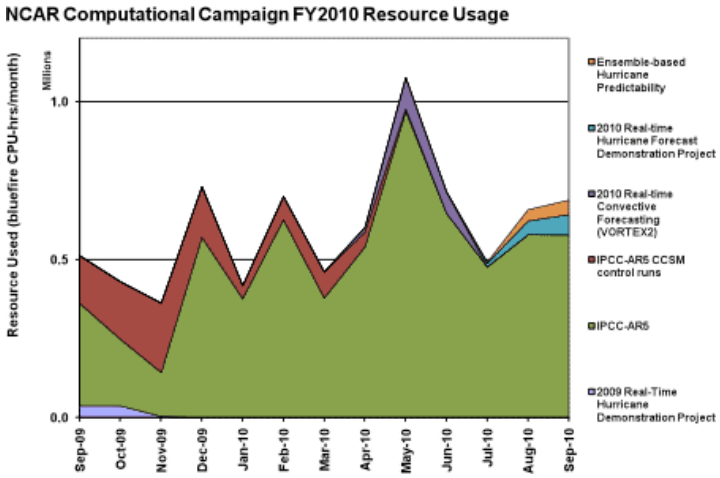
Special computational campaigns

The NCAR production supercomputing environment provides capacity computing to NCAR, university, and CSL scientists. Within this environment, CISL also supports special computational campaigns for ongoing and short-term computational projects, as well as on-demand capability computing, all via a priority-based and near-real-time job scheduling mechanism.

The following table lists the special computational campaigns supported by CISL during FY2010. Bluefire continued running the IPCC AR5 simulations and control runs, as well as three on-demand projects: the 2009 and 2010 real-time hurricane runs and the convective forecasts for VORTEX2.

FY2010 Special Projects	Principal Investigator	Begin	End
2009 Real-Time Hurricane Demonstration Project	Chris Davis	1-Aug-09	30-Nov-09
IPCC-AR5	multiple PIs	1-Jun-09	31-Dec-10
IPCC-AR5 CCSM control runs	John Wolfe	10-Aug-09	31-Dec-10
IPCC-CORE ESM 20th Century with Emissions	Mariana Vertenstein	24-May-10	-
IPCC-CORE ESM 20th Century with Concentrations	Mariana Vertenstein	25-May-10	-
IPCC-TIER1 CCSM4 LGM	Mariana Vertenstein	20-May-10	-
IPCC-TIER2 CCSM4 Last Millennium	Mariana Vertenstein	20-May-10	-
IPCC-TIER1 CCSM4 Mid-Holocene	Mariana Vertenstein	20-May-10	-
2010 Real-time Convective Forecasting (VORTEX2)	Morris Weisman, Wei Wang	22-Apr-10	20-Jun-10
2010 Real-time Hurricane Forecast Demonstration Project	Chris Davis, Wei Wang	11-Jun-10	31-Oct-10
Ensemble-based Hurricane Predictability	Ryan Torn	1-Jul-10	31-Oct-10

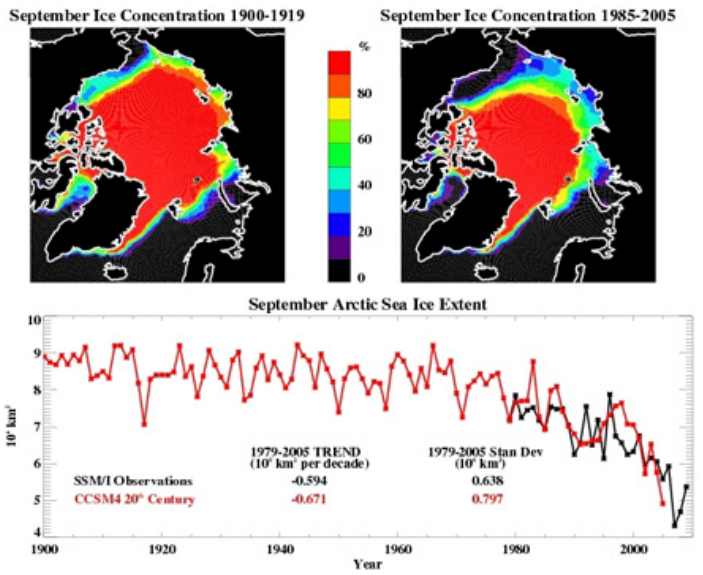
Using CISL computing resources during FY2010, the Community Earth System Model (CESM) project tackled an extremely ambitious set of climate change simulations in support of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) due in late 2013. As in other major international modeling centers, CESM is following the CMIP5 experimental design. CMIP5 describes a set of coordinated climate model experiments designed to address outstanding scientific questions that arose from the IPCC's last assessment



This chart shows the monthly usage of Bluefire for special computational campaigns during FY2010. CISL works to accelerate scientific discovery through numerical simulation by providing a significant portion of the Bluefire system to special campaigns.

report (AR4): to improve understanding of climate, and to provide estimates of future climate change that will be useful to those considering its possible consequences. CMIP5 is a 5-year experimental design, but CISL support means that a significant fraction of the CESM experiments can be completed in time to be included in AR5.

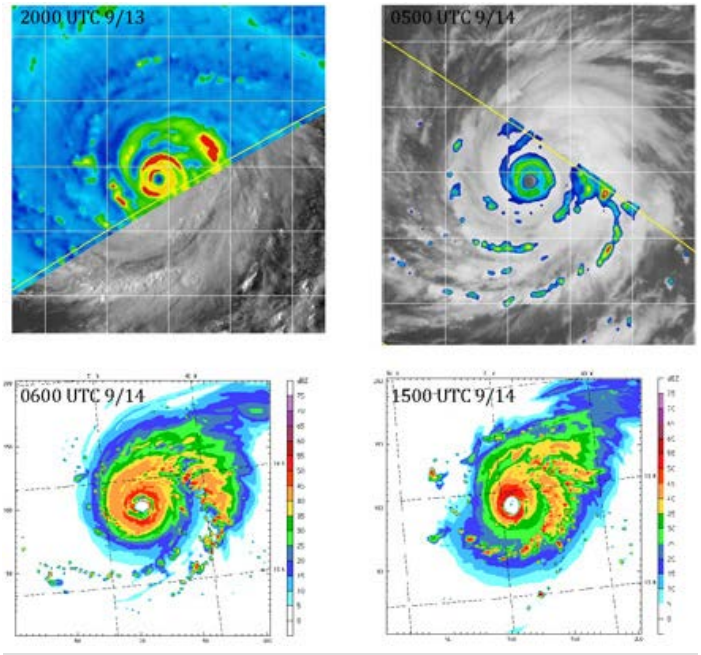
Under the CMIP5 strategy, two types of modeling experiments are being conducted: (1) near-term, initialized decadal prediction simulations (10-30 years) with relatively high-resolution climate models; and (2) long-term simulations from about 1850 through the end of the current century and beyond, using both physical climate system models and Earth System Models (such as CESM) that include a coupled carbon cycle.



Extent of Arctic Sea Ice from IPCC AR4 simulation. The CMIP5 simulations currently underway on Bluefire will refine the AR4 predictions. (Courtesy of Mariana Vertenstein, NCAR-NESL-CGD.)

The 2010 Real-time Hurricane Forecast Demonstration Project used a slightly modified configuration of the WRF-ARW model in real-time with the innermost nested grid using 1.3 km grid spacing. Similar to the 2009 season, the EnKF data assimilation method was employed to produce the initial condition. To improve the accuracy of storm intensity at analysis time, a high-resolution nested grid is added in the assimilation cycle. This is a continuing activity in the NOAA Hurricane Forecast Improvement Project (HFIP), and in support of the field campaign PREDICT (Pre-Depression Investigation of Cloud-systems in the Tropics).

One of the intriguing phenomena in hurricane evolution is the formation of concentric eye-walls and eye-wall replacement. This happened during the evolution of Hurricane Igor on 13–14 September 2010. The top left image in the figure above shows the concentric eye-wall visualized by the TRMM microwave instrument, and the top right image shows the single eye-wall structure about nine hours later. The bottom two figures show the forecast maximum column radar reflectivity at a time when the concentric eye-wall can be identified, and later when a single eye-wall was seen.



Eye-wall detail in the 13–14 September 2010 Hurricane Igor (top) and corresponding simulations on Bluefire (bottom). (Courtesy of Wei Wang, NCAR-NESL-MMM.)

These special computing campaigns and the provision of on-demand and real-time services support CISL's computing imperative for hardware cyberinfrastructure by provisioning computing, storage, data analysis, visualization, networking, and archival systems customized to support the atmospheric and related sciences. Further, special computing campaigns support CISL's strategic action item to provision the CI necessary to support the IPCC AR5. This work is made possible through NSF Core funds, including CSL funding.

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Support for supercomputer users

NCAR has a strategic commitment to provide robust, accessible, and innovative information services and tools to our customers. CISL staff members provide end-to-end services for NCAR's supercomputer users. User support includes both 24/7 frontline assistance as well as consulting services for in-depth expertise. In FY2010, 642 users joined the CISL computing community, with 674 university projects active during the year on CISL resources, along with ongoing NCAR and large-scale Climate Simulation Laboratory (CSL) projects.

The CISL Consulting Services Group (CSG) continued to provide user training in FY2010, teaching in-house classes on Fortran 90 and parallel programming. During the summer, CSG also trained 24 local students enrolled in courses on OpenMP, MPI, and Petascale Programming through the Virtual School of Computational Science and Engineering (VSCSE). Here, CISL consultant Siddhartha Ghosh (standing) conducts CISL's Introduction to Fortran 90 class at the UCAR Corporate Training Center. User training is a key activity in NCAR's strategic commitment to provide robust and accessible information services to our customers.

CISL's two-tiered customer support model enables CISL consulting experts to supply customized, one-on-one service for special campaigns such as the NCAR Capability Computing program, which provided opportunities for capability computing projects requiring hundreds of thousands of processor hours on Bluefire, the IBM Power 575 cluster. Special projects also included performance benchmarking, evaluation, and user support for Lynx, the Cray XT5m system installed in June 2010, and benchmarking and planning efforts related to the next-generation HPC environment that will be deployed at the NCAR-Wyoming Supercomputing Center (NWSC) in 2012.

In addition, the consulting group continued to maintain documentation and provide training for CISL's supercomputing, storage, and data analysis and visualization resources, support NCAR flagship models such as the Community Earth System Model (CESM) and the Weather Research and Forecasting model (WRF), and assist users with TeraGrid-allocated projects on Frost, CISL's 8,192-processor IBM BlueGene/L system.

User help requests are tracked using an ExtraView trouble ticket system. In FY2010, frontline support resolved 1,753 tickets between September 2009 and August 2010. In the same interval, advanced support resolved an additional 764 requests, for a total of 2,517. An additional 529 support tickets were fielded related to setting up user accounts and managing allocations. The average number of log entries per ticket was 4.63, and communication with users was highest on complex cases. Average response time for frontline support for ticket resolution was about 0.92 days, while an average response time of about 6.6 days (up from 5.1 days last year) was required for more complex issues. The average number of staff who worked on tickets was 1.19, demonstrating cross-team cooperation in resolving issues.

In FY2011, we anticipate further growth in scientific support for the user community during a year of several major transitions and enhancements to the CISL environment. In early FY2011, users will be supported as they transition first to the new GLADE file system environment, then to the HPSS archive system. Benchmarking and planning efforts related to the NWSC deployment will continue, then user support efforts will focus on preparing for the new resource environment at NWSC and ensuring a smooth transition for users.

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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NCAR's 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. These are allocated based on project needs. GLADE also hosts NCAR's data from the Research Data Archive (RDA), NCAR's climate model projections for the upcoming IPCC report (AR5), NCAR's Community Data Portal, and the Earth System Grid.

The GLADE high-performance storage cluster provides high-performance data services and 1.6 petabytes of storage for NCAR's HPC resources. This resource makes large amounts of data storage available to users, and it also provides access to NCAR's research data collections.

The goals of this effort are focused on shifting data workflows from a process-based design to an information-based design. Through a globally accessible storage infrastructure, users will now structure their workflows to use stored data directly without first needing to move or copy it. Additional services like high-performance data transfer protocols enhance our ability to bring computational data from other sites to NCAR for post-processing, analysis, and visualization.

In FY2010 we enhanced the centralized high-performance storage cluster to provide high-bandwidth data access not only between NCAR's supercomputers, data analysis cluster, and visualization cluster, but extended these services to other HPC offerings. This expansion included the installation of a 10-Gbps data network, 1.6 petabytes of new high-bandwidth storage, additional service nodes for hosting data collections, and large-memory data-processing resources.

In FY2011 we will refine the GLADE architecture for use at the NWSC. This will include evaluating additional parallel file system offerings, refining allocation, charging, and management policies, and producing meaningful usage metrics.

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 advances CISL's computing imperative for facilities by demonstrating high-performance data services that will be critical for the next-generation resources to be installed at the NWSC. By using GLADE-enabled workflows now, users will be prepared for a smooth transition to the NWSC's new environment. GLADE equipment was purchased with NSF Special funds, and it is supported by NSF Core funds including CSL funding.

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Archival systems

The National Science Foundation TeraGrid uses high-performance networks to integrate supercomputers, data archives, and data analysis facilities around the country. Its coordinated work environment enables researchers throughout the U.S. to collaborate on especially challenging scientific questions and to process vast amounts of data that would not be manageable on smaller or isolated computing systems. The IBM High Performance Storage System (HPSS) has been deployed by a number of the TeraGrid Resource Providers. The deployment of HPSS at NCAR will enable a homogeneous storage solution for the TeraGrid, allow potential data archive connectivity directly with Wide Area Network (WAN) filesystems on the TeraGrid, and provide a data management system administration learning opportunity in a security environment external to the UCAR security perimeter.

NCAR's HPSS robotic tape library was acquired in the AMSTAR contract. The library was initially sized to support 1.5 petabytes (PB) of data. It was expanded in FY2010 to support 7.5 PB of data, and it can be expanded to 10 PB at the current tape media density. Multiple libraries can be physically connected to provide hundreds of petabytes of seamless archival tape storage.

In FY2009 CISL deployed an HPSS system to be directly accessible from outside the UCAR security perimeter and provide higher-performance lower-latency access to archive data than what is currently available with the NCAR MSS. Also in FY2009 a decision was made to replace the NCAR MSS with HPSS by January 2011 in preparation for transitioning archive services to a new data center. A transition plan was developed in late FY2009 that is being executed in FY2010 and FY2011. A custom HPSS accounting solution was developed in FY2010 to provide archive data transfer and storage accounting data that are compatible with CISL's existing General Accounting Unit (GAU) system. Commonly used TeraGrid/open source and vendor-supported HPSS user interfaces are available with deployment consulting support and documentation for HPSS client machine system administrators. A LAN-GPFS test bed that includes HSM functionality with HPSS has been delayed due to unavailability of mature software and lack of CISL resources.

CISL initiated a Request For Proposal (RFP) at the beginning of FY2008 named "Augmentation of the Mass Storage Tape Archive Resources" (AMSTAR). Released in late November 2007, AMSTAR is a four-year subcontract awarded to replace the MSS StorageTek Powderhorn tape libraries (silos), 9940x tape drives, and media with new robotic tape libraries, tape drives, and media that will increase MSS data storage capacity to more than 30 PB and position the archive for future technology upgrades that will enable the management of hundreds of petabytes of data. AMSTAR contract negotiations were completed at the end of August 2008. The contract will meet NCAR's projected needs until the expected move to the NCAR-Wyoming Supercomputer Center in 2012. Production deployment of the AMSTAR technology was completed in December 2008 after which all new data are written to AMSTAR. A data migration (data ooze) to the new tape technology began in August 2009 after an optimized ooze process was implemented. The data ooze migrated 6 PB and finished in April 2010, well ahead of the December 2010 deadline, allowing an early decommissioning of the Powderhorn tape libraries, tape drives, and media plus a maintenance cost savings on that equipment. The decommissioned Powderhorn equipment was removed in August 2010. The HPSS Tape Library capacity was increased in FY2010 to support a larger workload, allowing the HPSS system to run in parallel with the NCAR MSS

prior to decommissioning the NCAR MSS in FY2011.

The existing NCAR MSS tape archive equipment acquired under AMSTAR will be reused by HPSS after the decommissioning of the NCAR MSS. However, HPSS server capacity will be enhanced in FY2011 to prepare for supporting the NCAR MSS workload by January 2011. The NCAR MSS will be decommissioned in FY2011. Both storage systems will be available in parallel during FY2010 and FY2011 to facilitate the user transition.

This effort supports CISL's computing imperative for hardware cyberinfrastructure by deploying a production HPSS instance and transitioning to HPSS as an alternative to the existing NCAR MSS system. The NCAR HPSS is managed by CISL under the UCAR/NSF Cooperative Agreement and is supported by NSF Core funds including CSL funding.

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Network engineering and telecommunications

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 to 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 FY2010:

- UCAR network infrastructure re-cabling
  - 3375 Mitchell Lane rewiring
- Network monitoring
- Multicast support activities
- UPS, grounding, wireless networking, Voice over IP
  - Wireless 802.1x certificates
- CISL LAN and SAN projects
  - Cisco end of service and GigE upgrades
  - FL/MAR: Pedestal switch upgrade
- Security redesign projects
- NWSC network design and construction
- UIS database project

NETS pursued these MAN projects in FY2010:

- Boulder Point-Of-Presence (BPOP)
- Boulder Research and Administration Network (BRAN)
- Boulder Valley School District fiber partnership
- Remote-working and home-access
- SPOL wireless
- Jeffco wireless upgrade
- Mesa Lab 15KV fiber
- Mesa Lab road and parking lot

NETS pursued these WAN projects in FY2010:

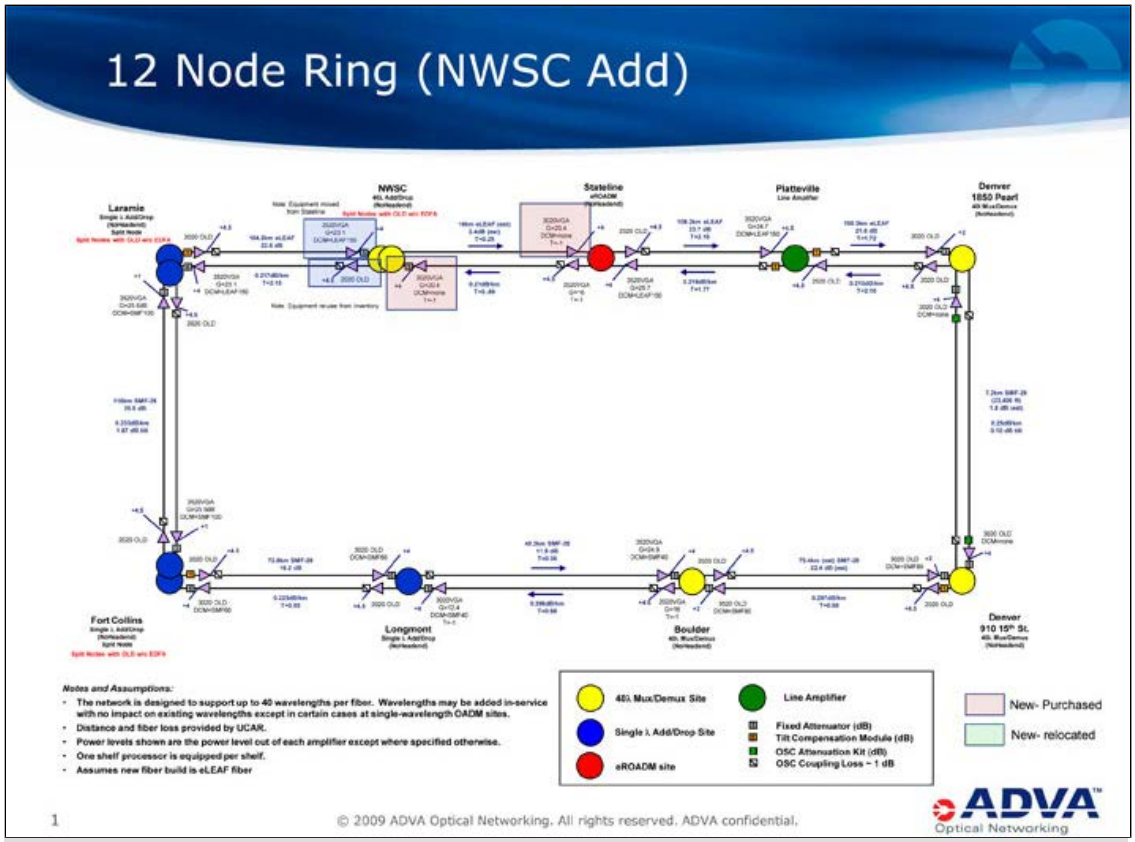
- Front Range GigaPoP (FRGP)
- UCAR Point of Presence (UPoP)
- National LambdaRail (NLR)
- Internet2
- Bi-State Optical Network (BiSON) NSF ARI proposal and upgrade
- NWSC WAN
- NWSC fiber design
- TeraGrid
- SUMMIT: The Mountain West Advanced Networking Cooperative
- Western Regional Network (WRN)
- NOAA Research Network (N-WAVE)
- The Quilt Project – National Regional Networks Consortium

In FY2011, NETS will continue to provide support and enhancements for these essential networking services. NETS activities are supported through UCAR Communications Pool indirect funds.

Four of these projects are described below: the The Bi-State Optical Network (BiSON) NSF ARI proposal and upgrade, the Western Regional Network (WRN), the NCAR-Wyoming Supercomputer Center (NWSC) network design and construction project, and the NETS directory project.

Bi-State Optical Network (BiSON) NSF ARI proposal and upgrade

UCAR submitted and was awarded $430,000 for an NSF ARI proposal to upgrade BiSON. The BiSON partners will also contribute $160,062 to this project. The Bi-State Optical Network (BiSON) is a high-speed optical network of fiber optic links that serves a collaboration of research and educational institutions in Colorado and Wyoming. The purpose of BiSON is to provide robust, redundant access to regional and Wide Area Network (WAN) services to its members. The Front Range GigaPoP (FRGP) participants using BiSON Network Services include Colorado State University (CSU), the National Oceanic and Atmospheric Administration-Boulder (NOAA-Boulder), the University of Colorado-Boulder (CU-Boulder), the University Corporation for Atmospheric Research (UCAR), and the University of Wyoming (UW).



This shows BiSON's detailed optical Wave Division Multiplexing (WDM) design. These are the components and locations that will be upgraded to support 10/40/100 Gbps from the current 2 Gbps. This project also expands the network to 910 15th Street to allow further redundancy for the BiSON members and includes the NWSC WDM device and engineering.

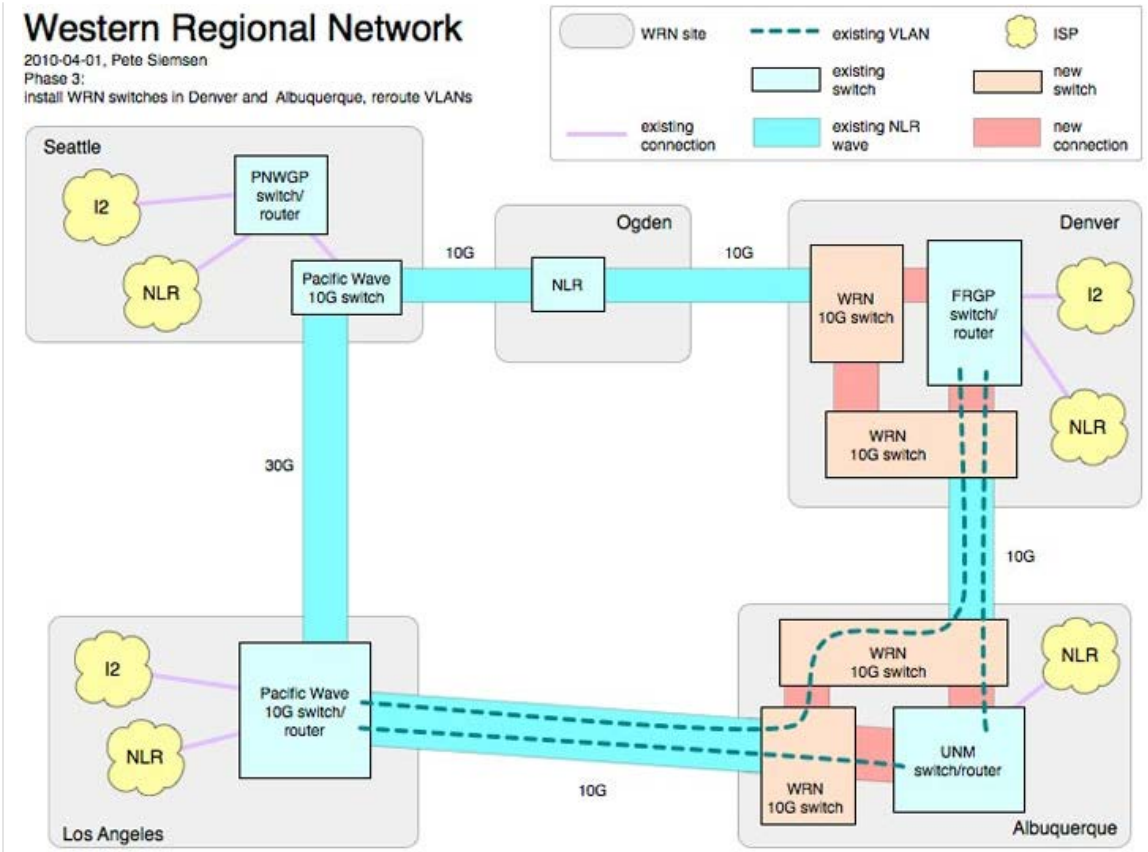
BiSON is a valuable piece of cyberinfrastructure connecting researchers at participating organizations to multiple sources of observations and data throughout Colorado, Wyoming, and the broader community via interconnections with Internet2, National LambdaRail (NLR), and TeraGrid. BiSON will also provide redundant, very high-speed connectivity for all FRGP participants to the proposed NCAR-Wyoming Supercomputing Center (NWSC) in Cheyenne, Wyoming.

This proposal will upgrade BiSON's current ADVA equipment from a single 2 Gbps ring to a wave division multiplexing solution capable of supporting up to forty 10/40/100 Gbps lambdas. The resulting cyberinfrastructure will enable scientists, educators, and researchers to much more efficiently transport enormous amounts of data intra-BiSON and over the WAN, collaborate with others in the community, access high-end resources such as the NWSC, TeraGrid, NASA, and Department of Energy (DOE) data and computing resources including Earth System Grid (ESG).

The design, orders, and installation plans are complete. Installation is planned for the week of 4 October 2010.

Western Regional Network (WRN)

The goal of WRN is to promote, advance, and sustain advanced networking services in support of research, education, and the members' respective missions. This includes participating in and sharing access to national research and education networks, commodity networks, transit/peering connections, and other similar services. Members and affiliates are located in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Utah, Washington, and Wyoming. WRN plans to establish, maintain, and sustain networking interconnections and share services among the members. Each member operates advanced networks for, and on behalf of, themselves, their members, and other affiliates.



This shows the WRN at its final phase. Most of the components of the network are ordered, all circuits are installed and operational, and the hardware is being installed for Layer 2 network support. The WRN network enables the FRGP to super-aggregate WAN connections to purchase larger bandwidth at significantly lower costs. WRN also builds a significant geographical consortium, which will allow increased influence over vendors and R&E network providers. By participating in WRN, UCAR will have access to more and higher-speed networks at lower cost.

The principal goal of this collaboration is provide an opportunity for the members to share services in a manner that appropriately balances the effectiveness and efficiency of subscription to, delivery of, and sharing of, the services. This includes the potential to reduce costs, enhance services, and coordinate participation in activities of mutual interest.

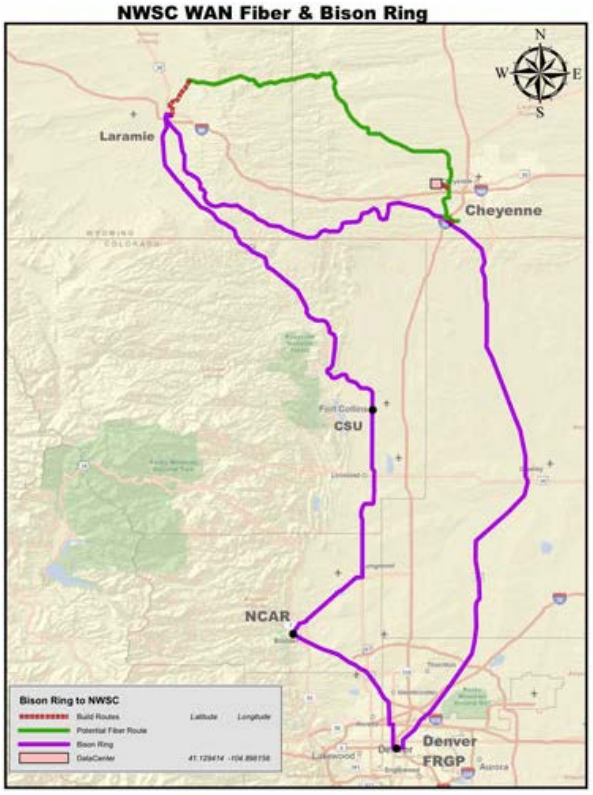
In 2010, the WRN agreement, cost model, and engineering design were developed and completed. Internet2 services were successfully transferred from SUMMIT to WRN on 1 July 2010. Level3 commodity Internet service is in the process of being transferred to CENIC via WRN. Intra-WRN peering is active. The Layer 1 optical waves, Layer 2 switches, and collocation are all purchased and in place to construct WRN. Network construction is in process and will be complete by 31 October 2010.

In FY2011, WRN will be fully operational and services will be transferred as appropriate from a cost and engineering perspective. WRN will complete the modification to the agreement to allow new membership. New members will be pursued as appropriate.

NCAR-Wyoming Supercomputer Center (NWSC) network design and construction project

NETS is the lead to design, test, verify specifications and standards, and install network hardware for the NWSC LAN and WAN. State of the art networking is a critical component for the NWSC, and the implementation must include high speed (4x10 Gbps initially), secure, redundant, and robust elements.

Extensive work began on the NWSC. Detailed network LAN and WAN designs were initiated and completed, including attending detailed weekly design meetings. Complete network LAN specifications were prepared. Construction has begun on the NWSC, and NETS staff are intimately involved in the construction meetings and construction review to ensure that specifications are



This shows the BiSON network with expanded fiber paths to integrate the NWSC into the fiber optic ring. The paths are fully redundant with diverse building entrances to protect the facility from fiber cuts, and there are redundant WDM shelves to protect the facility from hardware failures. It is expected that at least four 10 Gbps paths will connect the NWSC to the Mesa Lab, FRGP, and TeraGrid. It is also expected that the other BiSON partners will install dedicated 10 Gbps paths to the NWSC utilizing this infrastructure.

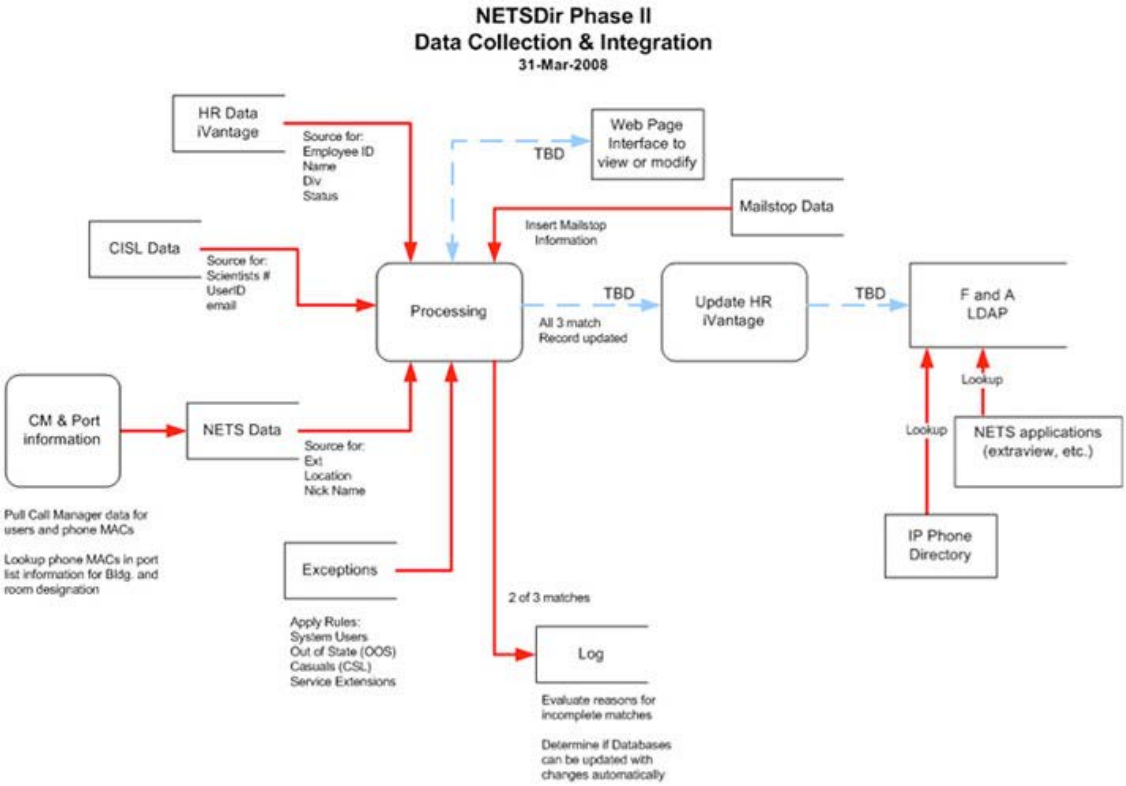
met and design changes are reviewed and approved. NETS staff attend weekly meetings and review sessions in Cheyenne, Wyoming which began in the summer of 2010.

Work also began in earnest on the WAN design. An RFP was issued by the University of Wyoming for the construction of the WAN fiber in September 2010 and is expected to be awarded by the end of October 2010. Construction must be complete by May 2011 and operational by July 2011. Considerable time was spent prior to the RFP ensuring the use of the State of Wyoming Broadwing/Level3 fiber.

In 2011, NETS will complete the installation and activation of both the LAN and WAN for commissioning of the NWSC in October 2011.

NETS directory project

The goal of this project is to provide accurate, up-to-date directory information. In addition to bringing together disparate elements not previously in any single location, NETS also hopes to reduce or eliminate the current manual, often redundant, steps involved in the manipulation of directory information. NETS emphasized secure solutions and worked to keep directory data in formats that can easily be exported and shared with other systems both now and in the future.



This shows the data flow for the web-based UCAR "Find People" application. The NETS directory provides an authoritative, continually updated source for UCAR room number and telephone extension information. This directory is part of a larger project to improve the efficiency of creating and maintaining people data while improving accuracy.

This effort will address issues specific to NETS at this time and not larger, organization-wide issues (though pieces of this effort may be adopted for that purpose later). One initial project assumption was that NETS will provide UCAR's authoritative source for room number and telephone extension.

NETS requires specific aspects of staff information to perform its daily tasks to support the telephone, network, and other systems. This information consists of: first name, last name, division or program or laboratory, username (to match UCAS login, email address, or other system login ID), telephone extension, and network device/phone location. To reduce the amount of manually entered data and increase the accuracy of people information generated by NETS, NETS obtained people information from existing systems including the Voice over Internet Protocol (VoIP) telephone systems.

The NETS directory relies on four main sources of people information: HR name/division data, CISL email alias/account names, telephone (Call Manager) extension numbers, and port list device (telephone/MAC) room locations.

This project developed an automatic method to integrate all the sources of staff information into one location and remove the hand-entry or correction of "people (or directory-type) data." This required new methods to obtain the data from text files and ways to export it into the NETS databases (Call Manager, ExtraView, and Cabling Database).

Stakeholders for these processes include the space planning office, the Archibus facilities database, the ExtraView work request system, the NETS cabling database, and IP Telephony team.

In 2010, work continued on this project with ongoing development of the database and data exchange codes. The project was transitioned to a new NETS staff member for ongoing development and support.

In 2011, the project will be completed. The NETS database will be integrated with the larger UCAR People Database to exchange authoritative data between databases. NETS will then be responsible for operational maintenance.

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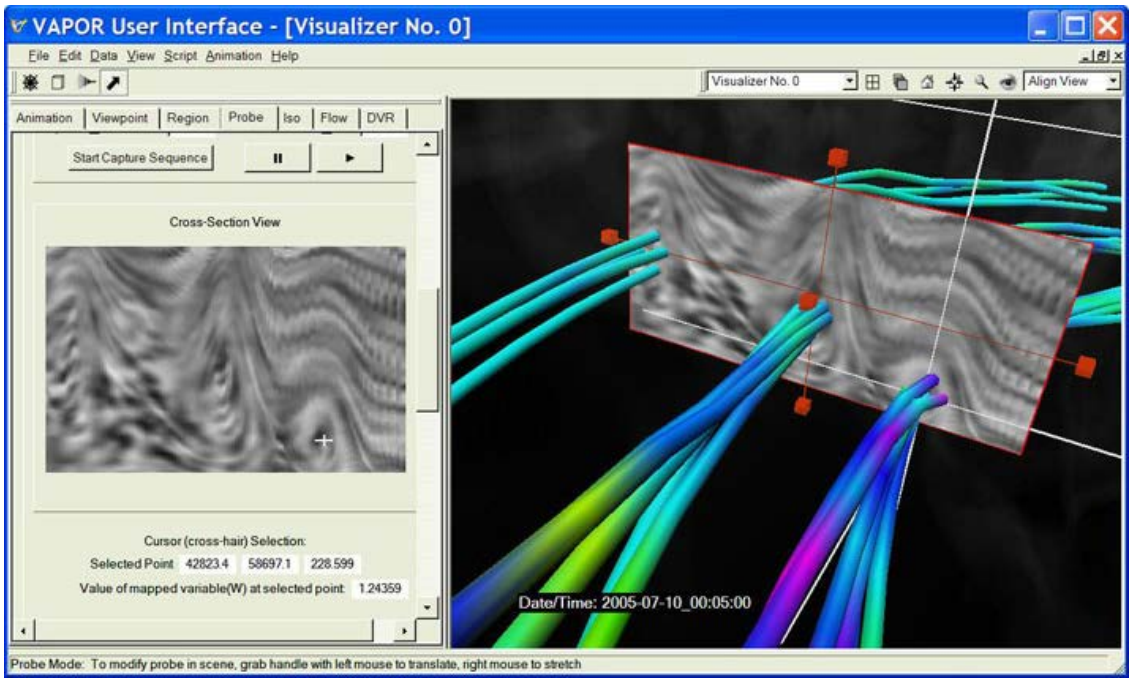
Data analysis and visualization environment

The Data Analysis and Visualization Lab enhances scientific workflow by providing UCAR's research community with a highly advanced, unified computing environment tailored for the specialized needs of interactive data post-processing, analysis, and visualization. This evolving environment is comprised of powerful, closely coupled, interactive processing and visualization engines and large-capacity, high-performance global file systems. We provide direct support to the research community by developing algorithms for relevant visualization and analysis methods and by producing animations and imagery on behalf of the scientific staff.



Vortices in the eye-wall of a WRF hurricane simulation, illustrated by a combined streamline and image-based flow visualization. This image was produced using VAPOR utilizing services offered by CISL's Data Analysis Services Group. Image produced by Yongsheng Chen, MMM/NCAR.

The goals of this effort are focused on addressing the growing size and complexity of scientific problems being researched at NCAR. A significant increase in resolution and data set sizes require not only the enhancement of NCAR computational resource capability and capacity, but also challenge CISL to provide advanced services and tools. The Data Analysis Services Group works directly with users to help develop new techniques and algorithms that allow scientists to push the boundaries of discovery.

The evolution of this facility from a collection of dedicated standalone resources into a tightly coupled unified computing environment has been a multi-year process. In FY2010 we enhanced the centralized high-performance storage cluster to provide high-bandwidth data access not only between NCAR's supercomputers, data analysis cluster, and visualization cluster, but also expanded these services into other HPC offerings. This expansion became a separate service known as NCAR's Globally Accessible Data Environment (**GLADE**). Additionally, we integrated a new high-bandwidth data transfer service, enhancing our ability to bring computational data from other sites to NCAR for post-processing, analysis, and visualization.

In FY2011 we will continue to support the current computational, visualization, and data transfer service offerings. No additional augmentations are planned for FY2011. However we will plan the architecture for similar services to be installed in the NWSC.

This work supports CISL's computing imperative for hardware cyberinfrastructure by provisioning computing, storage, data analysis, visualization, networking, and archival systems customized to support the atmospheric and related sciences. It also supports CISL's computing imperative for software cyberinfrastructure by developing and supporting software infrastructure specific to the simulation, analysis, and forecasting needs of the atmospheric and related sciences. Finally, the Data Analysis and Visualization Lab advances CISL's science frontier in understanding large and heterogeneous data sets by developing new methods and tools to visualize and extract information from such data sets. This ongoing service is supported by NSF Core funds including CSL funding.

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Cybersecurity

UCAR manages and maintains a large and diverse set of compute, data, email, web, and network servers that form the core information technology 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 for 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 confidentiality, integrity, and the availability of intellectual property, data, and systems. Appropriate measures balance the needs for availability and usability with those for integrity and confidentiality.

During FY2010, these factors 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 achieving the appropriate balance between reasonable protection and pursuit of the scientific mission of the institution.
- Maintained UCAR-wide token authentication using one-time password (OTP) tokens.
- Placed increased importance on computer and network security when acquiring and configuring new equipment (computers, storage, network routers, etc.).
- Engaged in collaborative efforts with peer and TeraGrid centers to share cybersecurity information, best practices, and incident notification.
- Enhanced our network and host monitoring tools to support increased traffic loads and provide redundancy using our other campuses.
- Introduced a second One Time Password token type utilizing the Radius protocol. This project greatly enhanced usability as well as technical and vendor flexibility.
- Introduced Kerberos authentication for all UCAR/NCAR users requiring the use of passwords for internal resources.

To maintain a meaningful security posture and to fulfill CISL's near-term security objectives, the following plans for FY2011 are in place:

- Complete the implementation of Kerberos and further expand its use by other systems groups at UCAR.
- Continue enhancing the automated monitoring tools to increase the security team's ability to proactively identify active attacks.
- Engage in collaborative efforts with peer and TeraGrid centers to share cybersecurity information, best practices, and incident notification.
- Actively design security and authentication systems for use with the NCAR Wyoming Supercomputing Center.

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

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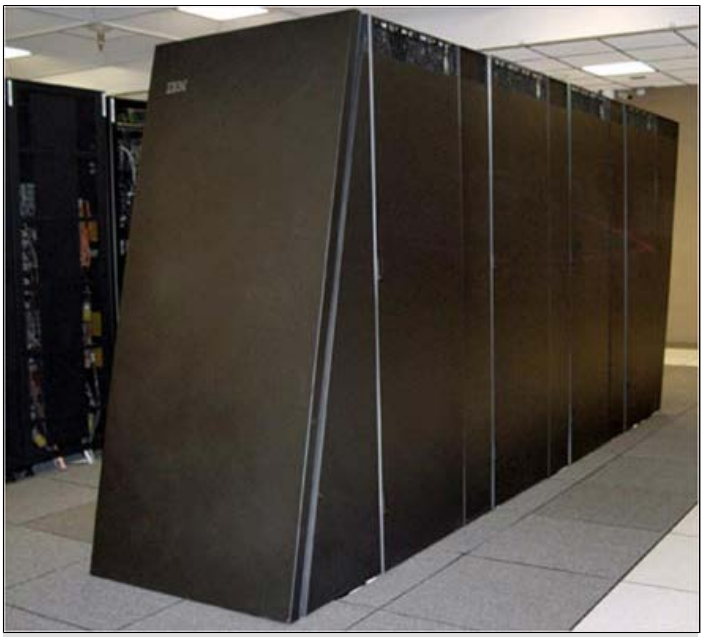
TeraGrid Resource Provider operations

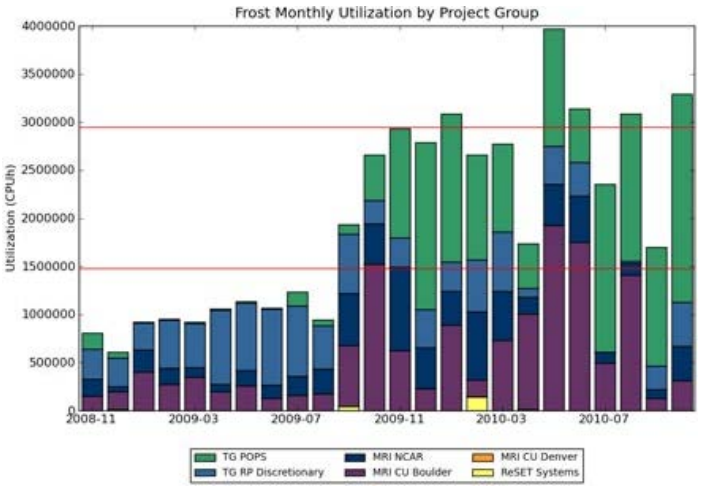
The National Science Foundation's TeraGrid uses high-performance networks and grid software to integrate supercomputers, data repositories, and special-purpose data analysis and visualization facilities throughout the U.S. NCAR participates in the TeraGrid project in a variety of roles. For example, some NCAR projects and scientists use TeraGrid resources at other institutions for their research, and NCAR's data collections and science gateways (such as the Earth System Grid) interoperate with TeraGrid resources and users. As a TeraGrid resource provider (RP) since June 2006, NCAR also makes a portion of its computational resources available to researchers who request support from NSF through TeraGrid's quarterly allocation process.



The IBM Blue Gene/L supercomputer at NCAR is designed to run parallel jobs using up to 8,192 processors with high performance and low power consumption. In addition to serving NCAR's traditional charter as a resource provider for the atmospheric and related sciences, Frost serves researchers across a broad range of disciplines as a TeraGrid resource.

NCAR's primary TeraGrid computational resource is a four-rack IBM Blue Gene/L supercomputer named Frost. The original Frost system (a single-rack IBM Blue Gene/L system with 2,048 processors) was procured in 2005 in collaboration with the University of Colorado at Boulder and the University of Colorado at Denver. In 2008, Frost was enhanced with 10-Gbps networking infrastructure, an additional 110 TB of disk storage capacity, and an associated visualization system named "Twister." In 2009, Frost was expanded with three Blue Gene/L racks acquired from the San Diego Supercomputer Center; the resulting four-rack system has 8,192 processors, and its peak performance is 22.8 TFLOPS. As a TeraGrid resource, Frost supports the Coordinated TeraGrid Software and Services (CTSS) stack that presents a consistent user experience across systems and institutions. Frost is shared between NCAR users, collaborating university users, and TeraGrid users. Approximately one-fourth of the system's available processing capacity is allocated to the TeraGrid community. Most of Frost's user community uses traditional interactive methods to access the system, but about 5.8% of Frost's jobs were run using automated Grid technologies in support of the NCAR Asteroseismic Modeling Portal.

As a production TeraGrid resource, Frost supports a user community spanning many organizations outside of NCAR's usual community of collaborators, so maintaining its uptime and availability is particularly important. In FY2010, the major causes of downtime were the scheduled half-day semi-annual preventive maintenance periods, as well as a three-day period of reduced-capacity operation caused by an electrical problem elsewhere in the facility. The Blue Gene/L itself has



This graph shows Frost's monthly usage in CPU hours (per month) by its various user communities. After the system was expanded from one to four racks in late FY2009, Frost's utilization rapidly surpassed the capacity of the earlier one-rack system and has settled into an average utilization of about 50%. While subject to the varying demands of computational campaigns, roughly half of Frost's expanded capacity – an entire Blue Gene/L rack – serves users accessing the system via the TeraGrid allocations process.

demonstrated a low hardware failure rate since its delivery. In 2010, only five compute card components required attention, and two required replacement. These maintenance activities were performed while continuing operations on the unaffected portions of the system.

NCAR plans to continue operating Frost as a TeraGrid resource through the conclusion of the TeraGrid program on 31 July 2011. At that time, TeraGrid will be superseded by the NSF's eXtreme Digital (XD) program, and Frost will no longer be made available as an allocatable TeraGrid resource. In FY2011, NCAR will investigate broader possible roles for participating in new cyberinfrastructure federation initiatives at the regional level (e.g., collaborations with universities) as well as XD. These initiatives may include more diverse interoperability technologies, such as federated authentication and data management, that are operational outcomes of TeraGrid experience.

This work supports CISL's computing imperative to provision hardware cyberinfrastructure for the atmospheric and related sciences, as well as CISL's computing frontier of developing center virtualization through Grid technologies and participation in national cyberinfrastructure initiatives. The acquisition and operation of Frost was made possible through NSF MRI Grants CNS-0421498, CNS-0420873, and CNS-0420985; through the IBM Shared University Research (SUR) program with the University of Colorado; and through NSF Core funding. The enhancements to Frost's storage system were funded by NSF Core funds, and Frost's FY2009 expansion was made possible by NSF Special funds.

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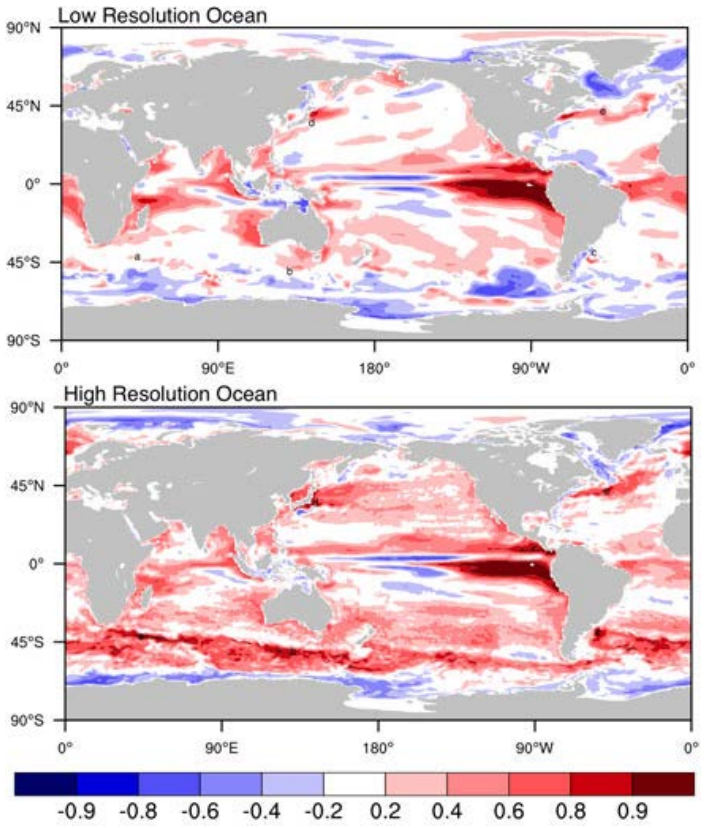
TeraGrid visualization server

As part of its involvement in the NSF TeraGrid, CISL provisions computing resources to the TeraGrid community for simulation. Beginning in FY2009, NCAR also began providing analysis and visualization equipment. NCAR's first TeraGrid data analysis and visualization (DAV) resource, Twister, is an HP xw8600 workstation with 8 processing cores, 64 GB of memory, and hardware-accelerated graphics. The system shares disk storage with the Frost computational platform, enabling Frost users to analyze and visualize their data as soon as it is output from their simulations. Further, Twister provides a remote visualization service that permits users to access the machine's hardware graphics capabilities from virtually anywhere with a network connection.



Both panels show the correlation of latent heat flux between the ocean and atmosphere and sea surface height. The latter is a proxy for upper ocean heat content. At high resolution (bottom image) this correlation becomes more positive, an indication that ocean processes become increasingly important in driving atmospheric variability. This analysis was performed on Twister.

Analysis and visualization is an integral component of the computational science workflow. By coupling a DAV resource with Frost, users are able to investigate model outputs without having to transfer their data to a separate resource. Moreover, provisioning of cyberinfrastructure for DAV is a computing imperative outlined in the CISL strategic plan.

In FY2010 a second DAV node was put into production to meet growing demands on the Twister resources as well as to improve reliability through redundancy. The venerable NFS file system was replaced with the higher-performing GPFS, and mounts were added for CISL's much larger GLADE shared storage system. The Twister cluster supported a Frost user base of over 20 research staff, and continued to support the NSF-funded PetaApps project (NSF-0749206, exploring high-resolution climate simulations), via the GrADS server deployed in FY2009.

Currently, the Frost system is scheduled for decommissioning in July 2011. CISL will continue to maintain and operate Twister, and augment it only as needed until Frost is retired.

This work supports CISL's computing imperative to provision hardware cyberinfrastructure for the atmospheric and related sciences. This work is supported by NSF Core funding.

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Support for TeraGrid users

CISL continues to provide user services and support for the TeraGrid infrastructure on the Frost supercomputer; the Twister visualization system; and the High Performance Storage System (HPSS). CISL staff collaborated in TeraGrid planning, resource allocation, and accounting, and we extended our scientific computational tools to a broader scientific community. In FY2010, more than 150 projects were given access to Frost through the TeraGrid allocations process.

Twister and Twister2 (below) provide visualization services for TeraGrid users. CISL staff provide user services and support for this system, the Frost supercomputer, and the HPSS, which is a common storage solution on the TeraGrid. CISL staff who select, configure, and support this equipment are collaborating to develop the virtual supercomputing centers of the future, and they are refining ways to support users in these environments.

During FY2010, advanced support staff in CISL reviewed and handled 73 NCAR-related TeraGrid user tickets. CISL Consulting Services also provided dedicated consulting support for users with TeraGrid allocations on Frost and access to HPSS. CISL staff participated in weekly teleconferences of TeraGrid's Services Working Group and coordinated NCAR-related documentation updates and corrections on the TeraGrid portal and website.

CISL's advanced support staff also helped NCAR scientists take advantage of TeraGrid resources at other sites, including support for the Intergovernmental Panel on Climate Change (IPCC) simulations conducted by NCAR's Climate and Global Dynamics division on the Kraken system at the National Institute for Computational Sciences (NICS).

In FY2011, we plan to continue supporting TeraGrid users on the Frost and HPSS systems and assist NCAR staff on other TeraGrid systems. During FY2011, NSF plans call for transitioning the TeraGrid program to the successor TeraGrid eXtreme Digital (XD) program, and CISL's advanced support staff will contribute to a smooth transition for Frost and NCAR users between programs.

CISL's contribution to the TeraGrid relates to multiple areas of the CISL Strategic Plan. CISL's computing imperative for facilities is to deploy and operate the physical and virtual computational facilities needed to support the science community, which involves integration with others to create virtual facilities. CISL's computing frontier in center virtualization involves developing Grid-based technologies to support and enhance the development of virtual organizations. Finally, CISL's computing imperative to provision hardware cyberinfrastructure includes operation as a TeraGrid Resource Provider at least through the end of the TeraGrid Extension. CISL's consulting service for TeraGrid users is supported by NSF Core funds.

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Technology research and development

CISL's Computer Science Section (CSS) conducts research and development to investigate how new technologies can be applied to NCAR computational science. CSS systems research focuses on high-performance scalable supercomputer systems and the integration of these systems with national cyberinfrastructure initiatives such as TeraGrid. NCAR's Blue Gene/L system, Frost, exemplifies this type of applied supercomputing research. Originally acquired in collaboration with the Universities of Colorado at Boulder and Denver as a hardware platform for investigating the obstacles to scalability in geoscience and mathematical applications, Frost was later also deployed as a production TeraGrid resource serving a larger user community. Even while serving as a production TeraGrid resource, Frost continued to support its original NCAR and university user communities, and also served as platform for continuing CISL investigations of balanced supercomputer system architecture.

CISL engineers Ben Mayer (left) and Michael Oberg (center) with student assistant Jon Lusk, stand in front of a new external PCI expansion cabinet containing an NVIDIA Fermi accelerator connected to a server with 1 terabyte of memory. This experimental computer system supports research investigating computer platforms for data-intensive computing and hardware acceleration of computational models.

In the upcoming year, CSS plans to investigate the nature of data-intensive computing as it applies to NCAR's current and future workloads. Platforms for data-intensive computing require the integration of computational, network, and storage components into a single supercomputing environment but in a configuration different from supercomputers that emphasize raw computational performance. Thus, one component of this research is the construction of large-memory systems that use either hardware or software shared-memory components with accelerated computing and flash memory technologies augmenting the traditional computational and storage components.

A data-intensive platform must also support high-performance data transfer and Grid-enabled remote processing capabilities as required by workflows that span multiple computer systems and storage systems, or even multiple sites and organizations. This research will investigate connectivity technologies, such as InfiniBand and Ethernet, as well as file system technologies that can allow a data-intensive platform to interoperate with a wide variety of systems both within and outside of CISL. This experimental platform will also enable NCAR and collaborators to develop and utilize computing environments for collaborative research programs that span multi-agency supercomputing centers. Further, this platform will also serve as a prototype for the federation of NWSC and university cyber-resources. The opportunity to experiment with systems and federated cyberinfrastructure, such as the Blue Gene/L with the TeraGrid and now these new systems with emerging collaborations, is essential for NCAR to maintain its ability to provide capability, capacity, and data-centric supercomputing for an increasingly distributed community.

CISL's technology research and development activities are funded by the Technology Development Division using NSF Core funds. These activities directly support CISL's center virtualization computing frontier objectives and imperatives, most notably in testing and evaluating future grid environments and virtual facilities that allow NCAR and other sites to interoperate. The research computing environment also provides a platform supporting CISL's identified science frontier investigations of accelerator-based technologies and the analysis of large and heterogeneous datasets.

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Building a new supercomputer

Engineers and scientists in CISL's Computer Science Section collaborated with the Front Range Computing Consortium, led by the University of Colorado (CU), to acquire and deploy a new supercomputer system provided by a NSF Major Research Instrumentation (MRI) grant award. The new supercomputer will be used by over 130 researchers, many from CU Boulder, CU Denver, and NCAR, to investigate and address the technical obstacles to practical petascale computing in areas focused on Earth sciences, biotechnology, nanomaterials, renewable energy, and star turbulence using advances in applied mathematics and computer science. CISL's Research Systems Evaluation Team (ReSET) provided the expertise for planning, configuring, and installing the hardware, software, and computer room facility for this new system.

These photos show the Front Range Computing Consortium's new supercomputer located at and operated by the University of Colorado (CU). Note that these photos were taken in November 2010, after the end of FY2010. Left: Delivery of the computer facility's chilled water infrastructure, the first of five shipments. The facility containing the computer system was fabricated offsite and assembled at CU in about one week. Right: Initial system layout inside the facility with computer racks being arranged in a "hot-aisle containment" configuration. CISL engineers assisted CU with planning, configuring, and installing both the system and its facility. The system will provide a prototype for CISL to work in a collaborative environment to investigate distributed file systems, virtualization in high-performance environments, and Grid and cloud computing technologies.

The new system is named Janus and has 1,368 nodes, each containing two six-core Intel Xeon Westmere-EP processors at 2.8 GHz, for a total of 2,736 processors and 16,416 processing cores. Each core has 2 GB of RAM for a total of 24 GB per node and 32 TB of memory in the entire system. In June 2010, 95% of this cluster sustained 152.2 TFLOPS to rank as the 31st most powerful computer on the Top500 list. Two aspects of this effort allowed ReSET to use this as a stepping-stone experience to CISL's preparation for petascale computing at NWSC in FY2012. CISL successfully combined this system architecture for the first time with this many processors and this much memory per node under the Linux operating system. Second, CISL welcomed this opportunity to develop the system and its support infrastructure outside the constraints of a pre-existing facility. This process paralleled NCAR's fundamental re-examination of its technological vision for the NWSC expansion, which includes how computation, networks, and storage are used by scientific workflows.

In addition to prototyping, building, and testing Janus in FY2010, ReSET staff also worked closely with Dell to commission a prefabricated building to serve as its computer room. The building, which includes climate-controlled space for the computer hardware, a separate room containing power and cooling equipment, and an adjoining cooling tower, was constructed offsite to custom specifications in about three months, shipped to Colorado, and all five modules were installed on a concrete pad at the University of Colorado in about one week. The building was constructed to match the requirements of the incoming system plus future expansion possibilities over the facility's lifetime. This new class of facility can be constructed much more quickly and at substantially lower cost than is possible with renovation or new construction of a permanent building. Janus' computer room features a 2 MW power feed and 337 tons of cooling, allowing an initial capacity of about 1.19 MW of computational equipment. The computer system itself is cooled using "hot-aisle containment," where only the outflow air from the computer is cooled, rather than the already cooled

ambient air from inside the computer room.

In FY2011, CISL plans to continue working with the University of Colorado's Research Computing Center to develop additional capabilities that support collaborative activities on the system. Possible areas of development include:

- Support for Grid computing: Janus can be operated in a way that supports participation in national Grid computing initiatives such as TeraGrid, interaction with other NSF and DOE supercomputer centers, and collaborations in other high-performance computing initiatives at colleges and universities.
- Support cloud computing research and resource allocation: Some university groups with loosely coupled workflows (unlike NCAR's traditional supercomputer codes) have expressed interest in using outsourced cloud computing resources such as science clouds and Amazon EC2. Janus may be extended to support cloud computing research using the Nimbus framework from Argonne National Laboratory, allowing users to develop, test, and run cloud-based applications.
- Support external collaborators using virtualization and dynamic virtual networks: Some specialized research groups, such as CU's Laboratory for Atmospheric and Space Physics (LASP), want to incorporate the power of Janus into their existing computational environment. Janus is designed to allow this seamless access by including a specialized login node just for members of the LASP community. When a job runs on the supercomputer, the network can be reconfigured to attach the node to the LASP network, providing that node with access to LASP's existing offsite storage systems. Input and final output can be read from their existing environment, and users may access high-performance storage attached to Janus. This also allows users to continue using specialized licensed software that is available only to their group and not to the entire community. Janus will appear as an extension of their own, private, existing computer environment.

This work advances CISL's strategic computing imperatives for facilities and cyberinfrastructure. It also advances CISL's computing frontier in center virtualization. CISL staff time during this development effort was supported by NSF Core funds.

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Computing Imperative: 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. An important change in CISL's SI portfolio occurred in FY2010 when the Earth System Modeling Framework (ESMF) core team moved from CISL to a new home at the NOAA-funded Cooperative Institute for Research in Environmental Sciences (CIRES), also located in Boulder, Colorado. This transition occurred smoothly, puts ESMF closer to its core user community, and has freed up resources in CISL that can be used to shore up other strategic activities in CISL's Technology Development Division. CISL maintains close collaborative ties with ESMF, both in SI development and in Education, Outreach, and Training activities.

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.

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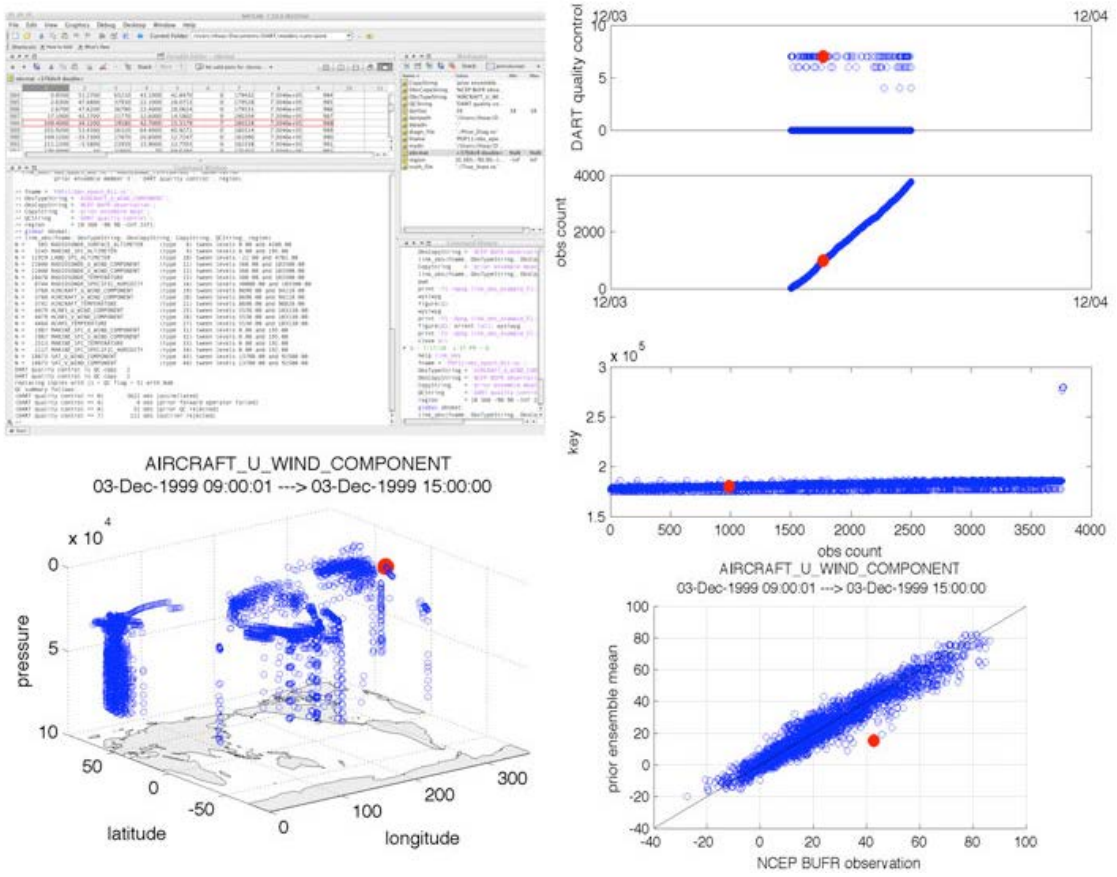
Data assimilation research

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 are interested in applying ensemble data assimilation methods with DART.



A linked observation diagnostic plot depicting the location, quality control value, prior ensemble estimate, and other information for observations assimilated by the DART assimilation system with the CAM5 atmospheric GCM. This tool allows a click on the observation in one of the plots to highlight the corresponding data in all plots and in a text window displaying the DART observation sequence files. This is an example of advanced DART diagnostic capabilities that empower users to better understand the behavior of a DART assimilation and to evaluate the quality and usefulness of different observations.

The DART software is continually upgraded and improved. During FY2010, DAReS supported the incorporation of many large geophysical models: CAM4 and CAM5, the Navy's NOGAPS global prediction model, the National Severe Storm Lab's NCOMMAS cloud-resolving mesoscale model, and the TIEGCM thermosphere/ionosphere model. DART interfaces and scripts for the MIT ocean GCM and the WRF regional atmosphere model were improved to increase functionality, and the WRF polar model version was included. The first partially coupled atmosphere-ocean data assimilation system was developed with assistance from CGD; an ensemble reanalysis with CAM4 or CAM5 provides forcing for an ensemble assimilation with the POP ocean model. A number of new diagnostic tools were developed including linked plots for exploring the use of observations. The website and online documentation were further enhanced and now include descriptions of each compliant model, and documentation links directly into the version-controlled DART code. Tools for obtaining DART-compliant observations from MADIS (Meteorological Assimilation Data Ingest System) and the World

Ocean Database 2009 were updated, and data sets for years since 1998 are now available. The ability to assimilate HFRADAR ocean radial velocity observations was developed. DART has been ported to the Cray XT5 architecture to give users the option of running on Lynx or Jaguar.

A major new release of DART is planned for FY2011. Many of the planned enhancements are focused on improving the performance of DART on large processor counts for large models. Features to allow improved control of assimilation experiments will also be included. A major enhancement to the core algorithms will allow forward operators for observations to be interpolated to the time of the actual observation, which should result in enhanced assimilation quality for most DART users. This release was originally proposed for FY2010 but was delayed because resources were diverted to support the generation of ocean ensemble initial conditions for NCAR's submission to the next IPCC assessment.

CISL's data assimilation research supports CISL's computing imperative for software cyberinfrastructure. 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, NASA Grant NNX08A23G, National Oceanographic Partnership Program Grant G0776112, and Ashima Research NASA Grant IMA10125.

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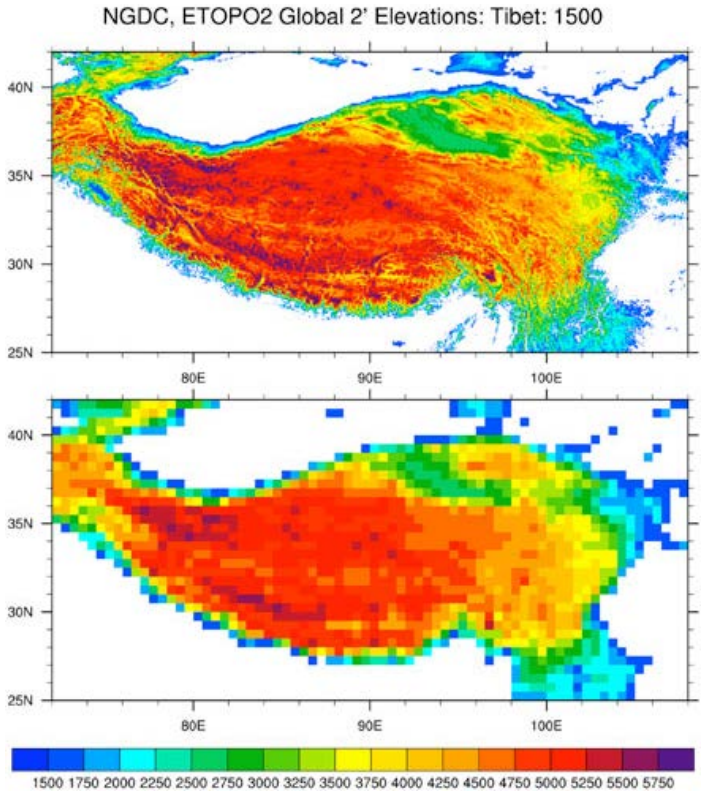
Community data analysis and visualization software

The NCAR Command Language (NCL) is a data analysis and visualization environment developed primarily at NCAR/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 systems to high performance computers. PyNIO and PyNGL are Python modules based on NCL's file input/output and visualization capabilities, thereby enabling NCL's software components to be exposed 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.



This image shows the surface topography for Tibet to illustrate the use of a local area-conserving remapping function in NCL. This function interpolates from a high-resolution grid to a lower-resolution grid. This kind of remapping is important when an area-integrated field like topography must be conserved.

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 for their research. Critical to the importance of these tools is that they are free, well supported, easy to install, and run across a wide variety of UNIX systems, allowing students and scientists to continue their research uninterrupted as they change organizations. NCL is a nationally well-established tool for Earth System sciences, and is being adopted internationally as well, including at the Max-Planck-Institut für Meteorologie in Hamburg, and MeteoSwiss in Zürich. There is a high level of interest for researchers at the Bureau of Meteorology and University of New South Wales in Australia to use NCL for processing CMIP5 data; we have been invited to teach two workshops there.

In FY2010 we released two versions of NCL that included long-requested support for creating PNG output, new variable types (to support new types in NetCDF V4), full support for OPeNDAP, numerous updates to the GRIB1/GRIB2 readers, and a new suite of user-contributed NCL scripts. Major versions of PyNGL and PyNIO were also released, including support for the same new data and graphical formats as NCL. Based on user requests, close to 100 scripts were written for the examples websites showing how to analyze numerous data types including ICON model, ISCCP, categorical, HDF-EOS5, and shapefile. Regridding and interpolation to different grids is a hot topic, and examples were created showing how to use various methods of regridding, do conservative remapping, and fill in missing data on a grid. In June, NCL was used to create a high-profile animation for the Gulf oil spill that saw over 900,000 hits on YouTube. We have over 10,770 reported registered users, and there were 24,219 downloads of the NCL, PyNGL, and PyNIO software in FY 2010; in April a new release of NCL was downloaded 2,654 times. The visualizations produced by NCL and PyNGL are used worldwide in scientific papers, presentations, posters, model diagnostics websites, and Ph.D. dissertations.

In FY2011 we will begin joint work with Argonne National Laboratory to improve the performance of our tools by developing a parallel analysis and visualization library geared toward ultra-large climate datasets (ParCAL). An immediate goal toward this effort is to finish addressing memory and scalability issues, in particular, the handling of large arrays (> 2 GB). Other priorities will be to finish upgrading an aging display model by allowing transparency and more fluid use of color tables to expand visualization capabilities (already in alpha-test mode), and to add transparent access to data in netCDF (V4) and HDF (V5) format. Other NCL/Python priorities are derived from collaboration with a number of core scientific groups and projects. These include preparation for CCSM-based IPCC AR5 studies, development of new visualization and analysis capabilities for WRF and other Earth System models and datasets, and integration of NCL with the Earth System Grid.

This work addresses 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. These community tools are primarily supported by NSF Core funding. Support for ParCAL comes from DOE's Office of Biological and Environmental Research (BER).

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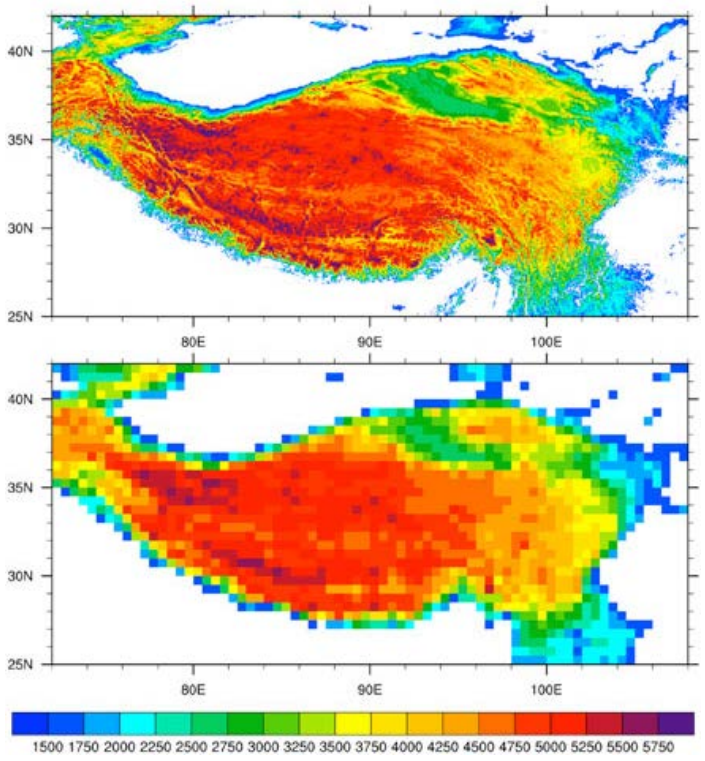

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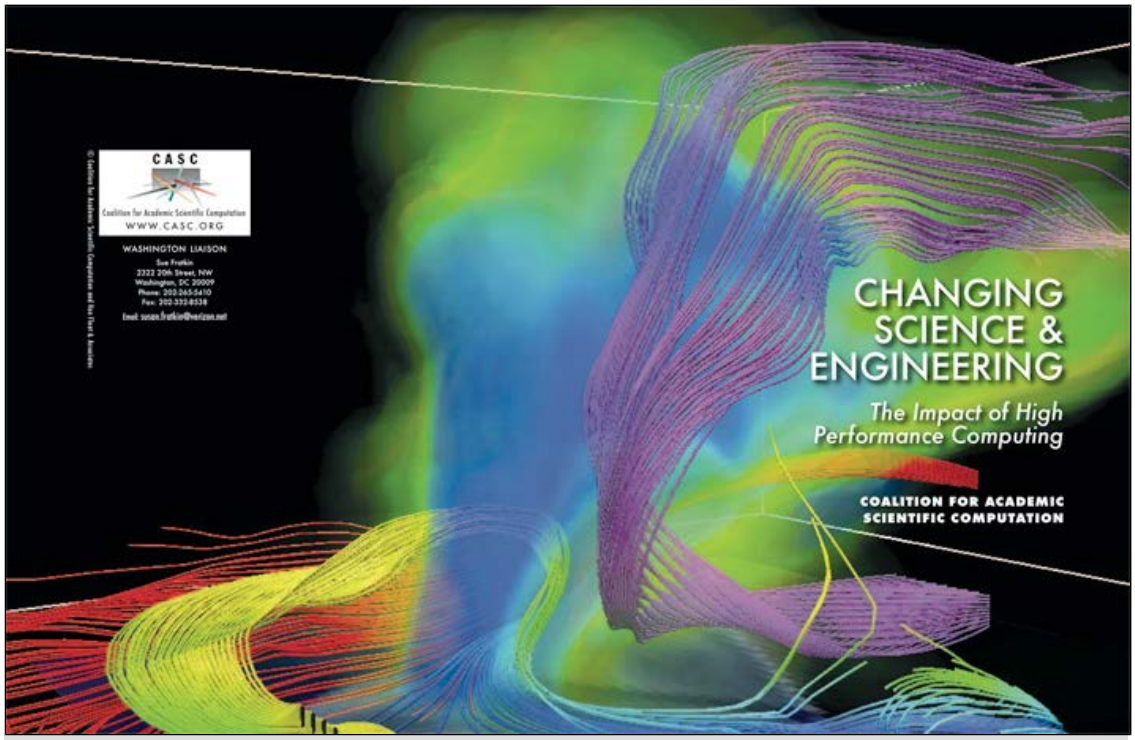
VAPOR visualization software for very large datasets

The VAPOR project is an Open Source software development effort aimed at improving the ability of researchers in the Earth 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. 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 sciences community; and a strong emphasis on supporting quantitative data analysis.



This visualization was produced using VAPOR and appears on the cover of the 2009 Coalition for Academic Scientific Computation (CASC) brochure. It depicts a snapshot in time of a numerically simulated supercell thunderstorm conducted by Associate Professor Leigh Orf at Central Michigan University. The goal of this research is to better understand the processes leading to tornado formation in supercells, the most powerful type of thunderstorm.

The goals of the VAPOR project are strongly aligned with the cyberinfractructure 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.

Efforts in FY2010 were largely focused on meeting contractual obligations of two external funding sources (NSF-09-06379 and a TeraGrid GIG award), as well as on developing and enhancing core capabilities. A new progressive access data model (VDC2) was completed, offering far greater compression than VDC1, resulting in greatly reduced storage bandwidth and capacity requirements. A Python calculation engine was incorporated into the GUI, permitting users to write sophisticated scripts for deriving new quantities on the fly. This was the most-requested new feature in a recent VAPOR user survey. Several key infrastructure components were re-architected to facilitate extension by third parties. The extensibility improvements were the basis for the development of a WRF data importer that provides WRF users with a convenient alternative to data translation for WRF data analysis. Finally, VDC1 data importers were written for both VisIt and ParaView, further improving the scalability of these parallel visualization tools. All of these enhancements will be available in the next release of VAPOR, planned for October 2010. In addition to development, CISL continued E&O efforts, providing VAPOR tutorials at TACC and the locally hosted WRF users workshop.

In FY2011 we will finish re-factoring the VAPOR infrastructure to facilitate extensibility. We will release a Fortran-callable, parallel API to the VDC2 data model, allowing computational scientists to write model data directly to VDC2 files from a running simulation. The addition of so many new capabilities to the VAPOR package has unfortunately cluttered the GUI and somewhat reduced the usability of the package. To address this, a significant emphasis in the coming year will be placed on ease-of-use improvements in the areas of improved documentation, more extensive training material, and a simplified GUI. Finally, we will continue our E&O efforts, offering courses and workshops on VAPOR's use.

This project is supported by NSF Core funds, NSF-09-06379, and a TeraGrid GIG PY5 award.

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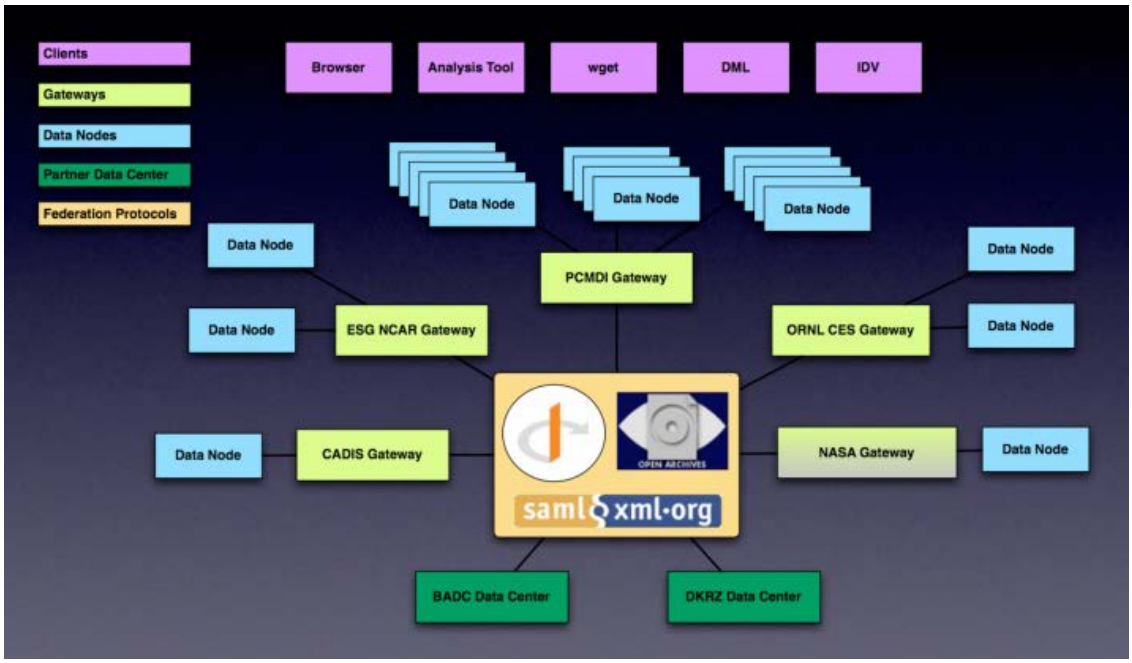
The Science Gateway Framework

Science Gateways have emerged as an important paradigm for providing scientific communities with convenient access to shared cyberinfrastructure. A science gateway typically provides a specific community with some level of integrated, web-based data and knowledge management and access, simulation capability, and analysis/visualization capabilities. NCAR/CISL is engaged in a number of efforts in this area, and is now developing the Science Gateway Framework (SGF) as shared software cyberinfrastructure to support a range of community activities. The SGF serves as a foundation for **ESG-CET**, **Curator** (NOAA/GIP), **CADIS**, **CDP**, **NARCCAP**, **WMO-WIS**, and **TeraGrid** science gateways.



This image shows the concept of globally federated science gateways built on shared cyberinfrastructure. The Science Gateway Framework (SGF) serves as the foundation for the gateway components in the figure. The SGF will serve as a foundation for ESG, CMIP5/IPCC data sharing, CADIS, WMO activities, and more.

Development of the SGF 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. Specifically, this effort fulfills CISL's strategic action item to refactor existing Earth System Grid and Community Data Portal infrastructure into a Science Gateway Framework. This project also advances 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. Finally, by developing new methods and tools to extract information from large and heterogeneous data sets, this work supports CISL's science frontier for understanding large and heterogeneous data sets.

In FY2010 we continued significant development of the SGF with a vigorous release schedule. In November 2009 we released a new CADIS Gateway to the Arctic community and have continued to refine and improve it over the course of the year. In 2010, we released two beta versions followed by six release candidates of the SGF for the ESG Gateway, finally reaching a major milestone in May 2010: V1.0.0 of the ESG Gateway. Version 1.0.0 included many additional features, improvements, and fixes including versioned datasets, access-controlled file downloads and deep storage transfers, data publishing performance improvements, and user interface refinements. We cut over all of our ESG production services that month as well, migrating over 16,400 users and publishing over 250 TB of climate data holdings comprised of over 1.3 million files. The transition went very smoothly. In July we released Version 1.1.0 which addressed OpenID logins, dataset replication, Gateway OAI RDF-based metadata exchange, application build system

upgrades, and a range of security improvements.

This was followed by a minor release, Version 1.1.1. As we progressed since then toward the critical Version 1.2.0 CMIP5 Baseline release early in FY2011, we further addressed federation capabilities and security infrastructure, and enhanced support for CMIP5 data specifics. Collaborating extensively with NOAA GIP, Curator, and the EU-based METAFOR project, we continued to develop capabilities for the “model trackback” interface and the corresponding METAFOR Conceptual Information Model (CIM) ingest capabilities. It should also be noted that we invested very heavily this year in project management infrastructure and process, utilizing BaseCamp, Atlassian (release control and issues), and Confluence (requirements and documentation). We made substantial progress toward a community development process, including developing a Contributor License Agreement (CLA) and working toward applying an Open Source license to the SGF. The SGF is currently running at NCAR, LLNL/PCMDI, ORNL, NASA/JPL, BADC, and DKRZ for purposes of evaluation and feedback.

In FY2011, we will continue to advance the SGF in support of ESG, CADIS, CDP, Curator, TeraGrid Science Gateways, and WMO-WIS. Our first major objective will be releasing SGF for the ESG Gateway V1.2.0, the critical CMIP5-Baseline release, and these will occur early in FY2011. This release must fully support the core capabilities for releasing and sharing CMIP5/AR5 scientific data. After that we plan to release an Open Source version of the SGF, accompanied by a community development environment. In the first half of FY2011, we will complete the migration of production CDP capabilities. CADIS capabilities will continue to be advanced as well throughout the duration of the project, with the hope that we will receive OPERA support to continue these in CY2011. Drawing on support from the TeraGrid-funded CCSM Science Gateway project along with the new NOAA Global Interoperability Program (GIP) Curator effort, we will continue to refine our capabilities for semantic query, the integration of modeling and data management, and support for collaborative group endeavors.

This project is supported through NSF Core funding, augmented by special projects including ESG-CET, NOAA GIP, CADIS, and TeraGrid.

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Computing Imperative: Data Curation

CISL's Data Support Section staff actively manages the Research Data Archive (RDA) at NCAR. The RDA is over 600 datasets and requires 603 TB of storage for the primary, user-accessible collection. This collection has gained international prominence through dedicated development and data stewardship. The RDA is known as a world data resource on the web that supports scientific studies in climate, weather, Earth System modeling, and increasingly other related sciences.

Scientific data archives are critical to supporting NCAR research. Professional data curation and stewardship amplify the value of the data for science. These services assure good quality data with complete documentation, long-term preservation, easy access, and knowledgeable data experts to fulfill a variety of consulting and service functions.

CISL, including its predecessors, has more than a four-decade history dedicated to data curation benefiting users at NCAR, within the UCAR university community, and in national and international research teams. Today these activities are realized as developments of the Research Data Archive (RDA) as a whole, and of one of its notable large subsidiary projects, the THORPEX Interactive Grand Global Ensemble (TIGGE).

Data curation is a computing imperative in CISL's Strategic Plan. The significance of NCAR's collection of research data is evident in the **usage and growth** of this open resource. RDA maintenance and development within CISL is supported almost entirely by NSF Core funding. A two-year NSF grant is now partially supporting TIGGE to improve its access and establish a complementary validation data portal.

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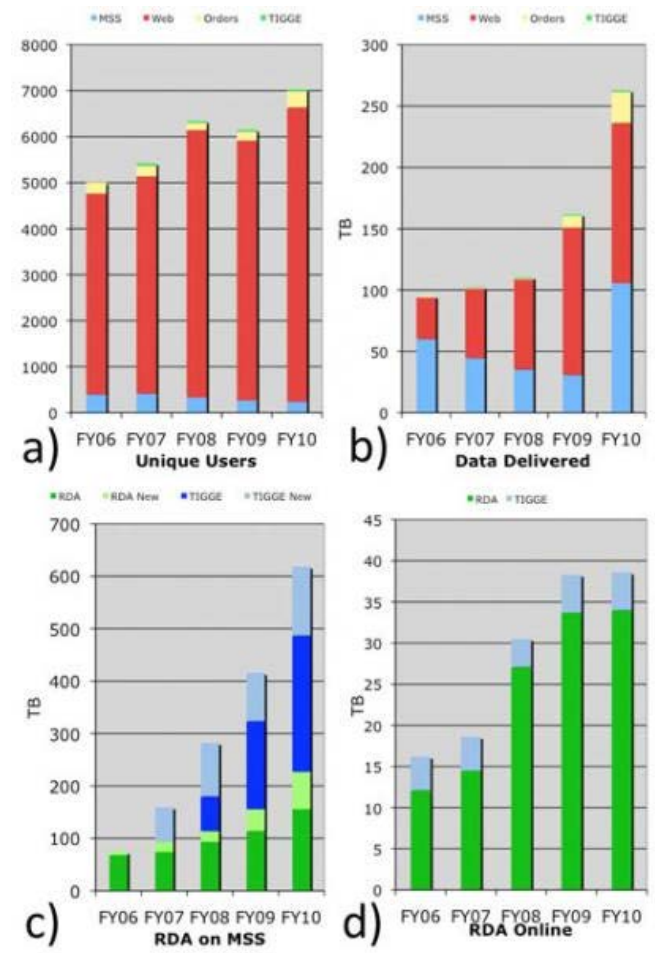
Research Data Archive

The Research Data Archive (RDA) is a key part of the CISL Strategic Plan computing imperative for data curation because it provides an information resource through a large 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 worldwide community also uses it. The RDA activities can be viewed from two different perspectives: user data access and archive content development, both of which are equally important.



These charts show the data access and growth metrics for the Research Data Archive (RDA) during FY2006-FY2010:
a) The number of unique users specified by access pathway: the NCAR MSS, 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 MSS archive, showing annual growth.
d) The amount of data on public web servers, showing annual growth.
Charts a) and b) indicate the RDA's great significance to the community, and charts c) and d) show the annual progress toward building more valued content into the RDA.

In FY2010, about 7,000 unique persons were provided 260 TB of data through various primary access pathways: the NCAR MSS, 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 web user group is the largest: 6,400 people downloaded 130 TB of data. The number of users who access the data directly at NCAR from the MSS is smaller, but their per capita data access amount is higher, 239 individuals and 106 TB, respectively. The remarkable increase in MSS usage in FY2010 is due to new reanalysis products that have been added to the RDA. These metrics indicate that the RDA is known as a world data resource on the web, and when it comes to accessing large significant reference datasets, working directly on CISL computational resources is very effective.

A simple measure of data content development is archive growth. The RDA expanded by over 193 TB in FY2010 (see chart c). TIGGE is part of the RDA, but it is shown separately because it alone added 122 TB. This overshadows the 71 TB increase in the remaining part of the RDA, which is nevertheless very important and a 46% increase in size from the previous year (chart c). The most-requested datasets from the RDA are available online through web servers. The current online data is about 39 TB (chart d), an equal amount to the previous year. Roughly, 15 TB of new or replacement data were put online, but the overall amount was not increased. Again, TIGGE is shown separately and does not change much between years because it is capped at a rolling three-week archive with only the most current

data. Older TIGGE data are copied and managed from the MSS.

As a whole, 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. Some of the major accomplishments for FY2010 were:

- Created easy-to-use data access software for the NCEP surface and upper air observations that are received and updated daily in BUFR format.
- Operated and maintained the TIGGE Archive and access on a 24×7 basis.
- Computed and published the high-resolution gridded products of ERA-Interim Reanalysis from ECMWF, 1989-2009.
- Acquired and published the 20th Century Reanalysis, Version 2.0, and the complementary International Surface Pressure Database observations.
- Acquired and published the monthly and hourly time series products (highest priority for our users) from NOAA Climate Forecast System Reanalysis (CFSR).
- Acquired and published about half of the ECMWF Year of Tropical Cyclone (YOTC) high-resolution operational model output dataset.
- Developed and published Release 2.5 of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) in collaboration with NOAA partners.
- Updated and extended the time series of many ongoing observational datasets and reanalyses, e.g., JRA-25, NCEP/NCAR Reanalysis, etc.
- Implemented an NCAR-based disaster recovery copy of the RDA primary data assets (files, documentation, metadata, database records, etc). Terminated our previous arrangement with UCSD.

Some major activities for FY2011 will include:

- Transition the RDA development and services to new storage, the disk-based GLobally Accessible Data Environment (**GLADE**), and a cluster of Linux servers. This will transform the RDA to higher capabilities for data receipt, greater server-side computing resources, and easier access at NCAR and via the web. Online publically available RDA data will grow to 250 TB.
- Transition the long-term preservation component of the RDA from the MSS to the new HPSS.
- Re-engineer and develop new RDA archiving and metadata management tools to take advantage of the GLADE and HPSS environments.
- Receive and extend ERA-Interim Reanalysis products to the most current date available, typically lagging real-time by three months.
- Complete the publication of YOTC and extend other ongoing reanalyses, e.g., JRA-25, NCEP/NCAR Reanalysis, etc.
- Complete deployment of the 6-hourly 3D atmospheric CFSR data in the RDA. Large portions, about 80 TB, will be accessible via GLADE.
- Through the two-year NSF grant, improve access to the TIGGE archive and build a validation data portal, with Model Evaluation Tools (MET) examples.
- Open user access to a new upper-air sounding database within the RDA.

Strength for the RDA is that its staff, data management practices, and ability to positively effect outcomes in the data arena are nationally and internationally respected. This position is an advantage when building collaborations that continually strive to provide better scientific data resources and access.

RDA maintenance and development within CISL is almost entirely supported by NSF Core funding. A two-year NSF grant is now partially supporting TIGGE to improved the access and establish a complementary validation data portal.

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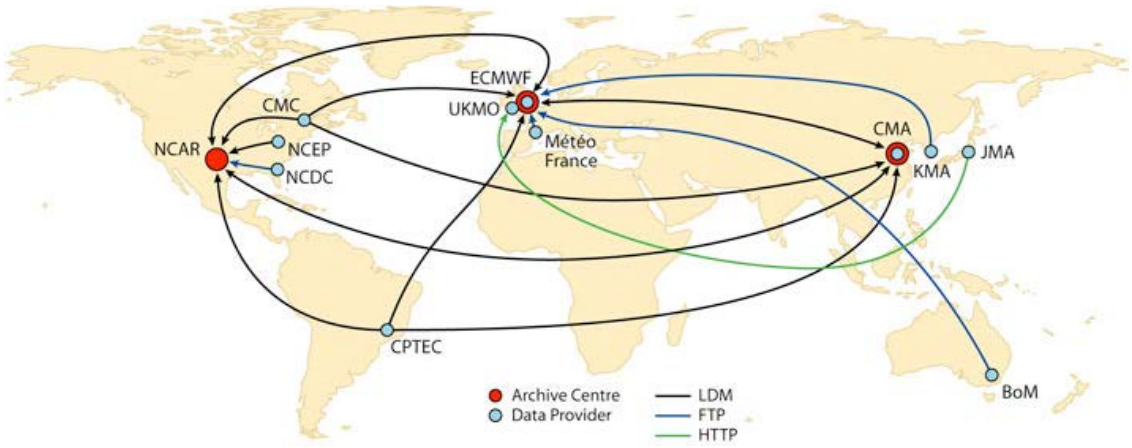
THORPEX Interactive Grand Global Ensemble

The NCAR TIGGE Archive functions in collaboration with the European Centre for Medium-range Weather Forecasts (ECMWF) and the China Meteorological Administration (CMA). The Archive Centers receive data from many international providers in real time and on a 24×7 basis. The data system is a range of software, hardware, and network communications that receive, archive, and provide user access.



This image indicates data flow from the providers to and between the TIGGE Archive Centers. NCAR, European Centre for Medium-Range Weather Forecasts (ECMWF), and the China Meteorological Administration (CMA) are Archive Centers that each hold near-identical data copies from all data providers. ECMWF, CMA, Bureau of Meteorology (BoM), Meteorological Service of Canada (CMC), Centro de Previsao Tempo e Estudos Climaticos (CPTEC), Japan Meteorological Agency (JMA), Korea Meteorological Administration (KMA), Météo France, MetOffice (UKMO), National Centers for Environmental Prediction (NCEP), and National Climatic Data Center (NCDC) are all data providers. Three different transfer protocols are used within the system: Local Data Manager (LDM) – a Unidata software package, File Transfer Protocol (FTP), and Hypertext Transfer Protocol (HTTP).

Development began in FY2006 and now largely runs in an operational mode receiving 3.3 TB per week. The data access options include direct file downloads, parameter selection, temporal and spatial subsetting, and regridding of the diverse native model grids to a user-selectable uniform grid. Output data format can be either GRIB2, which is the native format, or Climate Forecast-compliant netCDF. The high-volume NWP forecast data is augmented with a tropical cyclone data product that is low-volume and available in an easy-to-use XML format. Many more details about TIGGE data management, larger scope goals, and early scientific outcomes are published in the August 2010 Bulletin of the American Meteorological Society.

The FY2011 objectives for the NCAR TIGGE Archive are:

- Maintain all aspects of its real-time and archiving operations.
- Adapt the system to accommodate TIGGE-designed and derived products such as extreme precipitation consolidated for regional forecasts.
- Begin delivering on the goals established in an NSF two-year grant that will lead to improved access to this very large (380 TB) archive and complement the weather forecast data with observational data selected through a linked validation data portal.
- Reposition the archive and operations to new infrastructure to enable improved access. More online storage will be allocated, clusters of Linux servers will boost computing capability, and efficient offline data retrieval from a HPSS will permit research studies focused on long time series.

The TIGGE project supports CISL's computing imperative for data curation by developing and curating research data sets and maintaining user-centered online access to this archive. Further, this work fulfills CISL's strategic action item

to increase both the size and the value of the THORPEX Interactive Grand Global Ensemble for U.S. university weather research. NSF Core funding and a new grant (for the next two years) support TIGGE maintenance and development within CISL.

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CISL Science

CISL is an interdisciplinary science laboratory.

To support sustained progress in the computational geosciences, radically new techniques must be developed and tested in anticipation of emerging technology trends and scientific goals. Because of its unique juxtaposition of computer science, applied mathematics, statistics, and geosciences domain expertise, CISL is strongly positioned to function as a leading interdisciplinary computational science laboratory supporting these advancements in partnership with the atmospheric sciences community.

CISL's science Imperatives include:

- To support NCAR's strategic goals, CISL itself must be a first-class scientific organization. CISL's strategy is to derive research priorities from Earth System science problems, emphasize multidisciplinary teams and collaboration, and connect research activities to education goals. A central organizing theme will be addressing the challenge of Earth System modeling at the petascale and exascale.
- CISL must maintain a portfolio of research models to drive forward basic scientific research in computational fluids and basic algorithmic research.
- CISL will facilitate the production of high-quality scenarios of projected climate change and develop tools and methods for analyzing regional impacts, vulnerability, and adaptation to these changes. This effort integrates advances in geophysical modeling and statistical methods into the broader decision-making and policy communities.

CISL's science Frontiers include:

- Multidisciplinary approaches are required for building accurate, possibly stochastic, models of subgrid-scale behavior to advance model development.
- Algorithmic acceleration breakthroughs are needed: new algorithms, computational approaches, and hardware accelerators are all required to produce simulations capable of addressing grand challenges.
- New methods and tools are required to extract information from large and heterogeneous data sets.

This section of the FY2010 CISL Annual Report reports on the topics shown in the navigation tool at left.

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Science Imperative: Scientific Excellence

The research activities within CISL support scientific computation, numerical methods, geophysical modeling, and the analysis of geophysical data and model experiments. This research is important to maintain an innovative computational and modeling facility at NCAR, and more broadly, to lead the geophysics community in adopting new computational methods and mathematical tools that enhance scientific research. Hallmarks of this research are innovative and standout contributions that not only have relevance for the overall NCAR scientific program, but are also significant in their specific area of mathematical, physical, or computational science. The projects highlighted for this imperative reflect the breadth and quality of this scientific research.

Computational science and data assimilation groups made innovative contributions to the ocean modeling effort at NCAR through the evaluation of high resolution simulations and combining the coupled ocean and atmosphere model with observations. Progress was also made on acheiving higher resolution by spatially adaptive meshes using either radial basis functions or spectral elements. There were numerous accomplishments in modeling geophysical and astrophysical flows at the scales of turbulence with some fundamental results quantifying the interactions between waves and eddies. Contributions to the analysis of large geophysical simulations were made through using image compression for visualization and through Bayesian spatial models to quantify the uncertainty in regional climate simulations.

Because CISL research typically involves multi-year projects, work in these highlighted areas will continue in FY2011. Emphasis will be placed on more complete simulations and assimilations for the ocean and on increasing capability for atmosphere/ocean data assimilation.

Taken near the base of NCAR's Mesa Laboratory, this image is an icon for the challenges and relevance of our research. The complex topography and ecological diversity in this image suggest the many physical processes that determine our local environment and climate. A challenge to computational science and applied mathematics is to account for these processes in numerical simulations at many different scales. Often a direct simulation at small spatial scales is not possible due to the limitations of computational resources, so approximate models must be devised. Even the highest-resolution regional climate models (4 km for the NCAR model) would reduce the spatial elements in this image to a single grid point.

What is omitted from this image is equally telling of our geophysical challenges. The Pacific Ocean is approximately 1,500 km away, but Boulder's climate is inextricably linked to the long-term dynamics of the oceans, and in general to climate processes that operate at global scales. Thus, to accurately simulate climate changes for this location, the entire coupled Earth System must be considered. CISL research is focused on building better models for the finest scales of the atmosphere and ocean and on devising numerical and computational strategies to simulate the Earth System at the highest resolutions possible with given computational resources.

Equally important is to use mathematical and statistical approaches to quantify our limited understanding of the Earth System and to reconcile the imperfect simulations of climate with reality. The suburban setting of South Boulder also suggests that climate modeling skill may be location dependent based on the local infrastructure and economy. For example, this area's rainfall extremes that lead to flash flooding and drought conditions that increase wildfire hazards are important concerns. Accurately simulating precipitation extremes is difficult and is an active area of climate modeling research.

In summary, this image suggests two main themes of CISL's science research: modeling complexity in physical processes and handling the uncertainty in these processes when they are not well resolved. (Photo courtesy of Everett Nychka.)

More sophisticated models will be tested for adaptive numerical methods along with scientific applications to mantle convection. It is expected that the MUSE code will continue to mature with nonhydrostatic simulations using adpative refinement. The turbulence research will continue to explore systems with rotating flows and extend the GASpAR and GHOST codes to handle higher resolution. The statistics project will collaborate on the calibration of the LFM magnetosphere model and continue analysis of the regional climate simulations in NARCCAP.

CISL's science imperative for scientific excellence is primarily supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

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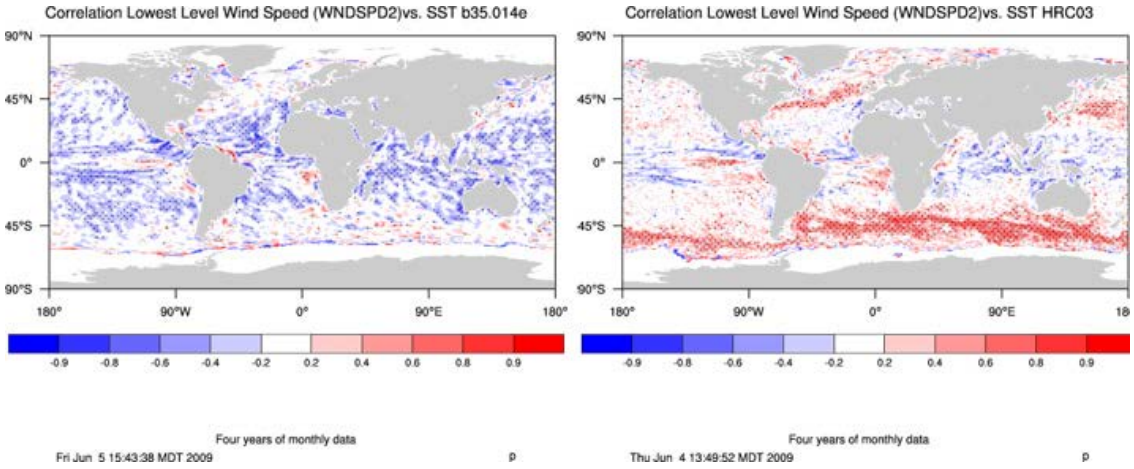
Ultra-high-resolution CCSM

Over the last several years we have made concerted efforts to significantly improve the scalability of the various components of the upcoming Community Earth System Model (CESM). Significant improvements have been made to the efficiency of the Parallel Ocean Program (POP) and the Community Ice CodE (CICE) at 0.1° on large processor counts. This work has focused on improving the simulation rate and reducing the computational cost to simulate ultra-high-resolution climate. All of these improvements, along with a new scalable dynamical core for the Community Atmosphere Model (CAM) based on the High Order Methods Modeling Environment (HOMME), have been made available through the official release of CESM. This scalability improvement has also enabled the completion of a 155-year control run that couples a 0.1° POP and CICE to a 0.5° CAM and LND on Kraken, a Cray XT5 system located at National Institute for Computational Sciences (NICS). This 155-year control run is part of the NSF-funded PetaApps project to investigate the impact of weather noise within the coupled climate system.



At gyre- to basin-scales, sea surface temperature (SST) and surface winds tend to be negatively correlated. However, recent high-resolution remote sensing observations have indicated that the sign of the correlation is reversed for scales smaller than 1,000 km. Over ocean fronts and eddies, higher winds are observed over warmer SST. An experiment with 0.5° atmosphere and 1.0° ocean models (left) does not capture this relationship very well. But the same atmosphere model coupled to a 0.1° ocean model (right) does an excellent job of reproducing the positive correlation between SST and low-level winds in the vicinity of strong ocean fronts.

While the analysis of the ultra-high-resolution control run is continuing, preliminary results suggest that there are significantly different characteristics relating to air-sea interactions. The figure illustrates the difference in correlation between sea surface temperatures and wind speeds for simulations using a 0.1° versus a 1° ocean. Recent remote sensing observations indicated that surface wind speed has a positive correlation to SST at scales smaller than 1,000 km. Unlike the 1° ocean, the 0.1° ocean does an excellent job of reproducing this positive correlation.

These advances are significant because it is now possible to simulate the Earth System on currently available supercomputing resources at resolutions that are 30 times as computationally demanding as the current production CESM simulation. While our current work is focused on addressing the scientific goals defined by the PetaApps project, we have used this project as a vehicle to enable a ultra-high-resolution climate simulation capability for the broader climate community. Our work demonstrates that we are prepared to use the upcoming NSF petascale system to finally resolve many of the important physical processes with the Earth System that previously had to be parameterized. We plan to continue improving the efficiency of the ultra-high-resolution CCSM configuration to address the needs of the PetaApps project, and transfer these advances back into the released CESM codebase.

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 and NSF PetaApps grant OCI-0749206. Additional funding is provided through the Department of Energy's CCPP program grant DE-FC03-97ER62402.

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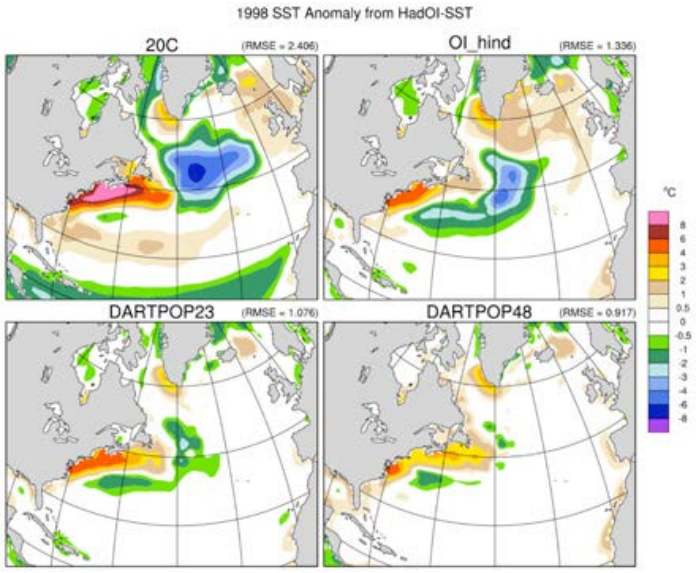
Data assimilation research

Data assimilation is the process of merging data from observations with computer models. It can transform diverse and incomplete observations to gridded estimates that can easily be used and interpreted. The assimilation process also produces quantitative information on model error, forecast skill, and observational errors, all of which allows us to improve models.

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 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 are interested in applying ensemble data assimilation methods.



Differences between four POP model estimates of the 1998 annual mean sea surface temperature and the HadleyOI analysis. The estimates include a fully coupled CCSM 20th century simulation (upper left), an ocean simulation forced by observed NCAR/NCEP reanalysis atmospheric fields (upper right), an uncoupled 23-member DART/POP ensemble assimilation (lower left), and a coupled DART/POP/CAM ensemble assimilation (lower right). The coupled assimilation is much closer to the observed sea surface temperatures and should lead to improved CCSM coupled model predictions for the next IPCC assessment.

A broad range of NCAR projects was advanced by DART during FY2010:

- The first five years of a DART/CAM4 reanalysis from 1998-2010 have been completed, and a corresponding POP ocean reanalysis is complete to 2001. The ocean ensemble analyses will be used as initial conditions for decadal predictions that are part of the next IPCC assessment.
- Year-long DART reanalyses with CGD's CAM4 and CAM5 climate models identified model shortcomings including insufficient diffusion damping and an error in the implementation of the damping algorithm. The uncorrected model produced large amounts of gridscale noise, especially in northern high latitudes.
- A sampling error correction algorithm based on an improved understanding of observation impact localization has been added to DART and tested in a variety of applications. This algorithm is being used to reduce noise in the POP ocean reanalysis and in real-time hurricane analyses.
- The potential impact of assimilating observations of cloud water, cloud ice, and cloud fraction were examined in a series of DART experiments with CAM and NOAA's AM2 atmospheric GCM in collaboration with NOAA/CIRES. The potential impact of cloud observations was found to depend strongly on the details of model subgrid-scale parameterizations.
- Researchers in CGD are continuing to use DART/CAM analyses and forecasts to explore mechanisms for the rapid loss of Arctic sea ice observed in the last three years. Results from assimilations led to the development of an improved stratus parameterization by CGD.
- WRF/DART has been used to make real-time analyses and forecasts of all 2010 Atlantic tropical storms by researchers in MMM and SUNY Albany. The use of a nested grid in the assimilation has produced improved forecast skill this year.

- Researchers in MMM and COSMIC have applied DART/WRF in the western tropical Pacific over the two-month TPARC period from 2008 to explore the impact of GPS radio occultation observations on forecasts of tropical storm track and intensity. Results show assimilation of GPS observations leads to improved track predictions.
- DART has been used with WRF to do high-resolution analyses and forecasts for short-term explicit predictions (STEP) of high-impact severe weather events over the Midwest. The impact of assimilating radar observations is being explored.
- A joint DAReS/University of Wisconsin project found that assimilation of advanced hyperspectral infrared retrievals leads to improved hurricane analyses in the Atlantic.
- Normal mode analysis has been applied to a DART analysis with CAM to increase understanding about how different dynamical components of the global circulation are impacted by assimilation in collaboration with CGD and the University of Ljubljana.

During FY2011, the coupled atmosphere ocean reanalysis will be completed for IPCC use. DART will be used with WRF to generate real-time analyses to initialize WRF mesoscale predictions of severe convective weather as part of the National Severe Storm Lab's Spring Forecast Experiment. A capability to assimilate radiance observations will be added and tested in WRF, then made available for other models. Assimilation of radar observations for short-term explicit prediction will be evaluated and improved. DART will be used to do parameter estimation for boundary layer parameterizations in WRF with university collaborators.

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 and NASA Grant NNX08A23G.

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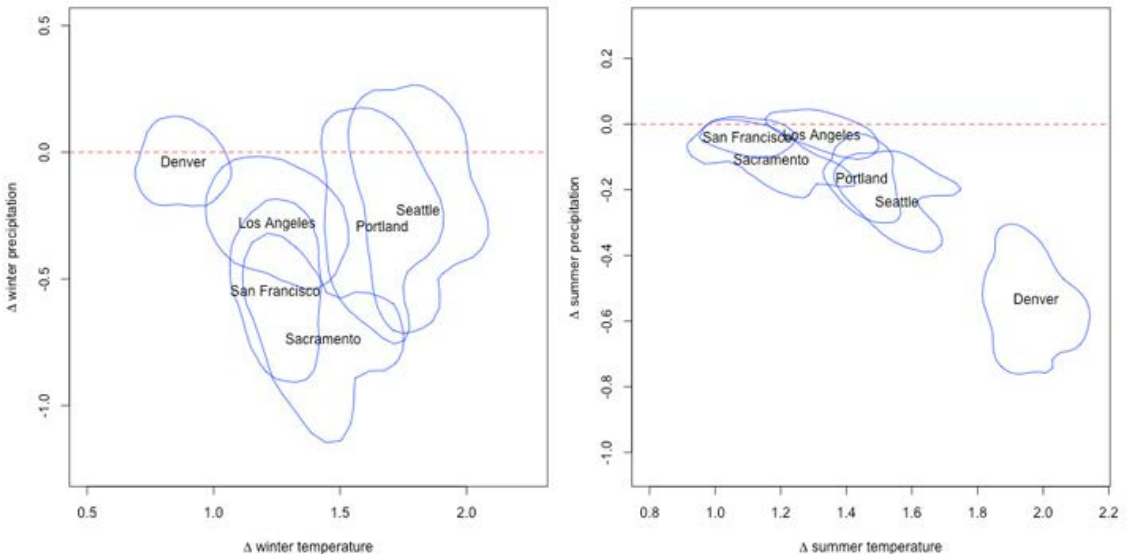
Geophysical Statistics Project

From our unique position within CISL and IMAGe, the Geophysical Statistics Project (GSP) has been a leader in training and research emphasizing the synergy between the geosciences and the statistical sciences. In addition to basic methodological and theoretical statistical research, GSP has a strong 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 applications in the geosciences.



Results from a statistical analysis of the uncertainty in the joint change in average temperature and precipitation from a regional climate model experiment. Shown are 95% contours of the posterior distribution for the average change for the consolidated metropolitan statistical areas in the western United States. In addition to exhibiting a consistent increase in average temperature, these contours show an association between increasing temperature and declining average precipitation.

In addition to these core activities, 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 statistical staff, and 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 FY2010, GSP researchers have been involved in numerous important projects, including:

- Design and analysis of computer experiments, in particular focusing on regional climate models and models of the upper atmosphere and the magnetosphere.
- Developing methodology for analyzing extremes of weather and climate.
- Stochastic weather generators.
- Modeling uncertainty in climate reconstruction.
- Impacts of climate and climate change on public health.

GSP continues to develop theory and methodology for analyzing spatial data, including nonstationary covariance models, models for spatial lattice data, multivariate spatial observations, spatial-temporal models, and general

methodology for computational statistics and Bayesian hierarchical models.

In FY2011, the scientific focus on computer models will continue, in particular through GSP scientists being involved in such NCAR programs as the North American Regional Climate Model Assessment Program (**NARCCAP**) as well as in collaborations with other computer modeling groups across NCAR, in particular with scientists in NCAR's High Altitude Observatory (HAO) studying the upper atmosphere and the magnetosphere. Beyond computer models, GSP scientists will continue to asses the impacts of climate and climate change on public health – especially vulnerabilities of certain target populations to climate change – to develop methodology for analyzing extremes, modeling daily weather scenarios, and quantifying the uncertainty in climate reconstructions. This work will also develop statistical methodology for the analysis of complex, spatial, and spatial-temporal data.

This project is made possible through NSF Core funding, as well as grants through NSF's Division of Mathematical Sciences, NSF's Division of Atmospheric Sciences, NSF's Collaboration in Mathematical Geosciences, the Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA).

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Geophysical Turbulence Program

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 progress in our modeling of the dynamics of the atmosphere, the oceans, weather, and climate, as well as the Sun and solar-terrestrial interactions, understanding relevant turbulent, nonlinear and hence multiscale 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 interact productively and collaborate with the worldwide turbulence community. From these beginnings, a sustained emphasis on geophysical turbulence at NCAR has emerged with specific research items, as well as visitors, seminars, and workshops, all activities that continue to this day. Most of this emphasis manifests itself currently in the Geophysical Turbulence Program (GTP), together with research on specific applications in other entities at NCAR.

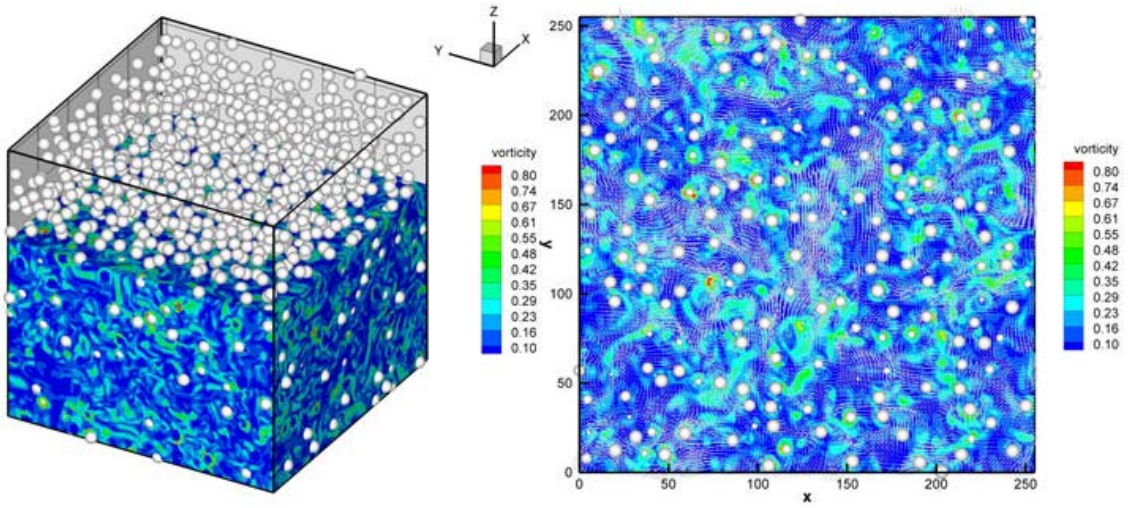
By design, GTP is an interdisciplinary group of about 50 active members that spans most divisions and laboratories at NCAR along with a few external affiliates, generally former members now working elsewhere. GTP encompasses research at NCAR on multiscale interactions. It helps develop tools as well as an array of applications in a broad variety of areas. It spans the fields of mathematics and algorithm development for the petascale and beyond, including physics, chemistry, and biological processes. GTP can also be viewed as the outreach arm of this research, which is performed in IMAGe/CISL by the Turbulence Numerics Team (**TNT**), and in many other divisions and laboratories at NCAR.

GTP activities advance several of CISL's strategic imperatives, e.g., to produce scientific excellence by conducting applied mathematics research in turbulence, for subgrid-scale modeling, for petascale computing, as well as for strategic educational initiatives. GTP works with the mathematics and geophysical communities in ways that accentuate the contributions of mathematical methods and models to scientific progress in the geosciences. GTP also develops enhanced numerical algorithms for the community.

GTP uses seed funding to foster interdisciplinary research at NCAR. In FY2010, GTP hosted nine long-term visitors performing research with staff and giving seminars, and it also sponsored six extra seminars. The GTP workshop this year focused on "Issues in Rotating Stratified Turbulence." It was organized by Vladimir Zeitlin (Paris) and Jean-Marc Chomaz (Saclay), with Chris Snyder (MMM) and Annick Pouquet (IMAGe) providing local support.

GTP produced two special accomplishments in FY2010:

- GTP obtained one-time stimulus funding for a two-year post-doctoral fellow to enhance the petascale readiness of turbulence research at NCAR. A committee was formed to attribute this fellowship, and in a tough competition, Zbigniew Piotrowski was selected to work in the group of Piotr Smolarkiewicz (MMM/IMAGe) on extending the study of numerical realizability of idealized boundary-layer convection to regional-scale moist atmospheric flows and global magnetohydrodynamics of the solar convection zone. The plan, on the numerical side, is to be able to use up to $O(10^5)$ cores on the IBM Blue Gene architecture.
- GTP held its quasi-decadal retreat in July with 16 members participating. The outcome of this retreat include these conclusions:
  - There is strong support for GTP, and raising its profile is viewed as necessary.
  - Presently, it would be desirable to re-focus GTP by fostering the creation of a trans-divisional working group on boundary layers, a theme common to many applications and divisions.
  - Stronger involvement of junior scientists should be encouraged by creating a new core fund in GTP dedicated to the part of their activities directly related to turbulence research.
  - The core budget of GTP should also be increased, after many years of stagnation or worse, to continue valuable support for its many functions.
  - GTP must continue to emphasize and further develop high performance computing and petascale activities in the future.



This image displays the vorticity of a particle-laden flow (perspective view, left, and two-dimensional cut, right) using a Lattice Boltzmann code parallelized with MPI (L.P. Wang and W.W. Grabowski, in preparation). It is an application of particle-resolved simulations to decaying isotropic turbulence with particle radius equal to 0.75 times the Taylor microscale. Of significance is the enhanced dissipation near the surface of the particles and the reduction of kinetic energy at large scales.

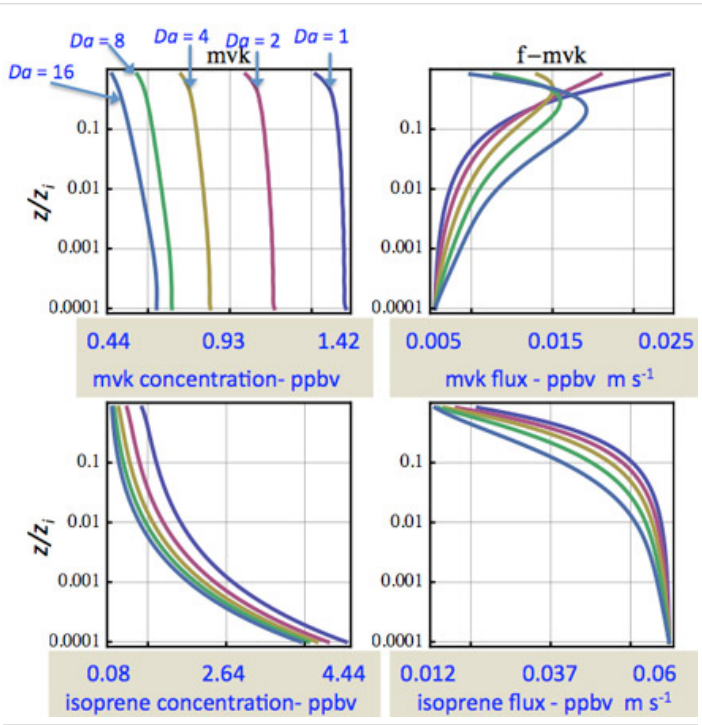
Notable scientific accomplishments of GTP members and visitors, in collaboration with members of the university community, include:

- Multiscale simulations of droplet-laden turbulent flows, in collaboration with the University of Delaware (see figure above).
- Applications of LIDAR and LES to turbulence problems in wind energy.
- Canopy turbulence.
- A Monge-Ampère enhancement for semi-Lagrangian schemes.
- The effect of subfilter-scale physics on regularization models of turbulence.
- Three-dimensional MPI parallelization of a nonhydrostatic anelastic fluid model.
- Vertical transport and reaction of isoprene in the convective boundary layer (CBL) with a second-order closure model, in collaboration with Case Western Reserve University (see figure below).
- Investigations of stable boundary layers.
- High Reynolds number magnetohydrodynamic turbulence using a Lagrangian model.

These activities led to papers, including review papers, to workshops, and to presentations at conferences and universities.

Several papers have appeared, have been submitted, or are in preparation, and several of these projects will continue in FY2011. Particular emphasis will be given to chemistry in the planetary boundary layer. This work will involve ACD, IPS (the Institute for Policy Studies), and MMM, as well as the University of Pittsburgh and IMAGe, emphasizing the changing of atmospheric composition through modeling and analysis. Finally, if core funds for GTP are enhanced, a special allocation of these new funds will be devoted to specific projects presented by junior scientists.

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



coming from the laboratories.

Concentration and flux profiles in the convective boundary layer (CBL) of methyl vinyl ketone (MVK, a product of OH reaction with isoprene) and isoprene as a function of Damköhler number Da, which measures the ratio of the mixing to the chemical reaction time scale (D. Lenshow and D. Gurarie). Increasing Da means decreasing diffusion through the CBL. Isoprene is emitted by vegetation and has a short (1 hour) lifetime affecting the dynamics of the CBL.

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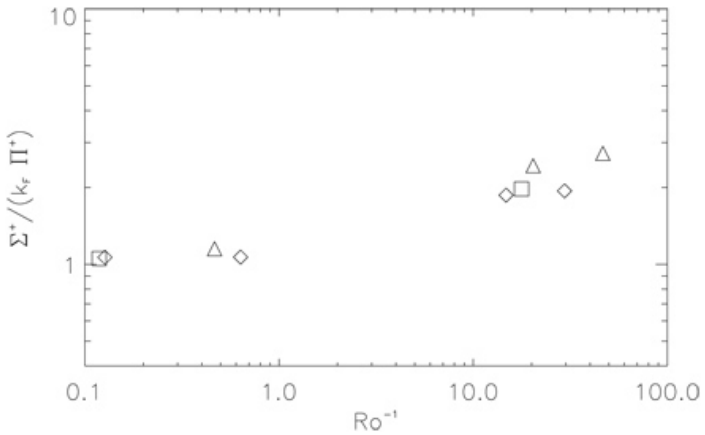
Turbulence science, numerical algorithms, and code development

The Turbulence Numerics Team (TNT) complements the Geophysical Turbulence Program (**GTP**) and is focused on the accurate simulation and understanding of turbulence for fluids such as those encountered in the atmosphere and the oceans, and for charged flows in the presence of magnetic fields as in space weather and in the solar atmosphere and corona. TNT research emphasizes simplified physical systems that still reproduce the complexity and multiscale properties associated with turbulent flows. Supplemental information appears in the links in the text to this annual report's Profiles In Science section.



This figure displays the normalized ratio of helicity to energy fluxes in the direct energy cascade to small scales as a function of the inverse Rossby number, a dimensionless parameter measuring the strength of the imposed solid body rotation. The data comes from direct numerical simulations with resolutions up to $1{,}536^3$ grid points, or in excess of 3.6 billion points. It shows that, as rotation is increased, the small-scale cascade becomes dominated by the helicity. This leads to a better understanding of such flows as encountered in the Earth's atmosphere.

This work supports CISL's strategic frontier to develop models of subgrid-scale behavior to advance model development and CISL's strategic imperatives to prepare for petascale and exascale computing, and the focus on extracting information from large and heterogeneous data sets. It also has an educational component through involving a graduate student and post-doctoral fellows in several facets of this research.

Research on turbulent flows

We have pursued investigations of homogeneous, isotropic, and non-isotropic turbulence and turbulent structures at high Reynolds numbers in a variety of fundamental contexts and physical conditions (with or without magnetic fields, with or without rotation, with or without subgrid-scale modeling). Through the course of these investigations and analyses, we have been able to make several statements about the fundamental nature of turbulence.

We emphasize the following accomplishments of the Turbulence Numerics Team (TNT), obtained in collaboration with members of the university community:

- The behavior of a fluid undergoing **solid body rotation** is very different when one includes helicity (correlation between the velocity and its curl, the vorticity), see Figure above. A parametric study of such flows in a wide range of Reynolds and Rossby numbers allowed us to show that the behavior can change when these parameters change, leading to the conclusion that, as found in MHD last year, non-universal behavior may occur for example when waves and eddies interact. A systematic study of the regimes that appear in turbulent rotating flows was undertaken, following a phenomenological approach based on two-point statistical closures. These studies led to the publication of several papers in 2010, and to the writing of a proposal to NSF, in collaboration with Leslie Smith (PI, U. Wisconsin) and Susan Kurien (Co-Pi, Los Alamos National Laboratory).
- A study of statistical equilibria of rotating flows examined whether such ideal dynamics is a good predictor of turbulent behavior, as has been found for fluid turbulence without rotation. Results are discussed in the context of partial two-dimensionalization of the flow undergoing strong rotation.
- In **magnetohydrodynamics** (MHD), a series of data sets were examined from the point of view of automated detection of structures at a fixed time, with different Reynolds numbers, different velocity-magnetic field correlations, and different forcing mechanisms. Scaling laws could be identified, and a connection to self-organized criticality (SOC) – as in avalanche dynamics – was made. A European proposal was written, and it will

be followed by an NSF proposal to be written in the fall with two U.S. laboratories (Bartol, Berkeley).

- In view of the very large Reynolds numbers of astrophysical and geophysical flows, it is necessary to use modeling in conjunction with direct numerical simulations. Several types of modeling have been tested, leading for example to a parametric study of rotating flows (see above). Moreover, a more detailed study of the Lagrangian model which acts as a regularization of the primitive equations, both for fluids and MHD, has led to a better specification of its subfilter-scale properties leading to a kind of bottleneck linked to an accumulation of energy in the small scales.
- In collaboration with an experimental team at the University of Buenos Aires, we also studied the conformal invariance properties of two-dimensional (2D) flows; this study is to be extended to the quasi-2D case in the presence of rotation using numerical data obtained through a special allocation at NCAR. This study was made possible by obtaining a grant from Ecole Normale Supérieure (Lyon) for a one-year pre-graduate study performed by Simon Thalabard, now going to CEA-Saclay to work with Bérengère Dubrulle.

Several papers have appeared in FY2010, are submitted or are in preparation, and most of these projects will continue in FY2011. The team also participated in the elaboration of two white papers in MHD and plasma physics ("Astrophysical dynamos'' and "Waves and Turbulence in Space and Astrophysical Plasmas,'' in the context of a Workshop on Plasma Astrophysics).

Algorithms, numerics, and code development

TNT develops both tools and models that enhance our ability to investigate geophysical turbulence, and it applies these capabilities to fundamental scientific objectives. TNT members have broad experience in developing a variety of algorithms, numerical schemes, and large development efforts for studying turbulence. This experience has been recognized this year by two awards, one internal to CISL attributed to Pablo Mininni and Duane Rosenberg, and one from Teragrid 2010 for the best paper (technology track), specifically for the development of a hybrid (MPI/OpenMP) method for pseudo-spectral codes (see the report on GHOST, the **Geophysical High Order Suite for Turbulence**).

The algorithms, numerics, and code development undertaken by TNT all advance the CISL strategic imperatives to produce scientific excellence and to develop mathematical research codes that improve modeling. For this second imperative, CISL must maintain a portfolio of research models to drive forward basic scientific research in computational fluids and in basic algorithmic research. TNT carries out three action items under this imperative:

- Further develop the Geophysical and Astrophysical Spectral element Adaptive Refinement (**GASpAR**) platform, a research framework for solving partial differential equations (PDEs) using 2D and 3D scalable adaptive spectral element methods.
- Enhance the Geophysical High Order Suite for Turbulence (GHOST) code, a proven and highly scalable suite for computing direct numerical simulations and modeling turbulence by solving the 2D and 3D Navier-Stokes and MHD equations (with or without Hall terms) using the pseudo-spectral method.
- Linked to this second goal is the development of a similar code written by Marc-Etienne Brachet (ENS-Paris) for fluids and MHD and implementing symmetries that lead to gaining a factor 16 in computing time/memory usage over a non-symmetrical code at the same resolution (and thus Reynolds number).

Several of the results delineated above lead to new questions worth pursuing. Our investigations of rotating turbulent flows will be continued. Our main activity will be running and analyzing a large computation, on a grid of 3,0723 points, of a flow for which the Ozmidov scale will be resolved. (At the Ozmidov scale, the eddy turnover time and the inertial wave time equilibrate, giving a priori access to the three-dimensionality of the flow at small scales.) This run, using in excess of 15 million hours allocated recently by NSF/TeraGrid (on Kraken, the Cray XT5 system at NICS), will take a large portion of the time for the team and will span two fiscal years just to run, let alone analyze. It is also hoped that the SOC study of MHD flows will be extended by adding the temporal dimension as one should. Similarly, ideal dynamics of flows as a precursor to fully turbulent behavior is currently being studied in 2D MHD, as well as for a variety of other turbulent flows. In 3D MHD, it will be pursued if sufficient computer time is allocated (an INCITE proposal has been written to this effect); this would allow us to examine the ideal behavior of such flows and the possible occurrence of singularities in MHD – a completely open problem – together with the link to dissipative processes and the occurrence of strong intermittent events through reconnection of current sheets as observed in space weather and in the Sun, as well as in the laboratory plasmas, e.g., at Princeton and UCLA.

TNT research and service activities are supported by NSF Core funding. Furthermore, a grant from Ecole Normale Supérieure (Lyon) for a one-year pre-graduate study performed by Simon Thalabard was received, as well as a two-year allocation of 15,482,400 CPU hours (out of the 21-million-hour request) on TeraGrid (NICS Kraken XT5) to study rotating turbulence.

A proposal has been submitted to NSF to study rotating stratified turbulence with Leslie Smith (U. Wisconsin, PI) and Susan Kurien (LANL). Finally, a U.S.-Europe collaborative proposal has been submitted to further study the large-scale (MHD) properties of the solar environment, with Bartol (U. Delaware) and Berkeley in the U.S., and U. Calabria (principal coordinator), Imperial College and Warwick in Europe: an NSF proposal is in preparation to bring funds to support such a collaborative endeavor. TNT is the coordinator for the large numerical simulations of MHD turbulence that will be undertaken, looking at properties of ideal flows, at reconnection processes, and at statistics of coherent structures and how they affect intermittency. In so doing, it would use a variety of tools taking into account the input of data from a variety of remote sensing experiments, as well as preparing for NASA's launch of MMS (Magnetospheric

Multi-Scale) instruments.

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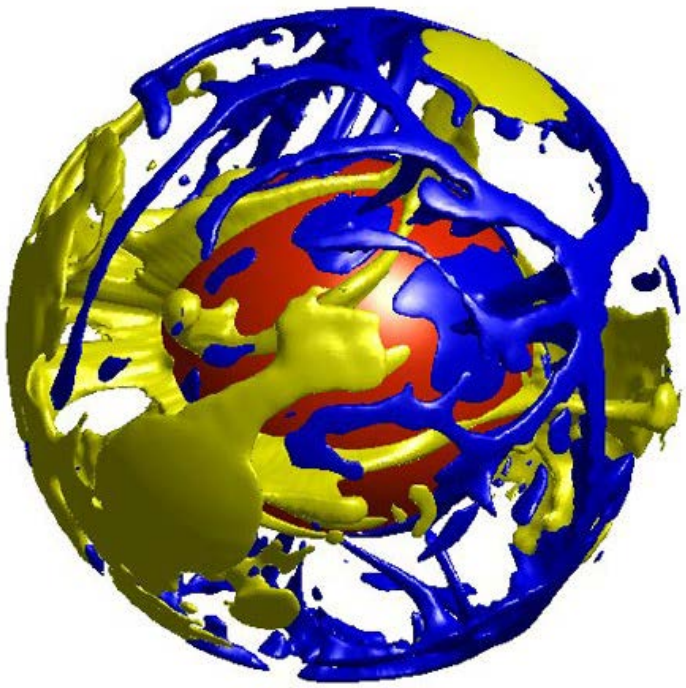
Radial basis functions for modeling

While computer technology has advanced dramatically in recent years, numerical schemes currently used for climate and solar modeling fall short of scientists' expectations. Spherical harmonics require large grids to resolve small features, and this is computationally impractical. Spectral element methods can resolve small features, but they require higher resolution near artificial boundaries to achieve high accuracy. Both methods involve high algorithmic complexity and are impossible or awkward to apply to irregular geometries. As a result, geoscientists and computational mathematicians are searching for new options. Radial basis functions (RBFs) offer the geosciences a novel numerical approach for solving time-dependent partial differential equations (PDEs).

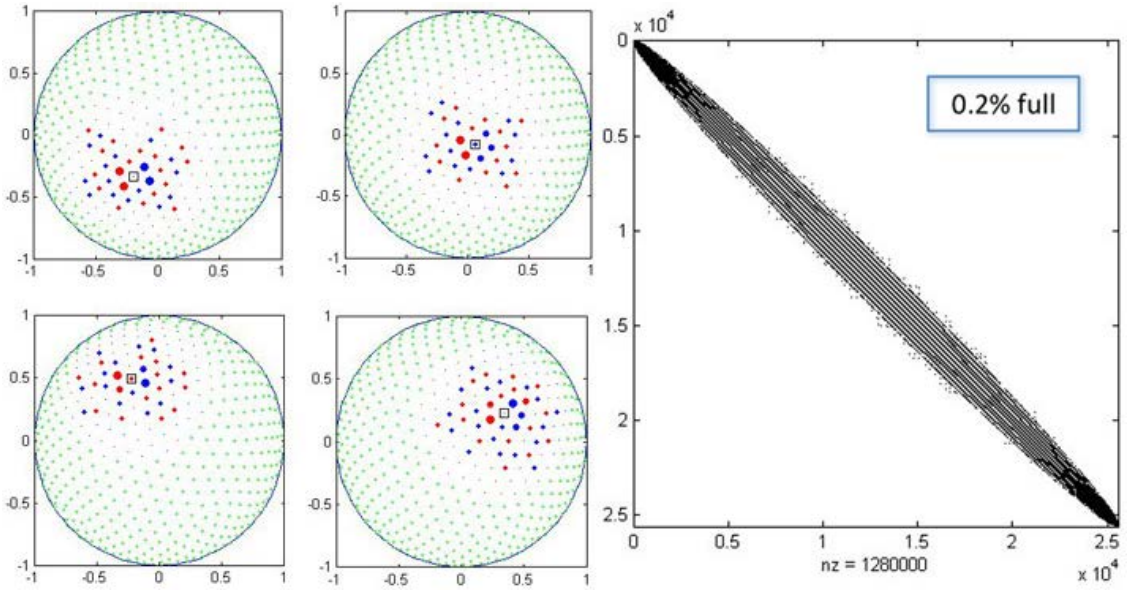


Snapshot from a simulation of thermal convection at Ra=1,000,000 using a radial basis function—pseudospectral method for thermal convection in a 3-D spherical shell. The image displays the isosurfaces of the residual temperature with yellow corresponding to upwelling and blue corresponding to downwelling. The red solid sphere shows the inner boundary of the 3D shell.

Building on the accomplishments of FY2009, the IMAGe Computational Mathematics Group together with Boise State University, the University of Colorado, University of Minnesota, and Uppsala University in Sweden continue research in the developing area of RBFs for climate and solar modeling.

The hybrid **RBF-Chebyshev method** developed in FY2009 for simulating 3D thermal convection in a spherical shell advanced the accuracy of geophysical modeling at high Rayleigh numbers (Ra) in FY2010. This year saw the first-ever purely spectral simulation at Ra=1,000,000, giving new insights into the convective behavior of an isoviscous fluid in this regime. The simulation (represented by the figure above) was recognized by the geophysics community and featured on the cover page of the American Geophysics Union journal *Geochemistry, Geophysics, Geosystems*.

In FY2011 the RBF methodology will be improved to become more computationally cost-effective in terms of scalability, memory, and runtime. A promising horizon is to develop RBF-generated finite difference stencils (RBF-FD) for approximating the derivatives in PDEs. The local character of this novel concept will allow for much sparser matrices (requiring less memory and computation) while still giving high-order accuracy and geometric flexibility. These concepts are illustrated in the figure below.



Four stencils (left) to calculate derivative approximations at the square marker using the 75 nearest nodes. (Global RBF methods would use all the nodes on the sphere, resulting in a full matrix.) RBF-FD matrix (right) to approximate the derivative at every node on a sphere having 25,000 nodes. Note that the matrix is only 0.2% full.

Preliminary results on linear convective flow are encouraging, decreasing the computational cost of the RBF strategy while maintaining high accuracy. In FY2011, exploration of the strategy for a variety of test beds in the geosciences will be conducted.

This work advances CISL's strategic imperative to produce scientific excellence. It may soon support CISL's science imperative to develop mathematical research codes to improve models. This development effort at NCAR is supported by NSF grants ATM-0620100 and DMS-0934317.

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Multiscale simulation techniques

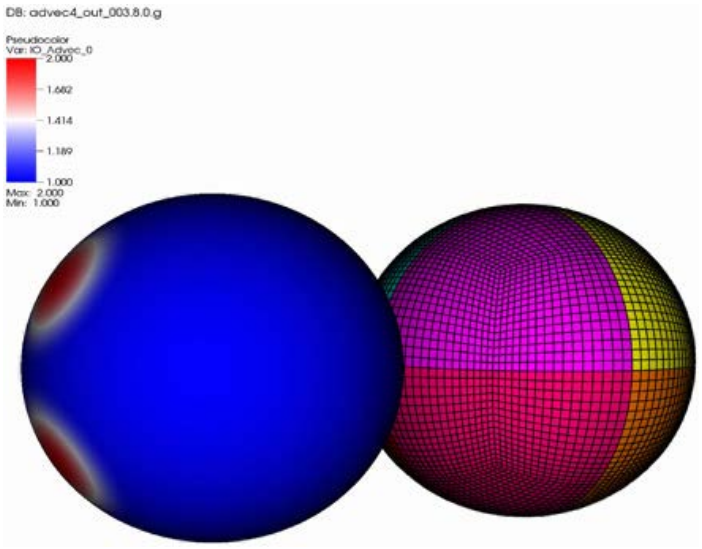
To continue its scientific leadership, NCAR needs a unified simulation environment that can dynamically resolve time and space scales on petascale computers. A framework that encompasses such an environment relieves scientists from becoming fluent in advanced scalable numerical methods and enables them to focus on their research issues.

Spatial and temporal scales projects

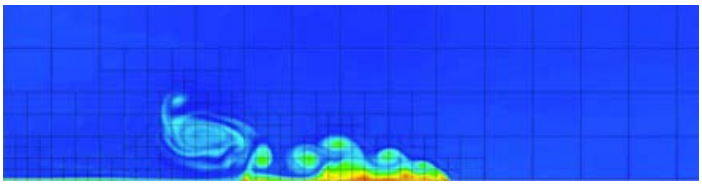
Co-sponsored by an NSF PetaApps award, the Multiscale Unified Simulation Environment (MUSE) is a project that could be used to build such models and enable predictions across scales. Due to the growth of this year's team, developments in MUSE made significant progress.

First, the model was extended to support spherical shells. Contrary to other "shell" models, this is not a pure 2D curvilinear implementation. For scalar advection tests, the velocity at the surface of the sphere is in fact three dimensional, but only "shell" elements are employed. The transformation employed within the model relies only on a numerical differentiation procedure, so arbitrary terrains and elevation are *de facto* supported.

One of the problems faced by high-order methods is their inability to produce stable solutions in highly under-resolved situations. This year, we addressed this problem using two techniques. The first one consisted of changing the Lobatto-Legendre-Gauss (LGL) points to Gauss-Legendre points. This produced much more stable simulations. The second approach introduced a sophisticated filter that is controlled by a "resolution indicator." The indicator dictates where the solution needs filtering (a.k.a. diffusion). The diffusion is injected into the model using a fast filter instead of using the discontinuous Galerkin discretization of a Laplacian. The results are promising and were tested on the



This simulation depicts the passive advection of a tracer onto the sphere. The tracer (left panel) consists of two cosine bells with maximums set to 2 and their minimal value fixed at 1. The high-order elements (right panel) represented by the quadrangles are dynamically load-balanced at each refinement step, and the various colors represent a processor number. (Click the image to view a brief 1.6 MB animation from this simulation.)

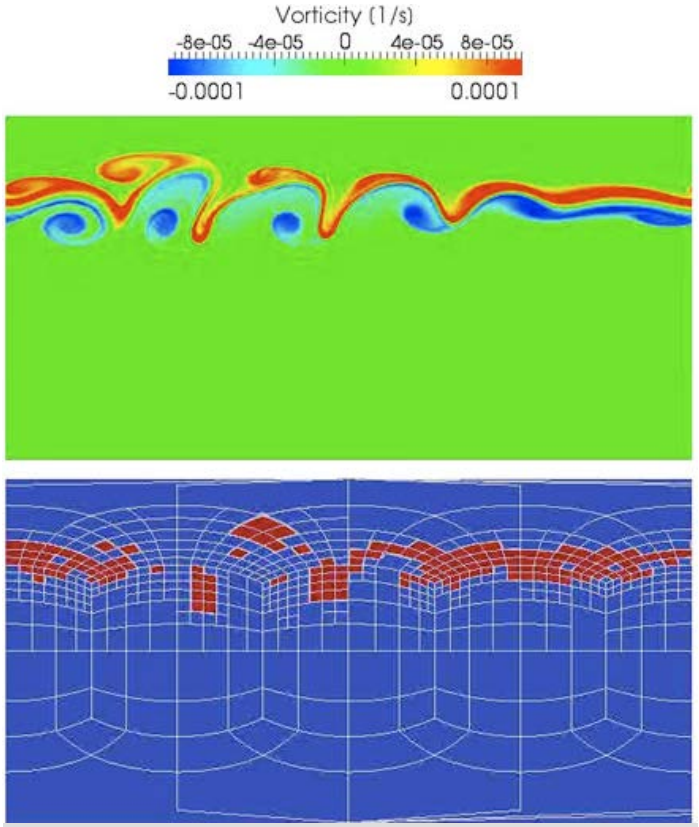


This simulation uses the non-hydrostatic equations of the atmosphere, which are valid for all scales relevant to weather prediction and climate simulation. The density perturbation is plotted with respect to a hydrostatically balanced atmosphere at rest. The perturbation consists of a cold air bubble that falls to the ground. The filtering approach described in the text was required to perform this simulation. (Click the image to view a 2.1 MB animation.)

sphere for advection fidelity and for the non-hydrostatic equations in 2D for an idealized setting.

MUSE is now able to support the shallow water equations on the sphere. This is a fundamental step for the model since those equations generate most of the waves that are relevant for climate modeling. The spherical shell implementation in MUSE does not support pure 2D curvilinear transforms. Therefore the shallow water equations are using a 3D momentum constrained onto the sphere using a Lagrange multiplier approach. All of the standard classical test cases were tested in both adaptive and non-adaptive configurations.

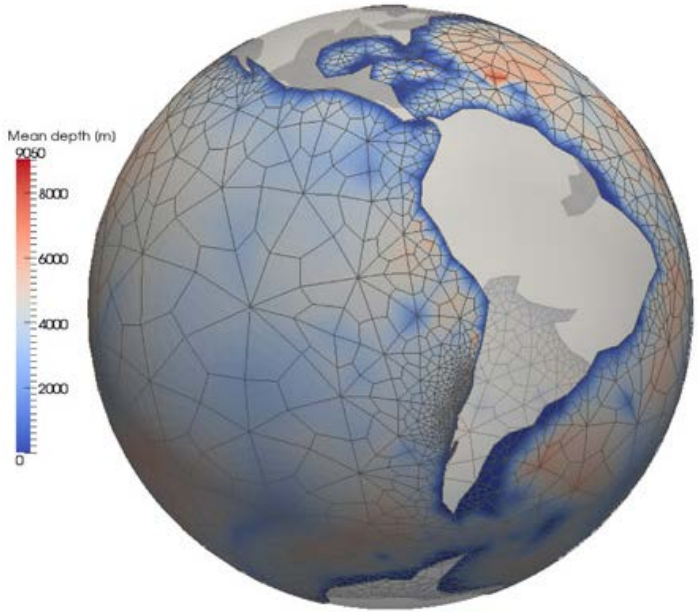
Finally, MUSE was employed to create a complete tsunami simulation application. This is the first realistic application of the model. Such a prediction system, when coupled with an inundation parameterization, could be employed to provide early warning of disastrous events linked to tsunami waves generated by seismic phenomena. The application also demonstrates what is possible with unstructured meshes that the MUSE model is currently able to handle, as well as the quality of the numerical prediction provided by the high-order DG techniques. In the following figures, the model was used to compute the propagation of the 2010 Chilean tsunami through the global ocean.



The shallow water equations are used to simulate a barotropic instability problem. In the top panel, a jet is introduced in the northern atmosphere with a small perturbation: initially stable, the perturbation breaks the jet into waves. The bottom panel shows the dynamically adapted cubed sphere mesh that tracks the waves. The blue region represents elements with lower accuracy (fourth order) while the red region represents high-accuracy (sixth order) elements. (Click the image to view a 2.9 MB animation.)

Scalable elliptic solver for spectral elements

This year, the multigrid code developed at Argonne National Laboratories was embedded into GASpAR to solve the coarse grid problem associated with the two-level optimized Schwarz preconditioning strategy. The optimized Schwarz strategy is 20-25% faster than the classical Schwarz approach. This enables the spectral element code GASpAR to run more than 10 times faster than before, and now it can handle previously inaccessible problems. However, issues within the code arose. For instance, some of the parallel exchanges need to be revisited to enable scaling past 32 processors and a large



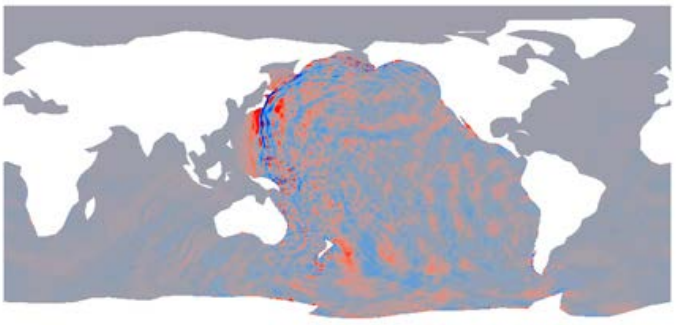
Mesh of the Earth with continents before the initial refinement and mean water depth for the tsunami simulation. Water depth can vary from 5 meters to 9,000 meters in a single grid element because of the ocean floor's topography.

number of unknowns. The goal for FY2011 is to extend the preconditioning approach to AMR and 3D spectral elements. For more information on this work, see the **GASpAR report**.

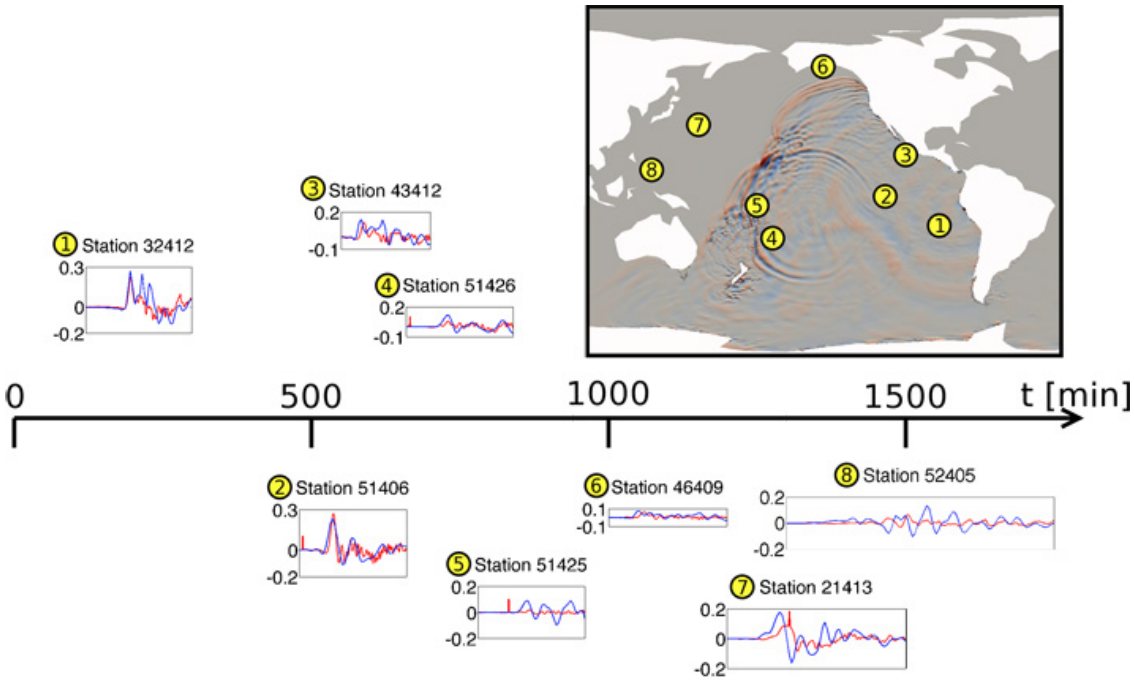
Support

This work supports CISL's strategic plan in various ways. It advances CISL's strategic imperative to produce scientific excellence, and it develops numerical algorithms for petascale and exascale computing. It also supports CISL's science frontier for algorithmic acceleration, and it fulfills a strategic action item to accelerate applications algorithmically by applying adaptive mesh refinement techniques, new time-stepping techniques, and efficient use of processor technology.

These projects are made possible through NSF Core funding and NSF PetaApps award number 0904599.



In this 24-hour simulation of the 2010 Chilean tsunami, the initial condition is computed by assuming that the initial sea surface displacement is equal to the static sea floor uplift caused by an abrupt slip at the interface between the Nazca and South American plates. As the tsunami propagates through the Pacific Ocean, the order of interpolation and the mesh are adapted to track the wave. The resolution remains high in the shallow areas along the earthquake initial uplift, where the propagation of the wave is slow due to the very low depth. The size of the elements varies from 250 km to 0.25 km. This simulation was performed on 256 processors of Lynx, NCAR's Cray XT5m system. The acceleration with respect to reality varies between 20 and 40 depending on how the error indicator step is performed, hence the 24-hour simulation is performed in a little more than 30 minutes. (Click image to view the 7.5 MB animation.)



The elevation of the free-surface has been compared with the DART data from the NOAA Center for Tsunami Research at eight different stations. This shows that the model accurately estimates the time at which the tsunami reaches the different stations. The amplitude of the waves is also well predicted, except at stations 5 and 8. Because those stations are located in very shallow areas with an irregular bathymetry and several small islands, the resolution of the model is probably not sufficient to accurately reproduce the heights of the waves.

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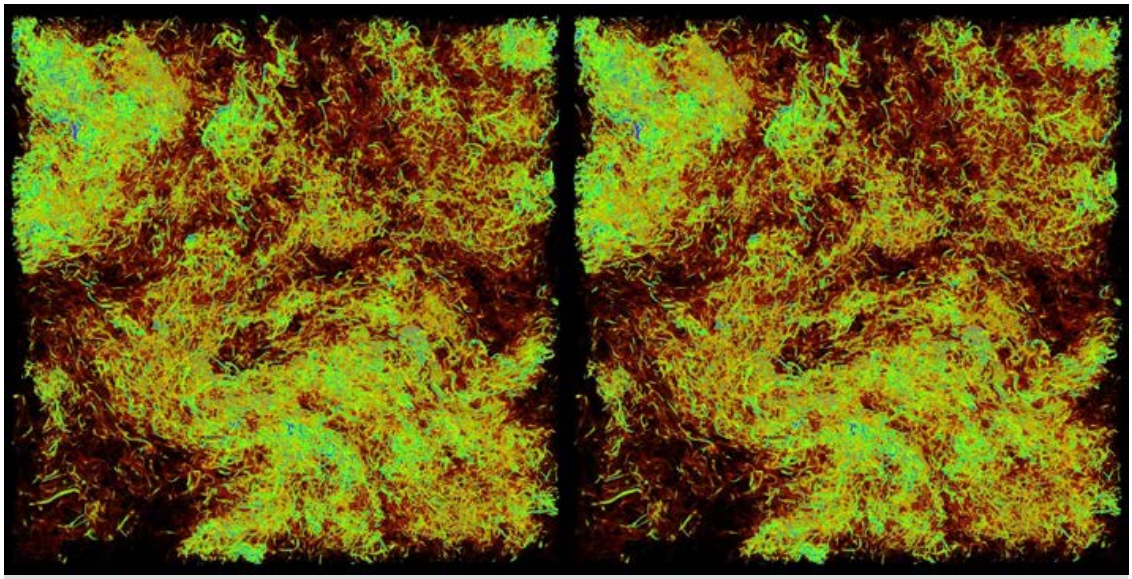
Scientific data compression research

The Scientific Data Compression Research project began in FY2006 and is built on the success of CISL's VAPOR work. **VAPOR** employs a simple wavelet-based, multiresolution progressive data access scheme to facilitate interactive analysis of terascale data sets. This project investigates the application of wavelet-based lossy data compression and more advanced progressive refinement techniques applied across a broad domain of computational science. The methods employed in our data compression research are similar to those now widely used in the compression of digital media. The goals of 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.



This image shows a side-by-side comparison of an enstrophy field volume rendering from a $4{,}096^3$ turbulence simulation: the original is at left, and the image at right shows the fidelity possible at 800:1 data compression. This figure qualitatively demonstrates the effectiveness of wavelet-based data compression and progressive 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. Lossy signal compression and progressive data access techniques, such as those ubiquitously used for digital media and now being investigated by CISL, may provide relief for researchers drowning in a deluge of data. Moreover, this research is well aligned with CISL's strategic plans aimed at preparing for petascale computing.

In FY2010 many of the outstanding research challenges to producing a usable scientific data compression and progressive data access tool were resolved. A collection of wavelet families were investigated for their suitability to the task, and a single wavelet family (Daubechies biorthogonal wavelets) was chosen for their ability to handle bounded domains. Then an efficient encoding scheme was devised for recording wavelet coefficient coordinates. Finally, research tools were hardened into a production toolkit for data compression and progressive access, and the toolkit was incorporated into the VAPOR package as the basis of a new data model. To improve computational performance of the

wavelet convolution kernel, a GPU implementation was developed (by a **SIParCS** intern) that exhibited speedups on the order of 20x.

In FY2011 our direction will shift toward applications to scientific data. We have already begun working with collaborators at TACC and LBL to investigate statistically how well compressed data preserves large vortical structures in a $4{,}096^3$ simulation of homogenous turbulence. Similar comparisons are planned for high-resolution ocean simulation data.

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

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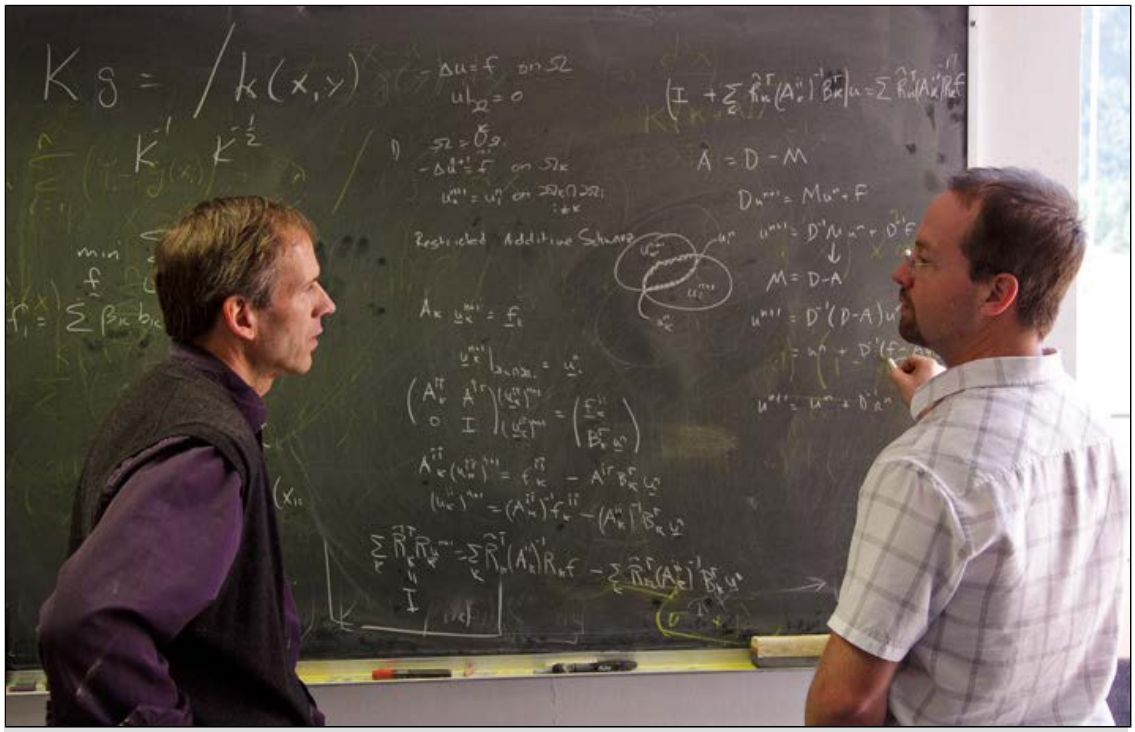
Science Imperative: Develop Mathematical Research Codes to Improve Models

CISL has a science imperative to develop research codes that reinforce and enhance geophysical modeling and community model development for NCAR and the larger Earth System science community. CISL's efforts provide flexible model test beds for research on new numerical and computational methods. These models must be scientifically credible but also support experimentation, algorithmic research, and rapid prototyping rather than satisfying the constraints of a large modeling community. The goal is to merge the most promising algorithms and computational strategies back into NCAR's production modeling efforts. The dynamical core implemented in the High Order Method Modeling Environment (HOMME) is an example of a successful code that was incubated in CISL and recently merged into the the NCAR Community Atmosphere Model (CAM). Note that the Multiscale Unified Simulation Environment (MUSE – an innovative next-generation modeling framework) represents a similar type of effort in an early stage of development.



Amik St Cyr (right) explains to a colleague the algorithm that he and Duane Rosenberg used to speed up the solution of fluid dynamics equations in the GASpAR code. The design and engineering of GASpAR is led by Duane Rosenberg and has benefited from St Cyr's expertise in producing this Optimized Restricted Additive Schwarz technique. By reducing solver iteration counts, the new preconditioning algorithm has improved GASpAR's time to solution by a factor of 10 or more. It therefore allows GASpAR to tackle significantly larger turbulence simulations. The success of this project to improve the preconditioning step emphasizes the need for team efforts in developing new research codes, and it also demonstrates a now-common blurring of research boundaries between innovative numerical analysis, computational science, and software design.

In FY2010, the Turbulence Numerics Team made improvements to two community distributed codes: GASpAR and GHOST. The improved preconditioners for GASpAR bring it closer to running research-level experiments. It is one of the few adpative, high-order codes that use an object-oriented code, so it is a unique contribution. GHOST is a cutting-edge spectral code and was recently configured to run for a large number of cores (> 30K) and to take advantage of the large computational resources that are becoming the norm in turbulence research. Also in FY2010, HOMME has emerged as a mature code that is now released as an alternative dynamical core for CAM. New developments for HOMME include the incorporation of a discontinuous Galerkin (DG) method that provides explicit conservation of momentum, energy, and passive tracers.

In FY2011, developments for GASpAR will advance its capability for 3D simulations, and the scaling for GHOST will be further improved. In addition, a new code that exploits symmetries to gain higher resolution, TYGR, will be improved with a view toward scalability. HOMME development will continue, and its performance improvements will be analyzed and compared with other dynamical cores for CAM.

CISL's science imperative to develop mathematical research codes to improve models is primarily supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

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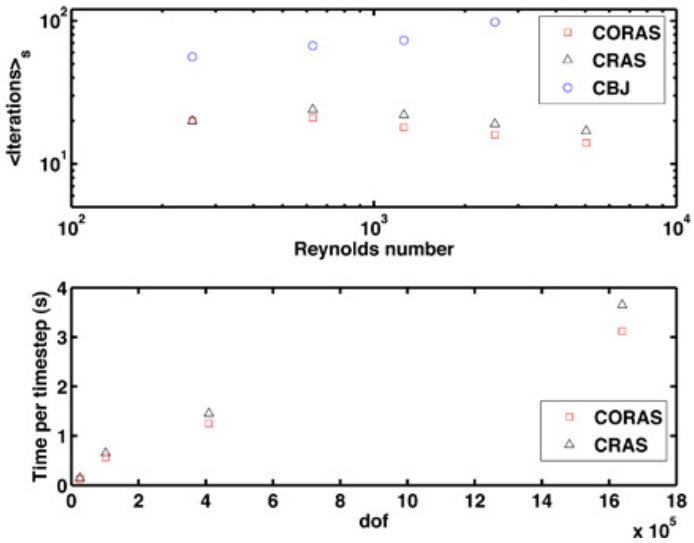
Geophysical and Astrophysical Spectral element Adaptive Refinement code

Turbulence is a stochastic manifestation of the dynamic interaction of fluid structures and fields at all scales, and it is studied scientifically through observations, laboratory experiments, and numerical experiments. In "direct numerical simulation," a numerical treatment of turbulence requires that the partial differential equations (PDEs) governing fluid dynamics be solved accurately and in a way that resolves all relevant spatial and temporal scales. The challenge is to resolve the spatial scales as the degree of turbulence increases, characterized typically by the (dimensionless) Reynolds number: as the Reynolds number increases, so too does the number of degrees of freedom (dof) required to solve the equations. Explicit or semi-implicit time stepping adequately captures time scales, but there are several techniques can be used for retaining accuracy and capturing spatial scales (fluid structures) with good fidelity. First is that the numerical discretization can be high-order. This is often necessary to simulate fluid properties correctly. Coupled with high-order, one can either add a sufficient number of grid points to the entire flow, or, in flows with a finite number of discrete structures or regions of interaction, adaptive grid mechanics can be used to dynamically place grid points where they are required to resolve structures as the flow develops. This process of adding or moving computational degrees of freedom to resolve fluid structures or interactions is called adaptive mesh refinement (AMR).



The upper plot shows a time average of the Krylov iteration counts for three preconditioners: the two-level ORAS (squares), RAS (triangles), and block Jacobi (circles), averaged over the entire run of an Orszag-Tang (OT) vortex problem. The lower plot shows the computational time for a single time step, averaged over the entire OT run when the new preconditioners are used. This figure shows that the new preconditioners tend to plateau in iteration count as the Reynolds number (and thus the complexity of the flow) increases. This contrasts with the block-Jacobi preconditioner, which has a nearly power law dependence on Reynolds number, rendering it a poor choice for turbulent flows. More importantly, the lower plot shows that ORAS outperforms RAS by increasing amounts as measured by compute time, as the Reynolds number (and the degrees of freedom required) increases. This suggests that ORAS will be well suited as a preconditioner for simulations of turbulent flows.

The Turbulence Numerics Team (TNT) continues its long-term program to develop high-order adaptive methods for use in problems relevant to the turbulence community. This work is carried out using the Geophysical and Astrophysical Spectral element Adaptive Refinement (**GASpAR**) code, which is a framework for solving PDEs using a spectral element method (SEM) designed for use with AMR.

This work supports CISL's science imperative to develop mathematical research codes that improve modeling by maintaining a portfolio of research models to drive forward basic scientific research in computational fluids and in basic algorithmic research.

In FY2010, we met most of our FY2009 goals for GASpAR development. The two-level preconditioner that was added in FY2009 for the pseudo-Laplacian operator, and that arises naturally in spectral-element method (SEM) discretizations, was modified in several important ways:

- It was made computation-ready by developing an interface for the XXT (low-order) coarse-grid finite element (FEM)-based Laplacian operator developed at Argonne National Laboratory by P. Fischer and J. Lottes. This step provides the coarse-grid solutions for two-dimensional (2D) and 3D problems.
- Several different types of coarse-grid discretization were developed and tested, as were operators for handling

projections of the fine-grid residuals to the coarse grid and back again.

- The fine-grid (optimized) restricted additive Schwarz – (O)RAS – preconditioners were modified to act on both the staggered pressure grid (p-grid) and on the non-staggered velocity grid (v-grid). This was done because it was found that at low-order, the p-grid blocks are most efficient, whereas at high-order, the v-grid blocks work best. Optimization in the sense of a plateauing of Krylov iteration counts behaves in a nearly textbook manner, which is a new result for the staggered mesh discretization.
- The two-level preconditioner was encapsulated into an object that accepts arbitrary fine-grid preconditioners to make it easy to integrate into any SEM PDE solver. This object allows the two-level preconditioner to be applied in two ways: additively, and in a hybrid (additive/multiplicative) fashion.
- Finally, that object was added to the explicit magnetohydrodynamics (MHD) solver and applied to a demanding 2D MHD turbulence problem. It was found through rigorous testing that the (O)RAS significantly outperforms the RAS preconditioner in terms of both iteration counts, and, importantly, computation time. It also does better as the Reynolds number is increased, suggesting that the (O)RAS preconditioner is well-suited for (incompressible) turbulence problems using high-order SEM. This development will enable us to solve flows such as those encountered in the heating of the corona that exhibit reconnection processes taking place at small scales.

This work on the two-level preconditioner was carried out in collaboration with IMAGe's **Computational Mathematics Group**.

We anticipate a number of developments for FY2011, barring any reallocation of resources to other TNT projects or other unforeseen efforts. The computational interfaces were enhanced in FY2010 for the coarse-grid and fine-grid preconditioners, but the communication interface for the corner-transfer of data required by the (O)RAS preconditioners has been adapted neither to 3D nor to nonconforming elements. These adaptations are therefore the main goal for FY2011. In addition, the existing operator for maintaining continuity between elements is outdated and must be replaced. We will fold this operation into the same class as that used to conduct corner-transfer, thereby saving memory, making the integration into the connectivity object simpler, and eliminating the need to generate unique indices for the element interface nodes.

GASpAR research and application projects are supported by NSF Core funding.

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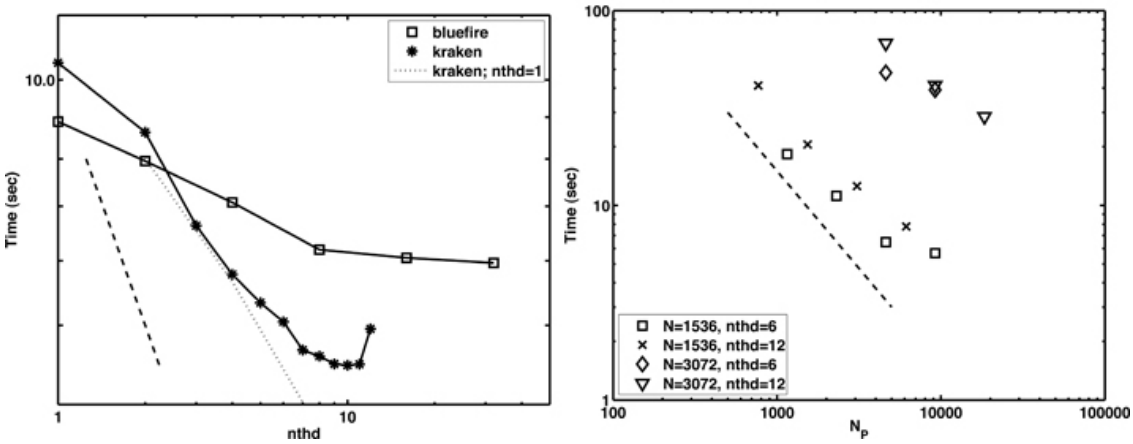
Geophysical High Order Suite for Turbulence

The Geophysical High Order Suite for Turbulence (**GHOST**) code is a highly scalable and accurate code developed to numerically integrate the hydrodynamic, magnetohydrodynamic (MHD), and Hall-MHD equations in two and three dimensions using periodic boundary conditions. It can also incorporate solid body rotation, and it includes two types of modeling of small-scale flows: one behaving as a regularization of the primitive equations (the so-called Lagrangian model), and one working with eddy viscosity and eddy noise, including the effect of helicity (velocity-vorticity correlations) on such transport coefficients (the Eddy-Damped Quasi-Normal Markovian approximation – EDQNM – model). GHOST is parallelized using MPI, and its hybridization using MPI and OpenMP is now complete. This allows the code to efficiently use up to 32,768 processors on Ranger. This latter work was recognized by two awards this year, one was an internal CISL award to Pablo Mininni and Duane Rosenberg, and one was for the best paper (technology track) at the TeraGrid 2010 conference.

This work supports CISL's strategic goals to prepare for petascale and exascale computing, to accelerate computational algorithms, to extract information from large and heterogeneous data sets, and to advance modeling by developing accurate models of subgrid-scale behavior. It also has an educational and outreach component since, as a state-of-the-art code written for the community, it can be used by students, engineers, and scientists.

GHOST

As stated last year, we adopted a "virtual" pencil domain decomposition scheme to efficiently utilize large numbers of cores within compute nodes. In this scheme, we use a hybrid MPI-OpenMP model that discretizes in slabs among MPI nodes and in "bricks" within the slab among OpenMP threads within a compute node. We have now tested this code on a substantially larger number of processors than last year, up to 32,768 cores on Ranger (Sun Constellation Linux Cluster) at TACC and up to 24,000 processors on the Kraken (Cray XT5) TeraGrid system at NICS. It has also been tested on 4,096 cores on IDRIS Babel (France) and on 2,048 processors using NCAR's Bluefire (IBM Power 575). We have determined that the code scales well on all of these platforms as shown in the figure below that gives the timing of GHOST with varying thread numbers, and the scalability (in log-log coordinates) of the code for hydrodynamic runs with up to $3{,}072^3$ grid points.



The timing plot at left shows GHOST performance on a single MPI task with multiple threads on two platforms. On Kraken, runs scale well up to 7-8 threads, even with only six cores per socket. The dotted line shows the timings for a single thread while varying the number of MPI processes, and the dashed line is for ideal scaling. The plot at right shows scalability for two sets of runs on Kraken with squares and crosses representing timings for N=1,536 points in each direction, using 6 and 12 threads respectively. Triangles and diamonds are for another three-dimensional hydrodynamical run, but now with N=3,072. Note the crossover in performance at about NP=10,000 where the nthd=12 configuration outperforms nthd=6 for both. (NP is the number of processors and nthd is the number of threads.) These results demonstrate that pseudo-spectral codes such as GHOST using FFT algorithms that are prevalent in numerous numerical applications can scale linearly to a large number of processors.

TYGRS

The knowledge developed for GHOST was then applied to a second pseudo-spectral code written by Marc Brachet (ENS, Paris) to study highly symmetrical flows – specifically the Taylor-Green flow between two counter-rotating cylinders – as encountered in several laboratory experiments in the U.S. (Maryland) and in Europe. Such flows are studied both for fluids and for MHD. The code (TaYlor-GReen Symmetrical, or TYGRS) had already been parallelized by Pablo Mininni using MPI following the methodology developed for GHOST. The code necessitated some rewriting for it to perform adequately, e.g., in the implementation of the Fast Fourier Transforms (FFTs). TYGRS has not yet been tested to a high number of processors, but up to now its performance appears similar to that of GHOST, although it is slower at a given grid resolution because of the extra computations needed to implement the symmetries of the Taylor-Green flow.

The work on GHOST and TYGRS supports CISL's science imperative to develop mathematical research codes that improve modeling by maintaining a portfolio of research models to drive forward basic scientific research in computational fluids and in basic algorithmic research.

Plans

In FY2011, we will continue our optimization of GHOST and TYGRS on systems with higher processor counts, as allocations for computing time on such machines are made available to us. We plan to achieve scalability using the hybrid code up to about 50,000 processors. With this, we will be able to apply the code to a number of problems of interest (please see the **FY2009 TNT annual report**). It is already in use for a production run on a grid of $3{,}072^3$ points, the highest to our knowledge today for studying rotating turbulence using a TeraGrid allocation. Note that the vast amount of data produced by such runs will require special tools to be developed when we move to the analysis phase of the research. As for our previous large computations, three-dimensional visualization using **VAPOR** will be an essential part of the analysis work, and VAPOR capacity will likely be extended to cope with such runs.

Support

The research and service activities of TNT are supported by NSF Core funding. We also received an allocation of 15,482,400 CPU hours on NSF's TeraGrid (spanning two years) to study rotating turbulence.

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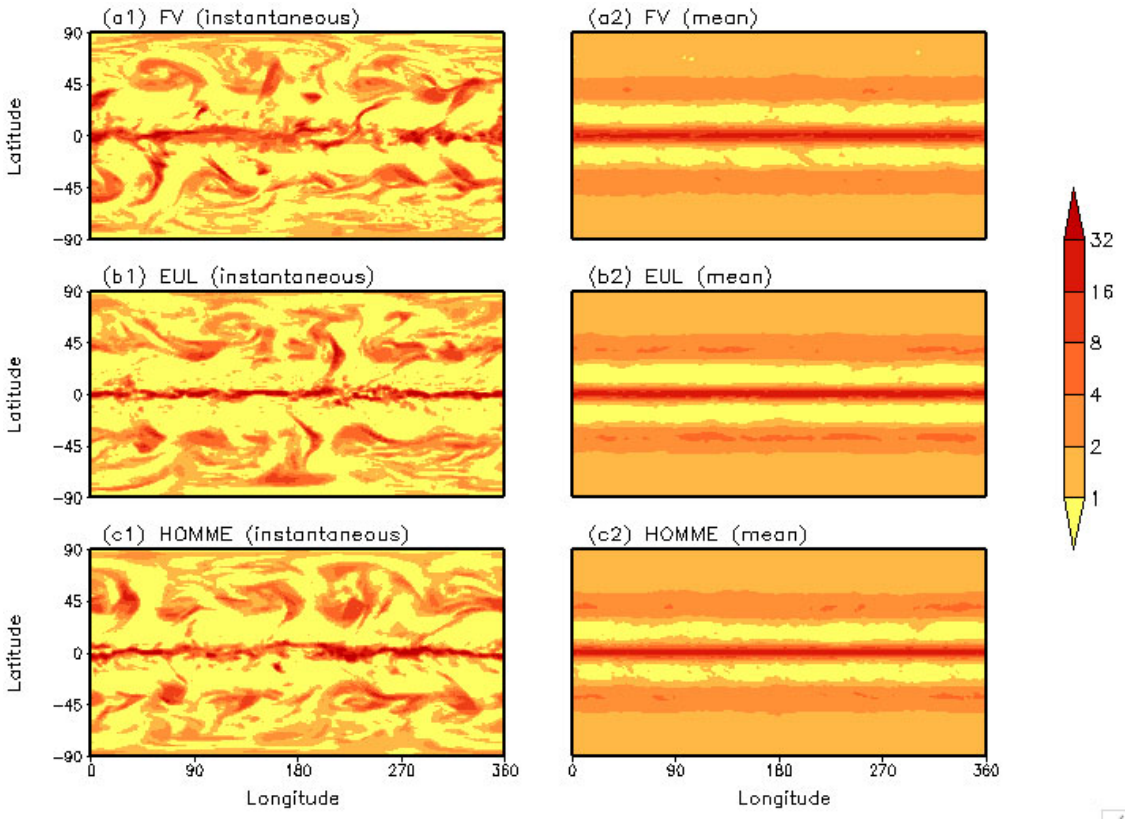
High-Order Method Modeling Environment dynamical core

The evolution of the Community Climate System Model (CCSM) into the Community Earth System Model (CESM) requires a highly scalable and accurate flux-form formulation of atmospheric dynamics. Flux form is required to conserve long-lived trace species in the stratosphere. Accurate numerical schemes are essential to ensure high-fidelity simulations capable of capturing the convective dynamics in the atmosphere and their contribution to the global hydrological cycle. Scalable performance is necessary to exploit the massively parallel petascale systems that will dominate high-performance computing (HPC) for the foreseeable future.

The High-Order Method Modeling Environment (HOMME) is a framework to investigate using high-order element-based methods to build conservative and accurate dynamical cores. Currently, HOMME employs the Spectral Element (SE) and the 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, and has been shown to efficiently scale to nearly 100,000 processors on an IBM BlueGene/L. 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 CCSM based on high-order numerical methods on the cubed-sphere that efficiently scale to hundreds of thousands of processors, achieve scientifically useful integration rates, provide monotonic and mass-conserving transport of multiple species, and easily couple to community physics packages such as Community Atmosphere Model (CAM) physics. Achieving these objectives will allow climate scientists to take full advantage of the petascale computing capabilities being deployed by NSF, and will lead to dramatic increases in climate science productivity.

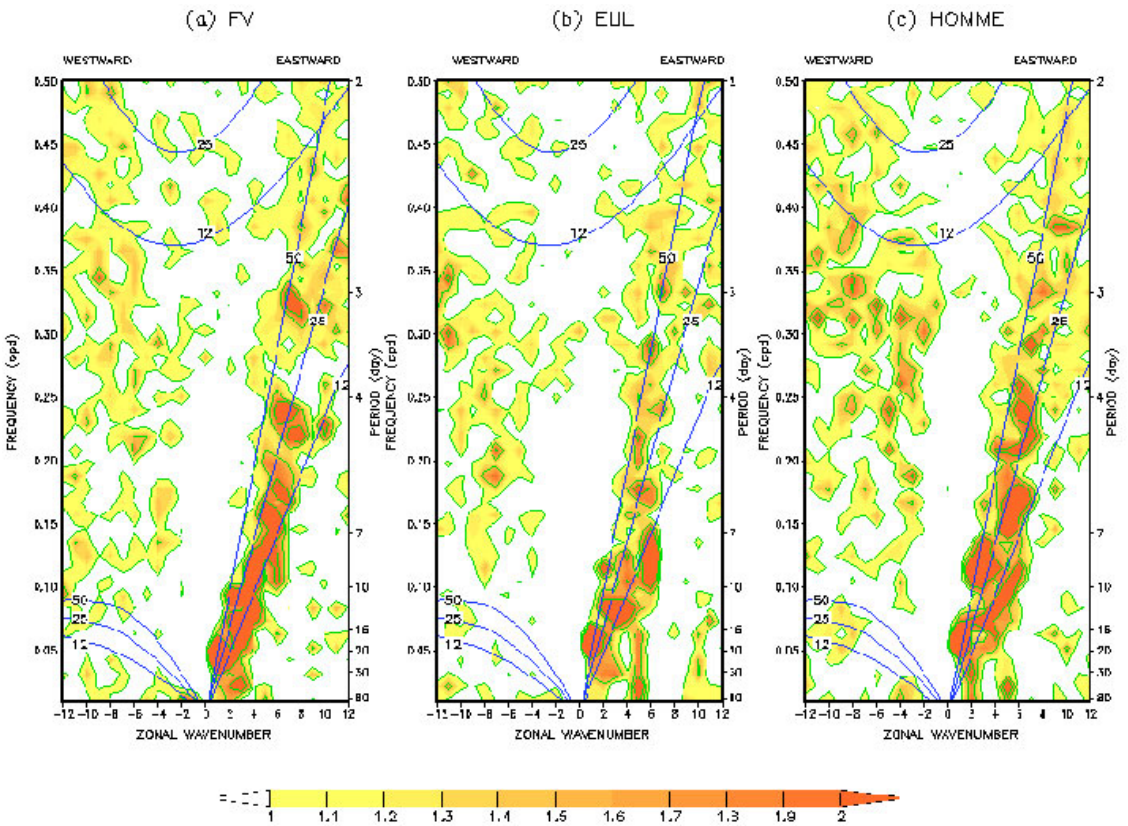
A major accomplishment for FY2010 was a comprehensive comparison of the SE version of HOMME/CAM simulations with other established CAM dynamical cores, based on finite-volume (FV) and spectral Eulerian (EUL) methods. Initial simulations have been completed in aqua-planet configuration of CAM4, which is the atmospheric component of CCSM4. The focus was assessing the HOMME model's fidelity in simulating mean and transient features of the Earth's climate system. Moreover, this study would help further tuning of parameters in HOMME to facilitate real-planet simulations, and comparing idealized simulations of the DG version of HOMME, which is planned for FY2011.



This figure shows the horizontal distribution of precipitation (mm/day) from finite-volume (FV), Eulerian spectral (EUL), and the HOMME (spectral element) dynamical cores for the aqua-planet simulations, in the Community Atmosphere Model (CAM4). The left column shows the instantaneous distributions and the right column shows the time mean states. This figure confirms that HOMME successfully captures the broad features of the mean climate.

To evaluate the mean climate, the focus was on the comparison of the simulated rainfall and its associated meteorological variables from HOMME, FV, and EUL. Instantaneous features of rainfall in HOMME are similar to FV and EUL. Like EUL and FV, HOMME simulates a single peak Inter Tropical Convergence Zone (ITCZ) over the equator (shown in the figure above). The strength of the ITCZ is found to be almost the same in HOMME and EUL, but more than in FV. HOMME and EUL produce higher surface evaporation that supplies more moisture to the deep tropicsthat results in more rainfall over the ITCZ. The altitude of maximum precipitation is the same in all three dynamical cores. This shows that HOMME captures the broad features of the mean climate (see right panel of the figure above). It shows that, in general, the climate simulated by HOMME falls in a regime between that of FV and EUL, indicating that HOMME simulates rainfall in an acceptable range with good fidelity.

To verify the performance of HOMME in the simulation of tropical transient features, an analysis of the equatorial waves has been performed. Equatorial waves govern the variability of the tropical climate. The analysis is based on the wavenumber-frequency diagrams of convection-associated variables, such as rainfall and outgoing long-wave radiation at the top of the atmosphere from FV, EUL, and HOMME. Although the gross features appear comparable, important differences have been found between the three dynamical cores. The phase speed of Kelvin waves in HOMME is faster and more realistic than in FV and EUL. The other modes of equatorial waves (the Madden-Julian oscillation) have been analyzed; it was inferred that HOMME simulates them in a satisfactory manner (see the figure below). In summary, model simulations using HOMME are reasonably good, with some improvement relative to FV and EUL in capturing some of the important characteristics associated with equatorial waves.



The symmetric component of the frequency-wavenumber distribution of outgoing long-wave radiation averaged between 15°S and 15°N is shown from (a) FV, (b) EUL, and (c) HOMME. This figure illustrates that HOMME simulates the equatorial waves as well as CAM's other established dynamical cores.

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 High Order Method Modeling Environment (HOMME) dynamical core. The HOMME/DG developmental effort and its integration into the CAM framework is partially supported by the DOE through the University of Colorado at Boulder (DE-FG02-07ER64464) and DOE/BER program DE-SC0001658. Primary support for HOMME is provided by NSF Core funding.

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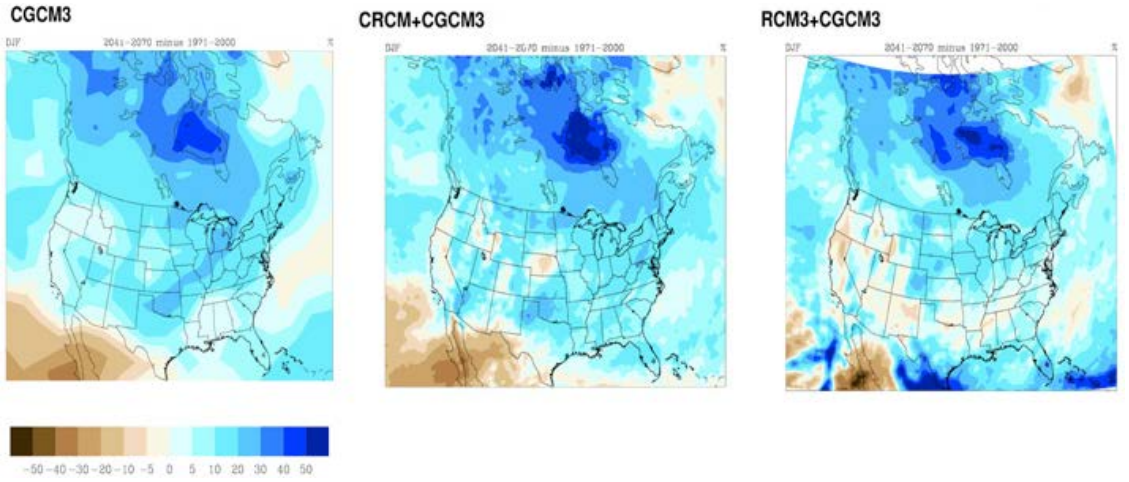
Science Imperative: Integrating the impacts of regional climate change

The Regional Integrated Science Collective (RISC) moved to CISL from NCAR's Research Applications Laboratory in late FY2010. In collaboration with a broad range of public and private laboratories and universities, RISC's mission is to generate high-quality regional-scale scenarios of projected climate change and 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.



This figure shows some NARCCAP results of projected climate change for winter precipitation. From just a small part of the full NARCCAP model runs, this figure illustrates the kind of detailed information that is provided by these numerical experiments. Pictured are the simulated differences in winter precipitation expressed as a percentage change between present climate (1971-2000) and a future period (2041-2070) under the A2 scenario for greenhouse gas emission. The results for the Canadian global model (CCGM) are in the left figure, and two downscaled simulations are given in the middle (CRCM) and left (RCM3) panels. Each of the regional models uses the global model boundary conditions but has higher resolution and more detail for physical processes. One striking feature is the increased heterogeneity in the projected changes over the Rocky Mountain region including large decreases in winter precipitation. Also note that the two regional models differ in their simulations. The scientific challenge is to integrate results such as these across many different global/regional model pairs and for different kinds of meteorological variables.

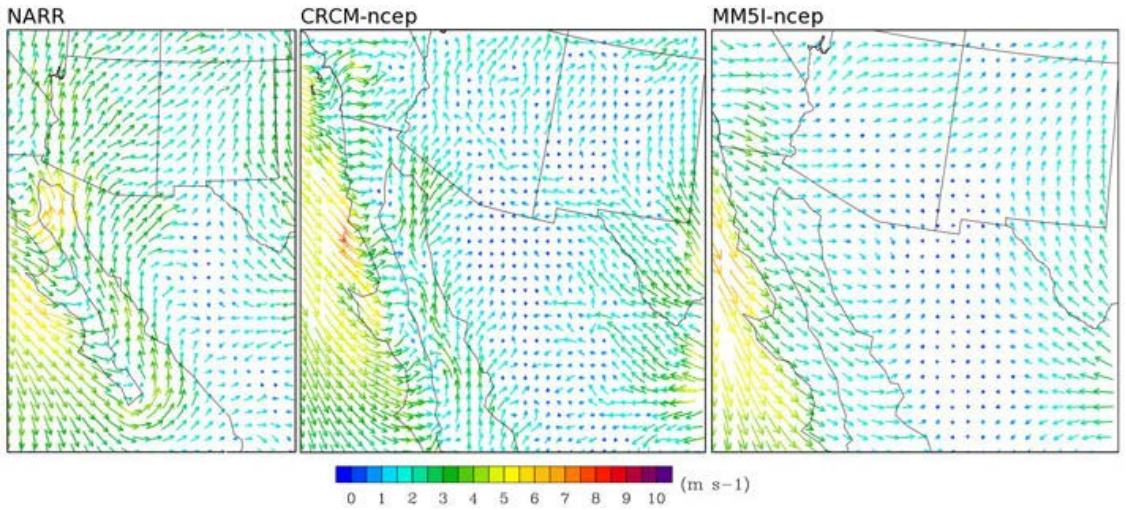
A centerpiece of RISC's activity is its leadership of the North American Regional Climate Change Assessment Program (**NARCCAP**). NARCCAP is systematically investigating the uncertainties in regional-scale projections of future climate. It is unique in its balanced design that allows for isolating the influence of individual regional and global models on the resultant climate simulations. The overall goal of NARCCAP is to produce high-resolution 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. This international program includes RCMs developed or maintained by European groups (PRECIS and RegCM3), the Canadian regional climate model (CRCM), and U.S. models including the ECPC regional spectral model (RSM), MM5, and the Weather Research and Forecasting Model (WRF). AOGCMs include the NCAR CCSM3, the Canadian Climate Centre CGCM3, the GFDL CM2.1, and the Hadley Centre HadCM3. High-resolution (50 km) global time slice experiments based on the GFDL atmospheric model (AM2.1) and the NCAR atmospheric model (CAM3) are also being produced and compared with runs of the regional models, also at 50-km resolution. 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.

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 the Climate and Health Workshop series.

In FY2010, substantial progress was made in completing the climate change simulations. Three new simulations of current and future climate were completed driving the WRF model with the CCSM, the MM5 model with the CCSM, and the Canadian CRCM with the CCSM. This gives us the opportunity for the first time to characterize the uncertainty across three regional climate models driven by the same AOGCM. Also more of the upper air data from the NCEP-driven runs were made available. Detailed analyses of the reanalysis-driven runs were performed, particularly for the southwest region. Simulations reproducing the major features of the North American monsoon showed considerable variations in quality (see figure below).



These plots illustrate some of the differences in performance between two of the NARCCAP regional models for one variable and process. Shown here is the 1980-2004 June-September average near-surface wind from the North American Regional Reanalysis (NARR, used as the “truth”), and two of the NARCCAP reanalysis-driven simulations (CRCM and MM5I). During monsoon season, shown here, northerly winds over the Gulf of California and onshore flow into Mexico and Arizona, dominating the seasonal average. Here, one model captures this process with only slight error, while the other performs substantially worse and contains no northerly wind component. The challenge is to decide if the error in the average wind field and the causes behind it in the MM5I are substantial enough to warrant less confidence in simulations of the North American Monsoon from this model. It may perform better than the CRCM in other aspects/variables during monsoon season in this region. The same challenge is present for other models, errors, seasons, and regions.

In FY2011, RISC plans to:

- Produce one higher-resolution WRF scenario over the western U.S. using boundary conditions from NARCCAP’s 50-km WRF model.
- Develop full Bayesian probabilities of climate change based on a full suite of global and regional model simulations.
- Collaboratively establish differential “credibility” based on careful process-level evaluation of model simulations.
- Apply continued funding for individual projects of WCIASP to focus on contributing to the interpretation of NARCCAP experiments.
- Hold the biennial Climate and Health workshop in summer 2011.

The Regional Integrated Science Collective (RISC) is primarily supported by NSF Core funding. Interagency support through NARCCAP includes additional funding from NSF, EPA, DOE, and NASA.

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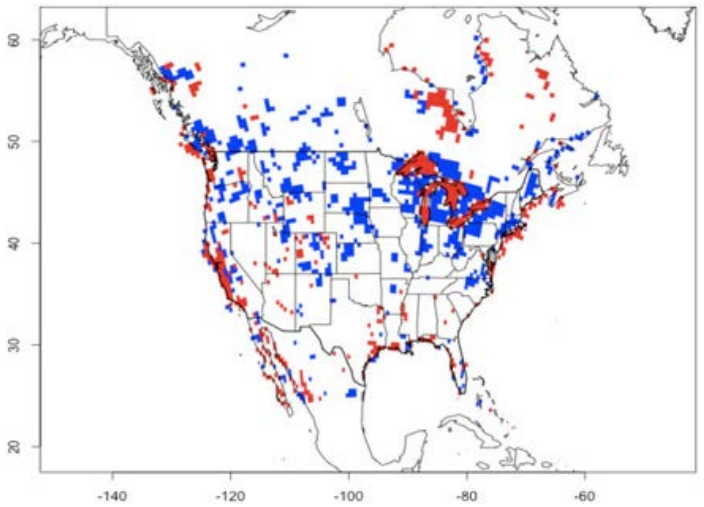
Science Frontier: Stochastic and Statistical Techniques for Model Development

The ability to conduct numerical experiments at unprecedented scales or with large ensemble sizes provides an opportunity for mathematical and statistical tools to be more directly involved in geophysical model development. One frontier is using statistical analysis of model experiments to support model building. This activity contrasts with the more traditional uses of statistical methods such as simply validating an existing model. Instead, model run analyses guide improvements and possibly subsequent model experiments. A statistical approach can add efficiency to model development by reducing the number of runs needed for testing and also provide estimates of empirical relationships among model components where the physical processes are not resolved.



This figure is a statistical summary of the differences between two different models simulating regional climate. It suggests that these two downscaling models supported by GFDL respond differently around coastlines and lakes. An interaction between two factors in an experiment is an important way to describe the predictability of a result and to identify situations where a unique process or a particular sensitivity might be present. The simplest way to predict a response in this experiment is to add an adjustment based on the climate scenario (present or future) to an adjustment based on the kind of downscaling (regional model, time slice). The interaction is the descrepancy between this linear prediction and the actual model response. Interactions typically identify a synergy or amplification between a specific set of experimental factors. This figure depicts grid cells with a significantly positive (red) or negative (blue) interaction (posterior probability exceeding 95%). The grid boxes where the interaction differs from zero appear around coastlines, lakes, and mountainous regions. It is speculated that this discrepancy is related to the different ways in which the models incorporate information about the orography across the domain and also how the model grids discretize the bodies of water.

Statistical analyses of climate simulation methods help point to salient differences in the methods that may not be obvious from a cursory graphical analysis. Numerical simulations that are nominally deterministic are amenable to a statistical interpretation with companion measures of uncertainty expressed in terms of probability. Work will continue on stochastic interpretations of the NARCCAP model experiments, and it will include the development of spatial analysis of model bias. Comparing climate simulations at different resolutions will also be a first step toward stastistical models for subgrid-scale variability.

CISL's science frontier in stochastic and statistical techniques for model development is primarily supported by NSF Core funding, with supplemental funding supplied by other sources as noted in the following reports.

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Science Frontier: Algorithmic Acceleration

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, for example, cloud-resolving resolutions for the atmosphere: each of these approaches are addressed in CISL's research program and described in the following subsections.

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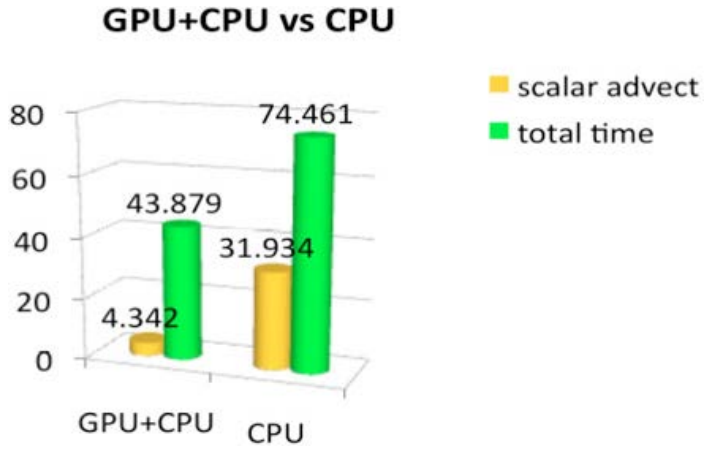
Accelerating applications using accelerator-based architectures

Clouds play an essential role in Earth's climate, but to this day remain a major source of uncertainty. Accurate cloud representations are not included in global simulations due to the extra computational cost of simulating cloud effects. At present, climate models use simple parameters to stand in for how clouds affect climate processes. To study the feasibility of including a Cloud Resolving Model (CRM) – also known as super-parametrization – in General Circulation Models (GCM), CISL continues its research in ways to use Graphics Processing Units (GPUs) to accelerate CRMs and reduce the total cost of more capable GCMs.



This chart shows the speedup of a GPU-accelerated version of a Cloud Resolving Model (CRM) over single-processor execution. In this experiment, the model's dominant routine implements an advection algorithm that was accelerated by about a factor of eight. This reduced the model's overall computational cost to about 60% of the original CPU-only total time. Accelerators offer the opportunity to explore the scientific impact of adding local but computationally intense processes (microphysics, for example) to future Earth System models.

During the year 2010, CISL's Technology Development Division made significant progress in this area. We re-implemented a standalone version of a CRM to fully exploit the performance characteristics of a GPU card, the NVIDIA Tesla C1060. We rewrote the dominant routines of the CRM using CUDA-C, and the model ran concurrently in a CPU-GPU architecture. After careful testing, we proved that the accelerated model maintains acceptable accuracy and that the results are consistent with the original standalone version of CRM, while achieving a factor of eight speedup of the dominant routine. This reduced the total cost of the CRM model to about 60% of its original time to completion.

In FY2011, we will pursue larger experiments by porting the accelerated model to a cluster of GPUs based on the standard MPI architecture. This will help us determine how to apply this GPU-accelerated technology to standard production systems, and how it will impact the overall performance of a GCM. We will also continue to track this field's evolution using new NVIDIA cards, such as the Fermi GPU, to understand how this evolution in high performance computing will benefit climate models.

This work advances CISL's science frontier in algorithmic acceleration by seeking breakthroughs in hardware accelerators that can help produce simulations capable of addressing grand challenges. Specifically, it fulfills a strategic action item to accelerate Earth-Sun science applications using accelerator-based architectures (coprocessors). This work is supported by NSF Core funding.

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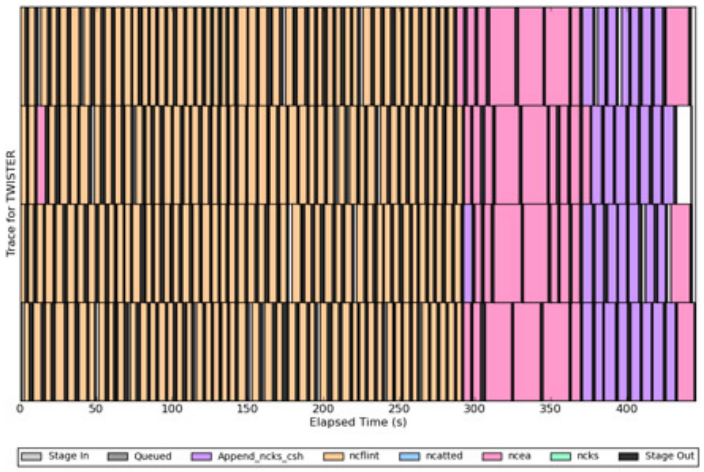
Accelerating the analysis of ultra-high-resolution climate

Recent advances in the computational capabilities of the Community Earth System Model (CESM) have increased the rate at which output data is generated by an order of magnitude. A single ongoing high-resolution climate simulation performed by the Kraken system at the National Institute for Computational Science (NICS) generates as much as 1 TB of data per wall-clock day. Unfortunately, the standard approach for post-processing used for analysis of output data remains serial in nature and thus creates a bottleneck.



This Gantt chart shows the execution of constituent tasks for the low-resolution diagnostic analysis workflow on a single node with four tasks. Tasks are color coded by executable; gray regions between the execution stages are data file manipulation performed by Swift.

In FY2010, CISL developed a prototype parallel version of the statistical component of the Atmospheric Model Working Group (AMWG) diagnostic package using the Swift language. Using Twister, a two-node visualization cluster at NCAR, we achieved a speedup of approximately 2.5x on history file processing for the 0.5° Community Atmosphere Model (CAM). This project is the outgrowth of a collaboration between CISL researchers and an undergraduate student intern in the Summer Internship in Parallel Computational Science (**SIParCS**) program. In FY2011 we will continue this work by testing scalability on larger systems and address efficiency issues discovered with the Swift development team.

This work advances CISL's science by preparing the foundation for petascale and exascale computing. The result described here is a direct byproduct of the SIParCS program which supports CISL's educational imperative to integrate research and education. This work is supported by NSF Core funding and NSF Grant OCI-0749206.

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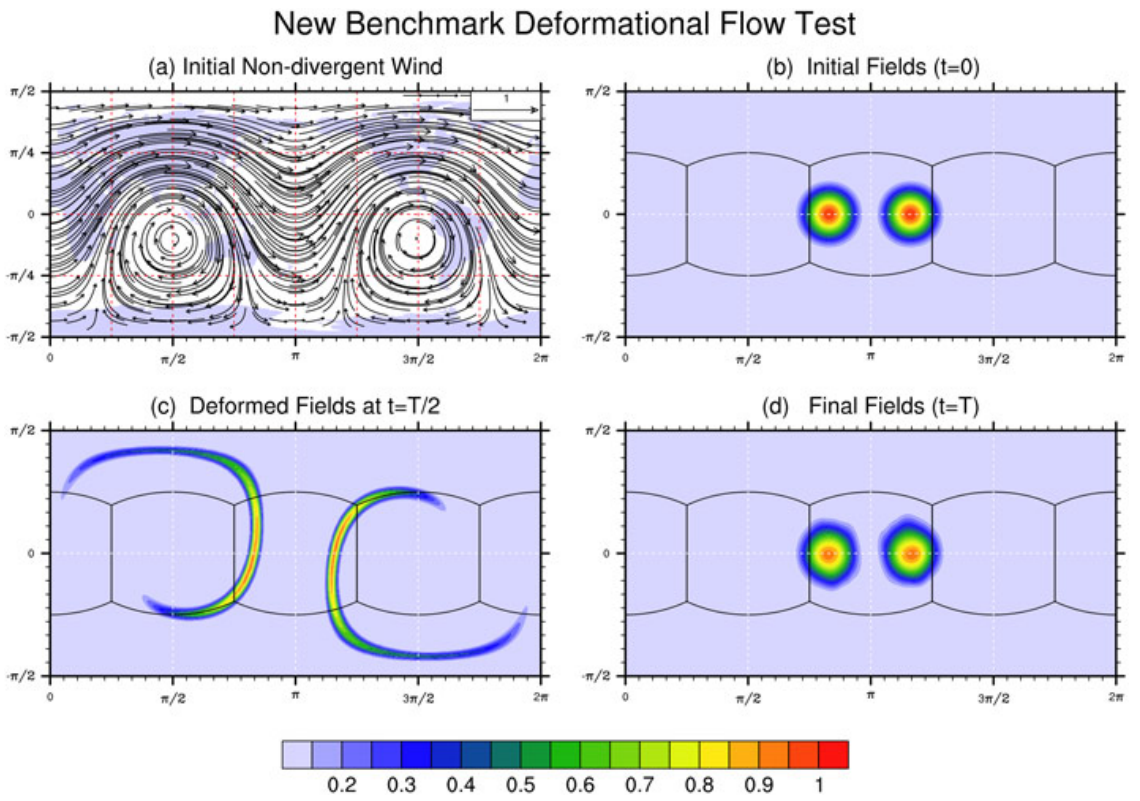
Accelerating applications algorithmically

Transport (advection) process are of paramount importance in atmospheric numerical modeling. In an operational climate model such as the Community Earth System Model (CESM), advection algorithms are responsible for the transport of several moisture variables and hundreds of chemical constituents (tracers or passive scalars). Transport schemes are the basic building blocks of complex models. In recent years, there have been numerous efforts to develop the next generation of global models based on non-conventional spherical geometry and advanced numerical methods. For example, NCAR's HOMME/CAM model employs cubed-sphere geometry, and is based on continuous (spectral element or SE) and discontinuous Galerkin (DG) methods. However, the current benchmark tests for transport schemes rely primarily on simple test cases that are not rigorous enough for next-generation global models. Validation and verification of the transport algorithms necessitates further development of more challenging benchmark tests.



This figure illustrates a new non-divergent deformational flow test case for the transport problems on the sphere (globe). (a) This shows the initial non-divergent wind fields on the sphere which deform and translate the tracer fields during the transport process. (b) The initial tracer fields are cosine-bells with a maximum value of 1 unit. During evolution, the initial circular patterns of the tracer deform into thin filaments and move along the zonal direction. (c) This shows the deformed field at half-time when flow reverses its course and the tracer fields return to their initial positions and shape as shown in (d). A third-order discontinuous Galerkin (DG) transport scheme based on the cubed-sphere is used for this simulation. For this test, the solution at the final time is identical to the initial solution, which facilitates a way to assess the accuracy of the underlying transport scheme.

In FY2010, a class of new benchmark deformational flow test cases was developed for the two-dimensional horizontal transport problems on the sphere. The scalar field follows complex trajectories and undergoes severe deformation during the numerical simulation. However, the flow reverses its course at half-time, and the scalar field returns to its initial position and shape (see figure). This process makes the exact solution available at the end of the simulation, and it facilitates assessment of the accuracy of the underlying transport algorithms. The test suite consists of four cases for

both divergent and non-divergent flow fields. The initial conditions are prescribed in terms of the regular latitude-longitude coordinates and are easy to implement.

The tests are specifically designed for conservative global transport schemes to test for conservation, consistency, and monotonicity (or positivity) of limiters/filters in a challenging flow environment. In the context of semi-Lagrangian schemes, the time-varying flow fields can be used to test trajectory algorithms where the exact trajectories do not follow great-circle arcs. For transport schemes capable of adaptive mesh refinement (AMR), the new tests can be used as a valuable tool for developing error estimators.

In FY2011, the test suite will be implemented in HOMME/CAM framework to validate new transport schemes including, the recently developed (FY2009) conservative semi-Lagrangian transport scheme (CSLAM), and other potential transport schemes being considered for CESM applications.

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.

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Science Frontier: Large and Heterogeneous Data

The progress of Earth System science hinges on ever more complex and ambitious analyses and assimilations of datasets – and these are growing rapidly in complexity, volume, and diversity. Across observational, simulated, and reanalysis data, all of these aspects pose formidable challenges. To deal with the burgeoning complexity of our data, we have engaged in substantial work in the area of metadata standards, ontology development, and first-generation semantic systems. Data diversity, in terms of formats, protocols, and probabilistic characteristics will be addressed in strategic steps for data assimilation complemented by other software application work (e.g., NCL, PyNGL, VAPOR).

In FY2010, we drove continued progress in developing analysis and visualization tools that utilize multi-resolution strategies for dealing with very large datasets. As we move toward the era of petascale data, we define R&D thrusts that combine scalable tools and systems along with pattern recognition and machine learning approaches to augment the precious human capital available for analyzing research results. These thrusts serve as a foundation for dealing with the ever-growing challenges of large, heterogenous scientific data.

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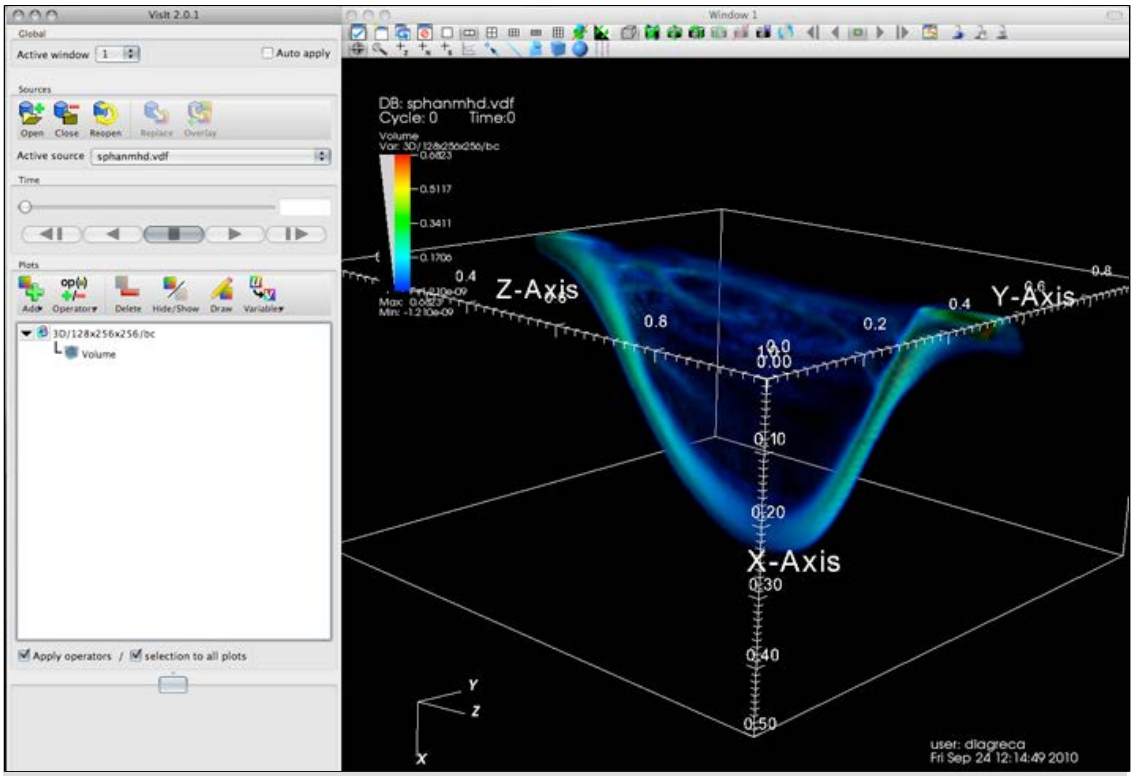
Visualization of large data sets

Computational scientists across a broad spectrum of application domains are benefiting from exponential advances in HPC technologies that are enabling numerical simulations of unprecedented scale. A direct result of the availability of systems with petaflop performance is the ability to produce staggering amounts of data. Unfortunately, the ability of numerical modelers to interactively visualize and analyze data has not kept pace with our ability to generate it. Computing technologies such as secondary storage – essential to, and often the rate-limiting factor for analysis – are advancing much less rapidly than microprocessor technology. Secondly, few HPC centers are positioned to deploy data analysis and visualization resources on par with batch computing resources. CISL is thus exploring a variety of approaches for addressing the visualization and analysis of large data sets.



This image depicts a screenshot of the parallel visualization tool VisIt with data imported from the VAPOR progressive access data model using plugins developed by CISL. Support for multi-resolution data in VisIt (and ParaView) provides a further level of scalability for these tools.

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 outlined in CISL's strategic plan. The CISL strategic plan 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.

In FY2010, CISL's large data visualization efforts were focused in two areas: 1) research and development of progressive access data models that substantially reduce demand on computing resources, particularly storage bandwidth and capacity requirements; and 2) preparing for parallel visualization clusters. In FY2010, a second generation of prototype tools for data compression and progressive access were hardened and integrated into VAPOR's new data model. The new data model provides approximately a 10x improvement in data reduction capability over the

previous data model. Work has nearly been completed on a Fortran-callable parallel API to the new data model that would allow MPI codes to write highly compressed data directly from a running simulation. CISL collaborated with partners at TACC, LANL, and LBL to develop and release Open Source progressive access data readers for the parallel visualization tools VisIt and ParaView. Also in FY2010, CISL deployed and evaluated a prototype visualization cluster with remote display capabilities.

In FY2011, CISL will complete development of the parallel API to our wavelet-based progressive access data model. We will identify and work with scientific collaborators to evaluate the new capability and release the code as part of the Open Source VAPOR package. We will continue to work with collaborators at LBL, TACC, and LANL to enhance the capabilities of the VisIt and ParaView packages to better meet the needs of the NCAR community.

Work in the area of large data set visualization and analysis is aimed at satisfying CISL's scientific frontier of understanding large and heterogeneous data sets. As outlined in CISL's five-year Strategic Plan, this work develops new methods and tools to visualize large data sets. It also supports CISL's efforts to prepare for petascale and exascale computing. This project is supported by NSF Core funds and NSF Grant NSF-09-06379.

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Dealing with complex, heterogenous scientific data

Progress in the Earth System sciences hinges on the analysis of a wide range of scientific data, including observational data, reanalyses, and simulation output. The scope and complexity of these data continues to grow, and this places new demands on how we address metadata and knowledge representation. CISL is engaged in a number of complementary activities that are focused on this facet of the data analysis challenge our community faces.

This work supports CISL's science frontier of addressing large and heterogeneous data products, and it also underpins our work of building and deploying environmental science gateways and delivering the Science Gateway Framework (**SGF**) to the community.

This image depicts a suite of projects that have a strong focus on enhanced metadata definition and integration. These efforts span global weather forecasting and observation, climate simulation and IPCC work, and polar research. Having extensive and complete knowledge about datasets is essential to being able to analyze and use them properly.

During FY2010, we made substantial progress – through broad international collaborations – in defining ontologies for climate model metadata and in implementing user interfaces for browse and search that will elevate the research community's ability to analyze petascale multi-model datasets. Through a collaboration with the EU-based **METAFOR** project, the NOAA-supported **Curator** effort, **ESG**, and **ESGF**, we collectively worked to develop an extensive metadata schema, adapt it to the Curator/ESG ontology, ingest it into the ESG Gateway, and provide a user environment where the information about models and experiments can be queried and explored. This work is in direct support of the CMIP5/IPCC effort. In the **CADIS** project, we continued to refine our metadata model in alignment with other international work for the International Polar Year (IPY). CISL staff also continued to play a primary role in contributing to the international WMO Information System (**WMO-WIS**) expert team on metadata.

We plan to continue all of these activities in FY2011, and we will put the new climate simulation metadata work into production for CMIP5 and IPCC in the first half of the year. We will also re-engineer some of the SGF to accommodate additional ontologies.

In addition to NSF Core funding, the Curator work is supported by NOAA, ESG work by DOE, and CADIS work with NSF special funds.

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CISL Education

CISL is an education laboratory.

CISL must teach the mathematical and computational science concepts and the skills students will need to make effective use of advanced cyberinfrastructure. Furthermore, CISL's mission of supporting 21st-century computational Earth System science research can succeed only if CISL replenishes itself with a diverse and talented staff. Therefore CISL must encourage students to embark on careers in supercomputing and the computational sciences.

As an education laboratory, CISL sees the following overarching Imperatives for the portfolio of education, outreach, and training programs that it deploys:

- CISL must better integrate its research and education activities to maximally leverage the impact of both.
- Because of the paucity of students entering the HPC workforce, CISL must take a more active role in training and workforce development.
- To reverse discouraging demographic trends, CISL must take bold measures to broaden participation in computational science.
- CISL must use aggressive outreach to attract qualified candidates, particularly those from diverse backgrounds.

A grand challenge in education has been identified by CISL as a CISL educational Frontier: leveraging information technology itself to transform education, outreach, and training (EOT). This multidimensional frontier represents perhaps the greatest challenge facing not only CISL, but the institution as a whole, and its solution will require engaging scientists, technologists, educators, and other subject matter experts.

This section of the FY2010 CISL Annual Report reports on the topics shown in the navigation tool at left.

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Education Imperative: Integrating Research and Education

Building a cadre of students interested in computational science is an essential part of CISL's mission. 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. 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 mathematical and geosciences communities.

Seven SIParCS interns attended "Scaling to the Petascale," a four-day Virtual Summer School in Computational Science and Engineering that was held 6-9 July 2010. This virtual school was organized by the Great Lakes Consortium associated with the Blue Waters project. It occurred simultaneously at 10 sites across the country that were linked together by Access Grid (AG) technology. NCAR's Visualization Lab served as one of the AG nodes and hosted 24 students. NCAR also provided supercomputing resources for the class. Providing CISL's interns with opportunities to participate in training classes like this helps them develop important skills, enriches their summer work experience, and ultimately improves research outcomes.

Topics such as multiscale modeling, data assimilation, and turbulence offer hands-on experience to young researchers. CISL budgets to support a core group of 10 SIParCS interns each year and actively recruits for diversity. The RSVP program is visitor-driven and generally operates on a first-come, first-served basis. In 2010, for the first time, RSVP travel support to CISL training classes was supplied to attendees from EPSCoR states and minority-serving institutions. TOY 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.

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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 10-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. CISL's contribution is to teach the mathematical and computational science concepts and skills that students will need to make effective use of advanced cyberinfrastructure.

SIParCS 2010 brought the largest summer intern class ever to NCAR: 20 students from 17 different colleges and universities. Students worked on projects in computational science fields such as applied mathematics, geostatistics, computer science, and software engineering. A fundamental SIParCS goal is to increase the number of trained scientists and engineers capable of using and maintaining 21st-century supercomputers.

CISL's strategy as an educational laboratory focuses on three imperatives: integration of research and education, training and workforce development, and broadening participation. The SIParCS program directly addresses all three. The program supports CISL's primary education imperative and fulfills a strategic action item to integrate research and education to maximally leverage the impact of both.

NCAR hosted the fourth annual SIParCS program in 2010. CISL opened applications for the Summer 2010 SIParCS program in mid November 2009. Applications were closed in early February 2010, and successful applicants were notified in the middle of March 2010. Most student interns arrived by June 1st, and their 10-week visit concluded in

August. Each student presented the results of their project at a colloquium during the last week of July.

The fourth annual SIParCS program was the largest yet: in total CISL hosted 20 students from 17 U.S. colleges and universities. Student research topics in 2010 covered diverse problems in applied mathematics, geostatistics, numerical algorithms, software engineering, HPC system administration, and computer science. Interns were drawn from a pool of approximately 55 applicants, an applicant-to-intern rate of 2.75. Two students met diversity criteria; four were from underrepresented groups. Seven SIParCS interns attended the 6-9 July Virtual Summer School in Computational Science and Engineering entitled “Scaling to the Petascale.” This virtual school was organized by the Great Lakes Consortium and occurred simultaneously at 10 sites that were linked by Access Grid (AG) technology. NCAR’s Visualization Lab served as one of the AG nodes and hosted 24 students. CISL provided supercomputing resources for the class as well as laptops for the local students to use during the four days.

CISL’s mentors for the SIParCS interns showed increased interest in continuing student involvement in follow-on projects after the end of the summer program: eight such inquiries were received by the SIParCS program office. In addition to highlighting the high quality of these interns’ contributions, this trend promises to increase the strategic impact of SIParCS by generating opportunities for employment and collaboration.

In FY2011 SIParCS will have 10 core-funded positions, and CISL’s outreach and recruiting effort will continue at the same high level. As in the past, NCAR will seek outside funding partners for internships. Also, NCAR will strive to further integrate SIParCS with relevant summer training opportunities.

SIParCS is made possible primarily by NSF Core funding, although in certain cases, intern support is provided by partner institutions or through special funds such as outside grants. Of the 20 internships in 2010, 12 were funded by CISL’s Core funds (either one time or recurring), six were funded by partner organizations or grants, and two were funded with diversity funds. SIParCS external partners this year included the University of Wyoming, the Colorado School of Mines, and NOAA. Internal intern support included the NCAR Director's Diversity Fund and IMAGe. FY2011 will have similar participation targets.

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IMAGe Theme of the Year

The Theme-of-the-Year (TOY) is a series of activities on an aspect of applied mathematics for the geosciences. TOY is designed to advance research and education between the mathematical and geoscience communities. The topics are selected by the IMAGe external advisory panel and coordinated by one or more visiting co-director(s).

TOY 2010 summer school students visited the University of Colorado (CU) Mountain Research Station (MRS) near the Continental Divide west of Boulder. An interdisciplinary facility of CU's Institute of Arctic and Alpine Research, the MRS is devoted to advancing the study of mountain ecosystems and provides research and educational opportunities for scientists, students, and the general public. Station manager Kelly Matheson describes the surface weather instruments at the "C1" location to 40 TOY students. Collectors in the background measure wet and dry deposition from the atmosphere; in the left foreground are wind baffles around a precipitation gauge. Data from this site comprises one of the longest continuous climate records in the Rocky Mountains, and the class used this data to explore time series analysis methods.

The yearly TOY programs support CISL's education imperative to integrate research and education, and they align with NCAR's education mission. TOY also fulfills a CISL strategic action item to encourage broader participation by sparking collaborations between the mathematics community and Earth System scientists. Computational science is an interdisciplinary enterprise at the intersection of computer science, applied mathematics, software engineering, and domain science. As universities struggle to fit computational science education and research into their existing academic structures, CISL – as an interdisciplinary education laboratory – finds and develops unique opportunities to lead and catalyze directions for computational science education at universities.

The thematic program for the FY2010 TOY, "Mathematicians and Climate," was co-directed by Professor Chris Jones (University of North Carolina), Dr. Hans G. Kaper (Argonne National Laboratory), and Professor Mary Lou Zeeman (Bowdoin College and Cornell University). Climate change research is about the future. The driving force is our need to

understand what is happening to our planet in terms of climate change effects and their societal impacts. For almost every question that arises, a mathematical model is the vehicle for extrapolating into the future. It is then essential that the mathematics community be involved and more mathematicians are brought into climate change research. This program used NCAR scientists and facilities as a hub to engage mathematical scientists in substantial problems to advance climate research.

Professor Chris Jones (TOY co-director) faciliates a discussion among the Ocean Field Trip participants on 16 April. This was a synthesis activity to integrate the different research topics that arose from presentations on the previous day. This meeting paired applied mathematics faculty with NCAR's oceanography scientists to explore collaborations beneficial to current research.

This TOY was developed and executed in partnership with the Mathematical Sciences Research Institute (MSRI). It leverages MSRI's deep and long-standing ties with the mathematics community to involve mathematicians who have a broad range of interests. The summer school would not have been possible without financial support from MSRI.

The FY2010 TOY hosted four key gatherings: a workshop in February, a field trip in April, a synthesis meeting in June, and a summer school in July. The 11-13 February workshop, "Mathematics of Interacting Climate Processes," provided an overview of climate science for mathematicians. It successfully directed mathematics researchers into climate problems and aided their productive participation in the TOY's subsequent activities. The 15-16 April field trip, "Ocean Modeling," brought together a diverse group of applied mathematicians with the Oceanography Section staff of NCAR's Climate and Global Dynamics Division (CGD). Following CGD presentations about their ongoing research and modeling issues, an open discussion identified and scoped areas that would benefit from mathematical collaboration. The 23-25 June synthesis meeting, "Data Assimilation and Climate Research" focused on applying emerging data assimilation methods to diagnose biases in climate models. The approach is to transfer techniques from numerical weather prediction to compare the dynamical processes in a model to observations on shorter time scales. The 12-23 July summer school, "Mathematics of Climate Change," brought together 42 graduate students from the mathematical sciences with numerous instructors and many others. The first week's program of lectures, discussions, and labs provided both the mathematical and geophysical contexts for studying climate. Students then spent the second week in teams guided by both senior and early-career researchers to work on specific projects that included dynamical systems, combining geophysical models and observations, and synthesizing large observational data sets.

These FY2010 TOY summer school participants included 42 graduate students, TOY's largest-ever group. This two-week experience provided an opportunity for students to meet peers from diverse backgrounds in the mathematical sciences and gain experience working on projects in multidisciplinary teams. The TOY program is designed to advance both research and education in the mathematical and the geoscience communities.

The 16 July minisymposium, "Mathematics and Climate," was a special session at the 2010 SIAM Annual Meeting in Pittsburgh. Though not a TOY program, this symposium spotlighted climate science and IMAGe at the primary U.S. meeting for applied mathematicians.

For FY2011, the TOY will be a multidisciplinary program entitled "Integrating Uncertainty on Climate Change." It will be co-directed by Linda Mearns (NCAR), Hayley Fowler (Newcastle University), and Mort Webster (MIT). The goal is to increase awareness in the climate modeling and statistical communities about the kinds of information needed to formulate policy and plan for potential changes in climate. A primary theme will be how uncertainty in climate projections is quantified and interpreted with respect to specific regions and extreme events. The program will involve both professors Fowler and Webster in extended visits to IMAGe and several conferences including coordination with the NCAR "Climate and Health" workshop and the "Mathematics and Regional Climate" workshop at the National University of Singapore.

TOY is supported by NSF Core funding, NSF Special funds, and also seeks grant opportunities to supplement its budget.

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Education Imperative: Workforce Training and Development

CISL must cultivate a cadre of young scientists and engineers with the basic skills required to use or operate high performance cyberinfrastructure as tools to answer research questions in the atmospheric and related sciences. To accomplish this goal, NCAR delivers training content synchronously through workshops and training classes, and asynchronously through web content. Two of the principal synchronous activities in CISL include training in scientific data analysis and visualization conducted by the NCL group, and training in MPI, OpenMP, Fortran, and other HPC technologies performed by the Consulting Services Group.

This photo shows some of the students attending a one-day “hands-on” Fortran 90 course at NCAR on 19 July 2010. NCAR offers this course twice a year because Fortran continues to be the language of choice for scientific models, and such curricula are not available at many colleges and universities. Always in great demand, this summer class had 22 students. NCAR plans to supplement this class with an offline version and a web forum.

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

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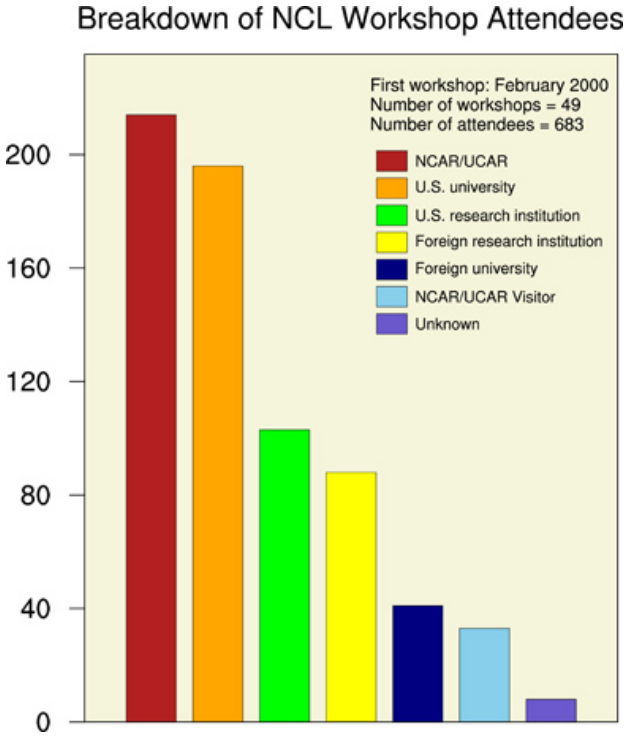
Training in geoscientific tools

Staff in CISL/VETS and NESL/CGD have collaborated for 10 years to provide a series of training workshops for NCL – a free, interpreted language designed specifically for geoscientific data analysis and visualization. To date, a total of 49 local and non-local workshops have been provided to 683 students. These workshops, which are free for students, are four days in length with morning lectures and intensive hands-on labs in the afternoons. A unique aspect of these workshops is that rather than using canned datasets and examples, students are encouraged to bring their own datasets for analysis and visualization. The instructors work with students individually during the labs, and by the end of the workshop most students have developed nearly complete NCL programs that produce meaningful results from their data.

This photo shows students and instructors from CISL's 20-23 July NCL workshop in Boulder. This course trained 14 attendees from U.S. universities and research organizations how to analyze their own datasets using NCL and other software. These workshops provide researchers with valuable tools and knowledge that they can use throughout their careers.

A core NCAR value is partnership with the university community. We proactively reach out to U.S. university students by offering at least one free 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 local workshops. (EPSCoR universities are located in states that are deemed to be underserved by federal research and education funding. The goal



Since its inception in February 2000, the NCL workshops have served a variety of scientific users, including international students and professionals. More than one fourth of these participants have been U.S. university students.

of the Experimental Program to Stimulate Competitive Research – EPSCoR – is to balance national research and education support by strengthening it in these states.) FY2010 was the third year we offered this free workshop, and we provided full funding for three EPSCoR/MSI students to attend our summer workshop in Boulder.

These courses are key to connecting with scientific users and providing them with the knowledge they need to use these tools effectively in their research. Most of the participants in the courses we teach at universities are graduate students. The chart at right summarizes attendee demographics since the NCL workshop was first offered.

In FY2010, we taught six workshops: two in Boulder, one at the University of California-Irvine (a UCAR member university), and three invited, fully funded workshops at Max-Planck-Institut für Meteorologie in Hamburg, Germany and at the Center for Climate Systems Modeling in Zürich, Switzerland. Our international efforts support the NCAR strategic goal of engaging a broader and more diverse community.

Mary Haley (CISL, shown) and Dennis Shea (NCAR Climate and Global Dynamics Division) teach the four-day NCL workshops. This photo was taken in UCAR's Corporate Technical Training Center in Boulder on 21 July 2010.

In FY2011 we plan to offer four to six NCL workshops: one at a U.S. university, two in Australia at the Bureau of Meteorology and the University of New South Wales, and the rest in Boulder by demand. A CISL strategic imperative is to develop a diverse workforce, and to that end we plan to continue providing one or more all-expenses-paid trips for students from EPSCoR universities and MSIs to attend NCL workshops. If time and funds permit, similar training might be extended to the diverse world of scientific Python users by offering courses in PyNIO and PyNGL (Python modules based on NCL's file input/output and visualization capabilities).

The training workshops are supported by NSF Core funding, and the instructors' international travel expenses are paid by the inviting institution.

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Training interns in computing at NCAR

Education is a core mission of NCAR. CISL's contribution is to teach the concepts and skills in computing, mathematics, and computational science that students need to make effective use of advanced cyberinfrastructure. In addition, CISL's work to advance the goals of 21st-century computational Earth System science research can only succeed if CISL attracts and retains a diverse and talented staff. Therefore CISL must also encourage students to embark on careers in supercomputing and the computational sciences. This work supports two education imperatives defined in CISL's Strategic Plan: Integration of research and education and Workforce training and development.

CISL takes an active role in mentoring and training student interns, and summer is an especially busy time. In FY2010, CISL's Consulting Services Group provided the following classes to a total of 307 participants, of which 186 were interns, protégés, undergrads, or graduate students and 107 were from underrepresented groups. (Note that many students took multiple classes, so these totals count some individual participants multiple times.)

- Fortran 90 for Scientists and Engineers, Part I, 11/9/2009
- Fortran 90 for Scientists and Engineers, Part II, 12/1/2009
- Parallel Programming in Fortran with MPI and OpenMP, 2/4/2010
- Introduction to Unix, 6/6/2010
- Programmer's Tools, 6/7/2010
- Introduction to Python, 6/7/2010
- Introduction to Parallel Programming with OpenMP, 6/8/2010
- Introduction to Parallel Programming with MPI, 6/9/2010
- Introduction to MPI, 6/7-18/2010 (hosted externally)
- Introduction to OpenMP, 6/21-7/2/2010
- Petascale Programming Environments and Tools, 7/6-9/2010 (hosted externally)
- Fortran 90 for Scientists and Engineers, 7/19/2010

In FY2010, CISL's Consulting Services Group provided training and mentors for two internship programs at NCAR: UCAR's Significant Opportunities in Atmospheric Research and Science (SOARS) and CISL's Summer Internships in Parallel Computational Science (SIParCS). CISL again provided computing mentors to supplement that program's existing collection of specialized science, writing, community, and peer mentors. All SIParCS interns were supported by CISL mentors. Computing and simulation are fundamental to the scientific research projects of a majority of the SOARS protégés. And the SIParCS program focuses on computational science, applied mathematics, computer science, and the computational geosciences. Ten SOARS protégés participated in six of CISL's computing classes in FY2010. Ten SIParCS interns participated in the virtual summer school entitled Petascale Programming Environments and Tools. This event was organized by the Great Lakes Consortium associated with the Blue Waters project. It occurred simultaneously at 10 sites across the country that were linked together by Access Grid (AG) technology. NCAR's Visualization Lab served as one of the AG nodes and hosted 24 students. NCAR also provided supercomputing resources for the class.

For FY2011, Consulting Services will provide a new multi-day Fortran 90 class for students and early career scientists. Fortran is heavily used in scientific modeling, yet there are very few opportunities for students to obtain advanced training in this language. We plan to teach the course initially at NCAR but will also make the course materials available online via the NCAR Multimedia Services website and possibly via the TeraGrid portal.

Intern training is supported entirely by NSF Core funding.

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Education Imperative: Broadening Participation

The CISL Strategic Plan elevates education, outreach, and training (EOT) to a core mission of the laboratory, at the same level as providing supercomputing and data services and doing computational science research. A key element of this role is broadening the diversity of the organization, as well as attracting members of underrepresented groups to careers in high performance computing and the related scientific and technical disciplines.

CISL has aggressively expanded its EOT and diversity efforts in recent years. Programs such as the Summer Internships in Parallel Computational Science (SIParCS), the Research and Supercomputing Visitor Program (RSVP), and IMAGe's Theme of the Year (TOY) have each served as vibrant, growing, and inter-supporting elements in CISL's EOT strategy. As described below, CISL has also applied for and made effective use of supplemental NCAR Directorate Diversity Funds. Since 2008, CISL has established the practice of supporting at least one mission-appropriate "diversity" conference each year: in early FY2011 CISL will again co-sponsor the Colorado Celebration of Women in Computing. UCAR staff also distributes CISL EOT materials at diversity conferences such as the Society for the Advancment of Chicanos and Native Americans in Science (SACNAS). CISL does outreach to colleges and universities through presentations about its programs, making contact with students and faculty at educational institutions a key strategic element of our recruiting activities. SIParCS is also cross-listed on TeraGrid's internship website, allowing effective cross-marketing to occur. CISL distributes information at the annual Supercomputing Job Fair and at conferences such as Supercomputing, AMS, and AGU.

In FY2010 CISL planned to take its efforts to broaden participation to the next level by using special NCAR Diversity Funds, in most cases coupled with matching CISL Diversity Funds, to dramatically broaden and enhance CISL's diversity initiatives across all of its EOT activities. We proposed to do this in five ways:

1. Lower the barriers to training access by providing travel funds to two NCL data analysis and visualization workshops or other CISL cyberinfrastructure-related training workshops for students and staff from U.S. minority-serving institutions.
2. Leverage matching CISL diversity funds for our visitor program (RSVP) to encourage university research visitors from diverse backgrounds to visit CISL and NCAR, perhaps in concert with SIParCS or Theme of the Year (TOY) programs.
3. Expand CISL-based outreach activities to include participation in additional diversity-oriented conferences and institutions. Specifically, CISL staff will conduct up to four outreach visits to minority-serving institutions or diversity conferences in FY2010.
4. Use NCAR Directorate funding to build a critical mass of diversity candidates large enough to enhance the diversity-friendly environment of our SIParCS internship program.
5. Cover some of the costs of professional enrichment for SIParCS diversity interns, such as participation in or giving presentations or posters at technical conferences, publishing papers in peer-reviewed journals, or paying modest follow-on salary costs to complete or extend a project after the SIParCS term ends in August.

In FY2010 CISL offered travel support for all of its in-house training classes to attendees from MSIs. This offer was extended throughout the year for NCL DAV training, Fortran 90 classes, and the Virtual School of Computational Science and Engineering. These opportunities were announced via email to a list of contacts within the MSIs and minority-serving professional organizations. Two attendees were supported in this way, one from Hampton University in Hampton, Virginia and the other from the University of Arkansas in Pine Bluff, Arkansas. CISL core funds in the Research and Supercomputing Visitor Program (RSVP) were also used to provide analogous travel support for attendees from EPSCoR states. These states 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. CISL supported two attendees from EPSCoR states. When considered in the context of CISL's partnership with an EPSCoR state in developing the new NCAR-Wyoming Supercomputing Center, we consider this support to be an appropriate component of our overall EOT program.

One extended summer visit to the Institute for Mathematics in the Geosciences (IMAGe) was supported with these funds. The visitor was from Morehouse College in Atlanta, Georgia.

CISL also participated in a visit to NCAR by faculty from four Tribal Colleges in North and South Dakota for in-depth

discussions that included a presentation to three of the four (one had to leave early and could not attend) about CISL capabilities in the area of cyberinfrastructure, tools, and EOT. The tribal college attendees were from Sisseton Wahpeton College, Turtle Mountain Community College, United Tribes Technical College, and Fort Brethold Community College. A climate simulation DVD for classroom use was provided to the instructors. The issue of engaging students and faculty at tribal colleges was discussed and included the unique experience of Native Americans and challenges faced by their threatened culture; the infrastructure issues faced by tribal colleges due to their distance from resources; the general lack of programs for Native Americans in the Dakotas and at national laboratories; and the need to balance local curricula needs such as preparation for college and the workforce. We also discussed ways to provide teacher training for in-service faculty at tribal colleges, and this still requires follow-up.

In FY2010, two diversity interns were recruited for SIParCS: one was originally a SOARS applicant from Frostberg State University who was deemed best suited for the SIParCS program because of her interest in computer science, and the other was from a minority-serving institution, the University of Texas, El Paso. Support for these student internships was split evenly between CISL Diversity Funds and NCAR Diversity Funds. The student from Frostberg State did summer research entitled “Parallelizing Climate Model Analysis Using Swift.” Parallelizing the data workflow of climate models is a critical step to accelerating the rate of scientific discovery. There are already indications that the work done by this undergraduate student will be quickly adopted by the climate modeling community. The UTEP student performed research on “A Third-order Non-oscillatory Transport Scheme.” Non-oscillatory transport schemes are important for modeling the advection of material quantities, such as trace gases, in the atmosphere. Finally, 20% of the SIParCS class was female this year, an important milestone in engaging this underrepresented group in computer science and the geosciences.

One of our diversity-funded interns submitted a poster presentation to SC10, but it was not selected. However, while no other diversity-funded interns took advantage of the additional professional enrichment services we offered, at least two SIParCS students were supported using core funds, including one female statistitician, who wrote, “I wanted to thank you a wonderful summer working at NCAR... I also wanted to thank you for providing the funding for me to attend the ENVR conference at NCAR from October 13-16. I really appreciate this and cannot express my gratitude fully in words. This whole experience has truly been wonderful! Everyone at NCAR was very hospitable and wonderful to work with. I hope to return to someday NCAR to do further research. Again thank you for a lovely time.”

We consider professional enrichment support to be an important aspect of the SIParCS program, and we will continue developing innovative ways to offer it. In 2011, CISL plans to maintain and expand these programmatic elements in its ongoing EOT efforts.

CISL’s education imperative for broadening participation is supported by NSF Core funding with supplemental funding from other sources as noted above.

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Education Imperative: Outreach

Outreach is a gateway activity: it is the conduit through which all 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

John Dennis (CISL Scientist I, right) and Matthew Woitaszek (CISL Scientist I, center) describe CISL internship and career opportunities at the SC09 job fair. In this venue, young people can explore research and engineering employment at major laboratories and manufacturers. CISL will continue to seek qualified new staff at future Supercomputing job fairs.

As described in this section, CISL has significantly expanded its outreach efforts at mission-appropriate conferences, as well as those serving minorities and underrepresented groups. CISL has greatly broadened its contact list to include faculty at many more minority-serving and EPSCoR-state institutions. In 2010, for the first time, CISL has integrated information about its computational science internship, visitor, and training programs in its direct emails to these contacts. CISL has also begun using social networking media for this purpose. Finally, CISL continued to invest in completing the modernization of its Visualization Laboratory.

CISL's education imperative for outreach is supported by NSF Core funding, with supplemental funding supplied by other sources as appropriate.

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Visualization Laboratory outreach efforts

CISL's Visualization and Enabling Technologies Section (VETS) operates a visual computing center that is used to conduct many of CISL's education and outreach 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 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 video conferencing platforms.

Vislab staff support a video conference that connected over 200 students from across the nation at 10 different sites for a multi-day petascale computing course. The Vislab's video conferencing systems are used for classes and meetings that enable remote interactions with important collaborators, thereby reducing travel costs, lessening impact on the environment, and fostering geographically distributed research.

The Vislab remains an important resource for CISL's education and outreach efforts as it supports meetings and educational activities for thousands of staff and visitors. Activities in the Vislab span from maintaining advanced collaboration environments that foster geographically distributed research and communication, to supporting a sizable outreach program that provides 3D presentations to a wide range of student, governmental, and scientific visitors each year. The Vislab's implementation and support of collaborative technologies help enhance communication while minimizing the need for travel between 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.

In FY2010, the Vislab continued to support 3D demonstrations to help educate visitors about NCAR research and environmental and scientific issues such as global climate change and severe weather. Staff upgraded the audio conferencing technology to enhance the quality and control of audio systems within the Lab, added a RAID storage device to their display system to enhance performance, and explored mechanical sound mitigation options and sound cancellation technologies to suppress projector fan noise. Staff continued their productive partnership with the NCAR

Public Visitor Program to provide K-12 audiences with engaging 3D visualizations of environmental and Earth System science. The Vislab supported CISL's participation in a multi-day Virtual School of Computational Science and Engineering (VSCSE) workshop to connect local students with multiple remote sites across the country in a summer school petascale course. In all, the Vislab supported over 160 meetings and demos to over 2,200 visitors and users in FY2010, and use of the Vislab's collaborative technologies increased by over 40%. The Vislab also continued to develop new and engaging visualization material including an animation of a potential outcome of the 2010 Gulf Oil Spill that became part of a UCAR press release, was shown on all major television networks, posted to countless external websites, and received over 900,000 views on YouTube. The Vislab also developed a visualization for another press release on "Parting the Waters: The Physics of a Land Bridge." This release received over half a million views on YouTube, and brought NCAR/UCAR to the point of being the most popular non-profit channel on YouTube for a day shortly after its release.

In FY2011 the Vislab will continue to provide support for 3D demonstrations to help educate NCAR visitors and the public about NCAR research and environmental and scientific issues. We will continue to provide video conferencing capabilities and a venue for scientific interviews with the broadcast media as well as digital materials upon request for broadcast and educational purposes. We will also continue our productive partnership with the NCAR Public Visitor Program to provide K-12 audiences with engaging 3D visualizations of environmental and Earth System science, including participation in and sponsorship of the MESA to Mesa Diversity Project to expose under-served math, engineering, and science student populations to the scientific tools and processes for modeling and visualizing scientific data. Additionally, we will explore implementing several equipment upgrades that will 1) enhance communication and information sharing between both local and remote meeting participants, 2) generate real-world 3D imagery for more engaging presentations, and 3) provide additional HD camera and microphone coverage.

The Vislab and VETS staff play an important role in advancing CISL's education imperative for outreach. This work fulfills the strategic action item for CISL to tell NCAR's story to the world. Specifically, it will continue and expand successful partnerships with the NCAR Public Visitor Program, Office of Government Affairs, and others to engage a broader and more diverse scientific community. The Vislab will create new and engaging visualization material and environments that will help capture the interest of and educate K-12 students, scientific, corporate, and government visitors, as well as the general public about NCAR research and societally relevant environmental and Earth System science. We will continue to make use of social networking by continuing productive collaborations with UCAR outreach programs. The Vislab will also upgrade and expand our collaboration and display technologies as needed.

This project is supported by NSF Core funding.

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Outreach activities at conferences

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 Geophyscial Union, and others. In recent years, CISL has focused its energy and resources on providing NCAR outreach at the annual Supercomputing and TeraGrid 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.

As part of NCAR's exhibit at SC09 on 17-19 November 2009, Sylvia Murphy of the collaborative Earth System Modeling Framework project presented a talk on implementing CMIP5 metadata in the Earth System Grid gateway. CISL conducts outreach activities using exhibit booths at the yearly Supercomputing conference, the TeraGrid conference, and other venues. By representing NCAR's science and technology efforts every year at gatherings of researchers, CISL shares its expertise with the research community and gains valuable insights in return.

CISL's outreach activities at SC09 included five daily science and technology presentations in the exhibit booth; at the SC09 Career Fair, two computational scientists described CISL's internship and career opportunities. CISL invited two NCAR scientists to give daily science talks in the exhibit booth shown above. Matthias Rempel (HAO Scientist III) presented the talk "Radiative MHD simulations of sunspot fine structure." He explained how NCAR scientists and colleagues modeled sunspots in a comprehensive 3D computer simulation, giving researchers their first glimpse below the visible surface to understand the underlying physical processes. Travis Metcalfe (HAO Scientist II) presented "NASA's Kepler mission and the quest for distant Earths." He described NASA's Kepler space telescope and the TeraGrid Science Gateway developed at NCAR that will be used to determine the true physical sizes of the stars and planets observed by the satellite. Sylvia Murphy, in her role with CISL's Earth System Modeling Framework project, presented

"Implementation of CMIP5 Metadata in the Earth System Grid Gateway." Anke Kamrath, CISL Operations and Services Division Director, presented "NCAR: On the road to a Petaflop computer." Mary Haley (CISL Software Engineer III) presented "Community Tools for Analysis and Visualization of Geoscientific Data."

In addition to its EOT efforts at SC09 in Portland, Oregon on 14-20 November 2009, CISL presented its science and technology efforts and plans at TeraGrid'10 in Pittsburgh, Pennsylvania on 2-5 August 2010.

Also in FY2010, CISL initiated collaborations with a variety of Wyoming organizations and began planning education and training programs and educational exhibits tailored to the new supercomputing facility being built in Cheyenne. The NWSC Education and Outreach Strategic plan, which was collaboratively written in FY2009 by the 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.

John Dennis (CISL Scientist I, right) and Matthew Woitaszek (CISL Scientist I, center) describe CISL internship and career opportunities at the SC09 job fair. In this venue, young people can explore research and engineering employment at major laboratories and manufacturers. CISL will continue to seek qualified new staff at future Supercomputing job fairs.

The NWSC education exhibit is being planned to inform K-12 students and the public about how high performance computing supports and advances scientific research and discoveries. The exhibit will be developed and produced in FY2011 and will be complete for the NWSC opening in FY2012.

In FY2011 and in coming years, CISL will continue to provide TeraGrid external relations support at the Supercomputing and TeraGrid conferences. The theme of the SC10 conference in November 2010 will be climate change, so CISL's exhibit booth will feature two of NCAR's senior climate scientists in addition to speakers highlighting computational science and providing overviews and updates about the NWSC. Also at SC10, a computational scientist and a computer engineer will staff a table at the job fair to reach out to early-career scientists and engineers by providing information about CISL's education and employment opportunities.

CISL's conference 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.

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Education Frontier: Transforming Education, Outreach and Training

CISL is beginning to leverage information technologies to transform education, outreach, and training (EOT). High performance computing has emerged as an essential research tool in science, technology, engineering, and mathematics. Information technology has global reach; it powerfully amplifies the scale and impact of EOT efforts, can connect widely distributed groups for educational purposes, and through open access to data, has the potential to level the educational playing field. However, universities across the country are struggling with integrating high performance computing in their educational programs. One reason is that the computing power driving this "computational science revolution" demands increasing power, space, and cooling for the equipment. The revolution is becoming a facilities headache for universities. Furthermore, the architecture of these systems is increasingly complex with intricate memory hierarchies and high levels of parallelism, all features that increase programming complexity. Graduate students' ability to complete their dissertations is, in many cases, increasingly constrained by their access to high performance cyberinfrastructure and their skill as programmers, or even worse, as system administrators.

In FY2010, CISL began exploring several possible ways to address these challenges:

- We began developing asynchronous, web-based teaching materials from our popular Fortran 90 class. We expect these Fortran 90 teaching materials to be available in FY2011.
- At the recent TeraGrid 2010 meeting in Pittsburgh, Pennsylvania, a computational scientist at Purdue University, Lan Zhao, presented the results of using a CCSM3 modeling portal they had developed as an educational resource for students in a Climate Policy course at Purdue. Based on this very successful outcome, NCAR and Purdue have agreed to build on the existing Earth System Grid collaborations between the two institutions to 1) develop the robustness of the modeling portal further; 2) upgrade it to CCSM4; 3) integrate the CCSM modeling portal with the existing ESG federation work between NCAR and Purdue; 4) Deploy a computational resource to host a CCSM portal at NCAR (the computing resource under consideration for this step is a portion of NCAR's 9.8% of the CU MRI system, Janus); and 5) identify one or two university professors willing to serve as friendly users of the system as it rolls out.
- We are investigating new ways of developing active education and research partnerships with universities in computational Earth System science. CISL's interest in working with regional university partners is based on the vision of building computing-based collaborations with these universities that would foster the growth and development of a regional distributed CI around the proposed NCAR-Wyoming Supercomputing Center. In FY2010 NCAR worked with the University of Colorado (CU) to integrate, test, and deploy a 184-TFLOPS supercomputer, Janus, at the university. CISL staff served on the Colorado School of Mines (CSM) resource allocation panel for their 22-TFLOPS Intel system, Ra, and participated in a joint NCAR-CSM symposium on computational science held on the CSM campus. In FY2010 CISL staff also provided cyberinfrastructure planning advice to CU, CSM, and the University of Wyoming. In FY2011 we intend to federate data storage and analysis resources located at NCAR with the CU cyberinfrastructure over a high-speed WAN link running at 10 to 40 Gbps. Our plan with other regional partners is to entrain students and faculty at local universities around issues of common interest. For example, these regional universities have proven to be a good source of student interns, many of whom have been used in projects related to cyberinfastructure development. For example, CU, CSM, and U Wyoming have each had at least one student intern in the SIParCS program since its inception in 2007. Thus, our efforts in this area foster the growth of a regional workforce qualified to tackle important computational science problems.
- In FY2010, CISL's Outreach Group began developing social networking technologies as vehicles for outreach activities. In FY2010 for example, CISL used Twitter® to draw attention to the SIParCS program and created two FaceBook® pages for networking both current and former interns. In FY2011, we plan to increase the usage of social media sites in both outreach and community-building roles.

In FY2011 CISL expects to achieve the following objectives:

1. Successfully complete deployment of the Janus system at CU in partnership with CU's Research Computing department.
2. Deploy a working prototype of the CCSM portal on Janus, the CU MRI system, using Grid infrastructure.
3. Assist in the University of Wyoming's acquisition and deployment of cyberinfrastructure.

4. Continue to expand the role of social networking software as a medium for attracting, linking, informing, and tracking current, prospective, and past SIParCS interns.

CISL's exploration of the education frontier for transforming EOT is supported by NSF Core funding and by TeraGrid Grid Integration Group funding through the Office of Cyberinfrastructure.

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CISL Fabrics

CISL's Fabrics are ethical standards that guide our actions and bind us together as a unit. CISL defines Fabrics as shared values that become daily habits so ingrained that they are almost invisible, yet they are strong forces that guide our actions.

CISL has identified six Fabrics that we consider the most crosscutting, key contributors to our success as a laboratory, namely:

- Service: Serving the scientific community is a CISL core value. Everything we do should either directly or indirectly support NCAR's science mission.
- Innovation: Information technology is a rapidly changing field. CISL must continually innovate to facilitate scientific progress.
- Leadership: A willingness to lead is another essential characteristic in a rapidly changing and forward-looking field such as information technology. Within CISL, leadership means asking what the next big thing is, or what needs to be done, then taking action to bring those things about.
- Collaboration: Collaboration is important: no organization can do everything. What is more, collaboration is especially important to an interdisciplinary laboratory: it fills gaps in resident expertise, infuses new ideas, and amplifies CISL's impact.
- Mentorship: All parties gain by mentoring: those being mentored benefit from the learning, experience, and insight of the mentor; for the mentor, it establishes a culture of giving, reinforces the habit of service, and encourages lifelong learning. Both top-down and peer-to-peer mentoring must be encouraged.
- Diversity: Promoting diversity in CISL's workforce not only improves the breadth of perspectives, approaches, and experience we bring to solving our problems, it also maximizes the size of the applicant pool.

CISL strives to infuse these values throughout all facets of the organization, instilling them in the people who work for and with us.

This section of the FY2010 CISL Annual Report reports on the topics shown in the navigation tool at left.

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Service Fabric

Service is a core Fabric that contributes to our success as a Laboratory. We strive to inculcate and measure this Fabric throughout the organization. The metrics listed below are specific to CISL's mission; they supplement the standardized metrics CISL reports in the NCAR Annual Report.

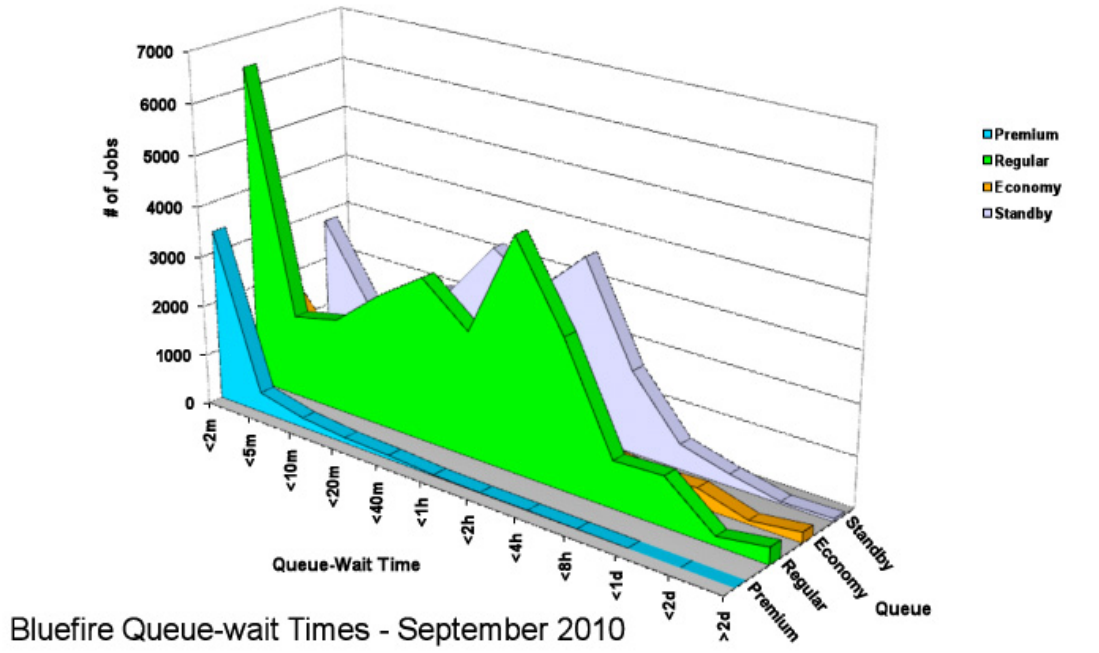
Serving the scientific community is a CISL core value, and it is one of the highest priorities of NCAR's facilities, research, and operations units. The Service Fabric is characterized by the following behaviors: valuing the science mission; understanding and empathizing with the user experience; listening and communicating effectively; and delivering services fully consonant with user requirements. CISL recognizes the role of a service mindset to its mission and uses its staff to a) analyze user requirements and needs, b) maximize use of facility resources for the science mission, c) share expertise within the internal and external service communities, and d) implement best practices to ensure the delivery of services and projects in an effective, efficient, and transparent manner.

Metric 1: System uptime, queue wait times, MSS response times, MSS archive policies, trouble ticket resolution metrics

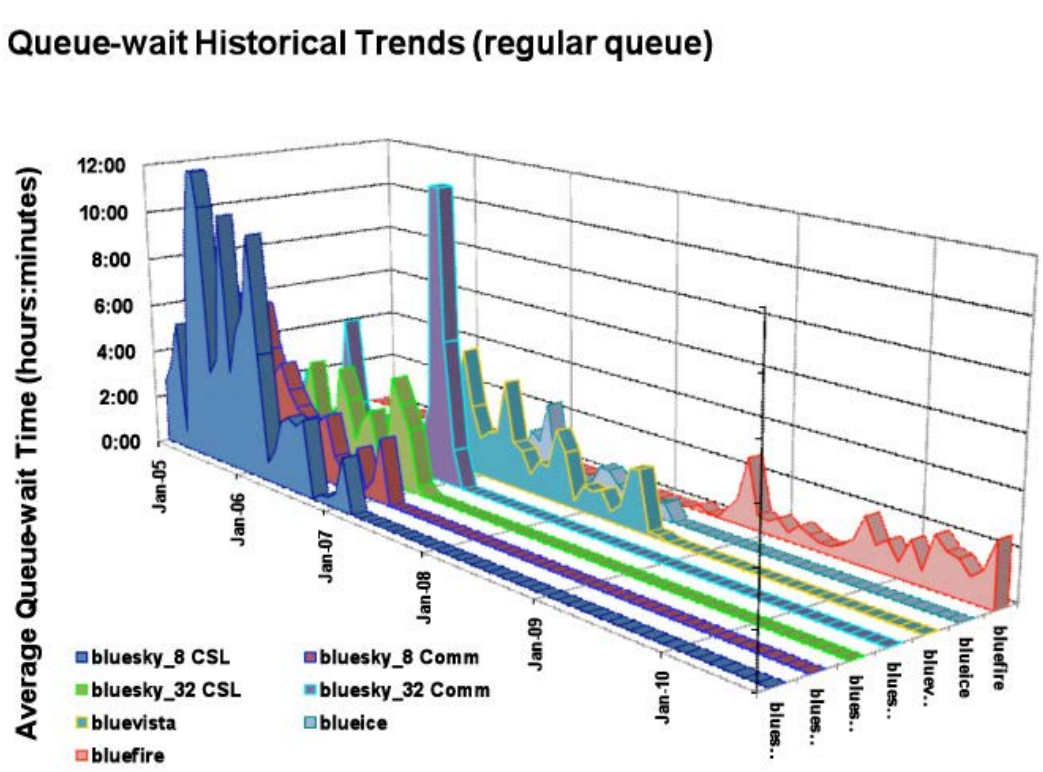
Service metric 1 is tracked in numerous areas throughout the NCAR computing facility.

Computing systems

During FY2010, CISL continued real-time monitoring of HPC and archival storage systems not only for the subsequent analysis of system workload and behavior, but for real-time operational event monitoring and notification. The former provides the basis for long-term analysis of computing and storage trends while the latter enables a more rapid notification of and response to operational issues when they arise.

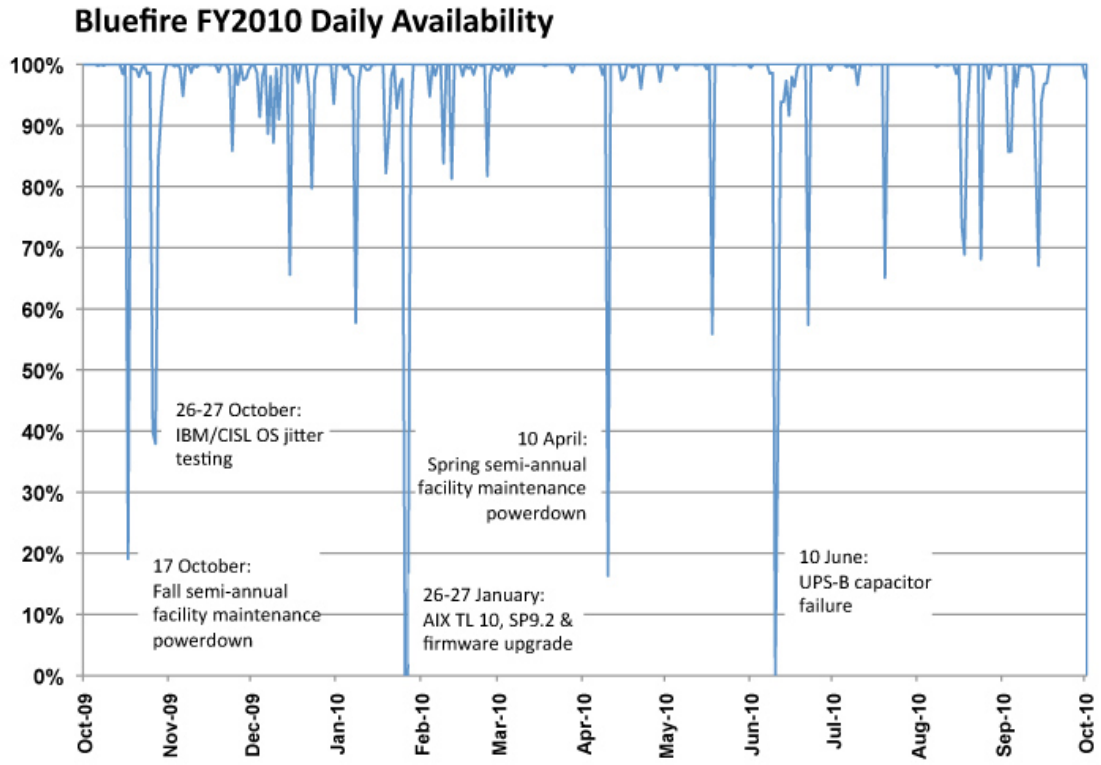


Monitoring job queue-wait times on NCAR HPC systems and analyzing trends are ways CISL evaluates the quality of its service to the user community.



While increased computational demand for CISL HPC resources and the resulting production workload caused average queue-wait times to rise from about one hour to just over two hours during FY2010 on Bluefire, they are still below the queue-wait times observed three or more years ago on predecessor HPC systems.

Overall system utilization, individual job utilization and job-based and system-wide computational efficiency are monitored continuously to generate daily, weekly, and monthly reports. Some analyses, such as a daily accounting of jobs that used Bluefire inefficiently, are provided to CISL's Consulting Services Group who can then help individual users improve the performance of their applications.



Real-time monitoring of Bluefire's operational health allows CISL to track overall system availability to users. Incident analysis

and component failure tracking also provide insights into trends observed during routine monitoring.

The primary HPC workhorse during FY2010 was the 77-teraflop IBM Power 575 cluster Bluefire, which exhibited an average 96.2% availability and 92.9% system-wide user utilization during the fiscal year. To augment CISL's computational capacity and ease some pressure on Bluefire, CISL acquired an 8-teraflop Cray XT5m system named Lynx as a test platform, and access was then provided to a set of "friendly users." Lynx was accepted at the end of April. Lynx exhibited an average 94.7% availability and 54.6% system-wide user utilization during FY2010, which is quite good for a "test system." Real-time monitoring, failure and incident analysis, and enhanced operational and administrative procedures allowed CISL to respond rapidly to component failures and performance issues.

CISL established a Science Advisory Panel as well as technical and business evaluation teams to collaborate on developing technical specifications for the HPC, data storage, data archive, and related equipment to be installed at the NWSC in FY2012.

During FY2011, CISL intends to continue real-time monitoring of our HPC systems and their workload, and to characterize workload performance, system responsiveness, and reliability. We will also investigate additional ways to identify outlier cases such as underperforming applications or unanticipated trends in system utilization and workload performance.

CISL, via the UCAR Contracts office, will release one or more Requests For Proposal in FY2011 for NWSC HPC and related systems, evaluate the tendered proposals. CISL intends to select and award contracts for that equipment by fiscal year end.

Data archival equipment

In FY2010, the migration of over 6 TB of data stored on older media to the new higher-speed, higher-density AMSTAR equipment was completed in April, well ahead of the December 2010 deadline. The effective data transfer rate on the new AMSTAR equipment is measurably higher than on the old media. HPSS was placed into production in FY2010 and is running in parallel with the NCAR MSS in preparation for the decommissioning of the NCAR MSS in FY2011. Many HPSS user transition documents were developed and placed on the CISL website. Group and one-on-one transition meetings were held to inform users of the changes required to access and manage data stored in HPSS.

In FY2011, the MSS-to-HPSS transition is scheduled for mid-FY2011. All data existing in the MSS at the time of the transition will automatically appear in HPSS. HPSS metrics and monitoring tools will be developed to ensure that HPSS responsiveness and performance matches or exceeds that of the NCAR MSS. Hierarchical Storage Management (HSM) functionality between GLADE (a high-performance shared filesystem) and HPSS will be investigated in FY2011. Initially targeted at project-oriented data storage space on GLADE, the HSM functionality can logically extend the amount of data that is directly available through GLADE by caching active data on rotating disk and transparently recalling less frequently used data stored on tape to the end user.

Customer service work request system

CISL's trouble ticket system provides statistics on speed of problem resolution and other key metrics, as well as metrics similar to the TeraGrid's help-desk metrics. An example of some average metrics is given in the following table; the Computer Production Group (CPG) initially reviews all tickets and either resolves problems or passes more complex problems to the Consulting Services Group. CISL is planning further enhancements of the trouble ticket system and its monitoring and metrics analysis capabilities for FY2011 in anticipation of the operational transition to the NWSC.

FY2010 CISL Consulting Services	CPG	CSG
Number of tickets	1,761	794
Number of incident updates	9,419	4,338
Average resolution time (days)	0.7	5.9
Average number of staff on ticket	1.1	1.1

Research Data Support

The NCAR Research Data Archive (RDA) grew continuously throughout FY2010 as many collections were routinely updated. Adding new key reference datasets also enriches it. This year the major additions were the high-resolution ERA-Interim Reanalysis and Year of Tropical Cyclone data from ECMWF, 20th Century Reanalysis from NOAA/CIRES, and the International Comprehensive Ocean-Atmosphere Data Set (COADS) from NCAR and two NOAA partners. The monthly and hourly time series products from NOAA Climate Forecast System Reanalysis (CFSR) were also added, and they will be supplemented with the 6-hourly 3D atmosphere products next year.

Data access is a key service fabric. User access will improve in FY2011 with the IT transition of the RDA development and services to the new GLADE storage (the disk-based GLobally Accessible Data Environment) and a new cluster of Linux servers. This will transform the RDA to have higher capabilities for data receipt, greater server-side computing resources, and easier access both via the web and at NCAR. Online publically available RDA data will grow from 40 TB to 250 TB.

Metric 2: User surveys

During FY2010, CISL surveyed its HPC users to evaluate its effectiveness in providing computational and data storage to support their needs, and to identify specific strengths and weaknesses in its services. CISL also conducted a Data Workflow Survey to understand specific user needs related to data and data management to improve the CISL environment and to understand upcoming needs for the NWSC environment. The results of the HPC user satisfaction survey are helping guide CISL in its transition of operations from the NCAR Mesa Laboratory to the NCAR-Wyoming Supercomputing Center.

HPC User Satisfaction Survey

In June 2010, CISL invited 1,141 users from NCAR and the university community to participate in a user satisfaction survey to identify specific strengths and weaknesses of its HPC environment. Of those users, 344 participated in the survey with a strong response rate of 30%. Just fewer than half of the respondents were from universities, about one-third were from NCAR or UCAR, and the remainder were from other types of institutions such as government agencies or non-profit research centers. Survey questions covered topics ranging from the user environment and capabilities of CISL's IBM Power6 cluster Bluefire to software usage, data analysis and visualization resources and software, user support services, use of the RDA, and accounting and allocations.

Overall, the survey showed that users as a whole were satisfied with most aspects of the CISL HPC environment, rating many aspects of Bluefire and customer support at 4.0 or better on a 5 scale (4 represents a response of "satisfied"). However, the survey responses did point to a number of areas for improvement that CISL has taken steps to address in FY2010 and will continue to improve in FY2011. The top issue identified by users was insufficient disk space to support their work on both Bluefire and the Data Analysis and Visualization (DAV) clusters. The same limitation was likely a contributing factor to dissatisfaction with the performance of the Mass Storage System (MSS). Additional areas identified by users included the six-hour wallclock limit on Bluefire, and the availability and accuracy of documentation, accounting data, and other information about the environment.

CISL moved forward with several activities in FY2010 that directly address some of these key concerns. Most significantly, CISL worked aggressively toward the deployment of the GLADE central shared file system. In addition, CISL's User Services Section began an effort to evaluate, reorganize, and update the documentation available to users.

Data Workflow Survey

In July 2010, CISL invited 457 users from NCAR and the university community to participate in a user survey about their data workflows and how they manage data on CISL's HPC resources. Of those users, 167 provided at least partial responses to the survey for a response rate of 36%. Survey questions focused on topics related to data workflow encompassing both CISL's supercomputing resources and CISL's Data Analysis and Visualization resources. The main goal of the survey was to measure how well the new GLADE environment might meet current and future data management needs, allowing us to refine CISL's Data Architecture for the NWSC.

NETS survey of UCAR staff

CISL's Network Engineering and Telecommunications Section (NETS) surveyed UCAR staff between 1 August and 1 September 2009. The survey was used to evaluate and improve networking services at UCAR. Partial responses were received from 196 people, and 179 people completed the survey. In FY2010, NETS evaluated the results in conjunction with the Network Coordination and Advisory Board and took a number of actions to improve services and communication for users.

User Survey plans for FY2011

In FY2011, CISL will continue to pursue a number of improvements to priority areas identified by users in the FY2010 user survey. In particular, the GLADE central file system will enter production in the first quarter of FY2011, responding to user challenges with the limited disk space on CISL resources. The GLADE deployment will also be leveraged by the RDA to make larger data sets accessible on disk, rather than on tape, to address user-identified bottlenecks. This file system will dramatically increase the rotating storage available to CISL users, and we expect it to address many of the concerns noted in the FY2010 survey.

Overall, the FY2010 data workflow survey showed that users as a whole were satisfied with most aspects of the CISL environment. However, the survey responses did point to a number of areas for improvement that CISL has taken steps to address in FY2010 and will continue to improve in FY2011. The top issue identified by users was insufficient disk space to support their work on both Bluefire and the Data Analysis and Visualization clusters. This is being addressed with the GLADE deployment in the first quarter of FY2011, and user satisfaction will be monitored leading up to deployment of the larger data environment at NWSC in FY2012.

Further, many other smaller-scale activities will address other user concerns identified in the survey. The Data Support Section, for example, is considering producing an audio/video tutorial about the Research Data Archive to help researchers use its various data discovery tools, which the survey indicated is sometimes confusing for users.

CISL traditionally surveys NCAR supercomputing users every two years. In FY2011 CISL will begin planning for the next user survey, to be conducted in early FY2012. In addition to gauging the performance of CISL staff and services in FY2011, the survey will collect input from users to further refine plans for the NWSC environment.

Metric 3: Community service activities

CISL staff serve the research community in a variety of ways. The following table summarizes our FY2010 service, and

full details are available in a spreadsheet accessible at the end of NCAR's annual Metrics Highlights report.

Number of staff	Type of service
14	Editorships
70	External committee service
206	Scientific and technical presentations
3	Colloquia, symposia, and tutorials hosted
17	Conferences and workshops hosted
10	Teaching appointments
14	Advisors on graduate research
8	Dissertation or thesis committee memberships
26	Advisors to students and postdocs
4	Service to K-12 schools
4	Awards from external organizations
1	Fellowships

Metric 4: CISL Incentive Awards for service

Twice each year, CISL recognizes outstanding staff performance by presenting awards at all-staff meetings. In FY2010, 13 staff received awards for outstanding service:

Awardee	Reason for Service Award
Nancy Collins	Producing an ensemble data assimilation system for the POP ocean model component of CCSM.
Jeph Cowan	Repurposing supercomputer management servers.
Irfan Elahi	Repurposing supercomputer management servers.
John Ellis	Repurposing supercomputer management servers.
Susan Guastella	Creating the invoice management system for UCAR and the FRGP.
Nathan Hearn	Producing an ensemble data assimilation system for the POP ocean model component of CCSM.
Tim Hoar	Producing an ensemble data assimilation system for the POP ocean model component of CCSM.
Ziahua Ji	Developing an extensive, robust, and scalable toolkit that is critical for RDA growth, maintenance, and user access.
Ryan McVeigh	Rebuilding the Visualization Laboratory with next-generation capabilities.
Kevin Raeder	Producing an ensemble data assimilation system for the POP ocean model component of CCSM.
Tim Schietlin	Rebuilding the Visualization Laboratory with next-generation capabilities.
Hannah Wilcox	Leadership in delivering a community release of CADIS.
Steve Yeager	Producing an ensemble data assimilation system for the POP ocean model component of CCSM.

CISL also provides incentive awards for **Innovation**.

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Innovation Fabric

Innovation is a core Fabric that contributes to our success as a Laboratory. We strive to inculcate and measure this Fabric throughout the organization. The metrics listed below are specific to CISL's mission; they supplement the standardized metrics CISL reports in the NCAR Annual Report.

Innovation is the transformation of creative ideas into better products and services or new approaches for solving problems. It is expressed as an attitude of curiosity, creativity, and skepticism toward the status quo. The integration of operations, technology transfer, and scientific research (often in matrixed projects) within CISL facilitates innovation because our staff is encouraged to see opportunities and problems from new and broader perspectives. All external research proposals are reviewed at the Lab level, and this also presents an opportunity to make connections between new ideas and needs in other parts of the Lab. Working within the Mesa Lab facility's power constraints and accommodating an exponential growth of archival storage have created an ongoing climate of innovation: power is related to UCAR's carbon footprint, and storage must meet the I/O requirements of petascale simulations. We recognize and reward innovation among staff at the semi-annual CISL town meetings.

Metric 1: External and internal awards for innovation

Two external organizations recognized CISL innovations in FY2010.

In the TeraGrid'10 research paper competition concluded in August 2010, the Best Technology Track Paper award was presented to CISL authors Pablo Minnini, Duane Rosenberg, Raghu Reddy, and Annick Pouquet for "Investigation of Performance of a Hybrid MPI-OpenMP Turbulence Code." This work describes "a hybrid scheme that utilizes MPI for distributed memory parallelism and OpenMP for shared memory parallelism" and "is motivated by the desire to achieve exceptionally high Reynolds numbers in pseudospectral computations of fluid turbulence on emerging petascale, high core-count, massively parallel processing systems. ... The hybrid paradigm leads to a new picture for the domain decomposition of the pseudospectral grids.... ... Details of the hybrid implementation are provided, and performance tests illustrate the utility of the method. It is shown that the hybrid scheme achieves near ideal scalability up to 20,000 compute cores with a maximum mean efficiency of 83%. Data are presented that demonstrate how to choose the optimal number of MPI processes and OpenMP threads in order to optimize code performance on two different platforms."

On 1 April 2010 the Community Climate System Model Version 4 (CCSM4) release incorporated, for the first time, HOMME as a dynamical core option. The HOMME spectral element dynamical core on a cubed-sphere grid vastly increases the computational scalability of the Community Atmosphere Model (CAM), the atmosphere component of CCSM4.

Internal awards. Twice each year, CISL recognizes outstanding staff performance by presenting awards at all-staff meetings. In FY2010, three staff received awards for their innovative contributions to the Laboratory's goals:

Awardee	Reason for Innovation Award
Pablo Mininni	Developing hybrid parallelization of the pseudospectral code GHOST
Alan Norton	Application of VAPOR visualization software to the numerical weather community
Duane Rosenberg	Developing hybrid parallelization of the pseudospectral code GHOST

CISL also provides incentive awards for **Service**.

Metric 2: Early adoptions of new technologies and evaluations of emerging standards

Each year, CISL strives to:

- Evaluate major procurements with respect to innovative components
- Track unique services, functions, and products that are not provided by other HPC centers and research groups

Track energy efficiency relative to other data centers

In FY2010, CISL's Data Support staff released an innovative user access feature for the Research Data Archive (RDA). Moderately experienced users can now directly access single 2D parameter grids from the RDA in an automated way. Both Unix and Windows users are offered access to the archive using cURL, a command-line tool that supports URL-based Internet transfers. From the home pages of various datasets, this Internet access option generates cURL HTTPS commands for users; these commands are then run in a script on the user's computer. This extracts the user-selected parameter fields from datasets and files, then transfers them to the user's host computer. This is especially useful for terabyte-sized datasets with large files containing many (possibly unneeded) parameters. Experienced users recognize the file-naming pattern in their first example, then customize their scripts to routinely acquire new data as it is added, thereby avoiding the less-efficient GUI we offer for beginners. Some notable datasets that have this feature include TIGGE, Climate Forecast Reanalysis, NCEP operational model output, and NCEP operational Final Analysis.

In FY2010, CISL's Distributed Services Group began deploying host virtualization in the operational environment. This reduces the number of physical computers requiring support for tasks such as e-mail virus scanning, software distribution hosting, and special-purpose websites. We are also using virtualization to provide individual Drupal sites for UCAR groups, with centralized configuration management using the "puppet" tool.

As in other innovative efforts throughout CISL's history, the NWSC has interwoven innovation into the entire design process. The primary purpose of the NWSC is to provide a productive computing environment to advance science, but we will accomplish this in the most efficient way possible. Maximizing energy efficiency makes good sense both economically and environmentally. CISL combined its expertise and an understanding of future computing platforms with its facilities expertise to take a whole-systems approach to design. Every system and every component was scrutinized to develop what should be a truly world-class demonstration of energy efficiency that will be combined with CISL's dedication to productivity.

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Leadership Fabric

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Leadership is defined as a process by which a person or group a) influences others to accomplish an objective, or b) directs the organization in a way that makes it more cohesive and coherent. A willingness to lead is an essential characteristic in a rapidly changing and forward-looking field such as information technology. Within CISL, leadership means asking what the next big thing is, or what needs to be done, then taking steps to bring those things about. Ways in which leadership can be measured as a quality, both internally and externally, are through stature among peer organizations, awards for excellence, and participation in formal leadership training.

Metric 1: Community service activities led and panels chaired

CISL staff are frequently asked or invited to make presentations on topics for which they are considered experts. They also participate on or provide chairperson guidance to advisory or steering panels that peer organizations use to establish directions for future endeavors. In FY2010, six CISL staff members served as chair or co-chair of six external scientific, technical, policy, and educational committees, and one served as a lead author for an external committee.

Metric 2: Awards and other forms of recognition received from outside organizations

Four CISL staff members received awards from outside organizations in FY2010.

Metric 3: Staff participating in formal leadership training

As CISL staff advance in their careers, they are encouraged to take formal leadership training as appropriate. UCAR provides two such programs, the UCAR Leadership Academy and the Executive Leadership Program. Three CISL staff completed the UCAR Leadership Academy in FY2010.

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Collaboration Fabric

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Collaboration is very important to an interdisciplinary laboratory: it fills holes in resident expertise, infuses new ideas, and amplifies CISL's impact. It manifests itself through a spirit of inclusion, openness, and a resistance to the "not invented here" syndrome. CISL strives to maintain strong collaborative relationships at all levels: within CISL divisions and sections, across NCAR laboratories and UCAR programs, and outward to the academic programs of universities, scientific research laboratories, and peer international research and computational facilities.

Metric 1: Collaborators and visitors attracted to CISL

Formal collaboration programs within CISL are promoted through activities such as RSVP and IMAGe's Theme-of-the-Year (TOY). The number of visitors to CISL and NCAR are recorded to quantify these collaborations. In addition, CISL has historically maintained collaborations with visitors from universities, federal research laboratories, and international research facilities. The types of collaborations include:

- Co-investigators on agency proposals
- Co-investigators on innovative research topics that result in co-authored reports and/or peer-reviewed scientific papers
- Memos of Understanding (MOUs) that allow for common facility challenges and/or successes to be shared and discussed

In FY2010, CISL conducted formal collaborations with 206 partner organizations.

IMAGe and CISL hosted a total of 131 visitors in FY2010.

Metric 2: Visits made by CISL staff to universities and government laboratories for collaborative purposes

CISL will begin tracking this metric in FY2011.

Metric 3: Collaborative proposals written and funded

CISL staff maintains strong collaborative relations with internal and external colleagues by writing proposals for funding from multiple external agencies. These proposals request funds for projects that act to benefit NCAR or the collaborators or both. We track the success, and resulting awards, of these proposals to provide guidance for future responses and submissions to agency announcements of opportunity.

In FY2010, CISL's Technology Development Division (TDD) and IMAGe submitted 28 collaborative proposals and 5 were funded during the fiscal year.

Metric 4: Joint appointments

In FY2010, IMAGe supported five staff on joint appointments with other NCAR divisions and UCAR programs, and TDD supported two. TDD also supported one joint appointment with an outside institution.

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Mentorship Fabric

Mentorship is a core Fabric that contributes to our success as a Laboratory. We strive to inculcate and measure this Fabric throughout the organization. The metrics listed below are specific to CISL's mission; they supplement the standardized metrics CISL reports in the NCAR Annual Report.

All parties gain by mentoring: those being mentored benefit from the experience and insight of the mentor; for the mentor, it inculcates a culture of giving, reinforces the habit of service, and encourages lifelong learning. Seen this way, SOARS and the CISL summer internship and visitor programs (SIParCS and RSVP) are opportunities for improving and enriching our work experience through mentorship. CISL has a substantial history of providing mentors in these programs.

Metric 1: CISL staff involvement in formal mentoring roles

In FY2010, CISL staff members served as:

- SIParCS research mentors: 14 mentors for 20 interns; in addition 3 more CISL staff served as co-mentors.
- SOARS computing mentors: 2 mentors for 3 protégés.
- SOARS writing mentors: 1 mentor for 1 protégé.
- Advisors on graduate research: 14 advisors to 14 graduate students.
- Advisors to graduate research assistants: 2 advisors to 2 graduate students.
- Advisors to undergraduate research assistants: 9 advisors to 9 undergraduates.

In FY2011, CISL will continue to investigate ways to formalize the mentorship of CISL staff by CISL staff. Relevant practices include supervisor-to-employee mentoring, succession planning, and peer mentoring.

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Diversity Fabric

Diversity is a core Fabric that contributes to our success as a Laboratory. We strive to inculcate and measure this Fabric throughout the organization. The metrics listed below are specific to CISL's mission; they supplement the standardized metrics CISL reports in the NCAR Annual Report.

Promoting diversity in CISL's workforce not only improves the breadth of perspectives, approaches, and experience we bring to solving our problems, it also maximizes the size of the applicant pool. In CISL, the diversity fabric is characterized by an environment that welcomes, values, and respects different backgrounds, points of view, and lifestyles.

CISL's contributions to training a diverse workforce depend partly on the quality of mentorship throughout the lab. The visitor programs also provide a useful platform for enhancing diversity as well as advertising research and training opportunities at universities with large populations of students from under-represented groups. Finally, CISL's education and training programs actively recruit for candidates who meet diversity criteria.

Metric 1: CISL staff visits to universities and conferences for encouraging a diverse visitor pool

CISL attracts students from diverse backgrounds at the annual Supercomputing Conference Job Fair. CISL also supports at least one mission-relevant "diversity" conference each year, and provides internship and career brochures to NCAR and SOARS staff who exhibit at the annual conferences of the American Meteorological Society (AMS), the American Geophysical Union (AGU), and the Society for Advancement of Chicanos and Native Americans in Science (SACNAS).

In FY2010, CISL's Director of Technology Development participated in a visit to NCAR by faculty from four Tribal Colleges in North and South Dakota for in-depth discussions about CISL capabilities in the area of cyberinfrastructure, tools, and EOT. A climate simulation DVD for classroom use was provided to the instructors. The issue of engaging students and faculty at tribal colleges was discussed and included the unique experience of Native Americans and challenges faced by their threatened culture; the infrastructure issues faced by tribal colleges due to their distance from resources; the general lack of programs for Native Americans in the Dakotas and at national laboratories; and the need to balance local curricula needs such as preparation for college and the workforce. We also discussed ways to provide teacher training for in-service faculty at tribal colleges, and this still requires follow-up.

CISL will again support at least one diversity-broadening conference in FY2011.

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CISL Profiles in Science

At fiscal year end, CISL scientists write reports to summarize their research efforts, discoveries, publications, innovations, and other accomplishments. These documents may describe the work of individuals or teams. Some of these reports are archived here as "Profiles in Science."

The following reports describe CISL science in FY2010:

Data Support, ERA-Interim Reanalysis Data

Grabowski, Wojciech, Multiscale simulations of droplet-laden turbulent flows

Lenschow, Donald, A Study of Vertical Transport and Reaction of Isoprene in the Convective Boundary Layer (CBL) with a Second-Order Closure Model

Lenschow, Donald, Applications of Lidar Technology and Large Eddy Simulations to Turbulence Problems in Wind Energy

Patton, Ned, Canopy Turbulence

Pouquet, Annick, MHD turbulence at high Reynolds number

Pouquet, Annick, Numerical simulations and modeling of rotating turbulence

Rosenberg, Duane, GASpAR Development

Rosenberg, Duane, New developments on two pseudo-spectral codes: GHOST & TYGRES

Smolarkiewicz, Piotr, A Monge-Ampère enhancement for semi-Lagrangian schemes; Three dimensional MPI parallelization of a nonhydrostatic anelastic fluid model; Towards petascale regional numerical weather prediction; Numerical realizability of Rayleigh-Bénard convection: Disparate approximations to governing PDEs

Sun, Jielun, Investigation of Stable Boundary Layers

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Integrated Science Program | ISP
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Director's Message

The Integrated Science Program (ISP) was formed in 2009 as an NCAR Directorate entity that supports scientists working on crosscutting research across NCAR Laboratories. The overarching goal of the Integrated Science Program (ISP) is to develop the understanding needed to manage and adapt to climate change, weather, and chemical weather through research that integrates the atmospheric sciences with other scientific disciplines. ISP is:

ISP Director, Peter Backlund

- Developing new connections among the atmospheric sciences, social sciences, ecology, hydrology, and health sciences
- Fostering collaborations across NCAR laboratories, divisions, institutes, and programs
- Building new relationships with university programs and other research institutions whose expertise complements NCAR expertise
- Promoting innovation in NCAR research and development

ISP is unique within NCAR as a “virtual” organization that does not maintain its own staff (except for a very small central administrative group) and carry out its own projects. All ISP activities are defined and undertaken in cooperation with other NCAR organizations and collaborators in the university community and other research institutions. ISP helps define, set up, and fund projects that are carried out by staff from NCAR labs and outside collaobrators.

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Frontiers and Imperatives

The work of ISP addresses frontiers and supports the imperatives of the NCAR Strategic Plan:

Two ISP projects are focused on NCAR Frontier 1: To advance modeling and analysis focused on informing climate change adaptation and mitigation.

- The **Integrated Assessment Modeling** (IAM) project is focused on developing and applying integrated socio-economic and biophysical models of the climate system.
- The **NCAR Vulnerability, Impacts, and Adaptation** (NVIA) project is focused on interdisciplinary basic research on social, economic, and political activities related to climate at local, regional and global scales.

One ISP project is focused on NCAR Frontier 2: To conduct and enable studies of water resource availability, vulnerability, and adaptation planning.

- The **Water System** project focuses on improved understanding and parameterization of the water cycle in climate models and examination of the impact of a changing water system on water management and policy.

Three of the ISP projects are focused on elements of NCAR's imperatives, "prediction and attribution" and "model development":

- The **Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics & Nitrogen** (BEACHON) project is focused on improving understanding of the roles of biogenic aerosols, nitrogen trace gases and oxidants in linking and regulating the carbon and water cycles.
- The **Biogeosciences** (BGS) Project is focused on modeling the biogeochemical cycles within the Earth system consistent with analyses of observations.
- The **Upper Troposphere/Lower Stratosphere** (UT/LS) project is focused on planning and conducting field campaigns, using the NCAR-NSF Gulfstream V aircraft, to investigate the coupled dynamical, chemical and microphysical processes in the UTLS and to complement the aircraft studies with satellite observations and multiscale NCAR models.

ISP is also supporting exploratory efforts in climate and marine ecosystems and weather communications and warnings. In its first full year of operations, ISP has also implemented new initiatives bringing postdoctoral research to NCAR in climate and health (in collaboration with RAL, ASP, and the Ceters for Disease Control) and climate and terrestrial ecosystems (in collaboration with the National Ecological Observatory Network).

All ISP activities are defined and undertaken in cooperation with other NCAR organizatons and collaborators in the university community and other research institutions.

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New Postdoctoral research themes at ISP

Postdoctoral Research

The Integrated Science Program (ISP) sees the support of postdoctoral research at NCAR as an effective means of seeding new, crosscutting research themes in the institution with short-term and collaborative funding. These new activities employ enthusiastic young researchers in building research programs that will remain relevant at NCAR and collaborating institutions well into the future.

ISP is collaborating with the Advanced Studies Program (ASP), the Research Applications Laboratory (RAL), and the Centers for Disease Control (CDC) to bring postdoctoral researchers to NCAR to study issues at the intersection of climate and health. Housed at RAL, these CDC-funded researchers represent the first of what is hoped to be a series of activities oriented to understanding the critical links between climate change and human health. This program is highlighted in the **NCAR Annual Report.**

ISP is collaborating with the National Ecological Observatory Network (NEON) to house two NSF-supported postdoctoral researchers who will conduct research on the interactions of climate change with terrestrial ecosystems. Such interactions will be an important factor in determining the evolution of ecosystems and the services they provide to human societies, the rate and magnitude of climate change, and the severity of climate change impacts during the next century. The co-location of NCAR and NEON in Boulder allows these new researchers to collaborate with scientists from both institutions and develop a well-integrated approach. This program is highlighted in the NCAR Annual Report.

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Integrated Science Program | ISP
2010 Annual Report

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Director's Message

Michael Thompson - HAO Director

It is my pleasure to present this annual report of the High Altitude Observatory (HAO). It showcases some of the outstanding work that has been accomplished by the HAO team in the past year, especially in the areas of scientific leadership and scientific support for the community. The report does not aim to be comprehensive. In particular, it does not describe the tremendous support that is provided by our administration team, our Computer Systems Management Team, and others; but the accomplishments that are described here would certainly not be possible without the sustained efforts of those colleagues.

The year 2010 has been a celebratory one for the National Center for Atmospheric Research (NCAR), which marked its 50th anniversary. At the same time, in a lower-key way, on September 8th we marked the 70th anniversary of the founding of the Observatory in 1940 by Walter Orr Roberts. We shall make a bigger splash in five years' time when we celebrate our 75th! During the year, several colleagues gained promotion: Peter Schmitt, to Software Engineer II; Liying Qian, to Project Scientist I; and Scott McIntosh and Matthias Rempel, each to Scientist III. Congratulations to all of them!

This is the first such report for a number of years, and so I would also like to reflect on events and changes that occurred a little before the formal period covered by the report. In August 2009, Michael Knölker announced that he was stepping down as HAO director, after 14 years of service in that position – the longest-serving HAO director since Walt Roberts and the longest serving since HAO became part of NCAR in 1960. Michael's many contributions and accomplishments in that role were celebrated on September 25, 2009, and we recognize the debt of gratitude we owe to him for his leadership of the Observatory over so many years. One of Michael's accomplishments in the final year of his directorship was to re-establish for HAO a seat at the NCAR Executive Committee, which it had not had since the reorganization of the NCAR laboratory structure some years before. HAO now has the same privileges – and responsibilities – as any other NCAR lab.

In October 2009, Stan Solomon took over as acting HAO director and continued in that role until the end of June 2010. We are all grateful to Stan for selflessly performing this role and for his careful stewardship of HAO – but none more so than me as the incoming director. Acknowledgement is also due to the various HAO staff – Roberto Casini, Mausumi Dikpati, Sarah Gibson, Rick Johnson, Phil Judge, Bruce Lites, Gang Lu, Rich Summers, Mike Wiltberger – who put in a substantial amount of work and care as members of the HAO Director Search Committee.

A great strength of HAO is that it has a broad science coverage of solar-terrestrial physics, from the solar interior, through the Sun's photosphere and chromosphere, into the corona and heliosphere, and to the magnetosphere and upper atmosphere of the Earth. The Observatory is an integral part of NCAR for sound scientific reasons: the Sun is the source of the radiative and particulate inputs that drive the Earth system and affect the near-Earth environment. As part of NCAR, through its research, leadership, and service to the community, HAO strives toward an understanding of the behavior of the coupled Sun-Earth system.

The stakeholders in HAO are diverse: the National Science Foundation (NSF) and other government agencies; the world-wide solar-terrestrial physics community (which I take to include solar physics, heliospheric physics, magnetospheric physics and upper-atmospheric physics communities); the universities; the rest of NCAR and UCAR; our own staff, visitors and students; and the wider public. In support of these stakeholders, HAO has a number of goals: to perform world-leading science; to provide scientific leadership and facilities to the wider community; to support the education and training of early-career researchers; and to provide advocacy for solar-terrestrial physics,

promoting its results, and articulating its societal importance. The Observatory held an HAO all-staff retreat on September 21-22, 2010, to discuss its mission and vision and to brainstorm elements of its strategic plans. As I write, we are developing our strategic plan for the next three to five years. It will be completed by the end of calendar year 2010, and this will then guide our activities for the next several years.

It is a privilege to be the eighth director of HAO, but it would not be possible to do such a job without strong and effective support. It is essential to have good administrative and personal support, and I am fortunate indeed to receive that from Rick Johnson and Bev Johnson. I also appreciate the great work that is contributed by Gang Lu as deputy director, Steve Tomczyk as assistant director for instrumentation, and the HAO section heads.

Finally, a big “thank you” to Gang who is the one primarily responsible for writing this annual report.

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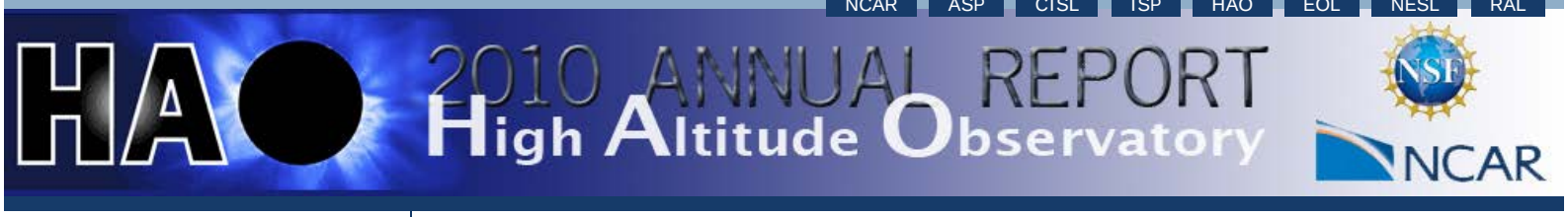

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Executive Summary

The High Altitude Observatory (HAO) leads and supports a comprehensive program of solar and solar-terrestrial research, emphasizing the interconnections between physical processes in the solar interior, solar atmosphere, and corona, the role of the Sun in geospace variability, and the weather and climate of the upper atmosphere and ionosphere. The NSF-supported program includes solar observational facilities at the Mauna Loa Solar Observatory (MLSO) and elsewhere, instrument development, data analysis tool development, data base support, upper atmosphere observational facilities, and upper atmosphere community modeling.

Through state-of-the-art numerical simulations of turbulent solar convection, HAO scientists investigate the origins of the large-scale differential rotation and meridional circulation in the Sun's interior. Seminal work by HAO researchers has revealed the importance of these flows to the operation of the solar dynamo, providing for the inductive generation of toroidal magnetic fields at the bottom of the convection zone, the transport of poloidal magnetic fields in the solar surface layers, and establishing the time-scale of the Sun's magnetic activity cycle. These insights have furthered the development of physics-based methods for solar-cycle prediction. Scientific discoveries based on observations from the Hinode satellite and MLSO, along with advanced numerical and theoretic investigations have revealed new underlying physical processes responsible for various solar phenomena such as flares and coronal mass ejections. These accomplishments help us to understand the origin of solar disturbances, which are the main cause of hazardous space weather effects on Earth.

HAO conducts an extensive program in space weather model development and data analysis, in partnership with universities, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC). These efforts include coronal and solar wind simulations, development of the Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) model, together with other modeling, measurement, and data analysis of the upper atmosphere and ionosphere. HAO supports the Center for Space Weather Integrated Modeling (CISM) project, leading the ionosphere-thermosphere thrust, and contributing extensively to coupled model development, software engineering, and validation. In FY2010 the CMIT model was transferred to the Community Coordinated Modeling Center (CCMC) where community users can request specific model outputs to aid their research. The CMIT model has also been transferred to SWPC for testing and evaluation, and HAO staff will continue working with SWPC as needed on the transition of our space weather models to operation. These accomplishments demonstrate our commitment to the challenge of obtaining a predictive capability for space weather through our continuing effort in numerical model development in order to support the university community and ultimately support government agencies in space weather tracking and prediction.

HAO scientists serve the broad scientific community through the development and support of our community models. The NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) has been released as a community model. HAO will take a lead role in the community transition of other components through the CISM effort. In collaboration with other NCAR divisions, HAO has made significant contributions to the development and release of the Whole Atmosphere Community Climate Model (WACCM). In particular, HAO researchers are responsible for the upward extension of WACCM, which now ranges from the surface of the Earth to the thermosphere at about 400 km. HAO models have been continually upgraded through improvements to atmospheric tidal forcing, auroral energy input, and coupling with magnetospheric electrodynamics. These model improvements directly address the community's need to better understand the interaction of solar, magnetospheric, and atmospheric processes that drive ionospheric and thermospheric variability, and to determine the dependence of anthropogenic global change in the upper atmosphere on solar activity.

HAO continues to support the community with observational facilities and databases. The HAO observational program emphasizes scientific community involvement, including an open data policy, student participation, and public access to scientific results. The two major efforts in FY2010 were the redeployment of the Coronal Multi-channel Polarimeter (CoMP) instrument and the development of a high-sensitivity K-coronagraph for MLSO. The new K-coronagraph will be capable of providing high-cadence, high-sensitivity measurements of geo-effective coronal mass ejections, including "halo" events. Combined with synoptic coronal magnetic field measurements by CoMP, these new observations will yield unprecedented insight into coronal eruptive processes that often cause space weather disturbances near Earth.

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Solar Modeling

3D Modeling of Convection in the Solar Interior

The challenge for solar dynamo theory is to determine how ordered patterns such as the 22-year magnetic

activity cycle arise from the highly turbulent, chaotic conditions of the solar convection zone. The generation of coherent, large-scale magnetic flux from smaller-scale turbulent motions is intimately linked to rotational shear and helicity in flows and magnetic fields. Numerical simulations of global-scale solar convection, such as presented in Figure 1, are shedding new light on this fundamental issue. Recent results indicate that as the rotation rate is increased from the solar value to a rate that is five times faster (as in the case of a younger Sun-like star), the scale of convective patterns decreases while helicity and rotational shear are enhanced. In the presence of a magnetic field, these flow features give rise to prominent toroidal magnetic structures that are pumped to the bottom of the convection zone under solar conditions but persist at intermediate depths in younger, more rapidly rotating stars. Quasi-cyclic polarity reversals of the toroidal bands are currently under investigation. These simulations demonstrate that magnetic self-organization and cyclic variability are common features in global convective dynamos and have important implications for understanding the dynamic origins of solar and stellar magnetic activity.

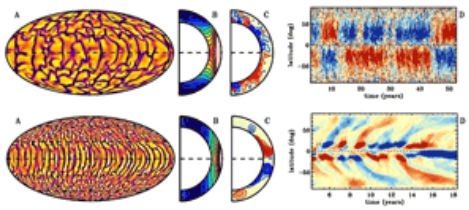

Figure 1. Magnetic self-organization and polarity reversals in numerical simulations of solar and stellar convection. The top and bottom rows represent solar-type stars rotating at the solar rate (rotation period 28 days) and five time faster (rotation period 5.6 days), respectively. (A) Vertical velocity near the top of the convection zone (yellow/orange denotes upflow and blue/black downflow). (B) Angular velocity averaged over longitude and time (pink denotes faster rotation, blue/black slower rotation). (C) Mean (longitudinally-averaged) toroidal magnetic field (red and blue denote eastward and westward flux; peak field strengths range from several kG on the top to about 20-30 kG on the bottom). (D) Time evolution of the mean toroidal field at the base of the convection zone, illustrating cyclic polarity reversals.

Radiative-Magnetohydrodynamics Modeling of Sunspot Generation

The solar photosphere is a transition region in which the primary energy transport mechanism switches from

convection to radiative transfer. At the same time the plasma becomes partially ionized due to the lower temperatures, which requires a more complicated equation of state. The role of the magnetic field is also changing: while the interior of the Sun is dominated by the gas pressure, in or above the photosphere the magnetic pressure becomes the dominant contribution. Due to the rather short density scale height, the photosphere is a highly stratified medium in which convective motions easily steepen up to supersonic flows

and shock waves. The combination of all these conditions makes numerical modeling of the photosphere challenging, but also extremely interesting due to the strong interaction between convection, magnetic field, and radiation, and the possibility for in-depth comparison with high-resolution observations.

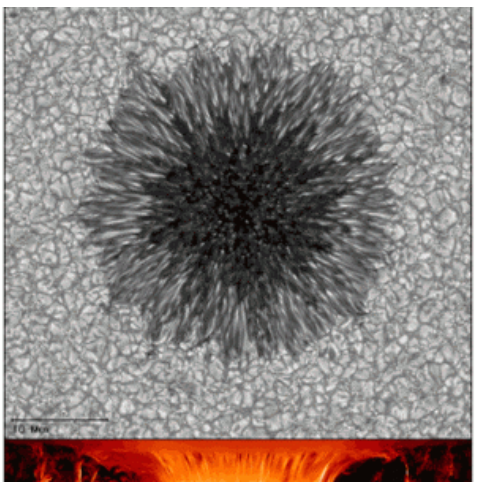

Figure 2. The top panel shows the photospheric brightness (bolometric intensity), and the bottom panel shows the field strength on a vertical slice through the sunspot (max values are 8 kG near the bottom boundary). The simulation shows sunspot fine structures including umbral dots and penumbral filaments. The use of different boundary conditions allows simulations of the outer penumbra with a clear transition between filaments and the surrounding granulation.

Studies of sunspot structure and associated flows continue at HAO through radiative-MHD simulations of flux concentrations in the upper portion of the Sun's convection zone and photosphere. After recent success in comprehensive numerical simulations of complete sunspots, new research has focused on two aspects: (1) high resolution simulations of sunspot fine structure to evaluate the robustness of numerical results with respect to resolution, and (2) simulations at moderate resolution that focus on large domain sizes and cover a time span of up to 48 hours. In work carried out this year, simulations were performed at different grid resolutions in order to evaluate the robustness of results compared to previous computations and to investigate large-scale flows (or moat flow) and the moat-penumbra relationship. Figure 2 shows the numerical simulations of a sunspot at a resolution of 16x16x12 km. The domain size is 49x49x6.1 Mm, resulting in a grid size of 4.8 billion grid points. This exercise resulted in the best-available sunspot model for helioseismic forward modeling.

Scientific Investigations Using the Hinode Satellite Data

The spectro-polarimeter instrument aboard the Hinode spacecraft was developed jointly by HAO and the Lockheed Martin Solar and Astrophysics Laboratory. The instrument has provided continuous, high resolution, high precision measurements of polarization of the Sun since the launch of the spacecraft in 2007.

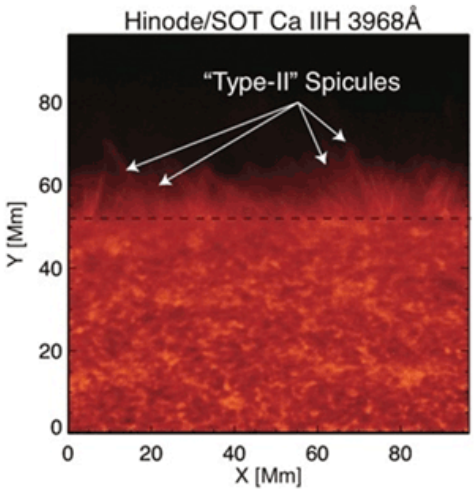

Figure 3. "Type-II" spicules observed by the Hinode satellite. These slender fingers of material protrude several thousands of kilometers above the solar limb and are rooted in strong magnetic field concentrations of the solar chromosphere. Much of the "mist" seen immediately above the solar limb in this image is the superposition of the fine spicules along the very long line-of-sight. Type-II spicules have a significantly shorter lifetime (10-100s) and travel much faster (50-150km/s) than their classical counterparts (several minutes and 20-40km/s).

HAO scientists continue to collaborate with colleagues from the U.S., Japan, and Europe for analysis and interpretation of Hinode data. Among the groundbreaking work this year was the discovery of a weak magnetic field in the upper solar atmosphere with a magnitude of approximately 2 Gauss. This discovery opens a new frontier for solar physics, that is, the need to implement multi-level atom models in order to correctly interpret the subtle polarization signatures observed in the radiation-dominated chromosphere.

Combining observations from Hinode and the Solar Dynamics Observatory (SDO) spacecraft made it possible for the first time to track plasma heating from the lower chromosphere into the extended corona. Figure 3 depicts the so-called “Type-II” spicules in order to distinguish them from their classical siblings that typically are several orders of magnitude larger in size and several minutes in duration. The spicules seen in this image were captured in a joint observation with SDO on April 27, 2010 at the north polar coronal hole. Recent studies have shown that the “Type-II” spicules are a ubiquitous signature of material being heated from several thousand °K to more than 2 million °K. In addition, they carry a flux of Alfvénic motions into the outer solar atmosphere that is sufficient to drive the fast solar wind. These studies suggest that the “Type-II” spicules play a crucial role in transporting the mass and energy needed for coronal heating. These observations, such as shown in Figure 3, pose a challenge to the existing models of coronal heating by demonstrating that the majority of coronal temperature mass is preheated prior to being dynamically forced out of the chromosphere. This provides strong constraint on the relentless cycling of mass between the Sun’s surface and outer solar atmosphere. Such knowledge will also permit the modeling of ultraviolet and extreme-ultraviolet radiation formation in the solar atmosphere that impinges on the Earth’s outer atmosphere.

Other scientific accomplishments related to Hinode include the observation and interpretation of granular-scale magnetic flux cancellations in the photosphere, and the interpretation of the magnetic field topology produced by magnetic flux emergence as inferred from a flare event associated with chromospheric jets.

Numerical Simulations of Flux Eruptions

Solar flares and coronal mass ejections (CMEs) are the common causes of adverse space weather disturbances in the near-Earth environment. Through coronal observations and 3D magnetohydrodynamic (MHD) simulations of the coronal magnetic field driven by the emergence of a twisted flux rope, HAO scientists have made significant advances in understanding the origin and dynamic evolution of CMEs.

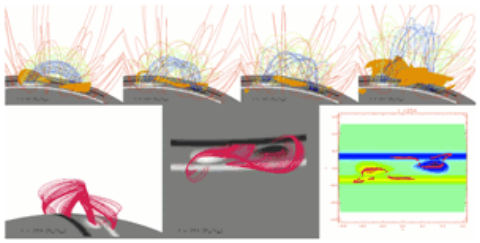

Figure 4. Top rows are snapshots of the 3D coronal magnetic field lines and the underlying current sheet (represented by the orange surfaces), showing the quasi-static rise and the onset of eruption of a coronal flux rope when the critical height is reached. Bottom rows show side (left panel) and top (middle panel) views of the post-reconnection flare loops and their foot-points (red dots in the right panel), which correspond to the locations of flare ribbons (or the brightening kernels due to precipitation of high energy electrons coming down along the post-reconnection loops) in the chromosphere. The color image in the bottom right panel shows the normal magnetic field on the surface.

Eruptive flares and CMEs are believed to result from the sudden, explosive release of free magnetic energy stored in the twisted/sheared coronal magnetic field. However, the detailed magnetic field structure for the eruption precursors and the physical causes for their sudden eruption remain fundamentally unanswered questions. Three-dimensional MHD simulations have been performed to model the evolution of the coronal magnetic field following the emergence of a twisted magnetic flux rope into a pre-existing coronal arcade field. It is found that the eruption of the flux rope in the corona is triggered when the flux rope rises to a critical height where the corresponding potential field declines with height at a sufficiently steep rate, a mechanism consistent with the onset of the torus instability of the flux rope. Figure 4 shows an example of the modeled magnetic field evolution resulting from a simulation. It is found that the magnetic field evolution during both the earlier quasi-static rise and the subsequent eruptive phase is able to explain some of the commonly observed features associated with eruptive flares in regions with pre-existing X-ray sigmoids.

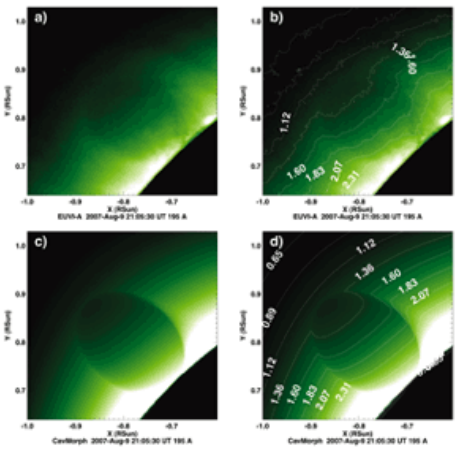

Figure 5. Forward modeling of a coronal prominence cavity: (a) STEREO EUVI-A image of the cavity, (b) intensity contours overlaid, (c) forward modeled (line-of-sight integrated) EUV emission using model density and temperature, and (d) intensity contours overlaid. Contours are in units of count/s.

The genesis of CMEs is both an intellectually intriguing, fundamentally unsolved problem in plasma astrophysics, and a societally relevant subject critical to space weather prediction and mitigation. Dark coronal cavities surrounding cool, dense prominence material are observed within CMEs, but also as equilibrium states in the magnetically-dominated corona. Their plasma properties as observed in their quiescent phase provide clues to the nature of such equilibria and how they may ultimately be lost during CMEs. Using observations from HAO's CoMP and NASA satellites such as STEREO, along with new modeling tools, HAO scientists were able to unveil the physical conditions leading to and affecting the dynamics of CMEs. These efforts led to the first observations of plasma flows in the coronal prominence cavities as well as the development of a three-dimensional model of these cavities that allows calculations of cavity density and temperature while properly treating the line-of-sight effects. An example of forwarding modeling of a coronal prominence cavity is illustrated in Figure 5.

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Space Weather

Space weather refers to conditions on the Sun and in the space environment that can influence the performance and reliability of space-borne and ground-based technological systems, and can endanger human life or health. Adverse conditions in the space environment can disturb satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socio-economical losses as well as impacts on our security. Space weather research seeks to understand and work toward predictions of the physical conditions in the geospace environment, which often originate from the Sun. This is a multidisciplinary field of research that requires an understanding of solar, solar wind, magnetospheric, and ionospheric/thermospheric physics. It covers a broad range of time scales, from solar cycle variations (years), recurrent high-speed solar wind streams (months), CMEs and geomagnetic storms (days), flares and energetic particles (minutes).

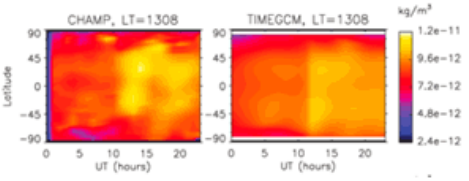

Figure 6. Comparison between (left) CHAMP observations and (right) TIME-GCM simulations of dayside neutral density enhancement during the solar flare event on October 28, 2003.

In order to achieve the ultimate goal of space weather forecast and prediction, it is of critical importance to discover and fully understand the physical processes that produce space weather and its effects. To this end, HAO scientists have continued participation in the Neutral Atmosphere Density Interdisciplinary Research (NADIR) multi-university research initiative led by the University of Colorado, and made significant contributions to the investigations of several leading causes of thermospheric density variations, including solar flares, high-speed solar wind streams, geomagnetic storms, electromagnetic energy input from the magnetosphere, seasonal and hemispheric variations of auroral particle precipitation. Figure 6 shows the comparison of the observed and modeled neutral density changes in response to the X17-class solar flare that occurred on October 28, 2003. The flare increased neutral density by ~30 percent at 400 km altitude where the CHAMP satellite orbits, causing significant increase on satellite drag.

Another major activity in FY2010 with regard to HAO's space weather program was the transition of our research models to the CCMC for "runs-on-request" and to NOAA's SWPC for testing and evaluation. The CMIT model consists of two modules: the Lyon-Fedder-Mobarry (LFM) magnetohydrodynamic magnetospheric module and the NCAR TIE-GCM module. Both modules were transferred to the CCMC where community users can request specific model outputs to aid their research. The CMIT model has also been transferred to SWPC for further testing and evaluation. HAO staff will continue working with the SWPC as needed on the transition of our space weather models to operation.

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Upper Atmosphere and Ionosphere Community Models

Numerical simulations of the upper-atmosphere/magnetosphere system and its coupling to other regions continue to be a primary objective for HAO research. HAO scientists have developed a suite of upper-atmospheric models, in collaboration with scientific visitors and scientists at universities, government labs, and other organizations. These models are made available for use by the community, typically through collaborations between HAO scientists and scientists in the community. HAO models include the **TIE-GCM**, the Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (**TIME-GCM**), and WACCM, which is a collaborative project with other NCAR divisions, and the CMIT model developed as part of the Center for Integrated Space Weather Modeling (**CISM**), which is an NSF Science and Technology Center led by Boston University. Other HAO models with extensive use by the community are the Assimilative Mapping of Ionospheric Electrodynamics (**AMIE**) procedure synthesizing high-latitude observations of ionospheric electric fields and currents, the Global-Scale Wave Model (**GSWM**) for calculating atmospheric tides and planetary waves from the ground through the thermosphere, and the **GLOW** model for calculating the effects of solar ultraviolet and X-rays as well as energetic particles. These models are used to understand the processes affecting the dynamical, electrodynamical, thermodynamical, and chemical conditions in the Earth's upper atmosphere, its response to the Sun's variable radiative, particulate and magnetic emissions, and its coupling to the lower atmosphere and the magnetosphere.

The models have been continually upgraded through improved understanding of physical processes as well as advancement of numerical/computational schemes. One of the main updates during the past year was the development of a high-resolution version of the TIE-GCM, which has doubled the spatial resolution over its predecessors, with 2.5-degree in latitude and longitude and one-fourth pressure scale height. This high-resolution version of the model is available to the community for runs on request.

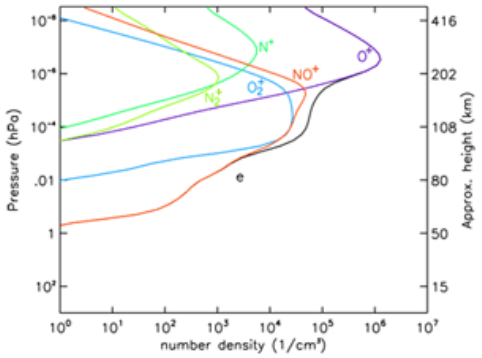

Figure 7. Altitude profiles of globally averaged number densities of various ion species and electrons from the WACCM-X simulations under December solstices and solar medium conditions.

WACCM has become part of the Community Earth System Model Program. The thermospheric extension of WACCM (or WACCM-X) with a partially interactive ionosphere (without electron and ion energy calculations or magnetic-field effects) was completed. Figure 7 shows the altitude profiles of major ion species and electrons from WACCM-X. Development of a parameterization of ionization rates by precipitating electrons has been completed, and the parameterization will be added to WACCM. Code testing of electron and ion energy balance has begun. Code development of an efficient elliptic partial differential equation solver for parallel computation, to enable the addition of a fully interactive ionosphere with self-consistent electro-dynamics to WACCM, has begun.

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Observational Facilities and Data Service

The Mauna Loa Solar Observatory (MLSO)

MLSO is a facility of the National Center for Atmospheric Research (NCAR) and operated by HAO. It provides observations of the Sun's atmosphere in support of the solar and space physics goal of understanding the Sun's continuous release of plasma and energy into interplanetary space and its impact at Earth. HAO is committed to providing the community with critically important, high-quality solar observations. MLSO was constructed in 1965 and is located at 11,200 feet on the northern flank of Mauna Loa on the island of Hawaii.

MLSO currently houses five instruments that observe the solar photosphere, chromosphere and low corona: (1) the CoMP instrument; (2) the Mk4 K-coronameter; (3) the Chromospheric Helium-I Imaging Photometer (CHIP); (4) the Precision Solar Photometric Telescope (PSPT); and (5) the Coronado Ha imager. In addition, HAO maintains the Global Oscillation Network Group (GONG) site, which was updated in July 2010 to include a full disk Ha imager that acquires images every minute. The real-time observations will be served from both GONG and the MLSO home pages. The deployment of the GONG Ha imager provides the opportunity for HAO to move the Coronado Ha telescope to the new Mesa Lab spar for education and public outreach groups to observe the solar chromosphere. Among the main efforts in FY2010 were the redeployment of the CoMP instrument and the preliminary design of the new K-coronagraph.

CoMP: The CoMP instrument was deployed to the solar spar of MLSO in February 2010, and two engineering runs followed in July and September. The commissioning of CoMP was completed on October 1, 2010, and the instrument has been obtaining regular observations of the corona every clear day since. CoMP is able to observe the polarization emission from the corona in the infrared lines at 1074.7 and 1079.8 nm, respectively, along with the prominence emission line at 1083.0 nm. Observations from CoMP have been used to determine the line-of-sight strength of the coronal magnetic field as well as its plane-of-sky orientation. CoMP can also observe waves in the corona, providing critical information on coronal plasma through coronal seismology. Work is ongoing on the processing pipeline with the goal of serving CoMP data in the near future to the community on a daily basis through the MLSO web site.

New K-coronagraph: Through a major commitment by NSF, HAO is designing and fabricating a new K-coronagraph that will be deployed to the Mauna Loa Solar Observatory in early 2013 to replace the aging MK4 K-coronameter. The K-coronagraph successfully completed its Conceptual Design Review (CDR) on May 13, 2010. A panel of coronagraph and optical experts from the National Solar Observatory, the Naval Research Laboratory and the Earth Observing Laboratory of NCAR reviewed the K-coronagraph conceptual design. The panel was pleased with the progress and provided several recommendations, including scattered light testing, objective lens material and polishing, filter designs and design paths for future upgrades. Considerable progress has been made since the CDR, and HAO is on target to meet the work required for the Preliminary Design Review in May 2011 when the panel will reconvene.

Other MLSO-related activities during FY2010 were: (1) providing the historical total solar eclipse archive from the MLSO home page; (2) upgrading the high-speed internet to 25 Mbps (from 1.3 Mbps) that will allow all data, including the new CoMP and GONG data, to be transmitted in real-time to optimize data use for better space weather prediction operations; (3) providing new formatted CME events to the community in an easier-to-use table; and (4) adding a featured event's page that includes movie highlights of solar activity and other solar-related phenomena.

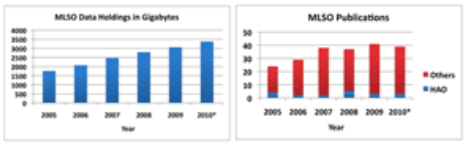

Figure 8. (left) MLSO data holdings in gigabytes. (right) MLSO publications led by scientists at HAO (in blue) and in other organizations (red). Note that the numbers for Year 2010 are only based on eight months (through August).

All MLSO observations back to 1980 are provided from the MLSO web site. The MLSO database serves the broad solar community both nationally and internationally. There are a total of 447 registered users (as of August 2010); among them 44 percent are university users and public outreach educators. Figure 8 shows the MLSO data holdings and publications led by HAO staff and scientists in other organizations, respectively.

The Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) Database

The CEDAR database was first established at HAO in 1985 as the Incoherent Scatter Radar (ISR) database. It was expanded in 1989 to include other instrument types and was renamed the CEDAR database at that time. The database continues to be supported through a long-standing commitment by NSF. The main goals of the database are to: (1) provide a long-term archive for observations and models of the Earth's upper atmosphere as well as geophysical indices and parameters needed to interpret them; (2) provide the browsing capability to effectively survey data holdings and identify the availability of data and model results for periods of interest; (3) provide reliable data access methods that are fast, stable, and interactive; (4) supply detailed information and documentation on data acquisition and reduction; (5) perform quality checks of the data; (6) assure that the required metadata, including references and contact persons, are specified; and (7) provide assistance to users of the database.

Over the years the CEDAR database has gone through several major renovations. In 1991, the first CEDAR computer was opened to the community for logins, with an ftp site for documentation. An internet web site for the database was implemented in 1995, with links to documentation. Summary plots of the data were added to this web site in 1997. In late 1998, the database logins were used to access the data via the web site using CEDARweb, and additional web pages were added to serve the broad upper atmosphere community, such as web pages for the annual CEDAR Workshop and CEDAR community pages. After the launch of the TIMED satellite in December 2001, the CEDAR database became a part of the TIMED-CEDAR Data system, and became the archive and access for some of the ground-based instruments supporting the TIMED mission. In 2007, web-based access was expanded using the Virtual Solar-Terrestrial Observatory (VSTO), replacing the CEDARweb in 2008. A wiki was added in 2007 for login and access to the database and to community wiki pages, including wiki pages for the annual CEDAR Workshop. HAO became a Madrigal node with Millstone Hill and Jicamarca data in September 2009. Data sets added in FY2010 were updates to geophysical indices and Arecibo FPI data. Database content information has been collected on-line since June 2009 (since February 2010 for protected text files), and this information is now available to data providers under wiki Special Pages as the 'Cedar Access Report'. As of April 2010, NetCDF files can be requested from the CEDAR database. CEDAR Workshop forms and pages also had some major updates for this year's workshop.

The CEDAR database provides long-term service of various data sets from predominantly ground-based instruments, including 11 incoherent scatter radars (ISRs), 12 high-frequency radars, 2 mesosphere-stratosphere-troposphere (MST) radars, 23 medium-frequency, meteor, or low-frequency middle atmosphere radars, 2 digisondes, 3 lidars, and 29 passive optical instruments. Three of the ISR data sets are dated as early as the 1960s. The database also provides access to some important geophysical parameters derived from satellite measurements such as the auroral hemispheric power, the auroral midnight equatorward boundary, and the interplanetary magnetic field and solar wind conditions. Other ground-based indices such as the 10.7 cm solar flux, Kp, and the Polar Cap Index (PCI) are also included in the database. A few new instruments are usually added each year. The CEDAR database maintains 747 logins, with about 75 new logins added each year. A total of 928 individuals have registered in the CEDAR database since 1985. During the past few years, approximately 85 users have accessed the CEDAR database each year, and approximately 45 of these are first-time users. Approximately 55 percent of the users are from U.S. institutions and about 25 percent are students. Figure 9 shows the user and data holding statistics from 2005 to 2009 (the numbers for Year 2010 are not yet available).

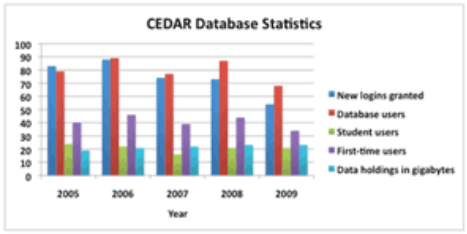

Figure 9. CEDAR database user and data holding statistics for 2005-2009.

The Community Spectro-polarimetric Analysis Center (CSAC)

CSAC stemmed from an NCAR Strategic Initiative, and it is now an integral part of HAO's base program aimed to provide a suite of community resource tools for the calibration, reduction, and inversion of polarimetric data in order to extract the magnetic and thermodynamic properties of the solar atmosphere. Significant effort has been devoted to develop a data-analysis software, namely, the Milne-Eddington gRid Linear Inversion Network (MERLIN). The code is designed for the inversion of photospheric data in the Fe I 630.2 nm spectral lines, and is now fully operational through the CSAC web site. More software packages are currently under development.

In addition, CSAC also provides support to a host of new instruments for measuring vector magnetic fields in a range of solar atmospheric layers. All Hinode spectro-polarimetric observations have been inverted through MERLIN, and are available via the CSAC web site. Through the CSAC website, one can also access the inversion-ready and calibrated Hinode data, and run customized inversions with MERLIN from the web-based inversion toolkit. Figure 10 shows an example of magnetic inversions of an active sunspot region, observed by the Hinode spectro-polarimeter instrument on December 12, 2006, in the spectral region around 630 nm.

Development of Coronal Solar Magnetism Observatory (COSMO)

MLSO has been collecting synoptic coronal data for over 40 years in support of the solar and heliospheric

community. Driven by society's need to understand the origins of space weather, NCAR scientists at HAO, along with colleagues at the University of Hawaii and the University of Michigan, propose to build the COSMO instrument suite. The facility, as sketched in Figure 11, 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-meter coronagraph with two detector systems: a narrow-band filter polarimeter and a spectro-polarimeter. 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.

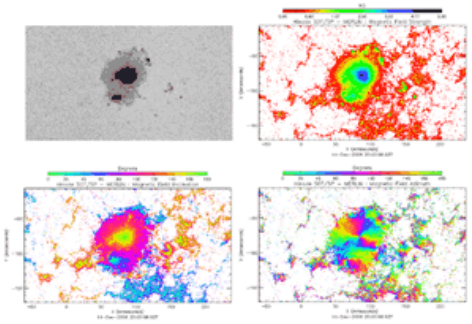

Figure 10. (top-left) the region of interest observed in the intensity continuum; (top-right) the magnetic field strength; (bottom-left) the inclination of the magnetic field vector from the local vertical; (bottom-right) the azimuth of the magnetic field.

Significant progress has been made in FY2010 on the COSMO program. The design of a new K-coronagraph is underway, and will be deployed to MLSO in early 2013 to replace the aging MK4 K-coronameter. In addition, HAO is planning to build a prototype tunable filter for the ChroMag instrument. This filter will be used to demonstrate the feasibility of a narrow-band tunable filter and polarimeter for observations of chromospheric magnetism.

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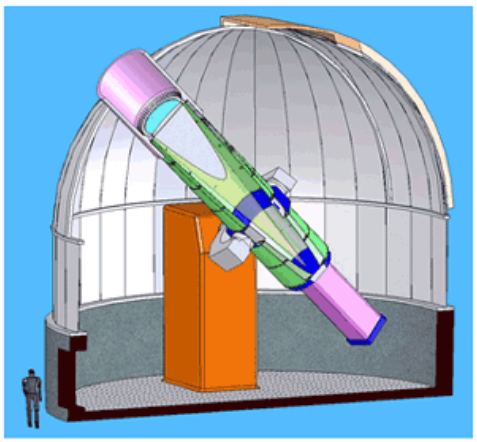

Figure 11. Conceptual drawing of the COSMO 1.5-meter coronagraph and dome. The telescope is a simple tube structure on an equatorial mount. The diameter of the dome is 12.2 meters.

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NSF Special and Non-NSF Supported Activity

Design of the Visible Spectro-Polarimeter (ViSP)

ViSP is a spectro-polarimeter designed at HAO for NSF's Advanced Technology Solar Telescope (ATST). ViSP will be able to observe up to three spectral lines between 380 and 1100 nm simultaneously in two orthogonal states of polarization. In FY2010 HAO was awarded $250,000 by the ATST project to develop the conceptual design of the instrument, and to provide a review-ready preliminary design for the optical, mechanical and software aspects of the project. This Preliminary Design Review (PDR) is planned to occur in January 2011. After going through a detailed trade-off study of different optical designs, the HAO team has reached the concept that is presently being finalized with the help of an external optical consultant. Several software tools were developed in-house in order to characterize the instrument performance and verify against the instrument's science requirements.

Data Service for the Solar Dynamics Observatory (SDO)

The Solar Dynamics Observatory (SDO) is a NASA satellite mission designed to study the causes of solar variability that impact life and humanity's technological development. Solar variability is intimately related to magnetic activity. The main goals of the SDO mission are to understand the mechanisms that produce these magnetic fields and drive them to the surface and to be able to predict when and where the energy stored in them is released in the form of particle ejections and changes in solar irradiance. SDO was launched from Cape Canaveral on February 11, 2010, carrying three instruments on board. One of these instruments, the Helioseismic and Magnetic Imager (HMI), is devoted to registering the velocity oscillations and the magnetic field on the Sun's surface. HMI measures the intensity and polarization of photospheric Fe I 6173 Å line in order to study velocity oscillations as well as the evolution of the vector magnetic field at the solar photosphere. In support of SDO data analysis, HAO has developed a spectral line inversion code called VFISV (Very Fast Inversion of the Stokes Vector) to process the HMI data and to determine the full 3-D topology of the magnetic field and the line-of-sight velocity at the solar surface. These are some of the data products that will be made available to the scientific community through the NCAR-sponsored CSAC. Figure 12 shows an example of magnetic field measurements by the HMI instrument. Our task at HAO is to maintain this aspect of the data pipeline, to perform quality control of the raw data, and to disseminate the final products. Among other characteristics, the VFISV inversion code is capable of processing the full disk image of the Sun with 4096x4096 pixels in less than 12 minutes, enabling us to offer to the solar community continuous high-quality measurements of the vector magnetic field on the solar surface at a relatively high spatial resolution and cadence.

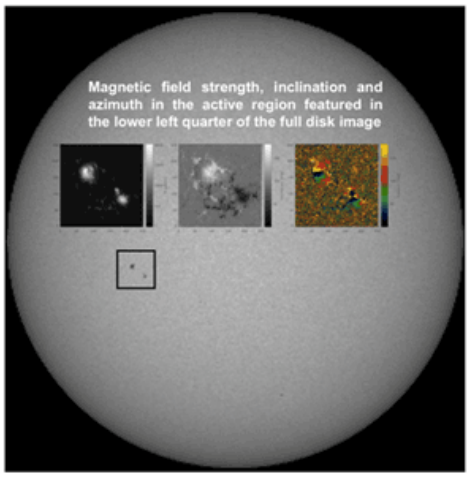

Figure 12. (top row, from left to right) Magnetic field strength, inclination, and azimuth field strength corresponding to the active region indicated by the open box in the full disk image.

MLSO Infrastructure

Through NCAR, NSF funds were provided in FY2010 and FY2011 for essential infrastructure maintenance. This funding provided for road access maintenance and repair in collaboration with NOAA, ongoing building upkeep needs such as interior/exterior repair and periodic cleaning services.

MLSO Telecommunication Upgrade

NSF awarded HAO one-time funds to upgrade the existing telecommunications system that transmits observation data from MLSO to HAO and the broader community. This upgrade began in late 2010 and is scheduled for completion in

mid-FY2011. The new system will increase bandwidth capacity from the current capacity of 1.3 Mbps to over 20 Mbps, and serve the increased data needs of the CoMP instrument installed earlier in FY2010. With this upgrade, images will be processed and posted on the MLSO web site within minutes of acquisition providing near real-time access to the data. Further benefits will include providing HAO scientists with the ability to assess data quality and instrument performance, correct problems in a timely manner, and provide scientists at SWPC and elsewhere in the community with data needed to create real-time forecasting of space weather conditions.

Fabry-Perot Interferometer in Antarctica

Instrument development work began on the new Fabry-Perot Interferometer (FPI) that is scheduled to be installed at Palmer, Antarctica. This effort is being conducted in collaboration with Australian scientists who have FPI instruments at Mawson and Davis Antarctica to jointly analyze the neutral wind and temperature data to address the following issues: (1) thermospheric neutral wind effect on the Weddell Sea Anomaly, (2) lower thermosphere wind effect on shuttle plume drift, (3) nonmigrating tides in the mesosphere and lower thermosphere, and (4) geomagnetic effect on the thermospheric wind. The deployment of the FPI to Antarctica will provide some answers to a long-standing question regarding the Weddell Sea Anomaly in the Antarctica Peninsula region. Deployment of the FPI will begin in early 2011.

High-altitude Interferometer WIND experiment (HIWIND)

HIWIND is a NASA-funded stratospheric balloon-borne FPI. It will measure thermospheric neutral winds by monitoring Doppler shift in the O 630 nm airglow emission during daytime and night. The mission involves a science flight from Kiruna, Sweden, in the summer of 2011, and will last for about seven days during which the balloon will fly westward from Scandinavia, across the Atlantic Ocean and Greenland, and finally land in northern Canada or Alaska. The thermospheric wind data will be used in conjunction with ground-based incoherent scatter radar (ISR) ionosphere measurements to study high latitude thermosphere-ionosphere interaction. These data will also be compared with various model simulation results from NCAR and other institutions. One of the major difficulties in studying the polar ionosphere is the lack of daytime measurements of thermospheric winds. This has led to great uncertainties in estimating energy transfer inside the polar cap. Understanding the energy transfer from the ionosphere to the thermosphere has a great implication for space weather research. HIWIND will fill this critical data gap.

Figure 13. HIWIND, in its full configuration, during integration testing in September 2010. The large white tubes pointed upward at an elevation angle of 50º direct light from four orthogonal directions into the FPI instrument located in the interior of the gondola in an environmentally sealed pressure vessel. Exterior equipment visible in this picture includes the rotator on the top, GPS and communication antenna booms, solar arrays, thermal radiator, ballast hoppers, and landing pads. The payload weighs close to 2250 pounds and will be lifted by a 40-million-cubic-foot balloon to the stratosphere. (Photo courtesy of Brett Vincent of NASA Wallops Island Facility.)

Flying an FPI on a balloon payload is an engineering challenge. The balloon-borne FPI will be in a harsh environment with extreme temperatures. Fortunately, HAO has the expertise in both balloon-borne systems and FPI measurements and is able to provide engineering solutions to solve these problems. The instrument development is moving forward according to the schedule. HAO's Instrumentation Group has done an excellent job in finishing the hardware construction and software development within a very compressed timeframe of eight months. The HIWIND team went to Ft. Sumner, New Mexico, in September 2010 for an integration test with NASA balloon facility communication and flight control systems. The instrument passed many critical tests. The HIWIND team was able to communicate to the payload via the NASA system to send commands and transfer data from ground support computers. Throughout the project, Design and Fabrication Services (DFS) of the Earth Observation Laboratory (EOL) provided invaluable support by fabricating various parts for the instrument and assembling the gondola. Figure 13 shows the HIWIND instrument in its full configuration undergoing integration testing at Ft. Sumner, New Mexico.

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Director's Message

For 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, with emphasis on large and expensive facilities that are better provided centrally rather than by a single university group. This part of the NCAR charge now rests primarily 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 we wrote our Laboratory Strategic Plan in 2010 we framed our activities as a lab in the context of not only our mission statement but of our "Four D's": Development, Deployment, Data Services and Discovery. This annual report describes the efforts we undertook in 2010 to carry out the objectives described in our Strategic Plan.

Development

EOL Engineer Cindy Bradley installs the new AVAPS III Dropsonde Launcher onto the Global Hawk UAV in preparation for NASA Genesis and Rapid Intensification Processes (GRIP) campaign which ran concurrently to PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT).

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 2010 efforts in this area include NSF/NCAR Gulfstream V (GV) enhancements such as the design, installation, and certification of optical windows suitable for instruments such as the High Spectral Resolution Lidar. New technology development included the Laser Air Motion Sensor (LAMS), which measures the GV's true air speed via laser remote sensing and the Holographic Detector of Clouds 2 (HOLODEC 2) which measures the size distribution of cloud particles within a large sample volume using ultraviolet laser holography. EOL continued our work to develop the next generation Airborne Vertical Atmospheric Profiling System (AVAPS) III Dropsonde system for installation on one of the Global Hawks as well as on the NSF/NCAR GV. This will have major positive impact on researchers' ability to take more accurate global warming and ozone depletion measurements, better predict hurricane tracking and landfall, and improve weather forecasting.

EOL's **Frontiers** in large part encompass Development efforts as well, though the focus is on emerging opportunities or developing needs in the Atmospheric Research Community that EOL will target for expansion. In FY 2010 EOL work in developing our Frontiers revolved around the development of a new Phased-Array Radar, a Modular Profiling Network, Driftsonde Development and the Front Range Observational Network Testbed (FRONT) that joins the forces of the NSF/NCAR S-Pol Radar and the CSU CHILL Radar.

Deployment

Deployment activities in EOL encompass 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."

The edge of sea ice near the Antarctic Circle. Taken from the NSF/NCAR GV during HIPPO Phase III flight to the Southern Polar Regions, April 5, 2010. HIPPO Phase III was one of six field campaigns EOL was involved in for FY 2010.

The fulfillment of Imperative I drives countless of our day-to-day efforts to preserve and consistently improve the NSF Lower Atmospheric Observing Facilities (LAOF) resources with which we are entrusted and maintain their readiness for our vigorous deployment schedule. Imperative I also encompasses major upgrades that become necessary due to old technologies becoming obsolete or new technologies that promise increased efficacy of the instrument. In FY 2010 our NSF/NCAR C-130 underwent an extensive upgrade to its avionics package.

Central to EOL's mission to support the atmospheric research community is Imperative II. We describe six such field programs in the Imperative II section, including the second and third phase of the landmark HIAPER Pole-to-Pole Observations (HIPPO) Campaign which deploys the NSF/NCAR GV Research Aircraft in the first comprehensive, global survey of the distribution of greenhouse gases and black carbon in the atmosphere. EOL also participated in studies involving winter storms, tornadoes, and hurricane genesis.

Data Services

During PREDICT, researchers dropped sondes into TS Fiona from the NSF/NCAR GV, using the Mission Coordinator Display to pinpoint hazardous weather. Hurricane Earl northwest of Puerto Rico. Each red dot on the flight track is 10 minutes.

EOL is committed to data processing, quality control, and archival for field projects as part of our expanding services that will be provided to the community, as expressed in **Imperative IV**, “Provide comprehensive data services, open access, and long-term stewardship of data.” This includes efforts to complete development of the Metadata Database and Cyberinfrastructure (EMDAC, formerly known as CODIAC) to access and browse products and data from field projects while integrating with the Community Data Portal.

EOL's Data mission encompasses real-time tools as well as the stewardship and accessibility to historical research data. An example of this is EOL's Mission Coordinator Display that was implemented for the first time during the PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT) in August and September 2010. This invaluable tool was developed to provide the onboard mission coordinator with storm hazard locations to safely navigate hazardous weather conditions - a necessity when studying the formation of hurricanes!

Discovery

We take seriously our responsibility to promote curiosity about Earth science and to inspire development of the next generation of observational scientists and engineers. In FY 2010 we undertook a lot of activities in support of **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 2010 we expanded our Field Project Education and Outreach offerings by hiring a specialist dedicated to developing and implementing comprehensive programs that include an online and social media presence, outreach and media events,

EOL expanded our Field Project Education and Outreach offerings with events such as this visit to a local school during PREDICT.

and educational modules for educators to use in conjunction with the field projects. We conducted two EOL educational deployments to educators wishing to gain access to observational facilities for classroom instructions and hands-on learning. Finally, 2010 was another record year in terms of applicants for EOL's Summer Undergraduate Engineering Internship Program, which focuses EOL's outreach efforts on the engineering community in a manner analogous to what UCAR/NCAR currently does for young scientists.

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Imperatives

Imperatives are those actions which EOL must do, must continue to do, or must enhance in order to fulfill its mission as an NCAR laboratory and to fulfill NCAR's role as a provider of observations for the communities we support.

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

- **S-Pol Radar**
- **ELectra DOppler RAdar (ELDORA)**
- **NSF/NCAR GV HAIS Instruments**
  - HIAPER Cloud Radar (HCR)
  - High-Spectral Resolution Lidar (HSRL)
- **NSF/NCAR C-130 Avionics Upgrade**

Imperative II

Support Observing Needs of Research Programs at a level that Serves NSF, University and NCAR Program Needs

- **HIAPER Pole-to-Pole Observations (HIPPO) Global Phases II and III**
- **Profiling of Winter Storms (PIOWS) 2009 and 2010**
- **VORTEX 2**
- **PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT)**
- **Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H20, Organics & Nitrogen (BEACHON)**
- **Concordiasi**

Imperative III

Anticipate Future Needs Resulting from Changing Priorities, Aging Equipment or Emerging Opportunities to Develop New Technology

- **Global Hawk AVAPS Dropsonde System**
- **Compact Atmospheric Multi-species Spectrometer (CAMS)**
- **Carbon Isotope Laser Absorption Spectrometer (CILAS)**
- **Water Vapor Reference Sounding System**

Imperative IV

Provide Comprehensive Data Services, Open Access, and Long-Term Stewardship of Data

- **EOL Metadata Database and Cyberinfrastructure (EMDAC)**
- **Mission Coordinator Display**
- **The Impact of Typhons on the Ocean in the Pacific (ITOP)**

Imperative V

Attract and Inspire New Generations of Scientists, Engineers and the General Public to Atmospheric Science

- **Educational Deployments**
  - DOW Radar Observations at Purdue study (DROPs)
  - Geoscience Research at Storm Peak (GRASP)
- **Field Project Outreach**
  - HIAPER Pole-to-Pole Observations (HIPPO) Global Phases II and III
  - Profiling of Winter Storms (PIOWS)
  - PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT)

- **Summer Undergraduate Engineering Intern Program (SUEIP)**
- **UCAR 50th Anniversary Open House**

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Director's Message

NESL Annual Report - Director's Message

Dear Colleagues:

Greg Holland - NESL Director

Preamble: FY 2010 has seen us steadily consolidating our new NCAR Earth System Laboratory and setting it on its future path. At the administrative level our goal has been to develop a strong, coordinated and responsive decision and administrative process, one that encourages laboratory-wide collaboration whilst retaining the identities and individual approaches of the Divisions. Our Executive and reorganized administrative structure is in place. And we have established a project management structure that provides a coordinated approach to establishing and running our many projects and collaborations, both within and external to NESL. I am confident that these provide a solid basis for us to weather the difficult times ahead and to benefit from those opportunities that arise.

We have developed the first NESL strategic plan. This sets out our priorities, major goals and frontiers for the next five years and beyond and is closely coupled to the NCAR strategic plan. Core to our strategic approach is the maintenance and enhancement of our leading-edge, integrative science, community interactions, and major community-facility support. NCAR has also developed a landmark Workforce Management Plan (WMP), which sets out your recommendations for your working and professional environment. Implementation of the WMP across NCAR has commenced with the enthusiastic and active involvement of the NESL Executive.

Evolution has been a hallmark of NCAR and is the basis of many of our flagship programs. This occurs in many ways, from subtle changes to existing programs to the development of major frontier areas. The Integrated Studies Program has evolved towards taking an entrepreneurial approach to nurturing new projects of merit; those that succeed move into the laboratory structure to become established programs, those that do not are closed and the funds applied to the next project. We are seeing this happening already with the transfer of BEACHON, UTLS and Water Cycle out of ISP and the closing of BGS. I am confident that ISP operating in this mode will support NESL strategic goals in the establishment of exciting new programs in much the same way that ASP has served us in helping excellent new scientists become established in our field.

Our mission: *To advance understanding of weather, climate, atmospheric composition and processes; to provide facility support to the wider community; and, to apply the results to benefit society.*

In performing this mission, we shall continue to:

- Work closely with other NCAR groups in furthering both our and NCAR's strategic goals
- Sustain and nurture fundamental disciplinary programs, while reaching out to engage other disciplines in accomplishing our goals
- Undertake transformational research, which involves an element of risk but is essential to improving our understanding of the earth system and to developing major community facilities
- Engage with community leaders and policy makers to convey research findings, to develop new research directions, and to emphasize the importance of investment in research and major facility development
- Invest wisely in the maintenance and continuing development of community modeling, instrumental and experimental facilities
- Develop next-generation tools and techniques in support of the atmospheric and related sciences utilizing

cutting-edge research and in collaboration with the wider community
- Encourage and promote new, diverse talent into our field through participation in educational programs from K12 through graduate university, and by mentoring students and young scientists

Laboratory Annual Report: This year we have mapped our LAR to the NESL strategic plan, which is closely aligned with NCAR Priorities and Frontiers. For 2010, our priority activities include:

- Advancing knowledge across a wide range of atmospheric, biological, chemical, climate and societal areas
- Prediction Across Scales and Earth Teleconnections
    - Decadal Global and Regional Climate Prediction, including preparation for IPCC V and time-slice decadal predictions of high-impact weather
    - Earth System Modeling, including the development of the Model for Prediction Across Scales and the Community Earth System Model
    - Development and expansion of the Weather Research and Forecasting modeling system, including the extensive data assimilation work
    - Development and maintenance of major instrumentation systems in support of the community
    - Participation in international field programs

Outlook: The next year will be a difficult one from a budgetary perspective. In minimizing the impacts, our priority will continue to be on supporting our colleagues in academia through advancing knowledge and through further development and continued support for our major modeling and experimental facilities. We shall further fine tune our lab structure and see implementation of parts of the WMP. It will also be a year of transition as a new Director will take over. I look forward to returning to a more scientific role and want to take this opportunity to thank the many NESL folks who have helped in the establishment of the laboratory and of our strategic plan.

Greg Holland
NCAR Associate Director
Interim Director, NCAR Earth System Laboratory

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Scientific Discovery

I. Scientific Discovery

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Aircraft-Induced Hole Punch and Canal Clouds: Inadvertent Cloud Seeding

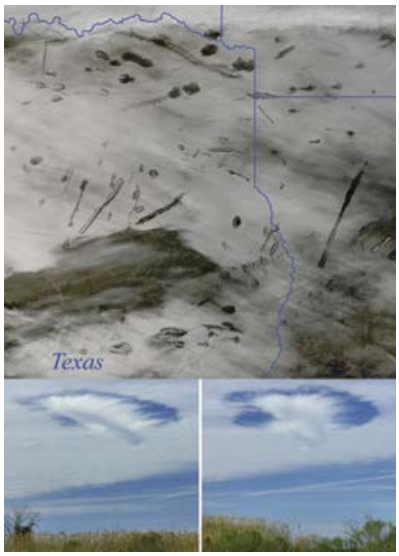

FIG. 1. Top: Image of hole punch and canal clouds captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite at 19:05 GMT on 29 January 2007 (Image courtesy of NASA Earth Observatory and specifically Jeff Schmaltz). State boundaries are shown. Bottom: Pictures taken from near New Orleans at 21:10 to 21:17 GMT on 29 January 2007, looking NW towards Shreveport, LA. Photos courtesy of Jafvis. [High Resolution Image]

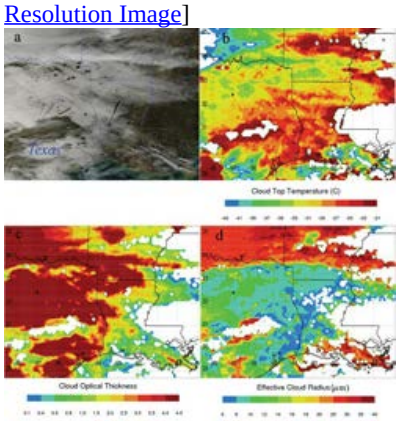

FIG. 2. Hole punch and canal clouds captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on 29 Jan 2007. State boundaries are shown. (a) High resolution imagery. (b) Cloud top temperature. (c) Cloud optical depth. (d) Cloud effective radius. [High Resolution Image]

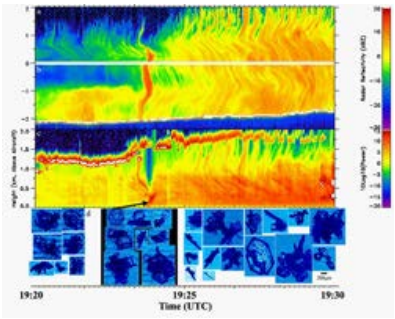

FIG. 3. (a, b) Radar reflectivity from WCR 95 GHz radar (a) zenith, and (b) nadir viewing. Height is altitude above or below the C130 altitude. (c) WCL lidar, zenith viewing. (d) Images of ice crystals sampled by the CPI probe. The scale is shown. Particles overlaying the black background were observed within the line echo. Note hole in precipitation above where the line echo crystals were intercepted. [High Resolution Image]

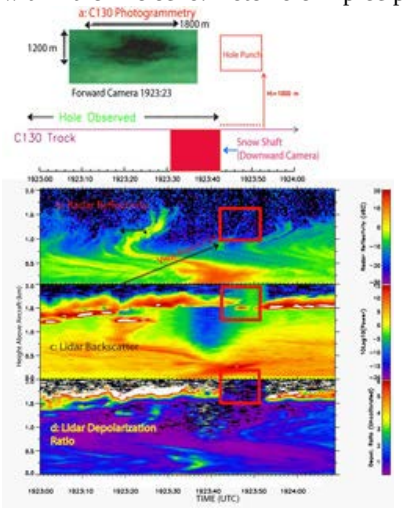

FIG. 4. Depiction of one minute of C130 data during the line crossing. (a) Enhanced forwardlooking camera digital photograph; the hole punch location is derived photogrammetrically (red box); the snow shaft is located where the ground is not visible from the downward-looking camera. (b) Upward-viewing C130 radar. (c, d) Lidar returned power and relative (uncalibrated) depolarization ratio. Red squares indicate the approximate location of the hole punch cloud. [High Resolution Image]

An interesting discovery was published by NESL scientists and university collaborators in BAMS (doi 10.1175/2009BAMS2905.1). The peculiar and striking formations called “hole punch” and “canal” clouds that are sometimes seen in midlevel altocumulus appear as circular or elongated channels or voids from which streamers of precipitation descend (Fig. 1). Altocumulus clouds are midlevel clouds that form typically at temperatures of about –15°C and are comprised of water droplets, especially near cloud top, sometimes mixed with a concentration of ice particles. The features of the altocumulus in which these holes form—visual shape, cloud top temperatures, optical depths, and cloud particle effective radii (e. g., Figs. 2a-d)—confirm that the parent clouds of the holes and canals are liquid.

Ice crystals can be produced by both turboprop and jet aircraft in and around supercooled liquid cloud layers. These crystals are produced by local adiabatic expansion at propeller tips attemperatures as warm as –8°C or over wing surfaces at temperatures <–20°C, and the resultant cooling chills droplets to a temperature of –37°C or below, causing the supercooled droplets to freeze via homogeneous nucleation. Through the Bergeron-Findeisen process, the ice crystals grow rapidly at the expense of the supercooled drops in the pre-existing cloud layer. Observations from the ICE-L case clearly demonstrate that this process can lead to linear, precipitating columns of ice comprised of a high concentration of ice particles, some growing to sizes of one millimeter and larger, with a detectable radar echo. As an aircraft ascends into or flies through a supercooled altocumulus, a hole or canal may be produced by aircraft wake vortex descent. However, when visual/optical indications of ice particles remain in the centers of the holes or channels, it is improbable that the clearings were caused by wake vortex-induced downward motions. In the absence of naturally occurring ice particle sources (i.e., fall streaks from overlying cirrus clouds, etc), the ice particles introduced by aircraft are probably responsible for many of the hole and channel openings observed in widespread supercooled altocumulus cloud decks.

Three factors may serve to widen the initial hole or channel with time: (1) dispersion of the aircraft’s exhaust trail, which spreads the ice trail laterally with time (t, sec) at a distance of order 4t0.5, or only about 200 m in 30 min. (see Schumann et al. 1995); (2) a manifestation of the B-F process, with the consequence that droplets at the edges of the ice/drop interface would continue to evaporate with time; (3) the net result of latent heating from ice growth, increasing the temperature in the hole. This latter mechanism would produce a locally warm region in a layer of neutral buoyancy, typical of altocumulus, forcing the air in the hole to rise and the air around it to subside. Transport of ice in this circulation and the subsidence in the liquid water region would further erode the surrounding liquid cloud. Whether a hole punch or canal cloud is formed—the channel’s aspect ratio—depends on the thickness of the cloud (time for the aircraft to climb through it), the thermodynamic stability and vertical and horizontal wind shear, and the air temperature. Of course, there may be situations where a hole is produced naturally, for example by ice streamers falling from cirrus clouds above. See figures 3 and 4 for observed and derived holes.

In effect, aircraft have the potential to inadvertently seed supercooled cloud layers. Figure 1 shows only the effect that aircraft can have on certain thin, liquid water clouds. Whether hole punch or canal clouds are detectable from the ground or from satellite observations depends on the presence of intervening cloud, background cloud on the opposite side of the feature, and/or flight through pre-existing radar echo. However, the question of detectability surely leads us to conclude that numerous aircraft effects on clouds and precipitation occur unnoticed in deeper clouds when the signal is not

so obvious. What are those effects? More extensive studies are needed to characterize regional implications of aircraft interactions with supercooled cloud layers. And for the research community, because ice nucleation in maritime clouds is of considerable significance, follow-up observations that document unexpectedly high ice concentrations and glaciation of maritime clouds at warm temperatures (Mossop et al. 1968) are of vital importance for understanding current and future climates.

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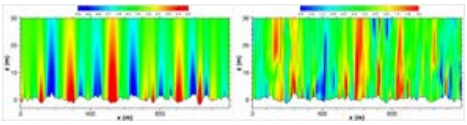
Atmosphere/ocean Interactions



Snapshot of static pressure fluctuations p′ /ρ in an x-z plane very near the water surface. The left panel is a swell dominated regime with wave age 4.8 while the right panel is a case near wind-wave equilibrium with wave age 1.4. The wave spectrum is a Pierson-Moskowitz spectrum. Notice the coherence between the wave field and the pressure fluctuations in the case with swell (left panel). The color bar is in units of m s-2 and the range is different between the two cases. [High Resolution Image]

In the past year NESL air-sea interaction research was directed towards developing and refining large-eddy simulation (LES) models of the marine atmospheric and oceanic boundary layers applicable to high wind regimes in the presence of surface waves. The LES model of the high wind ocean boundary layer is driven by time varying winds, surface scalar fluxes, and wave fields characteristic of Hurricane Frances. MMM scientist process studies examined the impact of resonant and anti-resonant winds and wave-current interactions on cooling of the OBL (ocean boundary layer). For the high wind atmospheric boundary layer, scientists adapted the massively parallel LES code to accommodate a general 3D time varying lower surface. The code is capable of simulating boundary-layer turbulence above moving ocean waves as shown in the figure below. These results illustrate the surprising and significant impact of swell on the near surface flow dynamics. One of the surprising results from the present simulations is the significant impact of swell on the coherence and magnitude of the near-surface pressure fluctuations. This is illustrated in figure where we compare p′ /ρ for two levels of wind forcing Ug = (5, 20) m s−1 , i.e., a low-wind situation with swell and a high wind case approaching wind-wave equilibrium.

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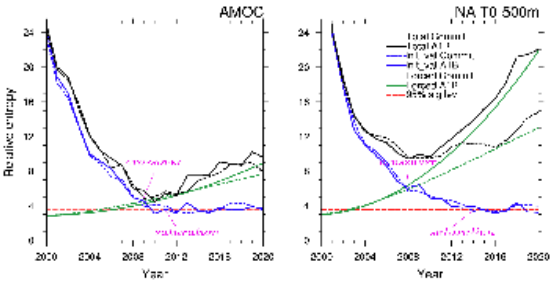
Decadal Predictability in CCSM

Overview

In contrast to weather prediction and seasonal prediction based primarily on ENSO, decadal prediction is still in its infancy. It is assumed that the oceans are the most predictable component of the climate system on decadal time scales, but there is no clear understanding of what their predictability limits are. In addition to predictability resulting from specification of the initial ocean state, increasing greenhouse gas concentration may also bring predictability to decadal forecasts. One key issue in this work is determination of the relative importance of these two contributions to predictability.

Recent Accomplishments



Information in two 40-member ensemble CCSM3 experiments as measured by relative entropy of (left) AMOC and (right) upper 500m temperature in the North Atlantic. The evolution of GHG forcing is different in the two experiments. As labeled, information resulting from the initial condition and from GHG forcing is plotted separately. [high resolution image]

The overturning circulation of the Atlantic (AMOC), with its inherently long-lived fluctuations, is often singled out as a component of the climate system that may be especially predictable on decadal timescales. To estimate and compare the contributions of greenhouse gas increases and information from the initial state to predictions of AMOC evolution, Branstator and Teng have analyzed a pair of experiments that have been carried out with CCSM3. Each experiment consists of 40 20-year integrations whose initial conditions are identical except for the atmospheric state. Because the climate system is chaotic the oceanic states diverge during the integrations and the “saturation” point, when realizations are as different as random states, is the forecast range at which utility from knowledge of the initial state has vanished. For the AMOC this limit turns out to be a little more than a decade while for all-important near surface North Atlantic conditions it is a few years longer. The pair of experiments differ in their specification of greenhouse gas evolution. Reactions of the ocean to greenhouse gases become stronger and stronger and eventually have a larger influence on the ensemble forecasts than the decreasing influence of the initial conditions. For the AMOC as well as for near surface ocean temperatures this "crossover" point occurs a few years before saturation and is not sensitive to the particular greenhouse gas scenario.

Branstator and Teng have also used these same experiments to estimate predictability in the North Pacific and found there too saturation of near surface temperature occurs after about a decade while crossover happens a few years earlier. Interestingly, in both basins predictability of about a decade can be seen in a prominent natural mode of the system. In the North Atlantic this mode corresponds to a weakening and strengthening of the AMOC and an associated anticlockwise propagation of near surface temperature anomalies in the subpolar gyre. In the North Pacific the mode is similar to nature’s Pacific Decadal Oscillation (PDO), which in CCSM3 propagates eastward across the basin in a predictable fashion.

2011 and Beyond

The forecast range at which information from an initial condition is lost depends on the particular initial condition and varies from one climate model to another. Branstator and Teng are developing methods for estimating this range that do not require computationally expensive ensemble experiments. Using these methods they plan to determine whether there are climate states and perhaps components of the ocean other than the AMOC and PDO that are especially predictable. Furthermore they will compare the predictability of a collection of climate models from various international research centers as a means of identifying the range of predictability behavior that climate systems, including nature, can have.

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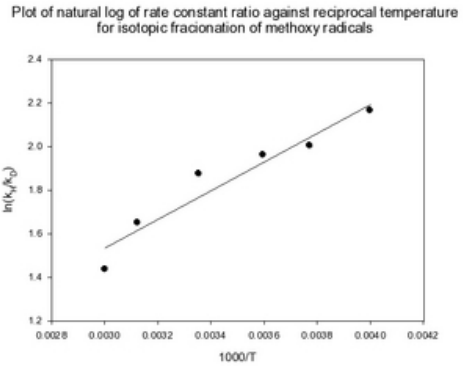
H/D Kinetic Isotope Effects in Reactions of Methoxy Radicals with O2

Laboratory Studies of Kinetic Isotope Effects in the Conversion of Methane to Molecular Hydrogen



[High Resolution Image]

The oxidation of methane (CH_4) in the atmosphere proceeds by OH oxidation. Different sources of methane have different isotopic signatures in the carbon (C-12 or C-13) or hydrogen atoms (H or D). Depending on the exact details of the oxidation mechanism, this isotope signature may be conserved in the reaction products (for example, in the production of H_2 or HD). If the details of the oxidation mechanism are understood via laboratory experiments, measurements of the isotope ratios in the atmosphere can provide constraints on the atmospheric source strengths.

The oxidation scheme for CH_4 and CH_3D (the singly deuterated variety) can be simplified as follows:

$>CH_4 + OH \rightarrow CH_3$
$CH_3D + OH \rightarrow CH_3/CH_2D$
$CH_3 \rightarrow CH_3O_2 \rightarrow CH_3O \rightarrow HCHO \rightarrow H_2 + CO$
$CH_2D \rightarrow CH_2DO_2 \rightarrow CH_2DO \rightarrow HCDO/HCHO \rightarrow HD/H_2 + CO$

Molecular hydrogen (H_2) is found to be enriched in deuterium in both the troposphere and the stratosphere relative to its known sources. It has been proposed that the enrichment is partly a result of the methane oxidation reactions shown above.

A critical step in this conversion is the reaction of deuterated methoxy radicals (CH_2DO) with molecular oxygen (O_2).

$CH_2DO + O_2 \rightarrow HCDO + HO_2$ Rate constant k_H
$\rightarrow HCHO + DO_2$ Rate Constant k_D

This reaction has been studied once before at room temperature, but the behavior under stratospheric conditions has yet to be determined. In collaboration with colleagues at the SUNY Environmental Science and Forestry Department at Syracuse, NESL/ACD scientists have studied the reaction of CH_2DO radicals with O_2 between 250 and 330 K. Measurements of the ratio HCDO/HCHO can be used to infer a value for the relative rates of the competing reaction pathways (kH/kD) . The data agree with the previous study at 296 K, but clearly show an increase in the production of HCDO at lower temperatures (increased enrichment). This increase will presumably enhance the production of HD relative to H_2 in the stratosphere.

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High-resolution simulations using CAM

Overview

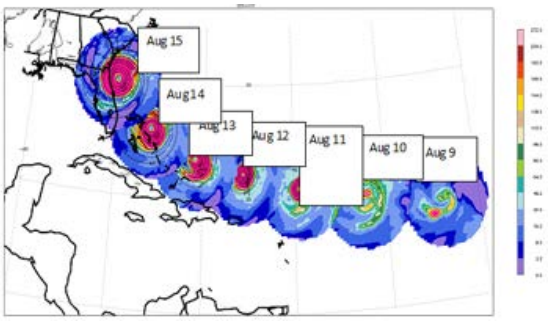

Figure 1. Powerful Atlantic hurricane which formed in a 0.23°x0.31° CAM5 run forced with observed SSTs. The figure shows instantaneous precipitation rates (colored shading) and surface pressure (contours) every 24 hours at 00Z beginning on Aug 9 2005. Fields are shown within a radius of 500 km of the diagnosed storm center. The storm is remarkably intense, attaining a minimum central pressure below 910 hPa, with maximum winds of over 140 kts (~70 ms^{-1}) at 50 m. Note the relatively dry eye at center of the storm in its mature phase. [high resolution image]

Increasing computer power has made it feasible to perform multiyear simulations using atmospheric general circulation models (AGCMs) with horizontal grid-spacings as fine as 25 km. Until recently, global simulations at these resolutions were restricted to short-term operational weather forecasts. These simulations blur the lines between weather and climate, and should, for the first time, allow faithful representations of both small-scale, high-frequency variability as well as seasonal and longer term means of atmospheric quantities. This is especially important for fields such as precipitation, which is highly-variable and whose seasonal, or even annual, means in a particular region may be dominated by a small number of intense events. Better representation of coastal mesoscale circulations, such as costal jets and sea-breezes could also have a positive impact on coupled atmosphere-ocean simulations.

The performance of global models with grid-spacings in the 10 to 50 km range is not yet well understood. Many parameterizations are formulated with a scale-separation implicitly or explicitly assumed between the phenomenon parameterized and the "large-scale" resolved by the AGCM. In the important case of deep convection this scale separation is doubtful when the AGCM grid-spacing is below 50 km. Many other parameterization schemes which were developed and tuned at much coarser resolution can also behave in unexpected ways at high-resolution. As a result, it will take some time and possibly recasting of key physics parameterization schemes to optimize AGCM simulations at high-resolution.

Recent Accomplishments

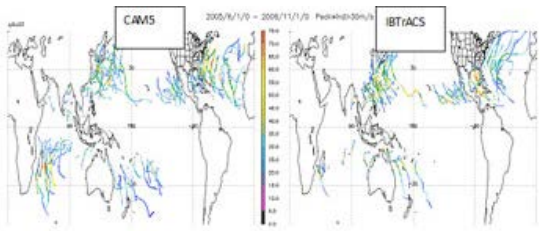

Figure 2. Tracks of simulated (left) and observed (right) tropical cyclones for the period June 1 2005 through Novemeber 1 2006. Observed tracks are obtained from the International Best Track Archive for Climate Stewardship (IBTrACS) Only storms whose 50 m winds exceeded 30 ms^{-1} (~60 kts) at some point during their lifetimes are shown. [high resolution image]

Both the Community Atmosphere Model version 4 (CAM4) and the newer Community Atmosphere Model version 5 (CAM5) have been run in multiyear simulations at a resolution of 0.23°x0.31°. The cloud, shallow convection, and boundary layer parameterizations used in these two models are different. We found pronounced differences in the resolution sensitivity of the models. Cloud radiative forcings and cloud amounts decrease sharply as resolution increases using CAM4 physics. By contrast, cloud properties in CAM5 are nearly insensitive to the 8-fold increase in resolution going from 2.0°x2.5° to 0.23°x0.31°. The change in CAM4 clouds at high resolution is detrimental and has so far eluded straightforward attempts at "re-tuning".

A substantial effort has begun to understand the small-scale, high-frequency variability in the multi-year 0.23°x0.31° CAM5 simulations. A number of promising features have come to light. The model develops tropical cyclones that appear realistic both individually and in terms of their overall geographical, seasonal, and interannual statistics. Figure 1 shows an intense storm which formed in one the simulations, which included the historically-active 2005 Atlantic season. The storm followed a classic Cape Verde trajectory, forming from an easterly wave off the African Coast, intensifying as it crossed the Atlantic, finally striking northern Florida. Figure 2 shows a global map of all tropical cyclones forming in one CAM5 simulation spanning the period June 1 2005 to November 1 2006. Observed tracks from the International Best Tracks Archive for Climate Stewardship (IBTrACS) for the same period are also shown. The figure illustrates both positive and negative aspects of the CAM5 tropical cyclone climatology. The overall pattern of the tracks is similar to that in the IBTrACS archive. This suggests that roughly correct numbers of storms are forming in each of the major basins. Both of the major southern hemispheric basins (S. Indian and S. Pacific) are somewhat overactive in the model. Interannual variability in the Atlantic basin (not shown) appears roughly correct with the variation in storm number for 1997, 2005 and 2006 captured in two independent simulations.

2011 and Beyond

Work will continue to characterize and understand the mesoscale variability that occurs in CAM at high resolution. Other forms of organized convection will be examined including mesoscale complexes in the midwestern US and sub-Saharan Africa. Initial examination of existing high-resolution CAM runs suggests that these systems are present in some form. However, their statistics and individual dynamics have not been studied.

Despite the surprisingly good performance of CAM5 at 0.23°x0.31°, without extensive tuning, it is likely that tuning or more substantial physics modifications will be needed to further improve the model at these resolutions. Several biases in the current high resolution simulations will be targeted in the near future. The overproduction of tropical cyclones in the southern Indian and Pacific basins is likely related to excessive rainfall in southern ITCZs across these basins – the "double ITCZ bias". As is the case in several other major climate AGCMs, this precipitation bias becomes worse in CAM at high-resolution. The intensity distribution of precipitation in CAM at 0.23°x0.31° contains too many events with extremely high rates (>1000 mm d^{-1}) while also containing far too many moderate events (5 – 20 mm d^{-1}). It is likely that all of these biases involve interactions between deep convection, shallow convection and large-scale cloud parameterizations. Finally, examination of cloud resolving model results strongly suggests that column mass contributions from precipitating condensate are not always negligible in $(25\ km)^2$ areas. This may indicate that AGCMs at these resolutions should implement prognostic precipitation, sooner rather than later, with the appropriate connections to the models pressure calculation.

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Improved parameterizations for use in Cloud Resolving Models (CRMs)

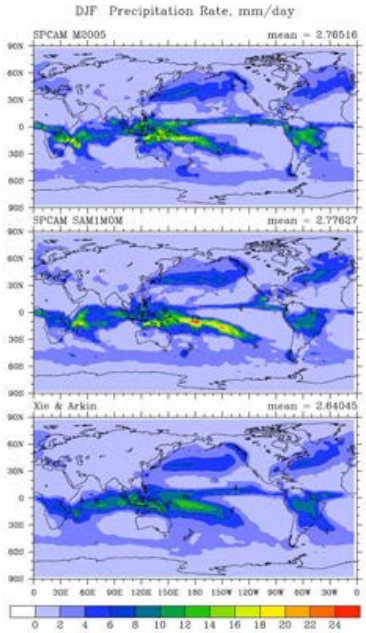

Figure 1: Surface precipitation rate from SP-CAM simulations using the Morrison et al. (2005) two-moment microphysics scheme (top), the default one-moment microphysics scheme (middle), and observations (bottom). [High Resolution Image]

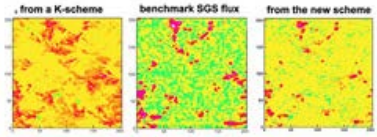

Figure 2: Horizontal distributions of the SGS vertical flux of moisture obtained from (1) the conventional K model (left panel), (2) the Giga-LES (center), and (3) the new SGS scheme (right), at z ~ 1.5 km. [High Resolution Image]

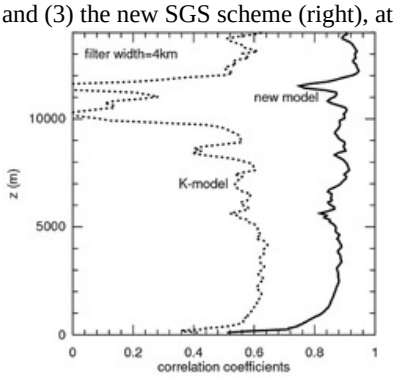

Figure 3: Vertical profiles of the spatial correlation coefficients between the modeled SGS fluxes and those retrieved from the Giga-LES. [High Resolution Image]

The multiscale model framework (MMF) will be used to better understand and quantify the roles of deep convection, precipitation, ice microphysics, and boundary layer processes in large-scale hydrological and chemical cycles and the effects on weather and climate.

Other work carried out in FY2010 involved development of a SGS (sub-grid scale) transport scheme for Cloud-Resolving Models (CRMs) using Giga-LES (large eddy simulation).

NESL/MMM scientists continued to analyze the Giga-LES to study the SGS transport process in CRMs (cloud resolving models). The Giga-LES flow field was separated into CRM-resolvable and CRM-SGS components and performed a detailed analysis on the retrieved SGS fluxes. This analysis led to a mixed SGS scheme for CRMs where a new term is added to the commonly-used K model. The new term explicitly accounts for the effect of the largest SGS eddies. A priori tests of the new scheme were performed that showed much improvement in the estimation of the SGS fluxes of moisture and momentum. Figure 2 compares the spatial distributions of the SGS moisture fluxes (left panel) estimated by the conventional K model, (right panel) estimated by the new scheme, and (center) retrieved from the Giga-LES.

Figure 3 shows the vertical profiles of the correlation coefficients between the modeled and retrieved SGS fluxes. The estimated SGS fluxes from the new scheme correlate better with those retrieved from the Giga-LES, with the correlation coefficients increase from about 0.6 with the conventional K-model to about 0.9 with the new scheme. This improvement is found for all other SGS fluxes, including the momentum fluxes.

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Efficient atmospheric cleansing of oxidized organic trace gases by vegetation

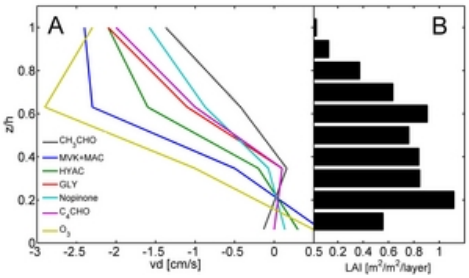

Figure 1: Canopy integrated deposition velocity for ozone (O_3), C_5 carbonyls (C_4CHO), nopinone, glycolaldehyde (GLY), hydroxyacetone (HYAC), MVK+MAC and acetaldehyde (CH_3CHO) as function of normalized canopy height (z/h), where a z/h of one represents the top of the canopy (A). Panel B depicts the leaf area index (LAI) per layer. Measurements were taken during a field campaign in the Amazon in 2008. [High Resolution Image]

Volatile organic compounds (VOC) fuel tropospheric chemistry and are a critical component for understanding radical cycling as well as ozone and organic aerosol formation. Biogenic sources are thought to dominate the global VOC budget (i.e. 80-90%). The fraction of low to moderately soluble VOC depositing back to vegetation currently remains practically unknown. This represents a significant uncertainty when constraining budgets of VOC (and subsequently organic aerosol), because these VOCs account for a large amount of carbon during the initial oxidation phase. ACD scientists and collaborators, including Kolby Jardine (U. Arizona), have analyzed a large number of micrometeorological field observations collected over the past 7 years and have shown that the removal of oxygenated volatile organic compounds (OVOCs) via dry deposition is substantially larger than currently assumed for deciduous ecosystems (temperate, sub-tropical and tropical). Laboratory experiments conducted by ACD scientists and collaborators Brenda Thornton and Chhandak Basu (U. Northern Colorado) identified detoxification mechanisms as a key explanation for these observations. These laboratory experiments also suggest that chemical stresses (e.g. elevated ozone levels) can potentially increase the uptake of OVOC via short (0-2 hours) and long-term (>1day) genetic upregulation of enzymes controlling detoxification. Incorporation of a modified dry deposition scheme into the NCAR MOZART global chemistry model leads to appreciable regional increases of predicted dry deposition. These results will have consequences for capturing the dynamic behavior and repartitioning of organic carbon (VOC+SVOC+SOA) in coupled Earth-system models.

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Prescribed burning reduces carbon footprint of wildfires

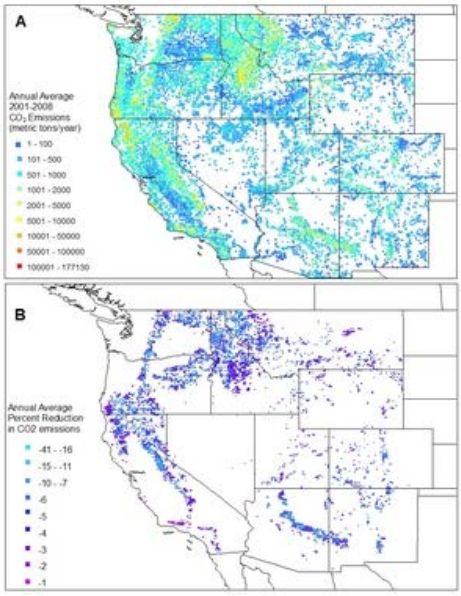

Figure 1: (A) Annually-averaged (2001-2008) fire CO_2 emissions for the western U.S. gridded to 4km horizontal resolution. (B) Annually averaged (2001-2008) percent reduction in emissions for the same grid. [High Resolution Image]

Carbon sequestration by forested ecosystems offers a potential climate change mitigation benefit. However, wildfire has the potential to reverse this benefit. In the western United States, climate change and land management practices have led to increases in wildfire intensity and size. One potential means of reducing carbon emissions from wildfire is the use of prescribed burning, which consumes less biomass and therefore releases less carbon to the atmosphere. ACD scientists collaborated with Matthew Hurteau (Northern Arizona University) to use a regional fire emissions model developed by NCAR to estimate the potential reduction in fire emissions when prescribed burning is applied in dry, temperate forested systems of the western U.S. Daily carbon dioxide (CO_2) fire emissions for 2001−2008 were calculated for the western U.S. for two cases: a default wildfire case and one in which prescribed burning was widely applied. Figure 2 shows that wide-scale prescribed fire application can reduce CO_2 fire emissions for the western U.S. by 18−25% in the western U.S., and by as much as 60% in specific forest systems. Although this work does not address important considerations such as the feasibility of implementing wide-scale prescribed fire management or the cumulative emissions from repeated prescribed burning, it does provide constraints on potential carbon emission reductions when prescribed burning is used.

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Particle growth and formation

New particle formation is the spontaneous creation of new nanometer-sized particles in the atmosphere. Observations spanning from megacities to isolated forests show that these events can occur frequently and extend for hundreds of square kilometers. While the impacts of these events are not well understood, they are often the dominant source of particles in remote regions and could play a crucial role in the Earth's climate by regulating the number and activity of cloud condensation nuclei (CCN). This effect of aerosols on cloud properties is recognized in the Fourth IPCC Assessment Report as the largest single contributor to uncertainty in predicting climate change. Knowledge of chemical composition, concentrations, and thermodynamic properties of the neutral molecular clusters that initiate new particle formation is essential. In addition, since cloud droplet activation normally occurs on particles of about 100 nm in diameter, it is important to understand and model growth rates of these newly formed particles. However, in spite of decades of research in this area, we still do not know what neutral molecular species are responsible for this process, nor do our models of growth agree with observed growth rates.

The primary objective of the Ultrafine Aerosols (UA) Research Group is to use theoretical models, laboratory and ambient measurements to understand the species and mechanisms that determine the formation and growth rates of freshly nucleated atmospheric aerosol. During the past year, the UA group focused on (1) analysis of data from recent field campaigns; (2) assembly and testing of the High Resolution Time-of-Flight Thermal Desorption Chemical Ionization Mass Spectrometer (HTOF-TDCIMS); and (3) laboratory measurements focusing on understanding nanoparticle formation and growth.

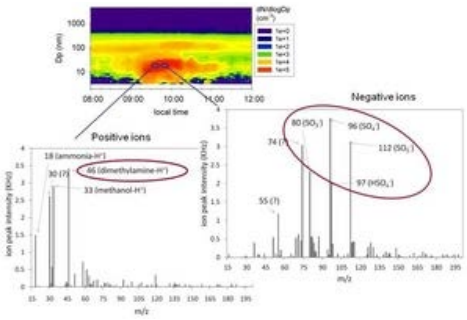

Figure 1. TDCIMS-derived mass spectra of 20 nm diameter particle composition during a new particle formation event observed during NCCN09. The negative ion mass spectrum (lower right) shows that nanoparticles were primarily composed of sulfate, however this sulfate is neutralized primarily by an amine, dimethyl ammonium (lower left), with ammonium comprising only about a third of the particulate bases. [High Resolution Figure]

1. The UA group recently completed its initial analysis of data obtained during the "Nucleation and Cloud Condensation Nuclei 2009," or NCCN09, campaign. NCCN took place from mid-July until the end of August 2009 in midtown Atlanta, GA; its goals included understanding the mechanisms by which particles nucleate and grow in this atmosphere. Results from TDCIMS measurements of the composition of nanoparticles formed from nucleation, such as those shown in Figure 1, confirmed prior observations from a variety of sites that organic salt formation plays an important role in nanoparticle growth. Organic salts are ionic complexes formed when an organic base such as an amine combines with an organic acid such as acetic acid. By combining these recently analyzed results from NCCN09 with those from four other field campaigns, we showed that organic salt formation could account for 10-45% of detected particulate organic compounds. These salt compounds thus contribute significantly to nanoparticle growth and must be accounted for in models to accurately predict the impact of new particle formation on climate. An invited manuscript describing these observations was published in 2010 in the Proceedings of the National Academy of Sciences.

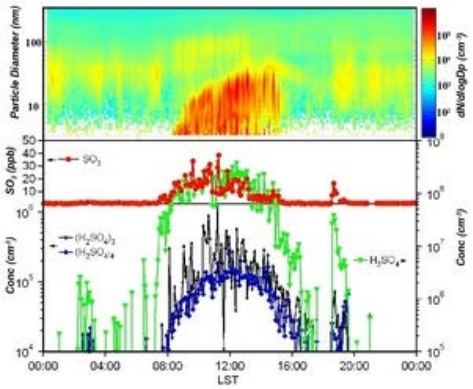

Figure 2. The particle size distribution (top) (measured by Prof. Peter McMurry's group, University of Minnesota) and the concentrations of the clusters (up to tetramers), monomer, and SO_2 on August 23, 2009 during NCCN09. High Resolution Figure

During NCCN09, the UA group also performed measurements of the composition of neutral molecular clusters using the Cluster Chemical Ionization Mass Spectrometer (Cluster-CIMS). As Figure 2 shows, measurements in Atlanta are consistent with those performed elsewhere in which concentrations of 10^4-10^5 cm^{-3} molecular clusters containing 3-4 sulfuric acid (H_2SO_4) molecules coincided with detected nucleation events. As the plot shows, sulfuric acid clusters are unambiguously associated with the new particle formation event (Figure 2, upper plot) that began at 8:00am and ended at 4:00pm local time. Measurements such as these provide the first direct observations of the species involved in nucleation, and are currently being used to develop a predictive module for nucleation that can be incorporated into regional and global models.

2. The HTOF-TDCIMS is a variation on the TDCIMS instrument in which the quadrupole mass spectrometer is replaced by a commercial high resolution time-of-flight mass spectrometer. During the past year, with funding from the National Science Foundation, we received the HTOF mass spectrometer and interfaced it with a TDCIMS inlet. The first high resolution mass spectrum was obtained in the summer 2010, and the new system is currently undergoing laboratory evaluation and further refinement. The current plan calls for the HTOF-TDCIMS to participate in two field campaigns in 2011: a winter campaign in Hyytiälä, Finland and a spring campaign at Mace Head, Ireland.
3. During the past year we continued laboratory experiments designed to further elucidate the chemical species and mechanisms that are responsible for the formation and growth of ambient atmospheric nanoparticles. These studies are described below:
    - We generated 10-20 nm diameter mixed ammonium/aminium sulfate aerosol using an electrospray aerosol generator and measured the composition of these particles using TDCIMS. These experiments confirmed that the more basic amine compound can displace ammonium in sulfate particles, suggesting that amines can be even more common in ambient aerosol than previously thought. These tests also showed that the TDCIMS can adequately quantify the mole ratio of both anion and cation constituents in salt nanoparticles.
    - In collaboration with the University of Eastern Finland, Kuopio, we studied aerosol formation from the oxidation of real plant emissions. These experiments, which use pine and spruce trees that dominate boreal forest emissions, explore the relative importance of O_3-initiated and OH-dominated reactions in new particle formation. Both of these oxidants lead to the formation of new particles, however, some important distinctions are observed. OH oxidation of VOCs plays an important role in the nucleation process and during the initial stages of particle growth. The highest average particle formation rate of 360 $cm^{-3}s^{-1}$ was observed for the OH-dominated nucleation events and the lowest formation rate of less than 0.5 $cm^{-3}s^{-1}$ was observed for the case with only O_3 present as an oxidant. In contrast to the particle formation process, ozonolysis of monoterpenes appears to be much more efficient to the aerosol growth process following nucleation. The second manuscript focuses on the calculation of aerosol yield from the oxidation of real plant emissions. That study found relatively small differences in aerosol yields, even when the VOC and oxidant levels are varied significantly. Depending on the amount of pre-existing aerosol, yields ranged from 2 to 14 μg m^{-3}. This is in the range reported from measurements of ambient aerosol in Hyytiälä, Finland.

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'Process' Modeling (GECKO, TUV)

Modeling the Formation of Organic Aerosols

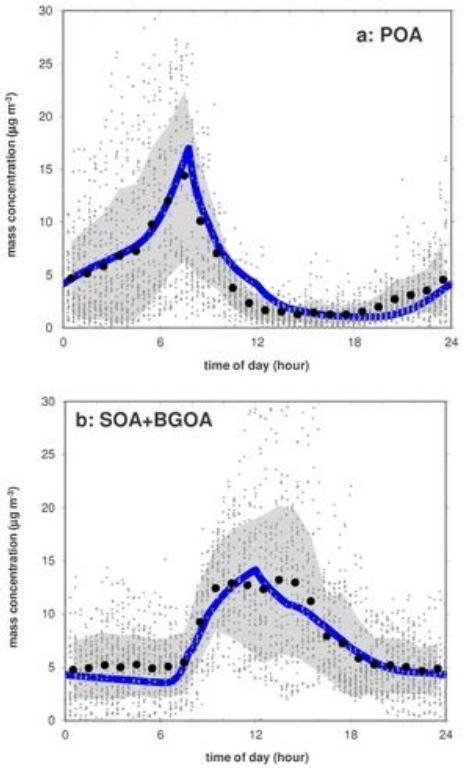

Figure 1: Organic aerosols in Mexico City during the MIRAGE field campaign. Individual measurements are shown as small gray points, with black points and shaded areas their mean and standard deviation. GECKO-A model results are shown by the blue curve. Top panel shows primary organic aerosols (POA) while bottom panel shows secondary organic aerosols (SOA) and regional background aerosols (BGOA). [High Resolution Image]

NESL/ACD scientists are using a detailed chemical model to explain the abundance of organic aerosols (OA) in the troposphere. The chemical model, named Generator of Explicit Chemistry and Kinetics of Organics in the Atmosphere (GECKO-A), predicts both primary organic aerosols (POA) from emitted hydrocarbons, and secondary organic aerosols (SOA) from hydrocarbon oxidation intermediates containing oxygen and nitrogen. The model computes kinetic and mechanistic pathways for hydrocarbon photo-oxidation, thermodynamic estimates of vapor pressures, and gas/aerosol equilibrium partitioning, to produce a detailed picture of the chemical composition of the OA.

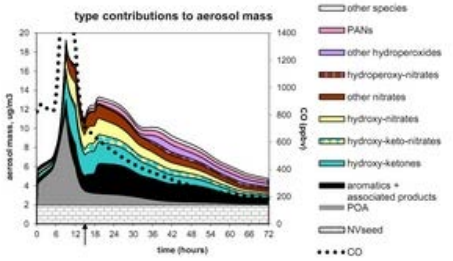

Figure 2: Chemical composition of simulated organic aerosol in Mexico City (0-15 hrs) boundary layer and in the outflow plume (15-72 hrs). Non-

volatile seed represents an estimate of the regional background aerosols. [High Resolution Image]

The model is being evaluated using measurements from the NCAR-led MIRAGE field campaign that took place in Mexico City during March 2006. Simulations were made for the urban boundary layer and for the outflow pollution plume. Figure 1 shows that the amount and diurnal cycle of both POA and SOA is well simulated by the model. Figure 2 shows that the aerosol is dominated by POA near the source (morning of first day) and by aromatics, hydroxy ketones, hydroxy nitrates, and other multifunctional molecules in the outflow plume.

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Organized Motion in Canopy Turbulence

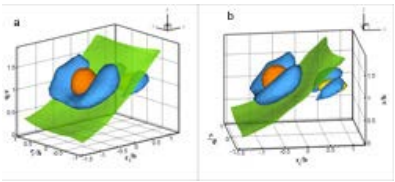

Figure 1: Three-dimensional images depicting the composite eddy structure from canopy-resolving large-eddy simulation from two vantage points. The isosurfaces shown in blue are of.A2 at a value of -0.77 and depict the 'head-up' and 'head-down' vortices. The translucent sheet in green is an isosurface of zero scalar concentration perturbation from the horizontal average. The isosurface shown in orange is of u' w' at a value of -0.6 m2 S2 in the sweep region, while that in yellow is the same quantity at a value of -0.15 m2 S2 associated with the ejection. Note that the u'w' sweep isosurface is drawn at a value that is four times greater than that of the ejection. The canopy top is located at z/h = 1. [High Resolution Image]

Vegetation covers nearly thirty percent of the Earth's land surface and influences climate through the exchanges of energy, water, carbon dioxide, and other chemical species with the atmosphere (Bonan, 2008). The Earth's vegetation plays a critical role in the hydrological, carbon, and nitrogen cycles, and also provides habitat and shelter for biota that deliver essential ecosystem services such as pollination. In addition, living foliage produces a variety of chemical compounds that can significantly influence the oxidation capacity (cleansing ability) of the atmosphere (e.g., Fuentes et al., 2000; Guenther et al., 2006). Plant-atmosphere interactions can also have negative effects with billions of dollars each year lost from wind damage to forests and crops. Therefore, understanding the processes controlling vegetation-atmosphere exchange at the most fundamental level is of critical importance for weather, climate and environmental forecasting as well as for agricultural and natural resource management.

Over the years, it has become known that exchange between a canopy and the overlying layers of the atmosphere is dominated by relatively large turbulent eddies generated near the canopy top (e.g., Raupach et al., 1996). These canopy-scale motions affect the flow well above the canopy (up to two or three times the canopy height), which results in the inapplicability of traditional flux-gradient relationships; this region is called the roughness sublayer. An understanding of these organized structures, how they form, how they evolve, and how they interact with both the vegetation and stratification is essential for developing parameterizations of roughness sublayer turbulence for larger-scale models.

Through recent canopy-resolving large-eddy simulations where ensemble averaged three-dimensional organized structure is deduced by triggering on canopy-top pressure (Finnigan et al., 2009), organized motions in canopy flows are found to consist of 'head-up' and 'head-down' hairpin vortices, which are both inclined in the downstream direction (Fig. 1). Consistent with observations (e.g., Gao et al., 1989), turbulent momentum transport near the canopy top occurs through frequent but relatively weak upward motions transporting low momentum fluid out of the canopy (ejections, yellow isosurface in Fig. 1) with infrequent but stronger downward penetrations into the canopy of high momentum fluid from aloft (sweeps, red isosurface in Fig. 1), where the ejections and sweeps are generated as induced flows between the counter-rotating legs of the hairpins. A scalar micro front lies between them in the convergence region between the downstream ejection and upstream sweep (green isosurface in Fig. 1).

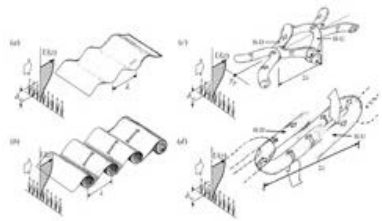

Figure 2: Schematic diagram of the formation of the dual-hairpin eddy: a) The initial instability is a KelvinHelmholtz wave of wavelength A, which develops on the inflected mean velocity profile at canopy top. b) The resulting velocity field is non-linearly unstable and successive regions of alternating span wise vorticity clump into coherent 'Stuart' vortices. c) Two successive Stuart vortices move closer together at some lateral location by the ambient turbulence. The mutual induction of tlleir vorticity fields causes them to approach more closely and rotate around each other. d) As the initial hairpins are strained by the mean shear, most of the vorticity accumulates in the legs and self-induction by the vortex legs dominates the motion of the hairpins resulting in the head-down hairpin, which was initially below, moving up while the head-up hairpin moves down. Adapted from Finnigan et al. (2009). [High Resolution Image]

At the canopy top, an inflection in the mean wind profile results from absorption of the fluid's momentum throughout the entire canopy depth as drag on the plant elements. The inflection point is inviscidly unstable with the initial instability taking the form of a linear Kelvin-Helmholtz (K-H) wave. This K-

H wave emerges preferentially when larger-scale motions from higher in the boundary layer bring high momentum fluid down to the canopy top and augment the canopy-top velocity shear (Fig. 2a). The mean background flow with this wave-like perturbation superimposed upon it is itself unstable; nonlinear analysis shows that the K-H wave can evolve into finite-amplitude transverse 'Stuart' vortices (see Fig. 2b and Stuart, 1967). In response to random turbulent perturbations two 'Stuart' vortices approach and rotate around each other (e.g., Fig. 2c) with the head-up hairpins deflected upwards and forwards by their downwind neighbors and the head-down hairpins deflected downwards and backwards by their upwind neighbors; where, this process matches the helical-pairing instability described by Pierrehumbert and Widnall (1982). Stretching of the hairpin legs by the mean shear and self-induction by the two hairpins completes the production of trains of hairpin vortex pairs comprised of a leading head-up and trailing head-down hairpin (Fig. 2d).

This model extends, and in some senses completes, Raupach et al.'s (1996) mixing-layer hypothesis that the inflected mean-velocity profile associated with the canopy's distributed momentum absorption plays a critical role in generating the coherent eddies which dominate canopy turbulence structure. Indirect evidence for the fundamental role played by this canopy-top instability comes from Harman and Finnigan's (2007; 2008) extension of Monin-Obukhov similarity theory to the roughness sublayer where using the vorticity thickness associated with the inflected velocity profile as an additional scaling length allowed their extension to match observed mean-velocity and scalar profiles through the roughness sublayer. Future analysis will emphasize the interplay of these organized motions with thermal stratification and distribution of the canopy elements.

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Radical Recycling in Reactions of Organic Peroxy Radicals with HO2

The HO_x family of radical species (including OH, HO_2, and organic peroxy radicals RO_2) are central participants in the chemistry of the atmosphere. In the lower atmosphere, OH initiates the breakdown of most organic species in reactions that usually produce either HO_2 or RO_2:

$$OH + RH (+ O_2) \rightarrow RO_2 + H_2O$$

Reactions of HO_2 and RO_2 then to first approximation lead to radical loss, for example in the self-reaction of HO_2,

$$HO_2 + HO_2 \rightarrow HOOH \text{ (hydrogen peroxide)} + O_2$$

or to radical propagation (i.e., OH formation), for example in the reaction of HO_2 with NO:

$$HO_2 + NO \rightarrow OH + NO_2$$

These and related reactions are collectively responsible for the destruction of most compounds emitted into the atmosphere and for the production of many secondary oxidants such as ozone, oxygenated organic species, and organic and inorganic acids.

Given the central role played by these HO_x radicals in tropospheric oxidative chemistry, it is then important to determine the relative rates of radical propagation versus radical termination. In the past, reactions of RO_2 with HO_2 were thought to be exclusively terminating,

$$RO_2 + HO_2 \rightarrow ROOH \text{ (organic peroxide)} + O_2$$

However, collaborative research involving laboratory scientists at NESL/ACD and Fresno State [Hasson et al., 2004] showed that in some specific cases, these reactions can also generate OH and thus act in part to propagate radicals, for example,

$$CH_3C(=O)O_2 + HO_2 \rightarrow CH_3 + CO_2 + OH + O_2$$

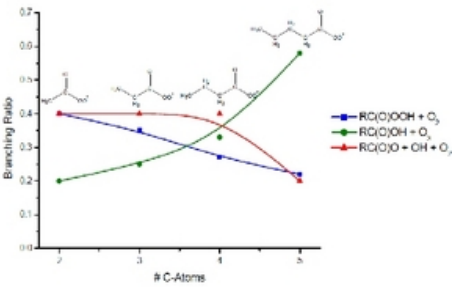

Figure 1: Branching ratios to formation of OH (and to organic acids and peroxyacids) in the reactions of simple acylperoxy radicals with HO_2. [High Resolution Image]

Work on these RO_2/HO_2 reactions has continued in recent years, and shows significant OH production in the reactions of all acylperoxy radicals (i.e., those of general structure $RC(=O)O_2$) with HO_2, see Figure 1. Also, OH production appears to be ubiquitous in the reactions of HO_2 with organic peroxy radicals of general structure R"C(=O)C(R')(R)OO•, with the yield appearing to increase with increasing complexity of the R and R' groups.

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CESM / CCSM

Community Earth System Model

Overview

An imperative for NCAR is to develop and continuously improve a comprehensive Earth modeling system that is at the forefront of international efforts to understand and predict the behavior of Earth's climate. For many years the Community Climate System Model (CCSM) met this challenge. Its output, for instance, has been used in hundreds of peer-reviewed studies to better understand the processes and mechanisms responsible for climate variability and climate change. In addition, simulations performed with CCSM have made a significant contribution to both national and international assessments of climate, including those of the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Global Change Research Program (USGCRP). A trademark of the CCSM project is that it is a community collaboration. It is unique in the climate modeling sphere because of its commitment to make the model readily available to, and usable by, the climate research community. Community members are actively engaged in the ongoing process of model development.

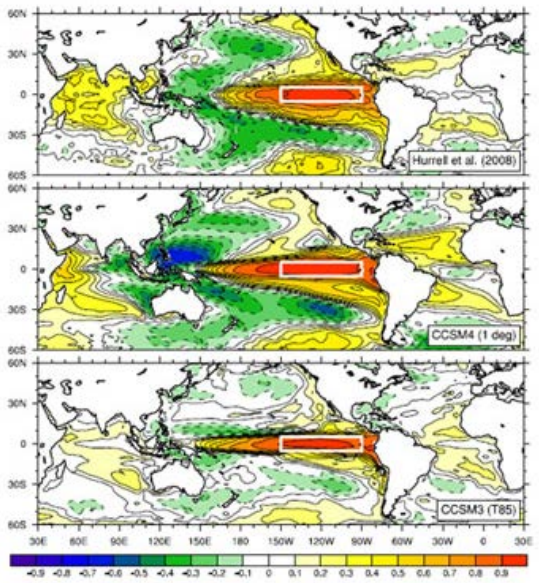

Figure 1: Correlation of monthly mean Nino3 SST anomalies with global SST anomalies for (top) observations; (b) CCSM4; and (c) CCSM3. Taken from Gent et al. (2010). [**high resolution image**]

Recent Accomplishments

CCSM4.0

The development of the model is a continuous process. Version 4 of CCSM was released to the community in April 2010, and it features many notable improvements over previous versions of the model (see,

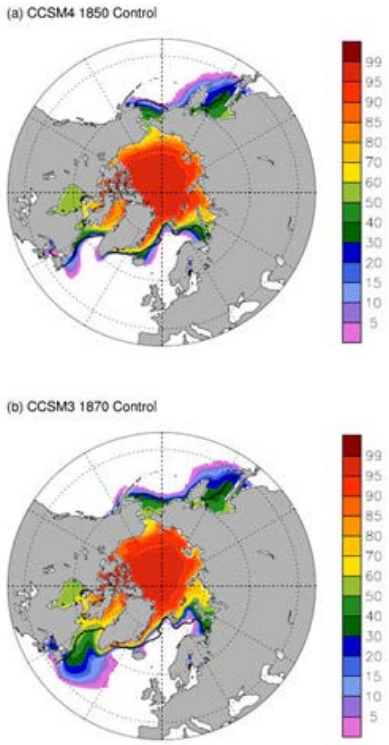

Figure 2: Mean Arctic sea ice concentration for: (top) CCSM4 and (bottom) CCSM3. Simulations were for pre-industrial conditions, and the black lines are the 10% mean concentration values from satellite observations. [**high resolution image**]

http://www.ccsm.ucar.edu/models/ccsm4.0/notable_improvements.html). One example of a significant improvement is the ability of CCSM4.0 to simulate the dominant pattern of interannual weather and climate variability over the globe, namely the El Niño/Southern Oscillation (ENSO) phenomenon. One aspect of this is shown in Fig. 1, which shows the correlation of monthly mean tropical eastern Pacific (Niño3) sea surface temperature (SST) anomalies with global SST anomalies. CCSM4.0 simulates a much more realistic meridional width to the positive correlations in the central and eastern tropical Pacific. It also captures the observed horseshoe pattern of negative correlations in the western tropical Pacific stretching into the middle latitudes of both hemispheres, as well as connections to the other tropical ocean basins. The improved ENSO variability in the CCSM4.0 compared to the CCSM3.0 and earlier versions will allow more plausible assessments of possible future changes in ENSO.

Simulations with CCSM4.0 also reveal improvements relative to CCSM3.0 in Arctic sea ice coverage. The mean sea ice concentration in the Arctic from both models is shown in Fig. 2, where the black lines are the 10% mean concentration values from satellite observations. The figure shows that the sea ice was much too extensive in the Labrador Sea and adjacent North Atlantic in the CCSM3.0, and this is much improved in the CCSM4.0 with the southern Labrador Sea being ice free. This improvement means that deep water formation can occur in the southern Labrador Sea in the CCSM4.0, whereas it was incorrectly located further east in the North Atlantic in earlier simulations. Credible simulations of Arctic sea ice are important, as there is a great deal of interest in what will happen to Arctic sea ice in the near future

Development of CESM1.0

To address a wider range of pressing scientific questions, additional capabilities have been added to CCSM4.0. These include, for instance, an interactive carbon cycle in the land component and an ecosystem-biogeochemical module in the ocean component. There is also an updated atmospheric chemistry component, a global dynamic vegetation component, and land use changes due to human activity in the land component. A new version of the atmospheric component model now allows scientists to study both the direct and indirect effects of aerosols. The model can be run using the Whole Atmosphere Community Climate Model (WACCM), in order to better understand the role of the upper atmosphere in climate variability and change. There is also an early version of a land-ice component that can be used to simulate changes to the Greenland ice sheet and its role in future climate change (e.g., the rate at which land ice will melt under future emission scenarios and the contribution of the melt to future sea level rise). Since the most widely used description of a model with these capabilities is an "Earth System Model", the project and supported model is now called the "Community Earth System Model", or CESM. The release of Version 1 of CESM occurred in June 2010.

CMIP-5 and IPCC

Both CCSM4.0 and CESM1.0 are being used to conduct an extremely ambitious set of simulations in support of the upcoming Fifth Assessment Report (AR5) of IPCC. The simulations are part of the so-called CMIP-5 experimental

design, which is a set of coordinated climate model experiments on two time scales: (1) near-term, initialized decadal prediction simulations; and (2) long-term simulations from 1850 through the end of the current century and beyond. The CESM project completed a large number of the simulations in 2010 so that they can be fully utilized by the community in time to be assessed in the AR5.

CESM Tutorial

The first, annual, CESM tutorial occurred in July 2010 and, based on participant feedback, was extremely successful. More than 180 applications were received, and 72 participants were selected. This included 40 'full' participants and 32 'auditors'. The auditors attended all lectures and were able to work on the practical sessions independently. The 40 full participants were almost exclusively graduate students, and the auditors comprised a mix of advanced graduate students, postdoctoral scientists and early career faculty. No single institution had more than 2 'full' participants in the tutorial. The represented institutions included 35 U.S. and Canadian (UCAR member) universities, six foreign universities, two NOAA facilities and four DOE National Laboratories.

2011 and Beyond

A major goal moving forward is to complete the CMIP-5 simulations using both CCSM4.0 and CESM1.0. Although CMIP-5 is a 5-year experimental protocol designed to address outstanding scientific questions that arose from the Fourth Assessment Report (AR4) of IPCC, the CESM project completed many integrations in 2010 and will strive to complete others in in early 2011. Among the many CMIP-5 simulations, a few points to note in particular include:

- To complete the decadal prediction experiments, CESM will fully integrate recent NOAA- and NSF-funded developments within the NCAR Data Assimilation Research Testbed (DART), permitting the capability of ensemble data assimilation for both the atmosphere and the ocean. The assimilation capability will also address the desire for ensemble predictions, which is necessary to optimally assess forecast uncertainty. Further work involves simulation of tropospheric chemistry at high-resolution.
- CESM will make a unique contribution to AR5 through the completion of CMIP-5 experiments with more than one configuration of the atmospheric model. Different atmospheric components of CESM, for instance, will allow community scientists to estimate the indirect aerosol effect, determine the role of upper-atmospheric processes in climate, and analyze transient chemistry-climate simulations.
- Completion of simulations with the Community Ice Sheet Model (CISM) will place CESM among the very few international modeling groups to directly estimate the response of the Greenland and Antarctic ice sheets to future changes in climate.
- Simulations with CESM will allow scientists to understand and quantify anticipated changes to the carbon cycle and their feedback to climate.
- Work will be completed on ozone, deposition (nitrogen and aerosols) and aerosol concentration fields for both historical and future emission scenario simulations using CESM. Output will also be used as part of the IGBP Atmospheric Chemistry and Climate (AC&C) activity, which is focused on the understanding of the various radiative forcing agents and their changes from 1850 to 2100.

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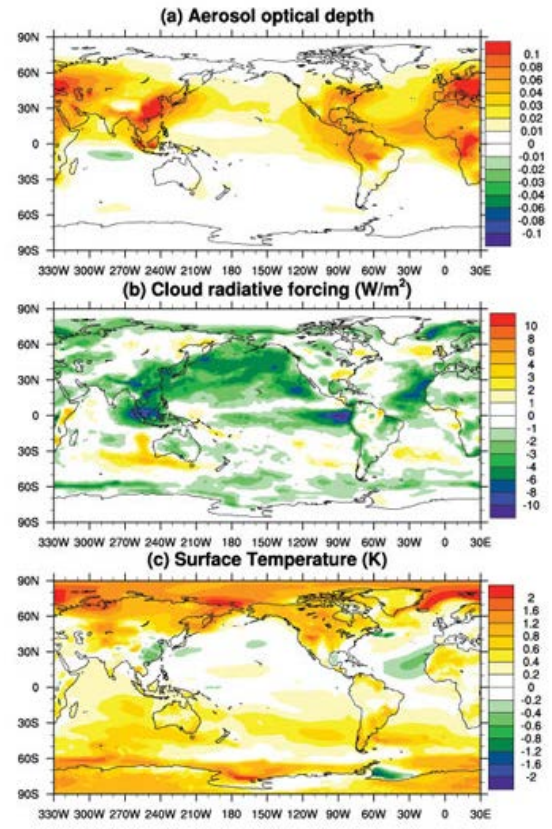
The Community Atmosphere Model (CAM5)

Overview

The newest version of the Community Atmosphere Model (CAM5) was released with CESM1 in June 2010. It represents a major step forward in the representation of atmospheric physical processes and simulating their climate impacts. New representations of cloud microphysical properties including ice and liquid droplet size and number concentrations and associated interactions with atmospheric aerosols have enabled a significant expansion in the research problems that can be addressed within the CESM. Cloud aerosol interactions impact cloud formation, condensed species properties and cloud lifetime as well as influencing weather statistics such as precipitation frequency and intensities. With further improvements in the representation of convection, boundary layer and radiative processes CAM5 is able to address many science questions related to the impact of anthropogenic emissions on climate that were not previously possible.



Late 20th century (1970-1999) differences from a pre-industrial climate in a fully coupled CESM(CAM5) run with evolving observed aerosol emissions showing (a) aerosol optical depth, (b) net cloud forcing and (c) surface temperature changes to the climate. [**high resolution image**]

Recent Accomplishments

The role of the indirect effects of aerosol has been examined in model simulations of the 20th century climate using observed aerosol emissions. Their impact in CAM5 leads to significant regional modulation of the general global warming trend (see figure). This is due to localized cooling in the high population, industrial regions first in Europe in the 1960s and 70s and then predominantly in south east Asia closer to present day. The local cooling results from a net negative cloud forcing response to increased aerosol emissions. The presence of optically thick low clouds with a greater number of smaller liquid drops drives extensive cooling over large parts of the northern hemisphere relative to pre-industrial climate conditions. The geographical extent of the influence of anthropogenic aerosols on clouds from Asia extending into the Pacific is crucial in determining the strength of the total indirect aerosol forcing on the global climate.

2011 and Beyond

Much remains to be learned from CAM5 both in terms of understanding the many interactions among the new cloud-aerosol processes and their response to near-term climate change and these will be the main focus of research over the coming year. With the need to provide climate information at ever increasing resolution further model development will aim to provide scale-invariance for the representation of physical processes, allowing the smoothest transition to high resolution. In particular we aim to perform model parameterizations at or near the cloud-scale regardless of model resolution to give seamless behavior across different model resolutions. With regional climate modeling in mind CAM5 will soon include the capability to locally refine the model grid in order to provide the highest resolution, but still within the framework of global climate model simulations.

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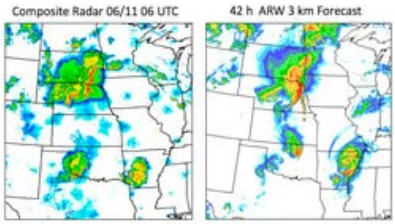
The Weather Research and Forecasting (WRF) Model and Data Assimilation System

In FY2010 work continued on the physics enhancements for hurricane and global model applications. NESL/MMM scientists improved the surface flux formulation in hurricane conditions to use the Garrett formula, which better represents observed estimates of the enthalpy exchange coefficient governing the heat and moisture fluxes. This was done in conjunction with using the more sophisticated Thompson microphysics scheme to enable representation of denser graupel particles that were lacking in the previous (WSM5) scheme. Overall these changes counteract each other in contributing to hurricane intensity, with the former generally weakening, and the latter strengthening simulated hurricanes, but allow better agreement with observational evidence.

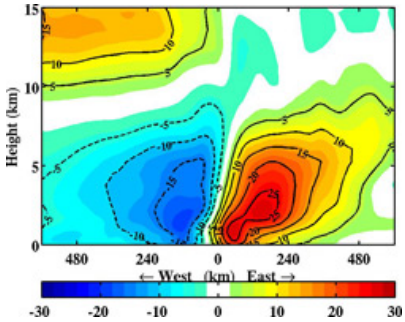


Using a 3 km horizontal grid resolution, WRF-ARW successfully predicts a severe wind and hail producing convective system in northeast Nebraska and southeast South Dakota, as well as a convective system producing severe flooding over Arkansas, 42 hours in advance. [**High resolution image**]

Another improvement eliminated a long-standing problem with spurious top-of-the-model longwave cooling by more accurately representing the atmospheric thermal profile above the model top in the stratosphere by adding layers above the model top for the radiation calculation. This was applied to the RRTM radiation scheme commonly used in ARW, and has shown improvements in the height field even extending into the lower in the troposphere.

WRF users around the World. [**High resolution image**]

Other research was focused on convection-resolving WRF-Chem simulations to investigate the North American monsoon season. The North American Monsoon simulation with chemistry was conducted for 10 July to 3 August 2006 which covers 3 weeks of heat wave events occurring over the United States and the beginning of the period when ozone enhancement occurred in the upper troposphere over the southeast U.S. The model results have been evaluated with meteorological data, surface monitoring data of various chemical species, aerosol optical depth, and vertical distributions of CO and O3. Analysis of the model results is ongoing and is focused on the chemical production of ozone for different regions of the model domain.



Caption: East-west cross-section of northward velocity through tropical storm Erika (2009) from the WRF/DART analysis 00 UTC 2 September 2009. The analyzed vortex tilts eastward with height. [**High Resolution Image**]

In FY2010 NESL/MMM scientists also conducted real-time explicit convective forecasts in support of VORTEX2 and the NSSL spring program. Real-time explicit convective forecasts at 3-km grid resolution were run in spring-summer 2010 to examine the latest ARW and to support the VORTEX2 field campaign and the NSSL Spring Program. 48-hr forecasts were produced twice a day, initialized at 0000 and 1200 UTC. MMM collaborated with NOAA/ESRL (Earth System Research Laboratory), which supplied high-resolution (13-km) analyses from the operational Rapid Refresh (RR) model (which uses the ARW core) to initialize the

forecasts. One of the features of the RR is the use of a Diabatic Digital Filtering Initialization (DDFI) procedure along with 3DVAR techniques. Analyses of differences between this year's runs using DDFI with last year's using DFI are ongoing.

Other NESL/MMM activities last year included hosting two WRF Basic Tutorials, which were held in January 2010 and July 2010. The January tutorial had 81 registrants for three different tutorials with a number of attendees participating in more than one tutorial (69 for Basic WRF, 32 for WRF VAR, and 41 for WRF MET). In July, there were 96 registrants in the four different tutorials (66 for Basic WRF, 33 for WRF Chem, 26 for WRF VAR, and 29 for the WRF MET Tutorial). The tutorials are a collaboration between NESL/MMM and RAL/DTC staff. More than 20 more community users were on the waiting list for the basic tutorial. The WRF Users Workshop, held 21-25 June 2010, had 232 attendees. The East Asian WRF Tutorial and Workshop, held in Seoul, Korea in April 2010, included approximately 80 attendees. In addition, WRF version 3.2 was released and is available for download at: http://www.mmm.ucar.edu/wrf/users/wrfv3.2/updates-3.2.html. WRF users continue to increase.

In FY2010, a WRF Data Assimilation web page with an online tutorial link was developed and can be accessed at: http://www.mmm.ucar.edu/wrf/users/wrfda/index.html

NESL/MMM supports several options for data assimilation with WRF, including an ensemble Kalman filter (EnKF) based on the Data Assimilation Research Testbed (developed jointly with CISL/IMAGe) and both variational and "hybrid" variational-ensemble options through WRFDA, which is part of the WRF release. A recent highlight is the real-time use of the EnKF to provide initial conditions for MMM's experimental high-resolution hurricane forecasts. The real-time analyses, which are a collaborative effort with SUNY Albany, utilize conventional observations, atmospheric motion vectors estimated from satellite images and the position and intensity of all storms classified as tropical depressions or stronger. During summer 2009 and 2010, the analysis system cycled continuously for roughly three months on a domain extending from the tips of Europe and Africa, across the Atlantic and covering the majority of the continental U.S. The figure shows the analysis for tropical storm Erika (2009). The analysis exhibits substantial tilt of the vortex with height. This vortex structure is not assumed a priori as in many other initialization schemes for hurricanes but arises naturally in the analysis owing to the effects of the environmental shear in the short-range forecasts used in the assimilation.

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WRF-Chem

Weather Research and Forecast model coupled with Chemistry (WRF-Chem)

The Weather Research and Forecasting (WRF) model coupled with Chemistry (WRF-Chem) has been and continues to be developed by NOAA scientists, in collaboration with the WRF community including NCAR/NESL scientists. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry. NESL scientists and staff provide support by integrating and maintaining the chemistry components in the evolving WRF modeling system, as well as contributing new code in the development of WRF-Chem and providing support to the university community. Models such as WRF-Chem are used to further the understanding of precipitation and chemical processes, including multiscale atmospheric chemical constituent transport, dispersion and transformations.

WRF-Chem activities in NESL focus on 3 areas: 1) research to advance the understanding and prediction of the chemistry and composition of the troposphere, 2) development of new or enhanced processes in WRF-Chem, and 3) support for WRF-Chem to the university community. ACD scientists play an active role in helping colleagues with learning and using WRF-Chem. WRF-Chem version 3.2, released in April 2010, includes several algorithms provided by NESL, including 1) tracer code that tracks air from the stratosphere, the boundary layer, and the horizontal boundaries and can be run along with any chemistry mechanism, 2) the MOZART chemistry mechanism, 3) emissions from aircraft, and 4) emissions of nitrogen oxides from lightning. In addition, two important preprocessors have been developed and released to the community via the ACD WRF-Chem web page, **http://www.acd.ucar.edu/wrf-chem**. A utility to download the global-scale MOZART model results and use those results as initial and boundary conditions for the chemical species in WRF-Chem has been released to the community. Additionally, a preprocessor for the MEGAN biogenic emissions module has been developed to enable users to create input files for the module. A preprocessor for the MOZART gas chemistry is also available to the community. Approximately 70 colleagues have downloaded these tools during the first 5 months of the release to the community. In the coming year, WRF-Chem development by NESL scientists will include a new routine describing the scavenging of gases by precipitation, creating a preprocessor tool for wildfire emissions, improving the parameterization of dust emissions, including an upper boundary condition for the chemistry to more accurately represent stratospheric species, and implementing chemical data assimilation.

Several different simulations have been conducted by NESL/ACD scientists to improve our understanding of air quality associated with mega-cities and with long-range transport and wild fires, and with thunderstorms and chemistry. The MIRAGE-Mexico City WRF-Chem simulations of gas-phase chemistry have shown the importance of oxygenated volatile organic compounds for ozone production. Additional simulations contrast the role of model resolution on surface gas-phase species. The model resolution affects the spatial distribution of the chemical emissions, the realism in representing the topography of the land, and the ability to represent processes occurring on small scales (both meteorological and chemical, which is non-linear). By evaluating the model results with measurements, it was found that for Mexico a 6 km resolution is optimal for accurate yet computationally efficient simulations. WRF-Chem simulations for MIRAGE-Mexico City continue to be conducted to explore the aerosol chemistry and the role of peroxy acetyl nitrate compounds on ozone. Simulations of the Shanghai region are being conducted to analyze the September 1-21, 2009 field campaign, which included participants from NESL/ACD scientists, from Texas A&M University, and University of Miami, as well as Chinese colleagues from Shanghai Meteorological Service, Peking University and Fudan University.

WRF-Chem simulations being conducted to analyze the ARCTAS-Carb field campaign measurements show that long-range transport is important to surface ozone over the U.S. Western States. This means that the boundary conditions for the regional model are important to get correct (see Figure 1). These WRF-Chem simulations were also examined to understand the contribution of different sources to CO (carbon monoxide). Long-range transport contributed 53% of the local CO mixing ratio, while local anthropogenic emissions and wild fire emissions contributed 22% and 18%, respectively, for the

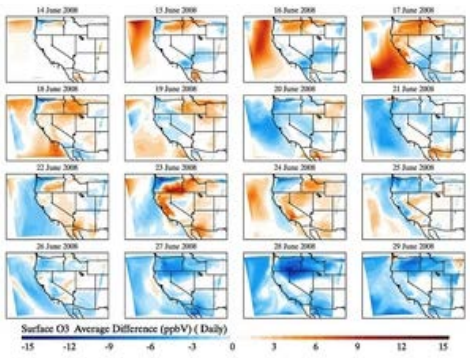

Figure 1. Daily average difference in surface O3 (ppbv) between a WRF-Chem simulation with temporally-varying (every 3-hours) and with temporally-averaged chemical boundary conditions from the global MOZART model. Simulations start on 14 June 2008. [**High resolution image**]

California region.

WRF-Chem simulations over the U.S. are being analyzed to determine the driving factors that cause the variability in surface CO and ozone over the US. This work will provide essential input to measurement requirements that are worked out for the GEOCAPE satellite missions.

A high resolution (Δx=4 km), large domain (4800x3600 km^2) WRF-Chem simulation of the 2006 North American Monsoon is being conducted to understand the role of the monsoon (thunderstorms) in affecting the composition and chemistry of the upper troposphere (UT) and to examine air quality during the summer 2006 heat wave. Evaluation of the model results shows good agreement between observed and predicted meteorological variables and major gaseous species, especially in the upper troposphere. The analysis of this simulation indicates that CO oxidation by OH in the upper troposphere dominates OH reactivity that can then contribute to ozone production, but in convective outflow regions formaldehyde and organic peroxides also have a high OH reactivity.

WRF-Chem simulations are also being conducted as part of the BEACHON project to investigate connections between emissions from vegetation, aerosol and cloud condensation nuclei formation, and clouds and precipitation. During the past year, sensitivity of precipitation amount and location has been found to be sensitive to the initial (and boundary) mixing ratios of ammonium sulfate aerosols. These simulations (see Figure 2) show that total precipitation decreases by about 10% when the aerosol mass is increased by a factor of 10. To investigate the impact of biogenic organic aerosols, an improved secondary organic aerosol chemistry module is being developed, as well as emissions of organic aerosols and biological particles.

This work is supported by the NSF, the NCAR-MIRAGE strategic initiative funds, and NASA.

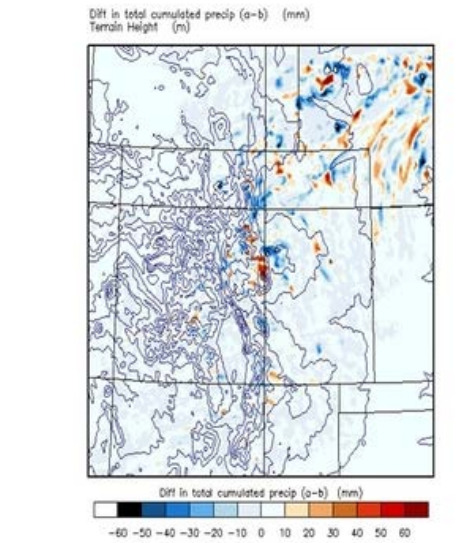

Figure 2. Difference in total cumulated precipitation over the greater Colorado region between a WRF-Chem simulation with initial and boundary chemical conditions from the MOZART global chemistry model and a simulation with 5 times less ammonium sulfate aerosol mass in the initial and boundary conditions. [**High resolution image**]

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The Impact of the Antarctic Ozone Hole on the Mesospheric Circulation and Temperature

The loss of ozone that has occurred in the Antarctic lower stratosphere during each spring since1980 is known as the ozone hole. Dynamical impacts of the ozone loss include a cooling in the lower stratosphere and changes in the stratospheric winds in the high southern latitudes during spring and summer. The wind changes affect the propagation of waves from the lower to the upper atmosphere. Some of the gravity waves that are generated in the troposphere propagate vertically through the stratosphere and into the mesosphere. Dissipation of these waves in the upper mesosphere (75-90 km) has a large effect on the circulation and temperature there. Through their effect on the vertical propagation of gravity waves, the stratospheric wind changes associated with the ozone hole can indirectly affect the mesospheric temperature.

Simulations with the Whole Atmosphere Community Climate Model (WACCM) reproduce the onset of the Antarctic ozone hole. The model simulations of the associated changes in stratospheric temperature and winds are larger in magnitude but similar in morphology to observations. The figure shows the simulated zonally averaged changes in temperature, zonal wind, and gravity wave momentum forcing over the period 1960-2006. The stratospheric changes are evident; strongest signals are at 70 hPa (temperature) and 20 hPa (wind). The large negative change in gravity wave forcing in the mesosphere has led to a weaker circulation and warming in the SH polar temperature near 65-80 km. The increase in temperature near the SH summer mesopause has implications for the presence of polar mesospheric clouds.

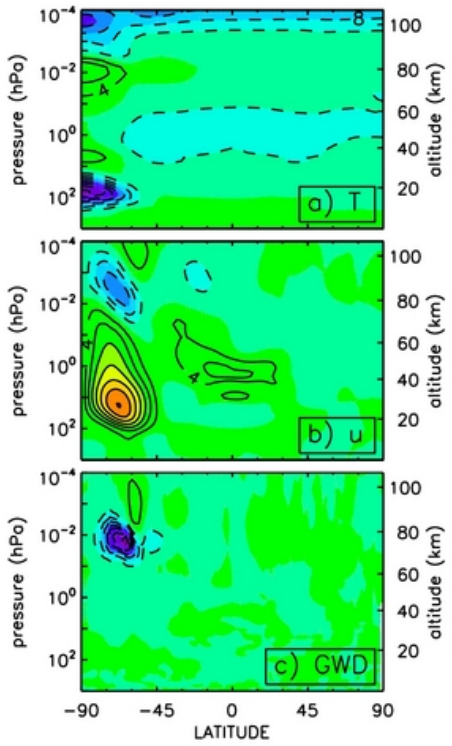

Figure 1. Changes in (a) temperature, (b) zonal wind, and (c) gravity wave momentum forcing over the period 1960-2006 averaged over the months of November and December simulated by WACCM. Results from four realizations of WACCM have been averaged to make the plot. [**High resolution image**]

References

Smith, A.K., R.R. Garcia, D.R. Marsh, D.E. Kinnison, and J.H. Richter, Simulations of the response of mesospheric circulation and temperature to the Antarctic Ozone hole, Geophys. Res. Lett., in press, 2010.

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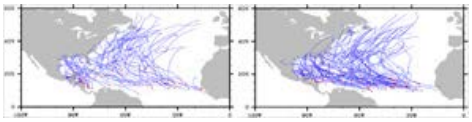
Nested Regional Climate Model (NRCM)

The NRCM is an adaptation of the Advanced Research WRF (ARW) for use in studies of regional climate in conjunction with the Community Climate System Model (CCSM) system. It combines the extensive NCAR weather and climate expertise and systems, with goals of providing a testbed for gaining experience in support of the next generation approach to seamless weather/climate modeling, enabling development and testing of new physical and dynamical core approaches, discovering remote impacts of local processes (upscaling), and providing initial assessments of regional climate changes to societal groups.



Tropical storm tracks (blue lines) and genesis locations (red dots) generated by the NRCM for (left) 11 years of current climate and (right) 11 years of future climate centered on 2050. **[High resolution image]**

In FY2010, a range of projections of North Atlantic hurricane activity over the next 50 years have been produced using a powerful combination of the latest NRCM data and novel statistical, theoretical and extreme value methods. Results show an increase in the annual numbers of storms, a shift in their geographical location to lower latitudes, and an increase in storm average and maximum intensity. This ambitious project provided for the first time decadal climate simulations of hurricanes at a resolution sufficient to identify key intensity and structural details. NRCM has been released under WRF 3.2 for community use and several academic groups, both domestic and international, are in the process of utilizing NRCM in their own research programs.

Statistical methods provided an ensemble of projections of future tropical cyclone activity and therefore estimates of uncertainty on the NRCM results, and extreme value analysis applied to the NRCM storms revealed that the most intense storms show the largest percentage increase over the next 50 years. The resulting damage to offshore facilities in the Gulf of Mexico has been assessed through the development of a damage index and its application to storms generated by the NRCM.

During the past year, three papers were published in a special issue of Climate Dynamics. The first established the skill of the NRCM to represent tropical modes of variability, while the others explored the data to further our physical understanding of the role of wave activity for tropical cyclone formation and of the interactions between the base climate of the tropics and tropical modes of variability.

The NRCM program directly supports several high priority NCAR Frontier Programs including informing climate change adaptation and mitigation, water resource availability, vulnerability and adaptation planning in western North America, and development of new methods to more accurately assess regional climate. Significant university collaborations include the Georgia Institute of Technology and many others through the Willis Research Network. NRCM has been released for community use and is in the process of being utilized by many academic groups including the U.K. National Centre for Atmospheric Science, the Coordinated Regional Downscaling Experiment (CORDEX) program, and the Caribbean Institute for Meteorology and Hydrology.

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The Earth System Model - Model for Prediction Across Scales (MPAS)

The ESM/MPAS goal is to develop a next-generation modeling system suitable for weather, regional climate, and climate and Earth system research and prediction. NESL is working to develop a new weather and climate model as a single system that will be suitable for simulating small scales (e.g., clouds, small hydrologic basins, and small estuaries), and large scales (e.g., planetary atmospheric waves and Earth-ocean circulations) that interact. Strong consensus exists among scientists that the challenge of simulating both climate and weather with a single modeling system will improve model fidelity for both applications, in addition to focusing and leveraging development efforts from both the climate and weather prediction communities. A critically important component of this project is to develop ESM/MPAS components (atmosphere, ocean, land surface models, etc.) that scale well on the new computer architectures, and that are capable of simulating all the scales necessary in our research and production applications.

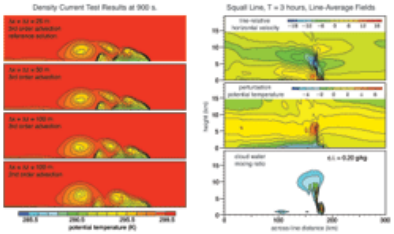

Fig 1: Simulations with MPAS of a two-dimensional density current (left panels) and 3D squall line (right panels). Fields for the squall line are shown after averaging in the along-line direction. [**High resolution image**]

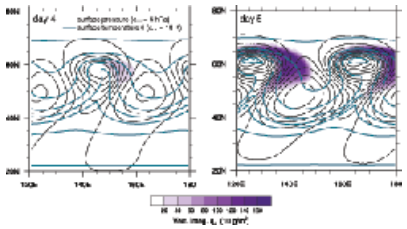

Fig 2: Surface pressure and potential temperature from an MPAS simulation of a 3D baroclinic wave on the globe. [**High resolution image**]

In FY1010, the initial coding and testing of the three-dimensional (3D) hydrostatic and nonhydrostatic atmospheric fluid-flow solvers were completed, together with solvers for two-dimensional and shallow-water flows. All these solvers use variable resolution unstructured hexagonal meshes for their horizontal discretization. The 3D solvers can simulate atmospheric flow on the globe, in limited-area regions of the globe (e.g. the continental U.S.) and on rectangular Cartesian regions. Preliminary testing of the atmospheric solvers has encompassed both small-scale flows for the nonhydrostatic solver (density currents, thunderstorms and squall lines on Cartesian domains, figure 1 a and b) and large-scale flows on the sphere for both the hydrostatic and nonhydrostatic solvers, including baroclinic waves with and without moisture (figure 2). The test results indicate that the solvers are robust with the expected efficiencies on uniform-resolution for both the hydrostatic and nonhydrostatic solvers.

In FY2010 testing began using meshes that incorporate local refinement. These nonuniform meshes feature both gradual and abrupt transitions between mesh densities. Preliminary results indicate that the gradual transition overcomes many of the problems encountered in traditional one- and two-way nested models, where the transition is abrupt. Initial tests of parallelization on a number of computational architectures have also been completed. These show that distributed memory parallelism works as expected compared to existing non-MPAS solvers. Shared-memory parallelism constructs are still to be implemented.

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NCAR Earth System Laboratory | NESL
2010 Annual Report

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Connecting Past, Present, and Future Climates

The Earth's present climate appears to be changing rapidly enough for discernable differences to occur within a lifetime; with more dramatic changes occurring at faster rates than have occurred previously. A unifying research strategy is to combine knowledge of large but indirectly observed past climate change with directly observed present climate to increase confidence in projections of future climate change.

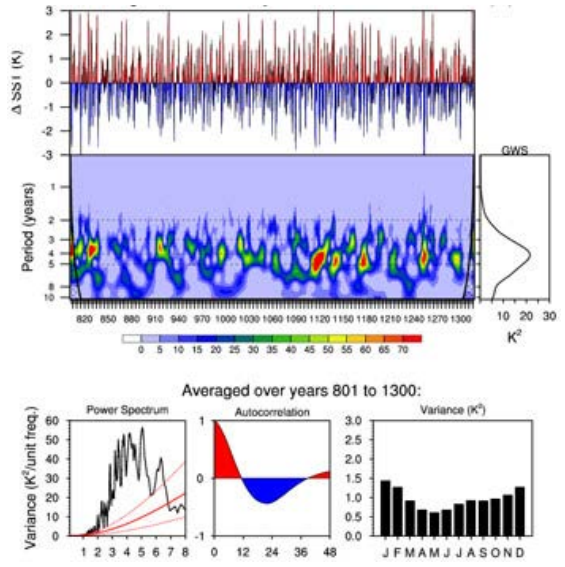
Past Climates

Overview

Paleoclimates offer a unique perspective to understand the Earth's climate sensitivity and its stability. Paleoclimate archives tell us that Earth has experienced a wide range of climates over various time scales, and that transitions in Earth's climate can take place rapidly. We know that many of these past climates were determined by changes in external forcing factors. To the extent that climate models can reasonably simulate past warm and cold climates, we gain confidence that the models can be used to study Earth's future climate.

Recent Accomplishments

The Coupled Modeling Intercomparison Project (CMIP5) recognizes the importance of using observations of past climate change to validate models that will be assessed in the next IPCC. For the first time, international modeling groups are being requested to perform simulations for three past time periods with the same model and same resolution as their 20th century and future projection simulations. At NCAR, we are completing the Tier 1 Last Glacial Maximum (21,000 years ago) and Mid-Holocene (6000 years ago) simulations and Tier 2 Last Millennium simulation with the CCSM4 1° CN model configuration. Forcings and boundary conditions follow the protocols developed by the Paleoclimate Modeling Intercomparison Project (PMIP3) for CMIP5. Some first, preliminary results from the Mid-Holocene simulation show a reduction of Nino-3.4 SSTs in qualitative agreement with proxy indications of ENSO variability for this past time period



Statistics for SST variability averaged over the Nino 3.4 region (5N-5S,170W-120W) of the eastern central Pacific for the mid-Holocene (6000 years before present) simulation with the 1 degree resolution of CCSM4 CN configuration of CESM. [**high resolution image**]

2011 and Beyond

The NESL/CGD Paleoclimate group, in collaboration with university and international partners, will continue to provide past climate simulations. As part of the internationally coordinated Coupled Model Intercomparison Project (CMIP5) and the Paleoclimate Modeling Intercomparison Project (PMIP3), CGD will finish three past climate change experiments using the CCSM4 configuration of CESM1. These have been designated as Tier 1: Last Glacial Maximum and Mid-Holocene, and Tier 2: Last Millennium CMIP5 simulations and will be with the same model configuration as the CCSM4 long-term projection simulations. In addition, CESM1 simulations will be initiated to more fully explore and quantify the model's climate sensitivity to levels of carbon dioxide and methane, which have been observed geologically. These experiments around long-term climate understanding are designed to make better predictions toward future climates with contributions to the USGCRP and IPCC assessment products.

Present Climates

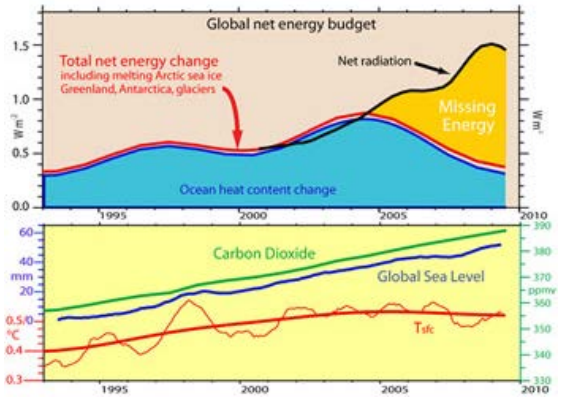
Overview

NESL/CGD researchers are exploiting observations and reanalysis of past observations to diagnose how the atmosphere and climate system has evolved in the past to get to its current state, both in terms of natural and human-induced processes and how these vary and change. Our ability to understand and model the past provides a vital test of the predictability and possibilities of predicting the future. Increasingly, diagnostic analyses are used to evaluate models that require extensive model-output analysis – output from CCSM being a good example. Researchers are using runoff, river flow and river discharge into oceans with moisture budgets of the atmosphere and the surface to provide better information on water and its changes in the climate system, including land processes in sea level variability. Many hydrological cycle variables that are derived separately – e.g., evaporation, rainfall, runoff – can be physically constrained to estimates of uncertainties and produce more reliable products. The main focus is on precipitation and its characteristics (including precipitation frequency, intensity, duration, amount, type, and the diurnal cycle).

Recent Accomplishments

In the past year high profile papers appeared in *Nature* and *Science* on the ocean heat content and global energy budget, with many media interviews and scientific talks. These detailed the inability to close the energy budget in recent years relative to previous years. It is hypothesized that the estimated change in ocean heat content, especially below the upper layers, is a primary suspect for the source of the imbalance (missing energy). This has implications for the observing system and what observations must be improved to properly understand climate variability and change. Because the missing energy can come back and influence future climate, it is important to remove this source of uncertainty in what is going on. This is but one example of how we strive to provide better context in informing the public about climate change versus climate variability.

Additionally, differences among trends in different analyses of SSTs have been explored by going back to the original data as well as other variables that are known to be physically related. For instance, surface winds typically blow into the region of increased SSTs and create additional cloudiness and rainfall. By carefully examining the consistency or otherwise of sea level pressures, clouds and rainfall with SSTs, Deser et al were able to determine which analyses were flawed.



Where does the energy go? (A) Estimated rates of change of global energy. The curves are heavily smoothed and somewhat simplified. From 1992 to 2003, the decadal ocean heat content changes (blue), along with the contributions from melting glaciers, ice sheets, and sea ice and small contributions from land and atmosphere warming, suggest a total warming (red) for the planet of 0.6 ±0.2 W/m^2 (95% error bars). After 2000, observations from the top of the atmosphere (black, referenced to the 2000 values) increasingly diverge from the observed total warming (red). (B) The observed steady increases in carbon dioxide and sea level contrast with the variability in global surface air temperature. Shown are the 12-month running means of global mean surface temperature anomalies relative to 1901 to 2000 from NOAA [red (thin) and decadal (thick)] in degrees Celsius (scale lower left), carbon dioxide concentrations (green) in parts per million by volume (ppmv) from NOAA (scale right), and global sea level adjusted for isostatic rebound from AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic Data) (blue, relative to 1993, scale at left in millimeters). [**high resolution image**]

2011 and Beyond

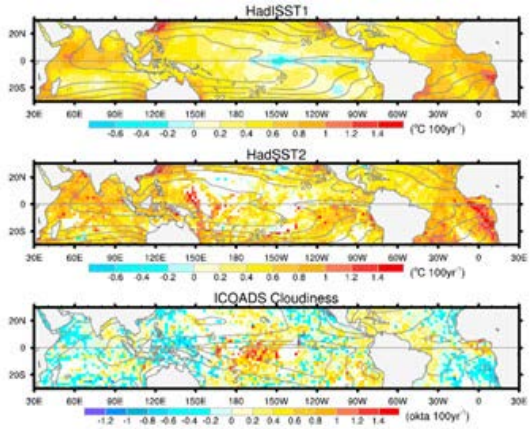
Additional studies will be carried out to help us to better understand weather patterns and how they affect our present climate. We expect to be able to uncover some level of attribution related to why changes are occurring. Topics of interest include separating the role of the ocean and changes in sea surface temperatures from radiative forcing effects in the climate response. NESL/CGD will explore at some depth the roles of the North Atlantic Oscillation (NAO), ENSO, Arctic sea ice, ocean heat content, ocean currents and heat transports, and clouds. This includes non-linearities, such as whether effects of Arctic sea ice decreases are simply the reverse of increases in sea ice. We are also exploring ecosystem impacts of climate change, along with the potential to predict them.

In the coming year we will:

- Continue processing of new NCEP Climate Forecast System Reanalysis (CFSR) reanalyses and comparisons with those from the European Centre for Medium-Range Weather Forecasts Re-Analysis (ERA)-interim and Modern Era

Retrospective-analysis for Research and Applications (MERRA) to provide guidance on their merits and usability for model evaluations.

- Use atmospheric and coupled simulations to study seasonal atmospheric circulation and climate response to future reductions in Arctic sea ice and high latitude snow cover.
- Exploit new 40 member ensembles of CCSM runs for examining natural variability and signals of climate change.
- Perform diagnostic studies of recent climate events.
- Improve understanding and modeling of precipitation.

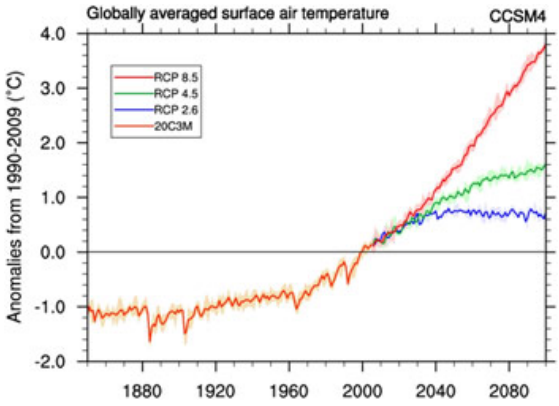


Twentieth century tropical trends from different sources: the top analyzed gridded SSTs record is at odds in equatorial regions of the Pacific with the actual observations (second panel) and physically consistent relationships, such as with cloudiness (third panel). [**high resolution image**]

Future Climates

Overview

Using models to predict and understand future climates is of the very highest priority. A new suite of future-climate simulations is planned following the internationally coordinated CMIP5 protocol. The NCAR Earth System Laboratory (NESL) is dividing the climate change problem into two timescales: short term, also called decadal prediction (out to 2035), and long term (out to 2100 and beyond). These two timescales will be addressed with two classes of models and two sets of science questions. For the decadal prediction problem, the timescale of interest (the next several decades) is directly relevant to adaptation decisions facing policymakers and stakeholders (e.g., water resources). For the longer term, the simulations will use the new Representative Concentration Pathways (RCPs), which are mitigation scenarios that will quantify the magnitude of climate change for different mitigation policy decisions. The decadal prediction experiments will use only one scenario, since all scenarios are very similar for the next several decades; four RCPs will be used, which encompass very low mitigation to nearly business-as-usual. The decadal prediction experiments will use the standard 1 degree atmosphere version of CCSM4 with the 1 degree ocean, as well as some simulations with a high resolution version of CCSM4 with 50-km resolution in the atmosphere, and the 1° ocean.



Globally averaged surface air temperature time series for multi-member ensemble simulations from CCSM4 for 20th century climate and three future RCP mitigation scenarios (the forcing data for the fourth scenario, RCP6, only recently became available and is currently being run). Note that only RCP2.6 keeps the planet from warming 2C above preindustrial, a goal often mentioned in international climate negotiations. The ensemble average is denoted by solid colored lines, shading indicates plus/minus one standard deviation among ensemble members. [**high resolution image**]

Included in the future climate simulation suite is a set of hindcast experiments, which have starting dates for every five years beginning in 1960, for 10 years each, with at least three ensemble members for each hindcast. Also in the suite is a set of three 30-year experiments with starting dates of 1960, 1980, and 2005. These hindcasts will quantify the skill of the decadal simulations; two different initialization strategies are being explored and hindcast success will be assessed with these two schemes. For the long term, the ESM version of CCSM4 will be used with a coupled carbon cycle and intermediate resolution (about 2° in the atmosphere). In addition to NSF, the Department of Energy (DOE) continues to be a major partner in our development of CCSM and its use in investigating climate change and its impact.

Recent Accomplishments

The recently released CCSM4 is being used to run both the decadal climate prediction experiments as well as the long term scenario simulations with the new Representative Concentration Pathway (RCP) mitigation scenarios. So far, a seven member ensemble of 20th century climate experiments has been run, and five member ensembles have been completed with three of the four RCPs for future climate out to 2100 (Figure). The forcing data for the fourth RCP (RCP6) has only recently become available and ensemble members for that scenario are currently being run with

CCSM4. Analysis of these experiments is underway, and has so far focused on interpreting the simulations of 20th century climate in the context of the equilibrium climate sensitivity of the new model, as well as comparing future climate changes with different levels of mitigation.

2011 and Beyond

New in the coming year are the long-term simulations with the carbon cycle-climate ESM version of CCSM4 (CESM). These simulations will examine the role of the carbon-nitrogen cycles and land use/land cover change in Earth system change. Two sets of simulations are planned: “fully coupled” simulations in which the model is forced with fossil fuel emissions from the RCPs so that atmospheric CO2 concentration is prognostic; a second set of "uncoupled" simulations with prescribed atmospheric CO2 concentration from the RCPs. In the latter simulations, the carbon cycle is still active, but does not influence atmospheric CO2. Additional "single-forcing" simulations will isolate the climate forcing of the carbon-nitrogen cycle from that of land use/land cover change.

The carbon cycle-climate simulations using the ESM version of CCSM4 ("CESM1 (BGC)") will be made available as part of the CMIP5 multi-model dataset for assessment in the IPCC AR5. These simulations will lead to better understanding of the effects of the carbon and nitrogen cycles on climate and Earth system change and will also identify the relation between human activity (land use/land cover change) and Earth system change. We believe that these simulations will lead to more informed choices by policy makers about strategies to reduce atmospheric concentrations of CO2 and Earth system change.

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Human Activity in an Earth System Hierarchy

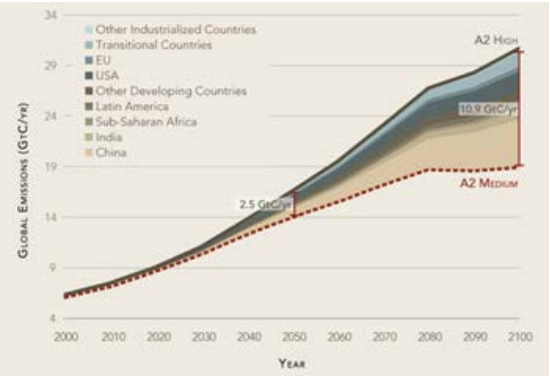
Overview

Integrated Assessment Modeling links knowledge across a wide variety of disciplines, including both the natural and social sciences, in a quantitative framework that can inform decisions regarding response options for the climate change issue. Response options include those relevant to emissions mitigation and to adaptation to expected impacts. As a model-based area of applied research, it fits naturally within CGD and NCAR more broadly as a complement to larger-scale modeling efforts of the climate system. For example, IA models can both directly link to Earth System Models by providing inputs and/or using outputs and indirectly inform ESM efforts by prioritizing research directions and identifying interesting scenarios to explore.

The newly-established integrated assessment modeling group was moved to CGD in FY10 and hired two new staff -- a demographer and an economist. The group, along with outside collaborators, has created and begun to use an initial version of an NCAR IA model, the Integrated-Population-Economy-Technology-Science (iPETS) model. This framework currently consists of three components: a global demographic model for projecting future population, urbanization, and living arrangements; a global, 9-region economic model that simulates changes in production, consumption, energy use, and greenhouse gas emissions; and a simple greenhouse gas cycle and climate model for projecting future atmospheric concentrations and changes in global average temperature.

Research in the IAM group involves development and use of the iPETS model, as well as collaborations with other research groups in the community, in order to explore three main topics: the influence of alternative socio-economic development paths on future greenhouse gas emissions and climate changes, better connecting long-term climate policy goals to shorter-term actions, and improving the treatment of uncertainty in integrated assessments. Over time the group aims to carry out research on the role of land use in responding to the climate change issue, to explore linkages between integrated assessment models and earth system models such as CCSM, and to improve the modeling of impacts and adaptation.

Recent Accomplishments



The effect of slower population growth on global CO2 emissions as estimated with the iPETS model. From O'Neill et al., 2010, PNAS. [high resolution image]

In 2010 the first set of global emissions scenarios developed with the iPETS model were completed and published in the Proceedings of the National Academy of Sciences. This analysis found that demographic change, including changes in population size, urbanization level, and aging, can significantly affect global emissions from energy use. In particular, it concluded that slower population growth could contribute significantly to emissions reductions necessary to avoid dangerous climate impacts, and that urbanization and aging can substantially affect projected emissions growth in particular world regions, especially Asia.

In addition, substantial model development took place in several aspects of the iPETS framework. For example, assessment of data sources and methodological options was completed to lay the groundwork for incorporating land use change into the iPETS framework, an essential step to facilitate future linking of the model to CESM to explore the effect of land use change on climate outcomes. Also, substantial effort was invested in the demographic module of iPETS with the aim of developing the capacity to generate global population and urbanization projections for our own use and for the use of the IAM community. In parallel, we are developing methods for generating spatially explicit population scenarios at the regional and global

level.

Along with development and application of the iPETS model, the IAM group participated in collaborative work with other research groups, including an assessment of the feasibility of attaining various long-term climate policy targets such as the goal of limiting the increase of global average surface temperature to below 2 degrees C. This work demonstrated the importance of achieving emissions targets in 2050 that would keep such long-term options open, and concluded that some of the targets for 2050 currently discussed in international policy debates may be more stringent than necessary.

2011 and Beyond

In 2011 IAM research will focus on two key priorities. First, initial work on the implications of alternative development pathways will be expanded by examining in more detail both the potential for rapid urbanization, particularly in Asia, as well as the implications of these trends for emissions from energy use and for well being at the household level. This analysis is taking place in the context of a community-wide model comparison projection, the Asia Modeling Exercise, in which the NCAR IAM group is taking place. It will involve expanding the capacity of both the demographic module and the energy system in iPETS, in particular to generate not just aggregate outcomes such as national emissions levels, but also outcomes for particular household groups, such as the level of energy use by low-income rural households.

Second, the groundwork completed on incorporation of land use into iPETS will be built on to develop a first set of scenarios exploring the implications of global land use patterns for future emissions. This work will facilitate exploration of linking iPETS to land surface models such as CLM, a first step toward linking to earth system models such as CESM. In parallel we will continue to pursue other means of linking IAM work to earth system modeling, for example through a collaborative project to develop reduced form emulators of regional climate outcomes in CCSM. Emulators could then be used as a more computationally efficient means of representing climate system outcomes within an integrated assessment modeling framework.

At the same time, progress will be made on further developing the iPETS modeling framework, and making it available to the community to run, modify, or expand. This process will involve completion of a demographic projection tool that can be made publicly accessible, as well as refinement of the code for the economic model.

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Field Campaigns

III. Field Campaigns

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BEACHON

BEACHON: Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics & Nitrogen

Figure 1. Chemistry tower and mobile lift at the Manitou Forest Observatory. [High Resolution Image]

BEACHON is an NCAR initiative designed to advance our understanding and ability to predict the bio-hydro-atmosphere interactions and feedbacks that impact air and water resources and climate. NCAR ACD/MMM/EOL/RAL and university scientists continued conducting and analyzing long-term atmospheric, chemical, ecological and hydrological measurements at the Manitou Forest Observatory (MFO), near Woodland Park CO, and are enhancing the infrastructure for the scientific community conducting research at MFO. This included the construction of several kilometers of rain gutters that are being used for a water manipulation study, led by Russell Monson (U. Colorado), which will quantify the impact of increasing or decreasing precipitation on biosphere-atmosphere exchange at this site.

In addition to these long-term measurements, ACD scientists led the BEACHON-ROCS intensive field campaign at MFO in August 2011. The study was one of the most comprehensive field studies to date focused on biogenic VOC emission, reaction products and impact on atmospheric oxidizing capacity. Scientists from ACD and 7 universities successfully deployed and operated instruments in 6 trailers and on a 28 meter height walk-up tower and a 15 meter height moveable lift (Figure 1).

Table 1 lists the 13 instruments that characterized the exchange, transformation and transport of organic carbon at the site. Many of these chemicals were measured with fast response instruments and will be combined with turbulence data to directly quantify the flux of chemicals between the forest and the atmosphere. Other compounds were measured with a gradient sampling system that allowed investigators to measure fluxes at 6 heights below, within and above the forest canopy which will enable investigators to understand the processes controlling chemical emission and processing at different levels of the canopy atmosphere. Enclosure measurements were used to characterize emissions and uptake from individual ecosystem components including soil, soil litter, branches and whole trees.

Data archiving and analysis is now being coordinated including a workshop that will be held in FY2011. Scientific questions that will be addressed with these integrated observations include the following:

- How well can we characterize the atmospheric oxidation of reactive organic carbon?
- Are we missing any important biogenic organic emissions from this forest ecosystem?
- Can photochemical models reproduce the measured OH and OH reactivity or are we missing important sources and sinks?

- Is non-stomatal deposition an important ozone loss and is it regulated by reactive gas fluxes?
- How does chemistry influences the covariance of reactive species?
- How do gradient-flux relationships need to be modified for reactive gases at this site?

Table 1. Measurements successfully conducted during BEACHON-ROCS August 2010 campaign.

Instrument	**PI (NCAR unless otherwise noted)**	**Other investigators**	**Measurement**
PTRMS	Thomas Karl		VOC and products
TOF-PTRMS	Armin Hansel (U. Innsbruck)	Lisa Kaser (U. Innsbruck), Ralf Schnitzhofer (U. Innsbruck), Martin Grause (NOAA)	VOC and products
TOF-PTRMS	Daniel Knopf (Stony Brook Univ.)	Tracey Evans (Stony Brook U.) Luping Su (Stony Brook U.)	VOC and products
LIF, OH reactivity PERCA	Yoshii Kajii (Tokyo Metropolitan U.)	Shungo Kato (Tokyo Metro. U.), Yoshi Nakashima (Tokyo Metro. U.)	OH reactivity, HO2, RO2
TOGA	Eric Apel	Becky Hornbrook	VOC
Comparative reactivity method	Saewung Kim	Ian Wrangham (Colorado College)	OH-reactivity
TD-CIMS	Frank Flocke	Wengang Zheng	PANs
PERCA-CIMS	Chris Cantrell		RO_2/HO_2
CIMS	Lee Mauldin	Saewung Kim	OH/H_2SO_4
PTR-MS	Jim Greenberg		Soil VOC
GC-MS	Peter Harley	Tiffany Duhl	Branch enclosure
Photolysis/radiation	Sam Hall		

Ceilometer	Barry Lefer (University of Houston)	William Brown	Clouds, PBL height
LIP	Frank Keutsch (U. Wisconsin)	Josh DiGangi (U. Wisconsin), Sam Henry (U. Wisconsin)	Glyoxal, methylglyoxal
GAUS	Fei Chen	William Brown, Jim Greenberg, Derek Starkenburg (U. Northern Colorado), Brian Butterworth (U. Colorado)	Boundary layer structure, PBL height
REA, GCMS	Alex Guenther	Andrew Turnipseed	Speciated VOC flux and ambient concentration
Meteorology	Andrew Turnipseed		U,v,w,T,wT
Chemiluminescense	Andrew Turnipseed		NO_x / O_3

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BEACHON-ROCS measurements of jNO2

BEACHON-ROCS: BEACHON Rocky Mountain Organic Carbon Study

Atmospheric Radiation Investigations and Measurements

The Atmospheric Radiation Investigations and Measurements (ARIM) group maintains Charged-coupled device Actinic Flux Spectroradiometers (CAFS) and Scanning Actinic Flux Spectroradiometers (SAFS) to measure up and down-welling wavelength dependent actinic flux in the UV and visible wavelengths. The measurements are based on a 2π steradian hemispherical zenith and nadir optical collectors coupled with UV enhanced fiber optic bundles to small, lightweight, monolithic CCD monochromators and double monochromator with photomultiplier tube detection, respectively. The instruments have an excellent record of performance on the NCAR HIAPER GV and C-130, the NASA DC-8, WB-57 and P-3B, the NOAA WP-3D and at numerous ground stations. CAFS detectors were recently delivered to the EOL Gulfstream-V as a part of the HIAPER Airborne Radiation Package (HARP). Filter radiometers to measure j(NO2) were deployed during the NCAR/NSF BEACHON-ROCS campaign.

The ARIM optical calibration facility is equipped with precision radiometric power supplies and multiple NIST traceable 1000W quartz tungsten halogen lamps to determine the spectral and angular response of each instrument. Secondary lamp standards are applied in the field. Mercury line calibrations are also performed to track the wavelength accuracy. The ARIM group provided the angular response calibration system to university collaborators for the improvement of irradiance optical collectors.

BEACHON-ROCS measurements of jNO2

The ARIM group deployed j(NO_2) filter radiometers in support of the 2010 NSF Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H_2O, Organics and Nitrogen - Rocky Mountain Organic Carbon Study (BEACHON-ROCS) campaign at the Manitou Forest Observatory, CO. The experiment seeks to quantify surface fluxes of energy, oxidants, aerosols, CO_2, water, and organic and nitrogen compounds and determine how they interact and regulate the carbon and hydrological cycles in a water limited area.

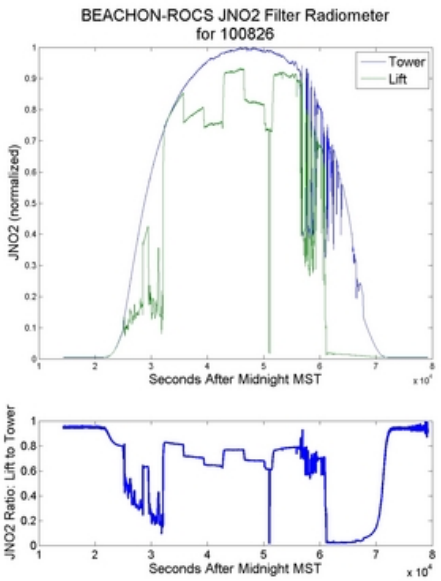

Figure 1. [**High Resolution Image**]

The j(NO_2) filter radiometers determine the rate of the in-situ NO_2 photolysis via a photoelectric measurement of the actinic flux in the appropriate action spectra. The voltage measurement is converted to a photolysis rate by comparison with accurate spectrally resolved actinic flux measurements. The j(NO_2) is critical for determination of the local energy environment as it drives atmospheric chemical interactions.

The radiometers were installed at three locations during the campaign. Up and downwelling measurements from the top of a 96 ft tower sampled above canopy conditions. Upwelling near the forest floor was measured in the vicinity of the fast chemistry (e.g. HOx) measurements. Upwelling and HOx were also measured from a vertically mobile lift that sampled at heights ranging from near the ground to approximately 40 ft. In the upper plot of Figure 1, downwelling j(NO_2) on the lift (green) is shown in comparison to the tower measurement (blue) from the morning to early afternoon. The lower plot shows the ratio of lift to tower downwelling j(NO_2) and indicates the gradual reduction of the radiation field with height in the coniferous forest. Not surprisingly, this is drastically different from a deciduous forest profile, where 90% of the light may be removed in the top 10 ft of the canopy due to the widespread leaf coverage.

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CARI Deployments

Community Chemistry Instrument Deployments

The CARI Community Chemistry Instruments were deployed on three airborne and one ground-based field missions during FY2010. Water vapor and the VUV CO instrument were flown on the C-130 during the Profiling of Winter Storms (PLOWS) mission, and on the GV for the third installment of the HIAPER Pole-to-Pole (HIPPO) deployment. The Fast-O3 HAIS and the TDL water vapor instrument were flown on the GV during the Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT) campaign. Much of the data is still being processed but some preliminary, interesting results are available.

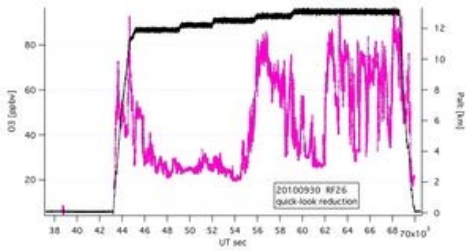

Figure 1. [High Resolution Image]

The primary goal of PREDICT was to increase predictability of hurricane formation in the central Pacific. Low-pressure systems of various grades of organization were overflown in order to allow dropsondes to be released into the storms from the GV aircraft. With increasing strength and level of organization in these systems, larger variability in mixing ratios of ozone was observed. Figure 1 shows the preliminary ozone data observed during the flight on September 30, 2010. The high ozone values are stratospheric filaments of air brought down into the troposphere (flight levels of 12-13 km in the tropics) by the storm activity.

The PANs CIMS instrument was deployed for about one month at the Manitou Experimental Forest field site near Colorado Springs during the BEACHON-Rocky Mountain Organic Carbon Study (ROCS) experiment in August/September of 2010. The instrument was operated in flux mode, measuring PAN at a rate of 10 Hz. PAN profiles between ground level and 50 feet above ground were also measured by means of an inlet line connected to a vertically movable platform. PAN mixing ratios during the night and morning hours were generally around 200 ppt, which is typical for the regional background in the remote Western US. During the afternoons however, upslope driven winds from the Front Range often brought more polluted air with PAN mixing ratios up to 1 ppb to the site (see example in Figure 2). Deposition fluxes of PANs can be expected during these time periods. The data is currently being processed to allow calculation of fluxes of PANs.

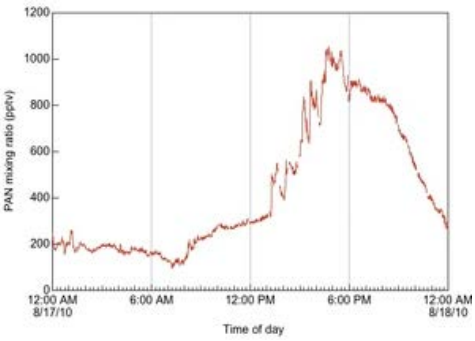

Figure 2. [High Resolution Image]

PAN CIMS Development and Characterization

Extensive instrument calibration and characterization was done on the Peroxy Acyl Nitrates Chemical Ionization Mass Spectrometer (PANs-CIMS). Response factors for a number of longer chain and unsaturated PANs species, which are commonly observed in the atmosphere, were determined. This was done by using the photochemistry chamber of ACD's kinetics group to photochemically produce mixtures of PAN and any one homologue from their parent aldehydes in the presence of NOx and determining the ratio of the two PANs independently with the FTIR spectrometer attached to the photochemistry chamber, the NCAR PANs GC, and a combination of a preparative-scale GC and a NOy instrument. Under field conditions, the instrument is continuously calibrated with ^{13}C isotopically labeled PAN, and therefore only the relative sensitivities are needed to accurately calculate ambient mixing ratios for PAN homologues. The detection method used in the PANs-CIMS is thermal dissociation of the PAN species (the primary products are assumed to be NO_2 and the peroxy acyl radical) followed by detection of the peroxy acyl (PA) radical by chemical ionization with negatively charged iodine ions.

The experiments revealed that the relative sensitivities can be strongly dependent on the temperature of the thermal dissociation tube as well as pressure and flow rate. While pressure and flow rate are typically not varied in our analyzer, the dissociation temperature initially was optimized for PAN at 150°C, where the PA radical yield plateaus before decreasing again at temperatures above 175°C. At these larger dissociation energies, an increased fraction of the PANs starts to decompose into NO_3 and the acyl radical, which does not produce a signal in the CIMS instrument.

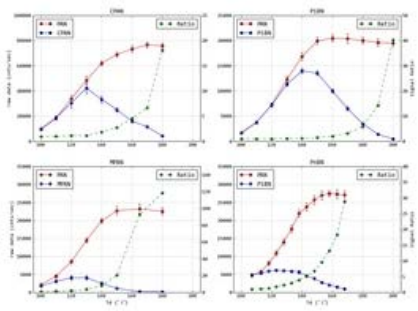

Figure 3. Ion signals for PAN (red) and some PAN homologies (blue) and the relative sensitivities (green) for a number of PAN species commonly measured in the atmosphere. [**High Resolution Image**]

Figure 3 shows plots of the measured dependence of the ion signals of a number of PAN homologues and the relative sensitivity to PAN. It can be clearly seen that the relative sensitivities are strongly dependent on temperature. This is likely a result of a number of competing processes such as the decomposition of the PANs into acyl radicals and NO_3, but also unimolecular decomposition of the peroxyacyl radicals themselves. Longer chain PANs (>C3) shown here and unsaturated PANs such as MPAN and CPAN are expected to have lower activation energies for these decomposition processes. PAN CIMS instruments are becoming more numerous in the community and a number of atmospheric studies using this type of instrument have been published in the literature. In many cases, relative sensitivities of unity have been assumed. Our study clearly demonstrates that each individual PAN CIMS has to be carefully characterized to allow for an accurate measurement of higher PAN homologues.

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DC3 Planning

The Deep Convective Clouds and Chemistry (DC3) Field Experiment will characterize the effect of midlatitude, continental convection on the transport and transformation of ozone and its precursors. Along with measurements of hydrogen oxide radicals, their precursors, and nitrogen oxides in both the inflow and outflow regions of deep convection, measurements of cloud microphysical properties, storm kinematics, and lightning discharges will be obtained. These measurements are planned for three locales in the United States, northeast Colorado, central Oklahoma, and northern Alabama, during May and June 2012 where remote continental regions can be contrasted to anthropogenically-influenced regions.

The nation's most advanced high-altitude research aircraft, the NCAR Gulfstream V (or G-V, formerly referred to as HIAPER), will be used to collect data for the DC3 Field Experiment. [**High Resolution Image**]

The primary goals of DC3 are to 1. Quantify and characterize the convection and convective transport of fresh emissions, including water, to the upper troposphere within the first few hours of active convection, investigating storm dynamics and physics, lightning and production of nitrogen oxides from lightning, cloud hydrometeor effects on wet deposition of species, surface emission variability, and chemistry in the anvil. 2. Quantify the changes in chemistry and composition after active convection, focusing on 12-48 hours after convection and the seasonal transition of the chemical composition of the UT.

The Scientific Plan Overview (SPO) and Experimental Design Overview (EDO) documents have been revised to reflect the guidance from NSF on planning the DC3 field experiment. The DC3 PIs submitted the facility request to NSF and EOL for the CSU CHILL radar, the NCAR mobile sounding system, and G-V aircraft using a payload that is optimal for both the DC3 and SEAC4RS field campaigns. The experimental design includes basing the aircraft in either central Oklahoma or Kansas so that the two aircraft, the NSF/NCAR G-V and the NASA DC-8, can easily ferry to Colorado, Oklahoma or Alabama. Ground-based radar and lightning mapping arrays will support the aircraft measurements by sampling kinematic, microphysical, and electrical characteristics of the storms. After NSF decides on which 2012 field campaigns to support and gives the DC3 PIs guidance to continue planning, a DC3 base of operations will be identified and the field campaign planning will continue, including test flights to certify new G-V instrumentation and model forecasting tests in spring 2011. Development of key G-V instruments is currently ongoing so as to be ready to fly during these test flights in 2011.

The DC3 experiment will benefit from both satellite and numerical modeling analysis. Satellite data provide the context of the environment in which the storms form and will be used to show regions of high nitrogen dioxide (NO2), a molecule that is a product of lightning discharges, near thunderstorm activity. Numerical modeling can provide both forecasts of where convection will be occurring and analysis of what processes contribute significantly to the observed constituent concentrations. Use of these data and modeling results will also be tested during 2011 to prepare for the field experiment. Additional information on DC3 may be found at **https://www2.acd.ucar.edu/dc3/** or at **http://utls.tiimes.ucar.edu/Science/dc3.shtml**.

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OASIS

The OCEAN–ATMOSPHERE-SEA ICE–SNOWPACK (OASIS) Field Campaign: Overview and Preliminary Data Analysis

The OASIS field campaign was conducted between early March and mid-April, 2009 in Barrow AK. Campaign goals were to provide a comprehensive study of the exchange of trace gases between the atmosphere and the cryosphere in polar regions and of polar boundary layer ozone depletion events (ODEs). The campaign was led by researchers at Purdue University and UC-Davis and involved participation from about 10 additional universities and agencies from the USA, Canada and Europe. NESL/ACD scientists deployed a series of about 10 instruments to characterize the gas- and aerosol-phase composition at the site, and were heavily involved in organizing campaign logistics and in archiving and merging campaign data.

Analysis of the data obtained during the campaign is in its preliminary stages. Major activities during FY 2010 included a data workshop (held at UC-Davis in Dec. 2009), a special session at the 2009 Fall AGU, and the creation of the final data merge (a process that is now nearing completion). Driven by measurements made by colleagues at both Georgia Tech and Purdue University, major steps forward in understanding the sources and behavior of inorganic halogens (chlorine and bromine) are emerging.

Some of the additional avenues of research being pursued are addressed in the figures below. A long-standing puzzle in Arctic boundary layer chemistry has been the lack of production of PAN species, compounds of general formula $RC(O)OONO_2$ which are obtained from the oxidation of aldehydes. For example, acetaldehyde (CH_3CHO) is converted to PAN ($CH_3C(O)OONO_2$) by the reactions shown below,

$$X + CH_3CHO\ (+ O_2) \rightarrow CH_3C(O)OO + HX \text{ (where X = Br, Cl, or OH)}$$

$$CH_3C(O)OO + NO_2 \rightarrow CH_3C(O)OONO_2$$

while analogous chemistry converts propanal (CH_3CH_2CHO) to PPN ($CH_3CH_2C(O)OONO_2$). Measurements of aldehydes and PAN compounds made by NESL/ACD/CARI scientists are presented in Figure 1. The data show that the ratio of the aldehyde precursors (acetaldehyde and propanal) to each other is higher than the ratio of the product PAN compounds (PAN and PPN). This result, coupled with the fact that propanal is actually more reactive toward OH, Cl and Br than is acetaldehyde, argues against significant local production of PAN and PPN.

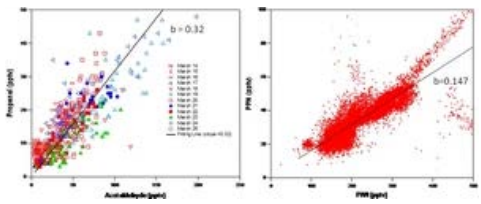

Figure 1: Measurements of Propanal/Acetaldehyde and PPN/PAN made during the OASIS campaign. [**High Resolution Image**]

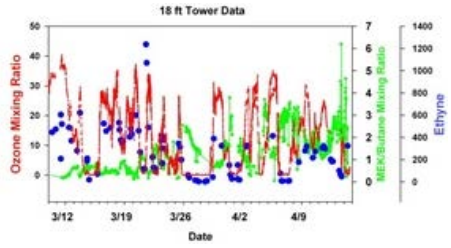

Figure 2: Measurements of ozone and selected VOC and VOC ratios during the OASIS campaign. [**High Resolution Image**]

Ozone depletion events, driven by the chemistry of chlorine and particularly bromine atoms, are clearly evident throughout the campaign, see Figure 2. Also shown in the figure are measurements of selected VOC (volatile organic compounds) and VOC ratios. Ethyne (acetylene, C_2H_2), a species relatively more reactive with Br-atoms than other VOC, is clearly depleted during ODEs, providing a marker for active bromine chemistry. In addition, the ratio of methyl ethyl ketone (MEK, an oxidation product of n-butane) to n-butane is seen to increase during ODEs, indicating the occurrence of significant chlorine-based chemistry. Analysis of the

VOC data to determine the relative impact of Cl and Br to ozone depletion and overall oxidizing capacity of the Arctic boundary layer will continue in the coming months.

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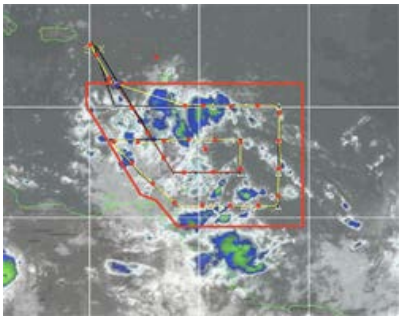
The PRE-Depression Investigation of Cloud systems in the Tropics (PREDICT)

The PRE-Depression Investigation of Cloud systems in the Tropics (PREDICT) field phase took place between August 15 and September 30, 2010. Based on St. Croix in the U.S. Virgin Islands, the NSF/NCAR G-V aircraft flew 26 missions into eight separate tropical systems, four of which became tropical cyclones (Fiona, Karl, Matthew and Nicole) and four which did not. Several flights were conducted in collaboration with aircraft from NOAA (the P-3 and G-IV) and NASA (the DC-8 and Global Hawk). Most of these collaborative flights occurred during the formations of Karl and Matthew.



Infrared satellite image with G-V flight track (yellow), dropsonde locations (triangles), 10-minute time markers (red dots along flight track) and flight reservation boundary (red polygon) for flight centered on 12 UTC 10 September. Latitude/longitude lines are spaced 5 degrees apartThe G-V (located at plane symbol) is exiting the pattern on return to St. Croix (STX). This disturbance developed into Karl four days later. **[High Resolution Image]**

The core objective of PREDICT is to map the mesoscale structure of tropical waves with emphasis on the three-dimensional structure of the circulation and the thermodynamic state. Dry air and vertical wind shear are well known negative factors for tropical cyclone formation. The primary hypothesis to be tested through data analysis is to what extent recirculation regions, in a frame of reference moving with the wave, create an environment protected from adverse factors that thus favors the formation of a nascent tropical cyclone. A typical flight track is shown in Fig. 1, valid September 10, 2010, four days prior to the formation of hurricane Karl. The flight pattern is a rectangular spiral. This pattern was preferred so that the G-V could be at maximum altitude (roughly 47,000 feet) when encountering the strongest thunderstorms that were typically near the center of the pattern. In the example shown, convection is in a rather disorganized state within a broad, weak counterclockwise circulation nearly 800 km across.

PREDICT observations of tropical cyclone formation processes will help determine how tropical cyclones form, and will increase the accuracy of numerical forecasts of tropical disturbances by improving understanding about what to include in climate models to correctly calculate the statistics of genesis. PREDICT is a collaborative effort with the NASA Genesis and Rapid Intensification Processes (GRIP) program and the NOAA Intensity Forecast Experiment (IFEX), both overlapping with PREDICT in time and spatial coverage. Primary universities involved include the Naval Postgraduate School, University of Illinois, State University of New York-Albany, Penn State University, University of Miami, New Mexico Technology University, Cooperative Institute for Mesoscale Meteorological Studies/University of Wisconsin/Madison, Oregon State University, and Howard University.

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SEAC4RS Planning

Campaign planning –SEAC4RS

In collaboration with NASA scientists, ACD Scientists have proposed to NSF and OFAP to participate in a NASA led field experiment, the Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC^{4}RS), using the NSF/NCAR research aircraft Gulfstream V (GV). SEAC^{4}RS is planned to take place in August and September of 2012. The aircraft operation is to be based in Thailand. This experiment is designed to address key questions regarding the influence of Asian emissions on clouds, climate, and air quality. The campaign is motivated by the region's unique meteorology and sensitivity to rapidly changing emissions of gas phase and aerosol pollutants in Asia. Enhanced levels of pollution in the UTLS are clearly seen in the A-TRAIN satellite observations. This region is also known to have high population density and is experiencing significant economic growth, which has led to significant increase in anthropogenic emissions. To date, no significant attempts have been made to observe detailed atmospheric composition over this region in situ. Such observations are critical to making progress in understanding the sensitivity of this region to changes in climate and air quality through the interplay between emissions and atmospheric dynamical, physical, chemical, and radiative processes. SEAC^{4}RS will be the first field study with a large suite of chemical and microphysical measurements from the boundary layer to the UTLS.

For this mission, the GV is proposed to join the NASA DC-8, providing observations from near surface to 12 km, and the NASA ER-2, providing 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. As the third aircraft, GV may play a critical role in sampling convective outflow and investigating chemical transport processes associated with the anticyclone in the 12-14 km altitude range. The SEAC^{4}RS is planned to occur following the DC3 experiment, planned for May-June 2012. The SEAC^{4}RS GV payload is synergistic with DC3, including a comprehensive suite of chemistry and microphysics sensors to target transport, gas phase and cloud chemistry and microphysics.

Figure 1: MODIS fire counts on August 10th 2010 and SEAC4RS planned region of flight operations. The two rings indicate the flight range with 2 hours of loitering (blue) and maximum operation range. [**High Resolution Image**]

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START08 data analyses

UTLS transport process study is the main focus area of the START08 post campaign data analyses. During FY10, ACD scientists, in collaboration with colleagues in the Juelich Research Center (Germany) and Texas A&M University, have carried out Lagrangian model simulations of troposphere to stratosphere transport observed on the GV aircraft during the START08 campaign (Vogel et al., 2010; Homeyer et al., 2010). **Figure 1** gives an example of back trajectory studies of the tropospheric intrusion event observed on April 18, 2008. Trajectory analysis shows that the intruding air masses can be traced back to the tropical upper troposphere and lower stratosphere. As shown in the figure, on 11 April (Fig. 1a), eight days before the intrusion was sampled, back trajectories show that the parcels are predominantly in a filament in the tropical upper troposphere that stretches westward from the western Pacific where the Rossby wavebreaking event is beginning. By 13 April (Fig. 1c) the air mass has moved through the break and into the midlatitude lower stratosphere, where it remains until observed on 18 April (Fig. 1e). At the time the aircraft sampled the tropospheric intrusion, it was completely separated from its tropical source by a strong subtropical jet and the air had been in the lower stratosphere for 7 days. Overall, these model analyses show that each intrusion observed during START08 can be related to a Rossby wavebreaking event over the Pacific Ocean. The analyses further estimated the time scale of the mixing processes, which is one of the key uncertainties in global models. The case study, connecting the aircraft observations to the relevant dynamical process on a global scale, demonstrated the broader impact of aircraft missions conducted on a regional scale.

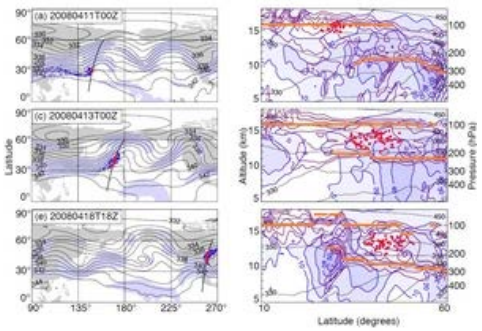

Figure 1. Left: maps showing positions of parcels in the intrusion observed on 18 April. On the maps, wind speeds (> 30 m/s) at 350K are shown in light blue, contours of Montgomery streamfunction (units of 10^{-3} m^2 s^{-2}) are shown in black, trajectory locations are shown as blue and red dots, and the locations of the corresponding vertical section are shown by the thick black lines (great circle arcs). Parcels shown in red on the map correspond to the parcels plotted in red on the vertical section (all parcels within 1° of section). Right: vertical sections from the GFS analysis of wind speed in m s^{-1} (blue colors and contours), potential vorticity in pvu (purple), and potential temperature in K (black). The orange lines are tropopause locations, including the secondary tropopause. **[High Resolution Figure]**

References

Homeyer, C.R., K. P. Bowman, L. L. Pan, E.L. Atlas, R. Gao, T. L, Campos (2010), Dynamical and chemical characteristics of tropospheric intrusions observed during START08, submitted to *J. Geophys. Res.*, doi:10.1029/2010JD015098.

Vogel, B., L. L. Pan , P. Konopka , G. Guenther , R. Mueller , W. Hall , T. Campos, I. Pollack , A. J. Weinheimer , J. C. Wei , E. Atlas , K. P. Bowman (2010), Transport pathways and signatures of mixing in the extratropical tropopause region derived from Lagrangian model simulations, submitted to *J. Geophys. Res.*, doi:10.1029/2010JD014876.

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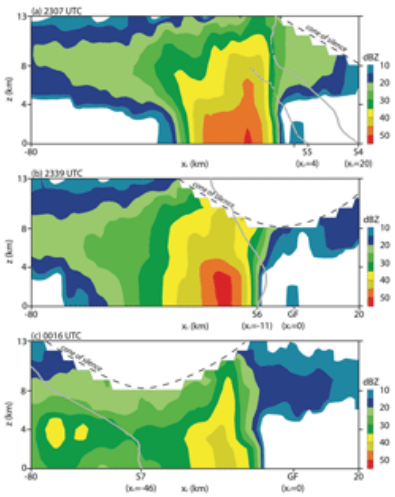
VORTEX 2

The Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2) is by far the largest and most ambitious effort ever made to understand tornadoes. NESL/MMM scientists participating in this multi-agency field program to investigate tornado genesis, maintenance, and demise collected a second year of data in the Great Plains in May-June 2010. Data were successfully collected on several tornadic thunderstorms as well as other atmospheric phenomena such as squall lines and flash-flood-producing convective systems.



Analyses of radar reflectivity at three different times in the evolution of a squall line. The trajectories of rawinsondes are shown by gray lines. The location of the storm's gust front (GF), which marks the leading edge of cool air at the surface, is also shown. The "cone of silence" indicates the region unobserved by the radar. [**High Resolution Image**]

Analysis of VORTEX2 data is underway in collaboration with numerous universities, particularly with Texas Tech University and North Carolina State University. In one study that was recently accepted for publication, researchers from NESL and NC State analyzed the data from rawinsondes (balloon-borne instruments for measuring temperature, humidity, and winds) from a squall-line event. They used nine soundings that were taken over a three-hour period, allowing for an unprecedented view of the squall line's internal structure and nearby environment [Fig. 1]. The analyses showed that cold air near the surface was 4 km deep -- several times deeper than previous research studies had found.

VORTEX2 datasets will serve as a testbed for numerical storm-scale prediction experiments, improving understanding of tornado genesis, and leading to improvements in tornado warning skill.

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Asian Monsoon Transport of Pollution to the Stratosphere

Transport of air from the troposphere to the stratosphere is known to be occurring primarily in the tropics, associated with ascending motion due to large-scale circulation known as Brewer-Dobson circulation. During Northern Hemisphere (NH) summer, the Asian monsoon anticyclone is the dominant circulation in the upper troposphere, which contributes vertical transport of air from the polluted troposphere into the stratosphere. Chemical constituents, such as carbon monoxide and hydrogen cyanide (HCN), can be used as tracers of pollution events originating from the surface. As a tropospheric pollutant, HCN is produced primarily as a result of biomass and biofuel burning and has a long lifetime of 2-3 years in the free atmosphere. A distinctive feature of HCN is that it has a strong sink from contact with the ocean, which results in a minimum in the tropical upper troposphere (see Fig. 1). Hence, the tropical upwelling cannot be the main source for HCN in the stratosphere. As shown in Figure 1, the HCN maximum in the Northern Hemispheric lower stratosphere shows that the Asian monsoon anticyclone provides an effective pathway for pollution from Southeast Asia to the global stratosphere.

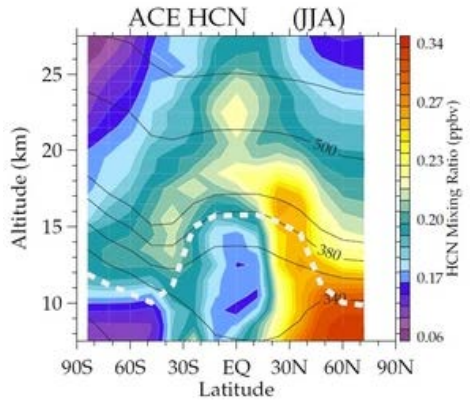

Figure 1. Zonal mean cross section of hydrogen cyanide (HCN) mixing ratio (ppbv) averaged for Northern Hemisphere summer (June to August) derived from Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) satellite measurements. The white thick dashed line denotes the tropopause and thin solid lines denote isentropic levels (from Randel et al., 2010). [**High Resolution Image**]

References

Randel, W. J., et al., Asian Monsoon Transport of Pollution to the Stratosphere, Science, 328, 611- 613 (2010).

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IV.B. Cloud Tops and tropopause/jet structure

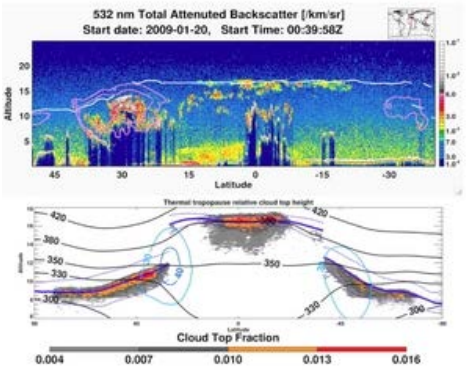

Figure 1. (Top) CALIPSO 532 LIDAR backscatter profiles and orbital track latitudes, and the background meteorological field, including the tropopause height (white), and jet stream locations (pink). (Bottom) Vertical distribution of the cloud top fractions calculated in topopause relative coordinates. The cloud top fractions for March 2007 are shown with the zonal monthly mean themal tropopause (large purple dots) and its 10th and 90th percentile (small purple dots). The zonal mean tropopause is calculated in two groups (tropical and extratropical), which are separated by the 14 km tropopause height. Also shown are monthly zonal mean of horizontal wind (blue) and selected potential temperature surfaces (black). Dynamical fields are from the GFS data. [High Resolution Image]

ACD scientists (Laura Pan and Leigh Munchak) examined the relationship between cloud tops and the tropopause/jet structure using four years of CALIPSO data, radiosonde, and NCEP Global Forecast System (GFS) data. The goal of this work is to characterize the constraint of the background thermal and dynamical structure on cloud occurrences. The results show that the thermal tropopause appears to be a significant constraint for the cloud top. The analyses show that there is no statistically significant cloud top occurrence above the tropopause in the midlatitudes. In the tropics, there are significant occurrences of cloud top above the thermal tropopause in regions known for seasonal deep convection. In these regions, which are associated with gravity wave activity, comparisons between the thermal and the cold point tropopause using the radiosonde data and the collocated CALIPSO data show that the cold point tropopause may be significantly higher than the thermal tropopause in the deep convection season. This vertical separation may be largely responsible for the cloud tops that do occur above the thermal tropopause in the tropics.

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Detection of Cirrus in the Upper Troposphere using HIRDLS

The High Resolution Dynamics Limb Sounder (HIRDLS) is orbiting on NASA's Earth Observing System (EOS) Aura spacecraft. HIRDLS is a limb-scanning infrared radiometer, with 4 of its 21 channels designed to measure emissions from clouds and aerosols. With its 1 km resolution and high sensitivity, HIRDLS is able to detect small amounts of cirrus along limb paths in the upper troposphere. The vertical depths of cirrus in the upper troposphere vary from less than a kilometer to several kilometers. It is important to know these depths in order to understand how cirrus contributes to the heating and cooling rates in the upper troposphere. A positive net heating (solar plus infrared) will impart a positive enhancement to the vertical motion field.

The figure shows the distribution of cirrus mapped by HIRDLS at 121 hPa averaged over season for the years 2006 and 2007. Note that near Indonesia (longitudes around 120°E) cirrus of kilometer scale vertical thickness occurs more frequently in regions north and south of the equator than over the equator. This is confirmed by measurements from the CALIPSO satellite. Fields of Outgoing Long-wave Radiation (OLR), show that the low values indicating deep convection occur over the equator. Thus, these thin cirrus clouds occur away from regions of deep convection. They produce positive heating in the upper troposphere, while thicker cirrus over the equator has a cooling effect. Ongoing research using these data will determine how this heating enhances vertical transport in the upper troposphere.

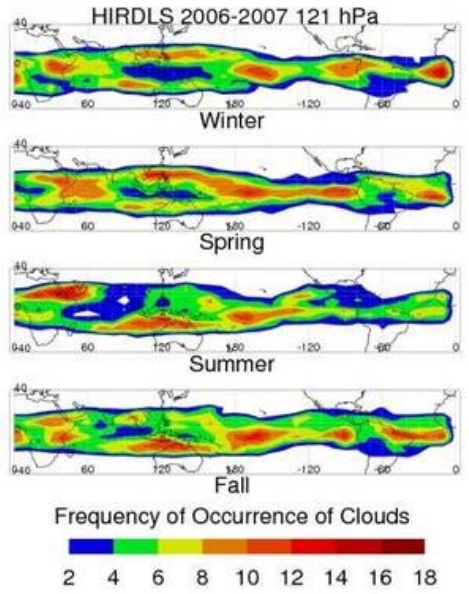

Figure 1. (cirrus) Frequency of occurrence (%) of cirrus clouds at 121 hPa for the years 2006-2007 determined from HIRDLS observations. Near Indonesia (around 120°E longitude) thin cirrus occurs more frequently away from the equator rather than over the deep convective clouds there, resulting in heating in the upper troposphere. Thicker cirrus over the deep equatorial clouds have a cooling effect. These data will be used to help determine how this heating enhances vertical transport in the upper tropical troposphere. **[High Resolution Image]**

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HIAPER Atmospheric Radiation Package (HARP): Spectrally resolved actinic flux and stabilized platform irradiance measurements

The Atmospheric Radiation Investigations and Measurements (ARIM) team, in collaboration with the Atmospheric Radiation Group (ARG) at the University of Colorado (CU), the Leibniz-Institute for Tropospheric Research, Metcon, Inc and Enviscope GmbH, Germany, developed the HIAPER Airborne Radiation Package (HARP), a comprehensive atmospheric radiation suite to measure spectrally resolved in situ actinic flux and irradiance.

The actinic flux instrumentation incorporates the CCD Actinic Flux Spectroradiometer (CAFS) detector to determine photolysis frequencies for atmospherically active compounds. Horizontally stabilized irradiance measurements developed at CU measure energy flux and determine albedo and layer properties, such as reflectance, transmittance and absorptance. The ARIM group coordinated and assembled the spectrometers, input optics and stabilized platforms, designed and built the data acquisition and control hardware and software, and maintains integration and flight management of the package.

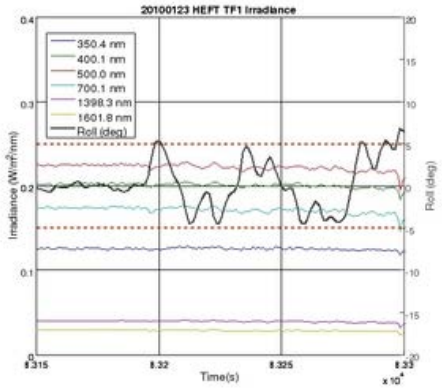

Figure 1. [**High Resolution Image**]

Final testing of the irradiance stabilized platform was completed during the 2010 HIAPER Aircraft Instrumentation Solicitation Experimental Flight Test (HEFT-10), as required by EOL policy for all mission-critical instrumentation. The ARIM team managed the successful calibration, integration, deployment and flight operation of the platform and spectrometers. They trained RAF staff on complex flight operations, remotely monitored operations and produced a comprehensive analysis report of platform results. The results included accurate comparison of the aircraft navigation and HARP inertial navigation system and irradiance stability during pitch, roll and reverse heading maneuvers. They also successfully demonstrated recoverability for in-flight power failure. The figure demonstrates the extraordinary stability of irradiance from 350-1600 nm during aircraft roll maneuvers within the 5 degree roll stability requirement.

The HEFT-10 project was augmented by the NSF to include extended testing / scientific objective by funding the AMAX-DOAS instrument participation and a three flight deployment to Hawaii to test the instrument in the marine environment. The ARIM group continued to support the HARP deployment for the extended flights, in scientific collaboration with the AMAX-DOAS and ARG teams at the University of Colorado. The resulting HARP derived ocean surface albedo will be critical for future missions, such as the Tropical Ocean tRoposphere Exchange of Reactive halogen species and Oxygenated VOCs (TORERO) mission.

This work supports the NESL and ACD goals of development and use of chemistry instrumentation, studies of chemical transformations and synthesis with models.

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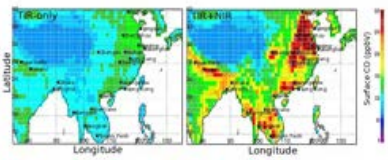
Multispectral Retrieval Algorithm Development



[**High Resolution Image**]

The MOPITT ('Measurements of Pollution in the Troposphere') team in NESL/ACD is responsible for (1) developing and improving algorithms to determine tropospheric concentrations of carbon monoxide (CO) from raw instrument data, (2) validating the resulting products, and (3) applying those algorithms operationally to produce an archival record of tropospheric CO. MOPITT is currently the only satellite instrument equipped to observe carbon monoxide (CO) using both thermal-infrared (TIR) and reflected near-infrared (NIR) solar radiation. In principle, these complementary observations should allow space-based measurements of CO in the lower troposphere, where CO affects human health and where important sources of CO are located. Compared to currently available satellite products for CO, such 'multispectral' TIR/NIR retrievals promise better sensitivity to CO throughout the troposphere and should yield substantial improvements in estimates of CO emissions.

The MOPITT team has made great strides towards the release of MOPITT multispectral CO products in the last year. We presented the first retrieval results based on both TIR and NIR measurements and showed that the results were qualitatively reasonable. This work was recently published in the Journal of Geophysical Research (Worden, H. M., M. N. Deeter, D. P. Edwards, J. C. Gille, J. R. Drummond, and P. Nédélec, Observations of near-surface carbon monoxide from space using MOPITT multispectral retrievals, J. Geophys. Res., 115, D18314, doi:10.1029/2010JD014242, in press). The figure below demonstrates how retrievals of surface-level CO over Asia improve as the result of simultaneously exploiting MOPITT's TIR and NIR observations. The left panel shows TIR-only results, similar to the current 'Version 4 Product', whereas the right panel shows experimental TIR/NIR results. Both panels are seasonal averages for 2005-2008, September/October/November (SON) in central/east Asia. Enhanced sensitivity to surface-level CO is especially evident in central/east Asia where source regions for urban areas with high population density are clearly identifiable in the TIR/NIR results. New Version 5 retrieval products based on TIR and NIR observations will be made available to the community in 2011.

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NDACC Update

ACD's Optical Techniques Group continues to operate infrared high-resolution solar spectrometers in the Arctic in Thule Greenland and in the tropics at Mauna Loa Observatory in Hawai'i. This work is performed in conjunction with colleagues who operate twenty other identically instrumented sites across the globe and is part of the larger international Network for the Detection of Atmospheric Composition Change (NDACC). Initial efforts for the network were directed at studying ozone depletion and recovery and the associated primarily stratospheric chlorine chemistry. The instrumentation also readily measures concentrations of trace gases affecting air quality and climate. Consequently the long term records and near real-time data for satellite validation for CO, HCN, C2H6, C2H2, H2CO, CH4, CO2 are acquired and made available to the community.

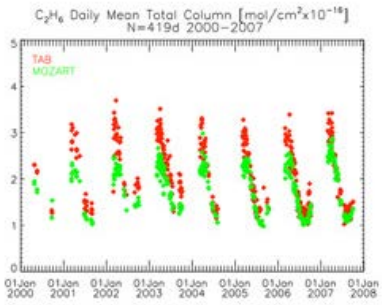

Fig 1. Eight year trend of total column C2H6 measured at Thule Greenland in red and same day total columns derived from MOZART4 comparisons. [**High Resolution Image**]

During FY10 we contributed to global model / measurements and budget analysis for formic acid, the largest acidic component in the atmosphere. It was found to be underestimated in the model by about a factor of 2 globally and more in the Arctic. Improved productions from isoprene and its oxidation products reduced the underestimation but the model budget was still biased low. Evidence points to aging organic aerosols being a source for part of the excess.

During the polar night large amounts of pollution build up in the arctic, and quantifying and understanding this process can aid emission estimates. Because we use a solar observing instrument, measurements begin at sunrise at 76°N in late February. Figure 1 shows an eight year trend in total column ethane measurements in red (note that the lack of data around the turn of the year is due to the polar night). The highest values in spring are due to the lack of photo-oxidation throughout the winter, and are followed by drawdown to background levels in summer. Of note is the consistent underestimation of the model run in green. Though model chemical processes accurately bring summer values to match observations they tend to lag. Quantitative assessment of differences should improve estimated of integrated emissions and model estimates for ethane as well as other anthropogenic gases.

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Planning for Future Atmospheric Composition Satellite Missions

The 2007 US National Research Council Decadal Survey calls for a geostationary (GEO) satellite mission for atmospheric composition and air quality (AQ) applications: the Geostationary Coastal and Air Pollution Events Mission (GEO-CAPE). The goals of this mission are an examination of the gas and aerosol emissions important for AQ; the way atmospheric transport, chemical evolution, and deposition determine tropospheric composition over scales ranging from urban to continental; chemistry-climate interactions; and the impact of intercontinental transport. Also of importance is how the continuous high spatiotemporal resolution data possible from GEO might improve AQ forecast and assessment models.

Detailed examination of the key measurement characteristics required for the successful use of satellite remote sensing in measuring environmentally significant pollutant trace gases and aerosols will be a prerequisite to future satellite missions. Especially important is an evaluation of the required horizontal, vertical and temporal measurement resolutions required to capture the variation of atmospheric constituents and processes determining air quality. For this, there is considerable interest in using chemical Observation System Simulation Experiments (OSSEs) to help define quantitative measurement requirements for these future missions and to evaluate the expected performance of proposed observing strategies.

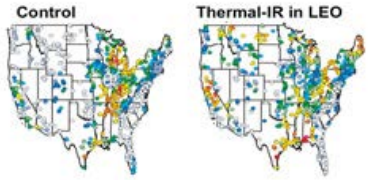

Figure 1: Results of an OSSE for surface CO showing the temporally averaged correlation with respect to the Nature Run "Truth" at the surface locations of a random selection of 1000 EPA sites. The assimilation of simulated multi-spectral GEO observations significantly improves the surface daily CO forecast (skill=0.84) compared to current capability using thermal-IR LEO observations (skill=0.58) and a control case (skill=0.07). From Edwards et al. [2009]. [**High Resolution Image**]

OSSEs assess the impact, via data assimilation (DA), of a hypothetical measurement on the chemical-transport model (CTM) description (and/or prediction) of the 3D distribution of the atmospheric trace gas or aerosol of interest. The candidate data are either added to, or withheld from, the DA/CTM system analysis, and the impact is assessed relative to a control case. The chemical OSSE framework being developed in the NESL/ACD/ACRESP group comprises the following key elements: (1) a quantifiable science-driven requirement for a chemical species observation; (2) a satellite instrument simulator and observing strategy that can be tested for producing a useful measurement; (3) a simulated retrieval of the species with 'nature' defined by an appropriate CTM; (4) a forecast of the species distribution using an assimilation of the retrieval in the model; and (5) a quantitative assessment of the value of the measurement.

A paper describing the new chemical OSSE approach and an experiment detailing the expected improvement in the spatial and temporal characterization of surface-level carbon monoxide (CO) from GEO compared to current low Earth orbit (LEO) capability, Figure 1, was a recent Editor's Highlight in JGR [Edwards et al., 2009]. This demonstrated the expected benefit of using multispectral measurements from a proposed gas correlation filter radiometer (GCFR) instrument for GEO-CAPE that builds on our previous experience with the MOPITT mission in LEO. We are Co-Investigators on this project (led by NASA-LaRC) that is currently under development as part of the NASA Instrument Incubator Program (IIP).

Edwards, D. P., A. F. Arellano Jr., and M. N. Deeter (2009), A satellite observation system simulation experiment for carbon monoxide in the lowermost troposphere, *J. Geophys. Res.*, 114, D14304, doi:10.1029/2008JD011375.

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Real-time chemical forecasts with MOZART-4 and MOPITT CO

The global chemical transport model MOZART-4 has been set up to run in real-time and provide global forecasts of tropospheric chemistry, including CO, O_3 and their precursors. The forecasts include fire emissions based on MODIS fire counts and the assimilation of CO retrievals from the MOPITT instrument onboard the Terra satellite. Each day, MOZART-4 is run for the previous day with the assimilation of MOPITT CO, and then continues for another 3 days driven by forecast meteorology from NCEP/GFS. These results are made available on a website (**http://www.acd.ucar.edu/acresp/forecast/**) as both plots and data files (see Figure 1). Regional subsets of hourly output are produced for a group at Washington State University to use as boundary conditions for regional air quality forecasts of the Pacific Northwest (**http://lar.wsu.edu/airpact-3/ozone.html**).

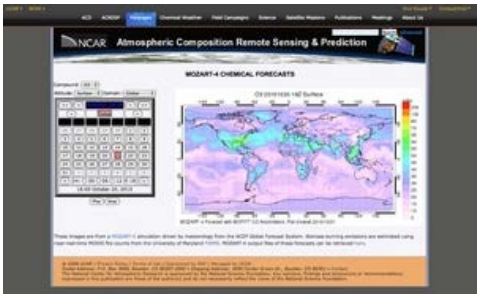

Figure 1. Screenshot of ACRESP Chemical Forecasts webpage. [**High Resolution Image**]

Figure 2 compares CO distributions in MOZART-4 with and without the assimilation of MOPITT CO retrievals, showing instantaneous results at 0Z on 4 September 2010 at approximately 640 hPa. The assimilated CO field shows slightly lower values over China, indicating the emissions may be overestimated in that region. However, the plumes being carried over the North Pacific and Alaska are increased by the assimilation, correcting for probably both emissions and transport errors.

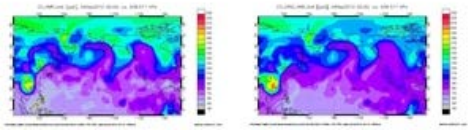

Figure 2. Results from MOZART-4 with (left) and without (right) assimilation of MOPITT CO for Sep. 4, 2010 at approximately 640 hPa. [**High Resolution Image**]

On-going research is exploring ways to improve the chemical forecasts with new assimilation techniques and the assimilation of additional chemical species such as ozone.

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Additional Instrument Development Activities

TOGA-HIAPER Instrument

The TOGA-HIAPER instrument was recently developed and completed this year. The system was fully custom designed and in-house built. Rapid, comprehensive measurements of a range of VOCs including, OVOCs, NMHCs, and halocarbons compounds are accomplished by fast preconcentration of air followed by fast gas chromatography and detection with mass spectrometry. TOGA-HIAPER is scheduled to operate during two upcoming NSF field programs, TORERO (Tropical Ocean Troposphere Exchange of reactive halogen species and oxygenated VOC) and DC3 (Deep Convective Clouds and Chemistry).

TOGA Instrument [**High Resolution Image**]

The TOGA-HIAPER instrument (Figure 1) offers a number of advantages as a complete package over competing technologies, including: 1) Unparalleled range of VOC measurements in a single instrument; 2) Reasonable time resolution (2.0 min. or better); 3) High sensitivities with limits of detection at the part per trillion level and lower; 4) Functionality at all altitudes within the range of the NSF-HIAPER aircraft, and 5) High selectivity. The TOGA-HIAPER offers two-dimensional separation with the gas chromatograph providing the first separation and the mass spectrometer the second, assuring that each organic species measured is uniquely identified and quantified. The instrument is contained in a standard HIAPER rack, weighs less than 400 lbs and consumes ~1 kW of power. The system is fully automated and designed to function without an on-board operator.

PAN CIMS Development and Characterization

Extensive instrument calibration and characterization was done on the Peroxy Acyl Nitrates Chemical Ionization Mass Spectrometer (PANs-CIMS). Response factors for a number of longer chain and unsaturated PANs species, which are commonly observed in the atmosphere, were determined. This was done by using the photochemistry chamber of ACD's kinetics group to photochemically produce mixtures of PAN and any one homologue from their parent aldehydes in the presence of NOx and determining the ratio of the two PANs independently with the FTIR spectrometer attached to the photochemistry chamber, the NCAR PANs GC, and a combination of a preparative-scale GC and a NOy instrument. Under field conditions, the instrument is continuously calibrated with 13C isotopically labeled PAN, and therefore only the relative sensitivities are needed to accurately calculate ambient mixing ratios for PAN homologues. The detection method used in the PANs-CIMS is thermal dissociation of the PAN species (the primary products are assumed to be NO2 and the peroxy acyl radical) followed by detection of the peroxy acyl (PA) radical by chemical ionization with negatively charged iodine ions.

The experiments revealed that the relative sensitivities can be strongly dependent on the temperature of the thermal dissociation tube as well as pressure and flow rate. While pressure and flow rate are typically not varied in our analyzer, the dissociation temperature initially was optimized for PAN at 150°C, where the PA radical yield plateaus before decreasing again at temperatures above

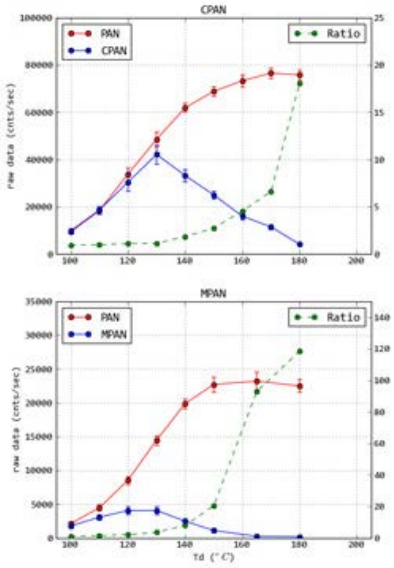


Fig.1: Ion signals for PAN (red) and some PAN homologies (blue) and the relative sensitivities (green) for a number of PAN species commonly measured in the atmosphere. [**High Resolution Image**]

175°C. At these larger dissociation energies, an increased fraction of the PANs starts to decompose into NO3 and the acyl radical, which does not produce a signal in the CIMS instrument.

Figure 1 shows plots of the measured dependence of the ion signals of a number of PAN homologues and the relative sensitivity to PAN. It can be clearly seen that the relative sensitivities are strongly dependent on temperature. This is likely a result of a number of competing processes such as the decomposition of the PANs into acyl radicals and NO3, but also unimolecular decomposition of the peroxyacyl radicals themselves. Longer chain PANs (>C3) shown here and unsaturated PANs such as MPAN and CPAN are expected to have lower activation energies for these decomposition processes. PAN CIMS instruments are becoming more numerous in the community and a number of atmospheric studies using this type of instrument have been published in the literature. In many cases, relative sensitivities of unity have been assumed. Our study clearly demonstrates that each individual PAN CIMS has to be carefully characterized to allow for an accurate measurement of higher PAN homologues.

Measuring the response of the atmosphere to climate change - ALICE

There has been an ongoing effort at ACD to develop the Advanced Limb Infrared Chemistry Experiment (ALICE) concept. ALICE is a long wave infrared (LWIR) satellite-borne limb-scanning spectrometer with high vertical resolution (≤1 km), spanning the wavelength range 6-15 μm, to measure globally dense profiles of species from cloud tops (≥~8 km) to the mesosphere (~80 km). ALICE builds on and goes beyond the Earth Observing System (EOS)-Aura High Resolution Dynamics Limb Sounder (HIRDLS) radiometer, which has proven uniquely valuable in stratospheric dynamical studies [*Alexander et al.*, 2008, 2010], and in UTLS chemistry and stratosphere-troposphere-exchange (STE) studies [*Pan et al.*, 2009]. As a spectrometer, ALICE will not only obtain profiles of all of the species measured by HIRDLS (T, O_3, HNO_3, H_2O, CH_4, CFC11, CFC12, NO_2, N_2O, N_2O_5, $ClONO_2$ & aerosols), but will have the added capability to measure additional species (SF_6, HCN, C_2H_6, OCS, SO_2, NH_3, HNO_4, PAN, $(CH_3)_2CO$, CCl_4, CH_3Cl, COF_2). ALICE measurement sampling and resolution will also make possible views of the latitude-height structure of equatorial Rossby wave, mixed Rossby-gravity wave, and Kelvin wave modes at altitudes above cloud tops in the tropical upper troposphere and stratosphere, at even better resolution than the unprecedented measurements of HIRDLS described in Alexander and Ortland, 2010. ALICE's superior spectral coverage allows it to differentiate significantly better between types of clouds, polar stratospheric clouds (PSC) and aerosols, and to do so at equal or better vertical resolution, giving ALICE significantly enhanced capabilities over those of HIRDLS.

A NASA-ROSES Instrument Incubator proposal recently submitted seeks to develop the ALICE concept to an advanced, pre-flight prototype, and demonstrate it in a relevant environment. ALICE is a collaborative project that includes participants from NCAR/ACD, CU/LASP and Ball Aerospace Corporation. The proposed work focuses on the development and testing of an Offner spectrometer subsystem with a machined convex metal grating critical component, integrated with a three mirror anastigmat telescope subsystem, to minimize in-band and out-of-field stray light on the focal plane detector in the 6-15 μm wavelength range.

The science objectives of ALICE can be summarized by a set of representative questions, related to climate change and ozone recovery, which ALICE will answer by providing the critical data: (i) What are the feedbacks between climate change and the distribution of radiatively active gases?; (ii) How is the upper troposphere lower stratosphere (UTLS) influencing and being impacted by changing climate?; (iii) Is stratospheric ozone recovering as expected?; (iv) What is the momentum flux of gravity waves into the stratosphere and above?

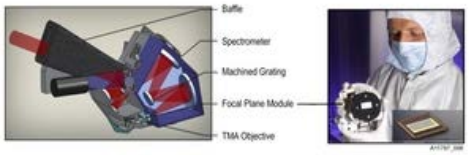


Figure 1. The ALICE optical subsystem achieves high vertical resolution limb scanning with an LWIR imaging spectrometer. The labeled items comprise the IIP spectrometer to be built for the high fidelity stray light characterization needed to define the ALICE operational mission. At right is the VLWIR HgCdTe large format FPA in the completed module. [**High Resolution Figure**]

ALICE is designed specifically to fulfill Global Atmospheric Composition Mission (GACM) science

objectives expressed in the NRC Decadal Survey [2007], which states: “To understand the dynamics associated with stratosphere-troposphere exchange and to determine changes in the stratosphere that affect UV radiation budgets at the surface, measurements of O_3, N_2O, temperature, water vapor and aerosols are required from the upper troposphere into the lower stratosphere.”.

ALICE will meet the recommendations of the NASA/Goddard October 2008 Atmospheric Composition Constellation (ACC) Workshop 2008 [*NASA/Goddard Report*, 2008], which determined that: “...continuous measurements of high vertical resolution ozone and chemically active trace gas profiles is the highest priority for atmospheric composition science and applications and requires action on the part of CEOS (Committee on EOS) space agencies.” ALICE can make these measurements with better combined vertical resolution, globally dense coverage and number of relevant species, than any other currently planned instrument.

The ALICE concept responds to priorities defined by the Stratospheric Processes and Their Role in Climate Chemistry-Climate Model Validation (SPARC CCMVal) [*Eyring et al.*, 2010] project, to acquire data to validate the models used to predict climate change and ozone recovery.

ALICE will be suitable for Earth Venture class missions and missions of opportunity. The ALICE development effort benefits the Atmospheric Remote-sensing Imaging Emission Spectrometer (ARIES) concept conceived as an AIRS follow-on, and future NOAA atmospheric sounders, as considered for the Geostationary Hyperspectral Environmental Sensor (HES).

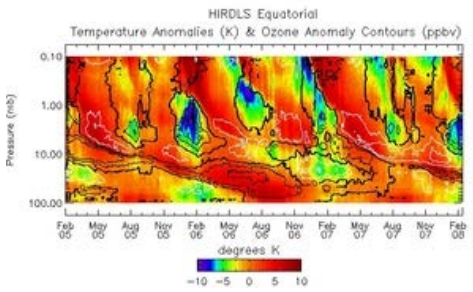
ALICE Collaborators:

NCAR/NESL/ACD, NorthWest Research Associates, University of Colorado - Laboratory for Atmospheric and Space Physics (CU-LASP), and University of Colorado - Center for Limb Atmospheric Sounding (CU-CLAS).

Release of Version 5 HIRDLS Data

The High Resolution Dynamics Limb Sounder (HIRDLS) team released in March a new, improved and more extensive version of its data. This Version 5 (or V5) was deposited in the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC), where it is freely available to the community. These data include improved versions of temperature and the species in previous versions: ozone, nitric acid, CFC 11, CFC12, and aerosol extinction. To these was added geopotential height. These data have the unprecedented 1 km vertical resolution for these species, which have been used to show the presence of tropical Kelvin waves, mixed Rossby-gravity waves, and equatorial gravity waves, and are now being used to extend studies of gravity waves in the stratosphere.

An example is shown in the figure, which shows equatorial temperature anomalies (color) for the HIRDLS data period. These show the descent of the quasi-biennial oscillation (QBO), with the semi-annual oscillation (SAO) shown above 10 hPa. Superposed on these, in the contours, are ozone mixing ratio anomalies, where black are positive anomalies and white are negative. These illustrate the anti-correlation of temperature and ozone above 10 hPa in the tropics, where the variations are driven by photochemistry. Below that level temperature and ozone variations are positively correlated, as both are controlled by vertical motions below the ozone maximum.



[**High Resolution Image**]

The data and how they may be accessed are described in the Data Quality Document, which may be found at **http://www.eos.ucar.edu/hirdls/**.

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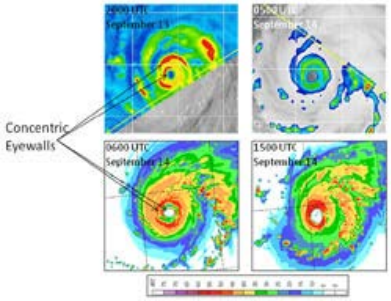
The Hurricane Forecast Improvement Project (HFIP)

NESL/MMM scientists are collaborating on this NOAA-led initiative to improve hurricane forecast skill, with an emphasis on hurricane intensity and structure. It involves a combination of operational and research efforts, including NCAR, universities, NOAA and the National Research Laboratory (NRL). The program goal is to (a) conduct resolution tests to determine if higher resolution systematically improves intensity forecasts, and (b) implement new models into a quasi-operational framework through the Superensemble led by Florida State University, in addition to models run operationally at NCEP.



The top right figure shows the concentric eye-wall depicted by TRMM microwave image (courtesy of Naval Research Laboratory, Monterey, California), and the top left figure shows the single eye-wall structure about 10 hours later. The bottom two figures show the simulated maximum column radar reflectivity from AHW at a time when the concentric eye-wall can be identified, and later when a single eye-wall was seen. [High Resolution Image]

During the past year, MMM scientists collaborated with the University at Albany SUNY to conduct retrospective testing, evaluation and implementation of modifications to the previous version of the ARW (Advance Research WRF) used for hurricanes, the Advanced Hurricane-research WRF (AHW). Testing was performed on Atlantic tropical cyclones from 2008 and 2009. Based on this testing, AHW was selected for the so-called Stream 1.5 HFIP demonstration during the 2010 hurricane season. This status is in between research and true operations, and gives forecasters at the National Hurricane Center the option of viewing the forecasts in near real time. In addition, the AHW was part of the FSU multi-model ensemble, a suite of several limited-area models used for hurricane prediction, including the operational models and research models from other groups. Modifications in 2010 included cloud physics parameterization and treatment of air-sea fluxes.

One of the more interesting forecasts produced this season was of the eye-wall replacement cycle of hurricane Igor, one of the largest hurricanes ever observed in the Atlantic. This cycle occurs when a new wind maximum develops perhaps 100 km or more from the center and gradually contracts to replace the previous eye-wall. This usually is accompanied by large fluctuations in storm intensity. This happened during the evolution of Hurricane Igor on Sept 13 – 14, 2010.

This HFIP work is focused on advancing research of simulating hurricanes into operations and providing the first high-resolution operational hurricane forecasts. It will also help us better understand the sensitivity of hurricane intensity forecasts to various aspects of modeling systems, including physics and initialization.

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The Antarctic Mesoscale Prediction System (AMPS)

The Antarctic Mesoscale Prediction System (AMPS)

AMPS is a collaborative effort among researchers at NCAR, the Ohio State University's Byrd Polar Research Center (BPRC), and the University of Colorado (CU), to provide high-resolution numerical weather prediction (NWP) guidance, based on the WRF model, in support of logistical and scientific forecasting efforts of the United States Antarctic Program (USAP). AMPS provides guidance for weather forecasting for the USAP, as well as for various scientific and logistic efforts over the continent. This work is vital to USAP activities, as the weather forecasters depend on a well-maintained and upgraded AMPS.

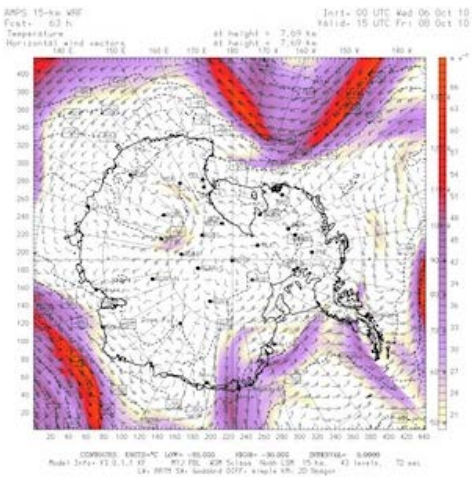

Figure 1: AMPS forecast of flight-level 25,000-ft winds and temperatures from 15-km domain. Forecast hr 63, 0000 UTC 6 Oct 2010 initialization. T (deg C): dashed, contour interval= 5C. Wind barbs: half-barb= 5 km, full barb= 10 kt, pennant = 50 kt. Wind speed (m/s): shaded. [high resolution]

AMPS continued to operate through the 2009-2010 season and is currently providing NWP guidance for the 2010-2011 season. For last season, AMPS provided a special 2.5-km forecast nest for the LARISSA (Larsen Ice Shelf System, Antarctic) field campaign, and for this season it is running a 5-km nest over the Central TransAntarctic Mountains where USAP activities occur.

NESL/MMM scientists and collaborators continued to upgrade and revise AMPS products based on user input. Such input was received from the Space and Naval Warfare Systems Command (SPAWAR) through a site visit, through SPAWAR visitors to NCAR, and through regular communication. The AMPS group also obtained input from the international user community at the 5th Antarctic Meteorological Observation, Modeling, and Forecasting Workshop held at Ohio State in July 2010. NESL/MMM staff contributed to the planning and organization of this workshop which attracted over 50 attendees, with international participation.

Collaborators at BPRC compared precipitable water (PW) among AMPS forecasts, ground-based GPS retrievals, and radiosonde observations. They found generally good agreement among the data sets, motivating future assimilation of the PW retrievals. Other work in 2010 involved new Self-Organizing map (SOM) products and a SOM analysis of the 20-km AMPS output was conducted and a manuscript submitted for publication by collaborators at CU. The SOM algorithm was used to objectively identify the primary synoptic weather patterns that occur over the Ross Sea sector, with the identification based on sea level pressure. The performance of AMPS forecasts was evaluated for each weather pattern by comparing the AMPS forecasts to automatic weather station observations. In addition, real-time SOM forecast products were added to the AMPS product suite, beginning with the 2009-2010 field season.

Other work in FY2010 included testing the effects of AMSU-A (Advanced Microwave Sounding Unit– A) in AMPS/Antarctic data assimilation. This work was completed, with satisfactory results. AMSU-A satellite radiances thus began to be assimilated into AMPS in the past year and are among the

ingest observation types. AMPS was further improved this year through updating the polar modifications for the WRF V3.2 and V3.2.1 releases and through testing in polar applications, for both the Arctic and the Antarctic, at BPRC, CU, and NCAR. The version of WRF running in AMPS received a modified longwave radiation parameterization after tests over Antarctica showed improved performance over the high latitudes. In addition, the latest version of polar WRF modifications in V3.2.1 has undergone testing.

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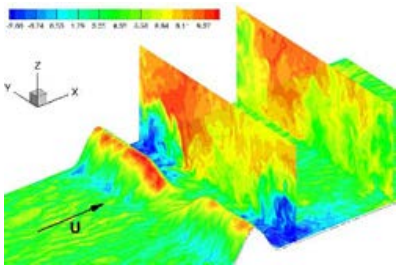
Wind Energy Research



Turbulent flow in a gap between two steep ridges. The primary flow direction is parallel to the x−direction. Contours of the instantaneous u−velocity component are shown and the color bar is in units of m s−1. The two y−z planes are located at x = (1500, 2000) m, and the ridgeline is located at x = 1280 m. The horizontal plane is about 4 m off the surface. The lower 150 m of the boundary layer is depicted. [High Resolution Image]

The importance and potential impact of wind energy research has been growing in recent years, yet wind remains among the most difficult weather variables to forecast. To address this, NESL scientists in collaboration with RAL scientists are conducting basic turbulence research that underlies wind energy.

Flows in gaps that separate ridges and hills are common landscape features. Turbulent interactions with surfaces comprised of modestly complex three-dimensional shapes (gaps, hills, craters, water waves) have not been thoroughly investigated and can significantly impact decisions surrounding wind turbine placement strategies. To investigate these complex flow regimes, NESL/MMM scientists developed a massively parallel algorithm and code for large-eddy simulation (LES) of atmospheric planetary boundary layers (PBLs). The algorithm is sufficiently general to allow simulations of PBLs over a range of surfaces (from isolated stationary three-dimensional shapes to a spectrum of time dependent moving water waves).

This work and future work will provide a better understanding of how land-surface characteristics such as hills, trees, and the turbines themselves interact with the atmosphere, which will further understanding of how these variables influence local wind speed direction, and turbulence characteristics. This information can benefit society by providing data that will help wind farms optimize wind-farm location and turbine spacing, which can lead to enhanced energy capture.

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Research Applications Laboratory | RAL

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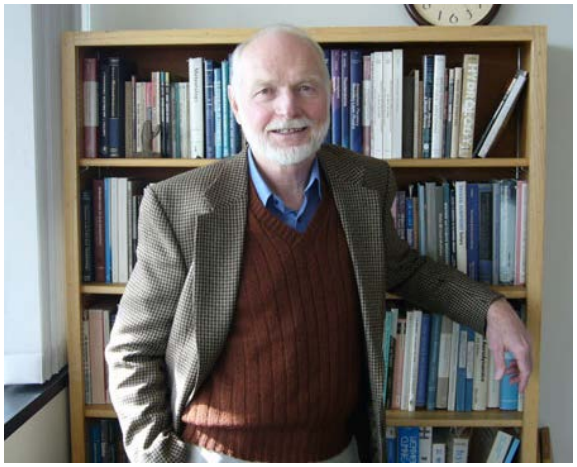
Director's Message



Brant Foote - RAL Director

Welcome to the Research Applications Laboratory's Annual Report for FY2010. Our mission is to conduct *directed research that contributes to the depth of fundamental understanding of the atmosphere and its interaction with society and the environment, 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 $43M and a staff comprised of nearly 240 scientists, software engineers, and management/administration personnel.

This Annual Report follows the outline of our **2009 Strategic Plan**, providing details on our many accomplishments over the past year and our plans for the future. We work to better understand and help mitigate weather and climate impacts that affect **aviation** and **surface transportation**, **national security**, **water resource planning and management**, **renewable energy**, and the general **health and welfare of the public**. The newest element within the Laboratory, the **Climate Sciences and Applications Program (CSAP)**, works closely with the Integrated Science Program to conduct interdisciplinary research on the interactions between society and weather and climate, as well as to support decision makers in increasing societal resilience to the impacts of climate and weather. An important element of the CSAP work is highlighted below, as are significant advances in two other research frontier areas outlined in our Strategic Plan:

- **Weather, Climate and Health**: Human health is inextricably connected to weather and climate. Social and physical scientists at RAL are exploring these connections in a variety of studies aimed at understanding the transmission of diseases like dengue fever and meningitis, the impact of extreme weather events on people who live in cities, and the ways in which the urban environment affects weather and climate. In FY2010 three new programs were launched: A NASA-sponsored effort is exploring human vulnerability to extreme heat in Houston, Texas; an NSF-funded program is investigating the spread of dengue fever along an altitudinal transect in Mexico; and a new post-doctoral program sponsored by the Centers for Disease Control and Prevention has created two positions to begin training a new generation of researchers to work across the public health and atmospheric science disciplines.
- **Renewable Energy**: In our first year of working with Xcel Energy, we successfully developed an operational wind forecast capability that helped the company more efficiently integrate wind-generated electricity into its power grid. In FY2010, we used a number of tools and systems developed at NCAR, such as the Real-Time Four-Dimensional Data Assimilation System, the Dynamic Integrated Forecast System, Variational Doppler Radar Assimilation System, and new ensemble modeling techniques to expand the system's capability to provide predictions of average wind, power generation and expected error for given wind facilities.
- Water in the West: With the award of major computing resources through an Accelerated Science Discovery competition, RAL scientists, working with the ISP-funded Water Systems Program, made significant progress in understanding the impact of climate change on winter precipitation, snowpack, and runoff in the **Colorado Headwaters region**. In addition to this fundamental, NSF-supported research, RAL scientists pursued a variety of applied science and technology transfer efforts. Using the **Water Evaluation Analysis and Planning (WEAP)** system, we engaged with a number of municipal water providers and regional management groups to develop decision support processes to help them assess water utility vulnerabilities and develop response plans to prospective climate variability and change scenarios.

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Next Generation Air Transport

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).

- **InFlight Icing**
- **Consolidated Storm Prediction for Aviation**
- **Winter Weather**
- **Turbulence**
- **Ceiling and Visibility**
- **Integration of Weather Information Into Air Traffic Management Decisions for Reduced Weather Impact**
- **Dissemination of Aviation Weather Information**
- **Oceanic Weather: Convection and Turbulence**
- **Avian Radar Performance Study**

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InFlight Icing

FY2010 Activities and Accomplishments

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 Icing Product (CIP), developed at RAL, is running at the National Weather Service's Aviation Weather Center and is approved for unrestricted supplementary use. The output includes 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. The Forecast Icing Product (FIP) with these outputs is expected to be approved for operational use in January 2011; the product available at this time only includes an uncalibrated icing potential and SLD likelihood.

Two significant upgrades have been developed for CIP and FIP this year. The first is the alignment of daytime and nighttime icing severity and probability estimates. Since at nighttime there is no visible satellite channel available, CIP lacked this valuable information used in calculating icing probability and severity. Those outputs were slightly different in nighttime hours. Assuming the daytime values were more accurate, the thresholds used in the final output of severity and probability levels were adjusted so that the distributions of severity and probability levels matched for daytime and nighttime hours. The second change was to adjust the fuzzy logic RH mapping functions used in the algorithms to update them for improved model-calculated values.

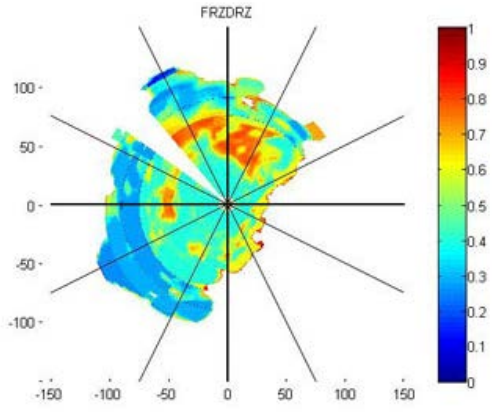
The Interactive Correction in 4 Dimensions (IC4D) software was obtained from NCEP Model Development Lab (MDL) and installed on a computer at RAL. This will allow RAL icing staff to learn how the IC4D workstation can help forecasters prepare AIRMETS and Area Forecasts of icing. The IC4D allows the forecaster to examine model fields that enter into FIP, and determine, for example, if the model is moving weather systems causing icing too fast or slow. The forecaster can then adjust the FIP-produced outputs accordingly. The Alaska Aviation Weather Unit (AAWU) is incorporating this into their forecast process and we have been working with them to use the workstation to evaluate FIP performance over Alaska. The NWS' Aviation Weather Center (AWC) just installed IC4D and intends to have their forecasters use it; we plan to develop training materials on icing forecasting and the use of our automated algorithms for these two organizations.

A Global Forecast Icing Product (GFIP) has been developed and delivered to NCEP. This is based on the Global Forecast System (GFS) model and provides severity and probability for icing around the globe to fulfill NWS' responsibility for global aviation weather prediction. The algorithm divides the globe into polar, mid-latitude and tropical regions and applies information via decision-tree and fuzzy-logic methods to derive the output fields. Installation and evaluation will take place in 2011.

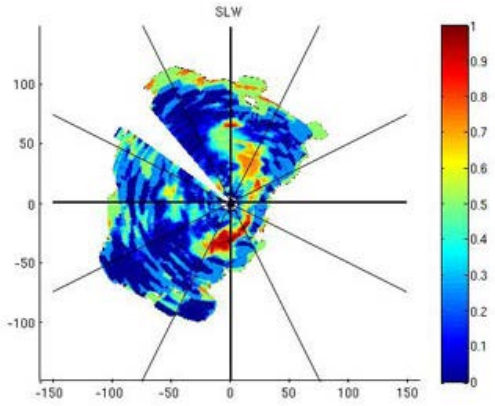
A preliminary concept for a High Ice Water Content (HIWC) forecast algorithm was developed and tested on cases over the CONUS where ample numerical weather prediction model, radar and satellite data were available. The concept looks for cold cloud tops, warm atmosphere (compared to a standard sounding), low radar reflectivity, and other factors to determine regions conducive to the HIWC hazard.

The FAA Nexrad Project Office supported a project to develop a Nexrad-based Icing Hazard Level algorithm, with the expectation that by the time of its deployment, the dual-polarization upgrade will be available. This work combines several algorithms developed here at RAL under previous programs, and concepts from the literature, to devise a radar-based icing detection algorithm to be deployed on the Nexrad Open Radar Products Generator. The output would either be available directly to a user or be used as input to CIP or another icing diagnosis scheme.

Identification of supercooled liquid water using dual polarimetric radar has been investigated before by researchers who developed the PID (Particle Identification) fuzzy logic algorithm. They found that the polarimetric membership functions for supercooled liquid water completely overlapped with irregular shaped ice, i.e., ice that is characterized by zero average Zdr (differential reflectivity) and zero average Kdp (specific differential phase). Recently, NCAR staff developed a freezing drizzle detection algorithm for the WSR-88D radars that is based in large part on various metrics of spatial texture of reflectivity. They found that drizzle exhibited smoother reflectivity textures than ice particles and thus they were able to discriminate between these two particle classes at least for 70% of their observed drizzle cases. Others have recently made similar type observations from comparisons of aircraft observations and radar data. Thus, these studies suggest that radar data, and in particular dual polarization radar data, can offer skill in identifying aircraft icing conditions.



CSU-CHILL radar results from 28 October, 2009, depicting relative potential of freezing drizzle in a 1.53^{o} scan.



Results using the CSU-CHILL radar near Greeley Colorado on 28 October, 2009 depicting the likelihood of mixed phase conditions (both supercooled drops and ice crystals) being present.

These figures show results using the CSU-CHILL radar near Greeley Colorado on 28 October, 2009. On this day there were several pilot reports of icing in the Front Range Colorado region ranging from light to moderate, in upslope stratiform cloud. The top figure shows the relative potential of freezing drizzle in a 1.53^{o} scan, applying the ideas described above which were combined into an Icing Hazard Level algorithm. The bottom figure applies these ideas to determine the likelihood of mixed phase conditions (both supercooled drops and ice crystals) being present.

NASA-Sponsored Activities:

In addition to the work performed on behalf of the FAA, RAL conducts several NASA-sponsored in-flight icing programs. Activities supporting the NASA Icing Remote Sensing System (NIRSS) focused on revisiting RES (Remote-Estimated Size) as part of the icing diagnosis scheme, and exploring the use of a new scanning radiometer. The RES concept was developed at NCAR and uses radar and radiometer (or dual-wavelength radar data) to calculate a drop size: the square root of the sixth moment (related to radar reflectivity) divided by the third moment (related to liquid water content) of the size distribution. This could provide information on large drop icing regions. Calculations on data collected in Cleveland, OH and Greeley, CO (using CHILL) were used to examine the dynamic range and related to other observables. This may be added to the icing hazard calculation within the NIRSS algorithm.

The NASA Narrow-Beam, Multi-Frequency Scanning Radiometer (NNMSR) was developed by Radiometrics Corporation under a NASA SBIR contract. The instrument is designed to have beam-widths matched to NEXRAD weather radars. With its broad K-band sampling capability it can profile (range) water vapor along the beam, discriminate liquid and ice phase hydrometeors with the W-band polarization, and by using data from both bands, calculate liquid water path. Adding to these measurement capabilities the system's elevation and azimuth scanning capability results in a measurement capability with the potential of providing terminal area icing detection and warning. Preliminary findings, from a short field exercise at CHILL radar, had the following preliminary results:

- Icing hazard was detected as high liquid water path (LWP), using NNMSR with NIRSS
- Low radar REFL/RHO_{HV}, high radiometer LWP and no preferred particle orientation was matched to many icing PIREPs
- High radar REFL/RHO_{HV}, low radiometer LWP and a horizontal particle preference was consistent with glaciated cloud and no icing PIREPs

Plans for 2011

In 2011 the CIP and FIP, which are now based on NCEP's Rapid Update Cycle model, will move to the Weather Research and Forecast model Rapid Refresh version (WRF-RR). This transition is anticipated in mid 2011. Also in 2011 we will prepare versions of CIP and FIP for the Initial Operational Capability of the Next Generation Air Transportation System (NextGen). This will demonstrate a basic level of weather products, communications and display systems. CIP and FIP will be upgraded with improved physics and logic, will produce 13-km resolution outputs, and will extend the forecast

period to 18 h.

The HIWC field program is now scheduled for January-March 2012 in Darwin, Australia. We will work with the HIWC science team to develop forecast methodologies for guiding the research aircraft into potential HIWC areas. We will also rewrite our initial version of an automated HIWC algorithm to ingest satellite, numerical weather prediction model output, radar and other data available in real-time at the Darwin site. The field data from a research aircraft and radar will be used to evaluate the performance of this algorithm and to provide information needed to improve it.

We will also continue our IHL work to apply the initial algorithm to more data sets from CHILL and possibly KICT and KOUN with dual-polarization upgrades.

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Consolidated Storm Prediction Algorithm (CoSPA)

Background

The Next Generation Air Transportation System (NextGen) is a national priority designed to meet the air transportation needs of the US 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.

For more than two decades the Federal Aviation Administration (FAA) has funded research and development efforts aimed at improving short–term forecasting of storm hazards affecting aviation. In FY07, the FAA started integrating the wealth of different forecasting tools by focusing on the development of a single authoritative forecast system, called CoSPA. This effort brings together researchers from NCAR's Research Applications Laboratory, MIT Lincoln Laboratory, and NOAA's Global Systems Division to create 0–8 hour forecasts of both summer and winter storms. The CoSPA forecasts are generated utilizing an advanced blending technique that merges heuristic–based extrapolation forecasts with output from a high–resolution, mesoscale numerical weather prediction model (i.e., the High–Resolution Rapid Refresh model) that includes radar data assimilation. CoSPA produces rapidly-updating, high-resolution forecasts of precipitation intensity and echo tops. The forecast system is being developed to satisfy the current needs of Air Traffic Management (ATM), as well as the future demands of NextGen, in which much of the strategic air traffic decision–making will be made utilizing automated decision support tools based on gridded probabilistic forecasts.

FY2010 Accomplishments

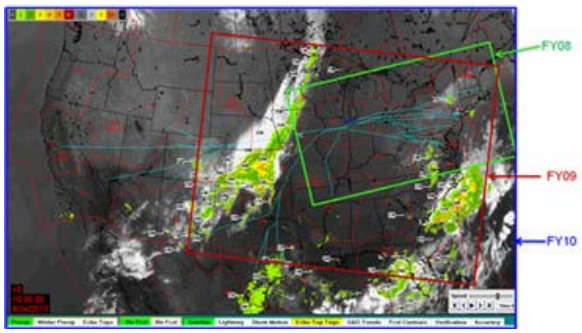

Figure 1: CoSPA has been running in real-time since 2008 with the computational domain expanding each of the last two years.

Figure 2: Forecast products made available to aviation planners via a web-based or dedicated Situational Display (SD).

CoSPA has been running in real-time since 2008 with the computational domain expanding each of the last two years (Fig 1). It now encompasses the entire continental US as well as parts of the Gulf of Mexico, Eastern Atlantic and Southern Canada. CoSPA reached a major milestone during the summer 2010 as it was fielded at a number of FAA and airline facilities, and used in the daily operational aviation planning process for the first time. As part of this Operational Evaluation (OpEval), NOAA/GSD, NCAR, and MIT/LL teamed with FAA and industry partners to help evaluate the CoSPA forecast products and to determine their suitability and effectiveness in improving the air traffic management decision-making process. The evaluation process involved intensive field observations where observer reports were collected at FAA and airline facilities. These data will be analyzed by the FAA in an

effort to quantify the benefits of CoSPA forecasts on the efficient use of the National Airspace System (NAS). Forecast products were made available to aviation planners via a web-based or dedicated Situational Display (SD) shown in Fig 2. The SD allowed users to overlay airports and associated arrival and departure fixes, route structures, and sectors on current and forecast weather facilitating the product's utility.

Research and development has continued on all aspects of the CoSPA forecast system as well as the system architecture. Major enhancements made to the forecast system for the 2010 demonstration include expansion of the numerical model to a 3 km resolution domain that spans the CONUS, improved calibration of model storm intensity, improved algorithm to correct model position errors and an improved treatment of storm initiation in the blending algorithm. Modeled storm intensities are now improved using a dynamic calibration procedure in which the modeled intensity distribution is matched to the observed one to produce continuously updating intensity correction functions. This upgrade has resulted in improved forecast skill out to 6 hours (Fig 3 below). Position errors are now corrected using a Lagrangian scheme which applies corrections along a trajectory of storms forecasted by the model. Improvements to the treatment of storm initiation in the blending has improved the skill of the blended forecast at leads of 3-5 hours.

The 2010 CoSPA OpEval has demonstrated that very high reliability (>98%) can be achieved with a distributed forecast system that uses real–time, network–enabled data exchange and a common data format (netCDF4). The labs continue to work toward a system architecture with a modular design to foster ease of plug–and–play experimentation with new technologies.

FY2011 Plans

Preliminary results from the 2010 OpEval indicated several areas in which additional work must be undertaken. Two standout issues are the treatment of storm initiation, particularly in the 1-3 hour time frame, and the inclusion of forecast uncertainty information. Storm initiation is an inherently probabilistic process. An effort to quantify uncertainty associated with storm initiation in both heuristic nowcasts and model forecasts using the Random Forest Statistical Method and time-lagged ensemble modeling is therefore underway. Algorithm development related to these efforts will also feed into the blending effort to improve the treatment of storm initiation in the 1-3 hour time frame. Another area of potential development is the extension of precipitation phase forecasts out to 8 hours. Preliminary results indicate that the modeled precipitation phase can be blended with nowcasts of precipitation phase similar to that done with storm intensity and echo tops. It is expected that new capabilities and products will be episodically demonstrated to users as technologies mature.

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Winter Weather

Background

End-user display of the Liquid Water Equivalent and Checktime Systems. The top panel shows the current weather conditions, and the bottom panel tells pilots and deicing crews how long a specified deicing fluid will last before it needs to be reapplied if the plane does not become airborne during that time.

Winter weather research and development at RAL related to aviation weather has focused on developing two new systems in support of Ground Deicing operations. The Liquid Water Equivalent (LWE) system combines a Hotplate and GEONOR snow gauge, a Vaisala PWD–22 precipitation type sensor, a Campbell freezing rain sensor, a Vaisala WXT wind, temperature, and humidity sensor, and a Decagon Leaf Wetness Sensor to estimate a real–time liquid water equivalent precipitation rate. This rate is a critical component of the Checktime System, a UCAR patented technology for aircraft ground deicing operations, that determines when deicing/anti-icing fluids applied to aircraft are is close to failure based on temperature measurements and precipitation rates that are updated every minute from the LWE system. Checktime is aircraft independent and only requires the end user to know the time that the aircraft was deiced.

FY2010 Accomplishments:

An aerial view of the winter weather instrumentation being evaluated at the Marshall Field Site.

The research and development focus in FY2010 was on testing the LWE and Checktime systems under freezing precipitation and ice pellet conditions. With the move of the US Airways hub from Pittsburgh to Cleveland, there has been a good deal of new activity with Continental Airlines and the local ground de-icing contractor Aeromag 2000, as well as with US Airways. The new Cleveland site also provided a unique opportunity to compare our data to the co-located Automated Surface Observing System (ASOS). In addition, we continued to conduct demonstrations of the systems at Denver

International Airport and Chicago's O'Hare International Airport. Pilots and ground crews provided feedback on the system, and their suggestions for improvements are being implemented for the 2010/11-winter season. An additional system was deployed at the Marshall Field Site in Boulder, CO, for system verification. Manual snow pan observations (measuring the water equivalent of melted snow every 10–min) were collected at the Marshall site during freezing drizzle events to assist us in verifying the results of the LWE system. The FAA is using this data to develop a specification for approval of LWE and Checktime systems for operational use at airports in support of ground deicing. An LWE system was also deployed at St. John's, Newfoundland, during March and April. St. John's is the site of the climatological maximum of freezing precipitation and ice pellets in North America. Several events were captured and students from Memorial University in St. John's provided manual pan measurements at the site. Development of a frost detection algorithm was also undertaken using a Decagon Leaf Wetness Sensor and a "skin-temperature" sensor for detecting the active formation and presence of frost on aircraft surfaces. And finally, outdoor testing of aircraft anti-icing fluids was undertaken for comparison to the Checktime algorithm.

FY2011 Plans:

The focus will be on collecting more data in St John's during freezing precipitation and ice pellet events. The site will be deployed in early November with data collection continuing until May. Students from Memorial University will again be available to assist with pan measurements. Incorporation of the frost algorithm into the LWE algorithm will also be undertaken with the necessary hardware modifications made at each of the LWE sites and feedback solicited from the pilots and ground crews. Continuation of the outdoor testing of aircraft anti-icing fluid for comparison to the Checktime algorithm will also be done for verification purposes.

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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 experienced 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. 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 will have time to fasten their seatbelts for an expected encounter.

For the past fifteen years a group of scientists and engineers at the National Center for Atmospheric Research's Research Application Laboratory (NCAR/RAL) has led the effort to address these needs. Working under the sponsorship of the Federal Aviation Administration and the National Aeronautics and Space Administration and in collaboration with several federal laboratories and university investigators, the team has conducted research aimed at improving fundamental understanding of the nature and causes of turbulence and has developed new techniques for better observing and forecasting turbulence.

Effort has been focused in three areas: (1) Development and implementation of new techniques for obtaining automated in situ measurements and reports of turbulence encounters from commercial aircraft; (2) development of an automated detection system of in-cloud turbulence using the national NEXRAD radar network; and (3) development and implementation of an automated turbulence forecasting system called Graphical Turbulence Guidance or GTG. While the R&D effort continues in each of these areas, the products that are being developed 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.

A fourth long-term effort, to develop and implement a turbulence and windshear warning system for the Juneau, Alaska airport, are also discussed in this report.

Automated In situ Measurements

Fig 1. Tracks of United Airlines(top panel), Delta Airlines (middle), and Southwest Airlines (bottom) showing automated turbulence measurements over a 24-hour period. Each line is composed of 1 minute interval measurements.

Despite the frequency and severity of turbulence encounters, our understanding of the nature and genesis of this complex atmospheric phenomenon remains limited. Turbulence research has been limited 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 light or severe to another). While computer models are very useful in forecasting other atmospheric hazards, they are of limited value here given that turbulence exists for short periods of time 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 measurements from selected commercial aircraft. These measurements and dissemination are completely automated, and provide a measure of atmospheric turbulence levels as measured by the eddy dissipation rate (EDR, $m^{2/3}/s$).

FY2010 Accomplishments:

Currently the in situ EDR software package is implemented on about 100 United Airlines (UAL) 757-200 aircraft and about 70 Delta Airlines (DAL) 737-800 aircraft. Initial implementation of the algorithm on the Southwest Airlines (SWA) 737–700 fleet (280 aircraft) was begun. The DAL and SWA implementations are based on heartbeat (tied to routine Meteorological Data Collection and Reporting System [MDCRS] reporting) and threshold reports (immediate transmission when one–minute peak or mean above a certain threshold is exceeded), thus substantially reducing communication costs from previous implementations. An example of EDR reports received from the UAL, DAL, and SWA implementations over a 24–hr time period is shown in Fig 1. The colors are peak (over 1 min flight time) EDR values, with blue smooth, yellow light turbulence).

A feasibility study using ACARS–AMDAR wind and temperature measurements to estimate EDR was completed. Initially this was used to construct a global climatology of turbulence, but with expanded data coverage it may also be possible to make real–time estimates of turbulence levels. A description of this method appeared in the *Journal of Applied Meteorology and Climate* (JAMC) in 2010. A follow-up study proved the correspondence between EDR statistics on constant pressure levels (flight levels) and constant altitude surfaces; these results were published in *Geophysical Research Letters (GRL)* in 2010.

FY2011 Plans:

We are currently in discussions with both United and Delta Airlines to implement the algorithm on their 767 fleets which will provide expanded national coverage as well as some international coverage. We also hope to have full implementation of the in situ algorithm on the Southwest 737-700 fleet in 2011.

Remote Sensing Measurements

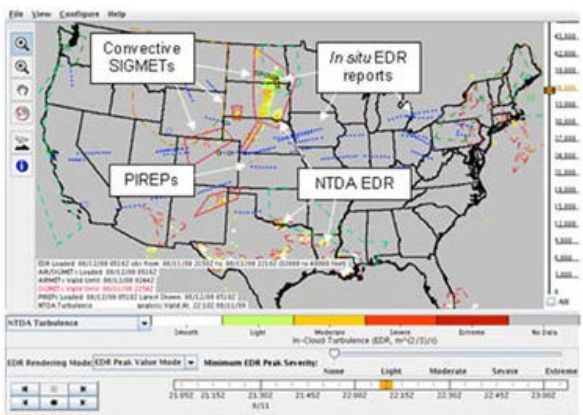

Fig. 2 Experimental ADDS display of the NTDA turbulence mosaic, with convective SIGMETs and turbulence reports overlaid.

RAL scientists have developed a product that uses ground-based radars to detect and measure turbulence within clouds. The results can then be mapped at chosen flight altitudes and displayed for users. This product, the NEXRAD Turbulence Detection Algorithm (NTDA), has now been adopted by the National Weather Service and implemented on all of its radar systems. A prototype of the system (NTDA–2) continues to run in real-time at NCAR, using a data feed from 133 NEXRADs in the Continental US. A sample of the 3-D mosaic of in-cloud turbulence produced by this system is shown in Figure 2.

FY2010 Accomplishments:

Several updates have been made to the NTDA algorithm and software this year to accommodate recent changes to NEXRAD operational modes (super–resolution, phase coding, and new volume coverage patterns). These changes are designed to provide greater robustness, accuracy and coverage. In addition, the prototype NTDA processing and mosaic system was successfully delivered to the NWS Aviation Weather Center and implemented for testing.

FY2011 Plans:

NTDA turbulence measurements will be used in the Graphical Turbulence Guidance Nowcast product, currently under development.

Nowcasting/ForecastingTurbulence

RAL has been developing and testing aviation-scale turbulence algorithms that provide forecasts out to 12 hours. These algorithms are based on operational NOW 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 Rapid Update Cycle (RUC) model output and uses what amounts to an ensemble weighted mean of various turbulence diagnostics normalized to a 0-1 scale to provide the forecasts.

In addition to the GTG forecast system, we are currently developing a nowcast system, dubbed GTG-N, which will provide rapid (every 15 min) updates and makes heavy use of the latest available turbulence observations from the in situ measurements, 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) are being developed to predict areas of likely out-of-cloud CIT.

FY2010 Accomplishments:

The Graphical Turbulence Guidance version 2 (GTG2) which provides RUC–based forecasts of turbulence became "operational" on 11 Feb 2010 and is now available on NOAA's Operational Aviation Digital Data Service (ADDS) web site. Since the RUC is due to be replaced by the WRF RR in May 2011, work has been focused on converting the current RUC-based code to a WRF RR-based code. Initial testing and verification have demonstrated similar verification skills. Other algorithms that make use of GTG output (GTG-N and DCIT) have been updated to use the WRF RR as well.

Work continued on the GTG nowcast (GTG–N) product, one component of which is the DCIT algorithm. Substantial effort has been invested in developing both a better physical understanding of the mechanisms responsible for CIT (two papers were published last year on this subject) and developing a real-time diagnostic product.

FY2011 Plans:

An update to the current RUC-based GTG to use the new WRF RR will become operational when the WRF RR model replaces RUC at NCEP. Currently this is scheduled for July 2011. A third version of the WRF RR-based GTG, GTG3, which includes mountain-wave induced turbulence (MWT) will begin formal evaluation sometime near the end of CY2011. The first version of GTGN (GTGN-1) will also begin formal evaluation at that time.

The GTG-like system that provides forecasts over the Taiwan airspace (for a program funded by the Taiwanese government) will be upgraded to incorporate an upgrade of the WRF system there sometime near the end of CY2011. The Global GTG will also be updated to accommodate the recent GFS model upgrade.

Juneau Terrain-Induced Turbulence

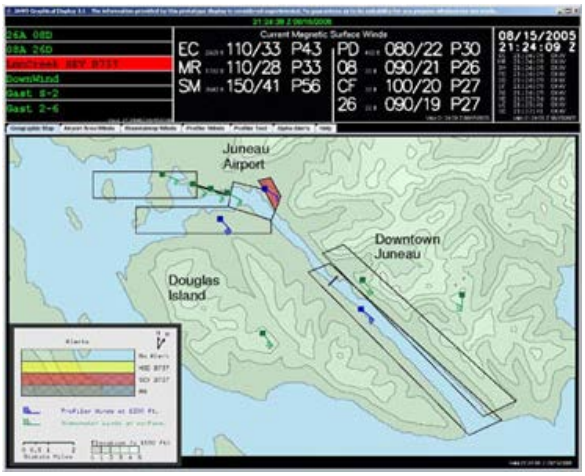

Fig 3: Geographic display of Juneau Airport Wind System. Hazard warning areas are outlined as boxes.

Fig 4: Sheep Mountain anemometer site in February 2007.

The Juneau, Alaska, environment is characterized by rugged terrain and adverse weather that combine on occasion to produce moderate to severe terrain-induced turbulence and wind shear for flights into and out of the Juneau International Airport. To address this problem, the FAA tasked RAL in FY1997 with the development and implementation of a new wind hazard warning system for the airport. Over the last twelve years, RAL engineers and scientists have built a prototype warning system that relies on statistical correlations between wind-related parameters observable by the system (i.e., speed, direction, shear, variance, etc.) and the location and severity of turbulence. Since terrain is fixed and there are distinct strong-wind scenarios, correlations are expected between winds and hazards. These correlations were established using the warning system's input measurements and hazards measured by research aircraft during three intensive field projects. The graphical display was designed for a variety of users including Automated Flight Service Station specialists, airline dispatchers, and pilots. It contains information that depicts current alerts and conditions as well as conditions during the past hour. The prototype warning system is used every day by airlines and pilots flying in and out of Juneau to assess current turbulence hazards in the vicinity of the airport.

FY2010 Accomplishments:

RAL continued to operate the prototype (JAWS-P) and hybrid (JAWS-H, which integrates NCAR algorithm and display software with FAA communications) systems. A new JAWS-H software version was released and installed early in FY2010, and the JAWS-H system was evaluated in a side-by-side comparison with JAWS-P to ensure continuity of alerts. Upon successful completion of the evaluation, the JAWS-P was shut down and JAWS-H commenced operations. After a suitable time period to ensure JAWS-H was operating optimally, the JAWS-P was permanently shut down and dismantled. The FAA took over anemometer site maintenance activities from NCAR. Documentation of the JAWS-H system continued and several

maintenance-related documents were delivered to the FAA for inclusion in their technical manuals. The end-state JAWS Operational Ready Date is still on schedule for the end of FY2011.

FY2011 Plans:

RAL will continue to operate the JAWS-H warning system. While the FAA is developing the end-state (JAWS-E) system, RAL will provide engineering support for activities such as converting from Debian to Red Hat Linux and integrating the NCAR Improved Moments Algorithm (NIMA) into the system. At the end of FY2011 RAL will turn the JAWS-H system over to the FAA and begin the process of disposal of excess equipment not desired to be retained by the FAA. Documentation of JAWS-H will continue, and preparation of "reference documents" such as Algorithm Design Description, NIMA Description, and Application Software Description will begin; delivery of these documents to the FAA is planned for FY2012.

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Ceiling and Visibility

Background

Impacted ceiling and surface visibility (C&V) conditions create costly reductions in flow capacity at airports with 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 to produce 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.

FY2010 Accomplishments

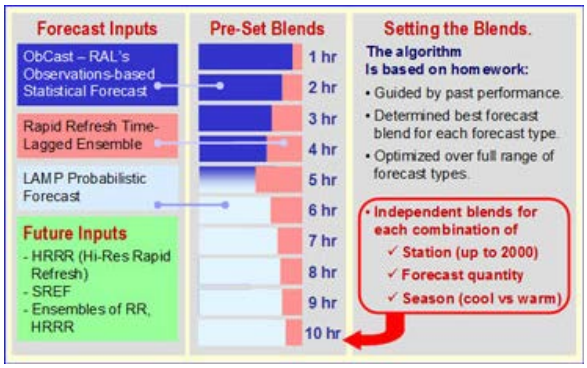

Figure 1: Overview of the 1-10 hr probabilistic C&V forecast system designed and prototyped in FY10. Forecast inputs are shown at left. Forecast blending (center) transitions from primarily statistical inputs at 1-3 hr to primarily numerical model inputs at 5-6 hours and beyond. As shown at right, independent blends are predetermined for each combination of three factors – forecast location, forecast quantity and season.

FY10 work has focused on prototyping and testing the 1-10 hr probabilistic C&V forecast methodology illustrated in Fig. 1. The approach taken uses past performance to optimize pre-set blends of statistical and numerical model forecast methods.

Statistical Forecasting:

Observations-based statistical forecast methods play a dominant role in shorter-term forecasts (e.g., 1 to about 3-4 hr), where the skill of statistical methods operating on current observations exceeds that of numerical modeling. RAL's 1-5 hr logistic regression-based statistical forecast method was refined and tested at a wide range of airport sites, and new procedures were developed to enable efficient derivation of forecast equations for new sites and predicted quantities. The improved method and procedures have produced several key improvements in RAL's C&V forecast system: Low latency (~ 10 minutes), good forecast performance and the ability to produce 'customized' 1-4 hour forecasts for any set of ceiling or visibility thresholds desired.

Time-Lagged Ensembles:

FY09's work in verifying Rapid Refresh and Rapid Update Cycle (RUC) time-lagged ensemble forecasts was extended in FY10, and the lessons learned were used to incorporate Rapid Refresh time-lagged ensembles in the C&V forecast system as shown in Fig. 1 above. These forecasts are found to be strongly complementary to the statistical and operational LAMP forecasts used by NOAA and thus boost the system's overall forecast skill significantly.

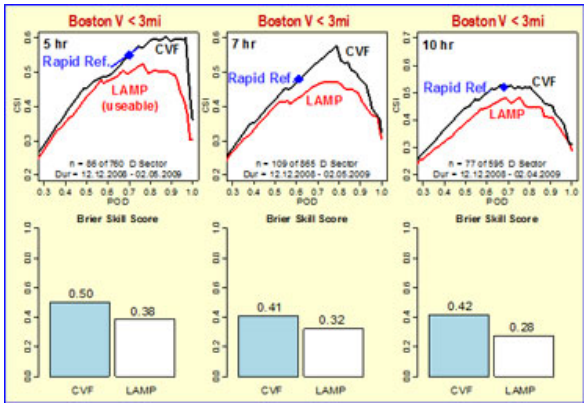

Figure 2: Verification of forecast skill for the RAL forecast system (CVF), a time-lagged Rapid Refresh ensemble, and NOAA's LAMP for 5, 7 and 10 hr forecasts of visibility less than 3 statute miles. The case shown is for Boston's Logan Airport over the period October 2008 through March 2009. Upper row: Critical success index vs. probability of detection. Lower row: Brier skill score. Realistic values of forecast latency are assumed here – nominally 2 hr for the Rapid Refresh, 1 hr for LAMP and 10 min for CVF. CVF, which utilizes both the Rapid Refresh and LAMP, is seen to achieve the highest skill scores of the group

Probabilistic Forecast Blend Algorithm:

FY10 work produced a first-generation forecast blending algorithm yielding overall forecast performance which most often exceeds that of its input forecast sources. The algorithm addresses each forecast situation (defined by location, forecast quantity, and season) as a specific sub-problem for which an optimal forecast blend has been predetermined through training using past data. With immediate access to the predetermined blend parameters, a set of new forecasts can be generated from current statistical, LAMP and Rapid Refresh forecast data with 5-10 minutes latency. An example of forecast results is shown in Fig. 2.

Forecast Verification:

To enable critical comparison between the prototype method above and current operational C&V forecast guidance, a substantial capability to verify prototype blends, LAMP, and Rapid Refresh probabilistic forecasts was developed in FY10. Verification metrics related both to probabilistic and deterministic forecast performance are derived and displayed. An example is shown in Fig. 2.

FY2011 Plans

Work will focus on improving the probabilistic C&V forecast system through:

- Refinement of the blending algorithm as needed to incorporate new insights revealed through broadened testing;
- Implementation of a first-generation gridding scheme to interpolate forecast data across a 5 km CONUS grid;
- Cooperative testing of the prototype forecast product by one or more NWS weather forecast offices in the NE U.S.;
- Expansion of the forecast system domain to full CONUS coverage by December, 2011.

FAA evaluation of the CONUS C&V analysis product developed earlier by RAL will be completed in FY2011. This product supports improved visualization of local and regional-scale ceiling and visibility conditions – a particular priority in the general aviation and helicopter emergency medical service communities. We anticipate that this product will be approved for operational use in FY2011.

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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 by which weather is observed, forecast, disseminated, and used in decision-making is of critical importance to the operation of the National Airspace System. As the U.S. moves to significantly increase the capacity of the NAS through implementation of the Next Generation Air Transportation System (NextGen), it becomes even more important to integrate weather information into air traffic management decision-making. RAL is a major contributor to this effort.

Methodologies for translation of weather information into probabilistic impact information for integration with ATM decision support tools

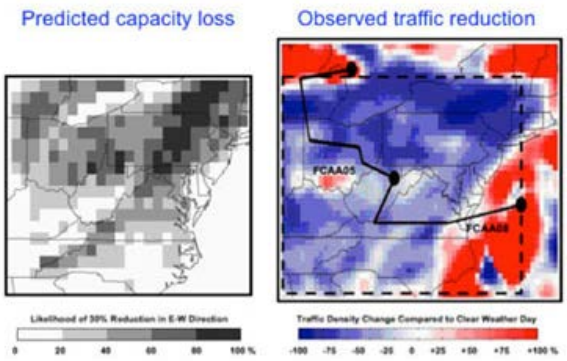

Fig 1: The figure shows a 9–hour probabilistic forecast of the likelihood to lose 30% airspace capacity (left panel) compared to the observed traffic reduction (right panel).

Our initial focus has been on defining complementary methodologies for translating weather constraints into air traffic management (ATM) impacts. This step offers advantages in terms of integrating weather into decision support tools, while allowing the human to remain in and/or over the loop during the decision making process. It further facilitates human intervention when automation fails or is inappropriate.

Aviation users need 0 – 12 h forecasts that provide not only details about the likely weather outcome, but also information about storm structure, intensity, organization, and associated forecast uncertainty. One approach to accomplish this is based on short–range (0 – 2 days), high–resolution (<10 km spatial resolution) ensemble weather forecasting systems. Optimization of air traffic management, especially under future scenarios of anticipated increased demand, has to build upon automated decision support tools that integrate probabilistic weather information to estimate airspace capacity and provide guidance for managing air traffic flows under consideration of the associated uncertainties in prediction. NASA sponsored an initial RAL study that developed and refined new concepts of how probabilistic weather forecasts can be tailored for aviation needs and integrated with automated decision support tools. The novel approach entails a translation of ensemble weather forecasts into probabilistic predictions of the impact on air traffic capacity.

FY2010 Accomplishments:

The focus of this work has been on convective storms primarily because of their disruptive influence on air traffic flows. However, we have also shown that the ensemble–based approach is applicable to other en–route weather hazards, such as turbulence. During the past couple of years several additional case studies were carried out that focused on the performance assessment of ensemble–based probabilistic scenario forecasts as a function of lead-time, spatial scale, and magnitude of the weather event. A proper calibration of these probabilistic forecasts requires long-term data, which are not currently available, but the database of six multi–day events reveals dependencies of forecast performance to the type of weather encountered, scale of analysis, and criteria used for evaluation. The results are described in detail in a paper published in the September 2010 issue of the *Air Traffic Control Quarterly*

journal.

FY2011 Plans:

A real-time prediction system is under development that enables translation of time-lagged ensemble forecasts into ATM capacity impact information. This forecast system utilizes the vertical integrated liquid (VIL) and echo top (ET) output generated by the NOAA/ESRL Global Systems Division (GSD) hourly-updating High-Resolution Rapid Refresh (HRRR) model runs. The VIL and ET forecasts are combined into a Weather Avoidance Field (WAF), a heuristic approach developed at the MIT Lincoln Laboratory that mimics pilot's deviation around storms. The capacity reduction is estimated based on Metron's MinCut technique that computes flow bottlenecks.

ATM/Weather Integration Planning

Planning for implementation is a large step toward realizing an initial NextGen operational capability (IOC) in 2013. RAL has taken the initiative to lead part of the effort to consolidate potential tools and methods for inclusion in the JPDO ATM–Weather Integration Plan. These tools are state-of-the-art algorithms and mathematical techniques 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 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 AWRP and Reduce Weather Impact (RWI) programs, both part of the FAA's AWO.

FY2010 Accomplishment:

The first version of the JPDO ATM–Weather Integration Plan was released in 2010. RAL continues its interface with the JPDO to update the Plan on an annual basis.

Optimizing Sensors and Platforms to Meet the Needs for NextGen

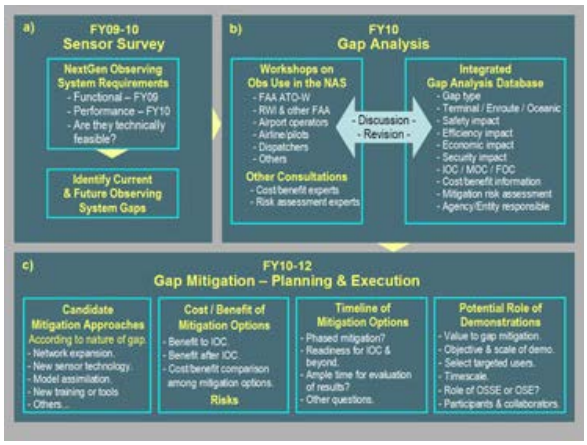

Fig 2: Road map for "Right Sizing" towards NextGen.

Optimization of relevant weather observation and forecasting capabilities are essential for conducting safe and efficient flight operations in the National Airspace System (NAS). It is imperative, therefore, to ensure that the FAA's current and future weather observing and forecasting capabilities are adequate to satisfy NextGen requirements. Under the Reduce Weather Impact (RWI) program, the FAA has set up a multi-institutional team for conducting an assessment of relevant weather sensors on the ground, and on airborne and space platforms. This sensor assessment is also known as "Right Sizing" effort. Collaborators in this research include the National Center for Atmospheric Research (NCAR), the Massachusetts Institute of Technology (MIT) Lincoln Laboratory, the University of Oklahoma (OU), and Indiana University (IU).

FY2010 Accomplishments:

In FY09 an inventory of ground–based, airborne, and space-deployed sensors was completed and an initial identification of gaps conducted for the IOC assessment. The focus during FY10 has been on an in-depth identification of specific gaps for super–density airports (the 35 busiest airports of the US). In addition, the NextGen performance requirements have become available to complement the functional requirements initially utilized in FY09. Identification of opportunities (i.e., "low–hanging fruits") for demonstrating improved capabilities continued.

FY2011 Plans:

The "Right Sizing" effort will continue in-depth gap analyses utilizing the sensor catalogue and other means (e.g., workshops) as appropriate. The focus will expand from super-density airports to en-route airspace. Moreover, plans will be developed for demonstration experiments that showcase potential improvements that can be achieved toward meeting NextGen requirements.

ATM/Weather Integration Activities within NOAA

An Aviation Weather Cooperative Agreement (AWCA) with NOAA has been executed to facilitate work on weather integration and to transition that work from research to operations across federal agency lines for the NextGen IOC in 2013. The collaborative effort has been defined in general terms to include turbulence, convection (specifically, Autonowcaster deployment and use), ceiling and visibility, and in-flight icing with a specific focus on developing and using human-over-the-loop (HOTL) forecast techniques

FY2010 Accomplishments:

- For in-flight icing: The NCEP Model Development Laboratory (MDL) provided NCAR the latest version of the Interactive Correction in 4 Dimensions (IC4D) software. RAL installed the software and brought in data files for testing and training for HOTL evaluations.
- For storm forecasting: Deployment and testing of the AutoNowcaster (ANC) in Florida; research was also conducted to identify the important predictor fields to use in the ANC system's warm season regime.
- For turbulence: Reconfiguring and evaluating various components of the Graphical Turbulence Guidance algorithm for use with the Weather Research and Forecasting Rapid Refresh (WRFRR) model, to include convectively-induced turbulence and mountain wave turbulence.
- For ceiling and visibility: Preparing for the Northeast trials planned under the AWCA, and developing/testing automated systems for HOTL evaluations.

FY2011 Plans:

The NOAA Aviation Weather Cooperative Agreement will continue the 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).

FY2010 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 June 2010, and the AMS ARAM Conference at Atlanta GA in January 2010. Both were well received, showing RAL's leadership in this area. Additionally, RAL is participating as a team member in several NextGen systems engineering and planning initiatives being conducted by the JPDO and FAA.

FY2011 Plans:

RAL will participate in the 2011 ATCA/NASA/FAA New Technologies Workshop and the 56th ATCA Annual Meeting. RAL will continue to participate in as many team partnerships as feasible to ensure and support a comprehensive transfer of our technology to the NextGen IOC and subsequent implementation.

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Dissemination of Aviation Weather Information

Background

The Next Generation Air Transportation System (NextGen) is now beginning to take shape on the design board of several Federal Agencies under the auspices of the Joint Program Development Office (JPDO). The JPDO has parsed the complex next generation system into several components and has endorsed the concept of Interagency Working Groups to coordinate the R&D associated with each. One such Working Group 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. NextGen Network Enabled Weather (NNEW),
2. Aviation Digital Data Service (ADDS), and
3. Weather Technology in the Cockpit (WTIC).

NNEW is a program to develop next generation technology and infrastructure for dissemination of weather data to US Government and other users. ADDS uses web pages and data services to deliver weather data to today's aviation community. WTIC is developing methods for making the best weather information available to pilots for decision making in the cockpit.

NextGen Network Enabled Weather (NNEW) Program

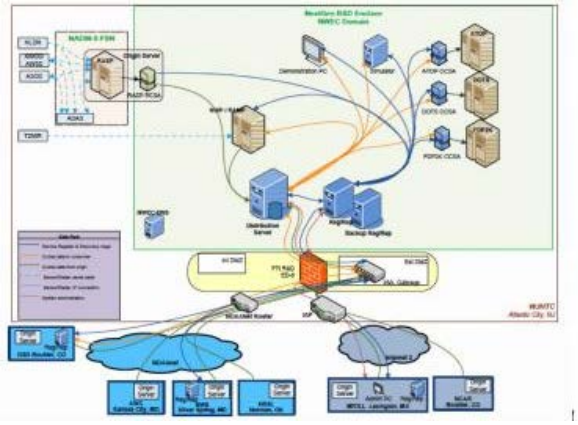


Diagram of the NNEW 2010 Capability Evaluation

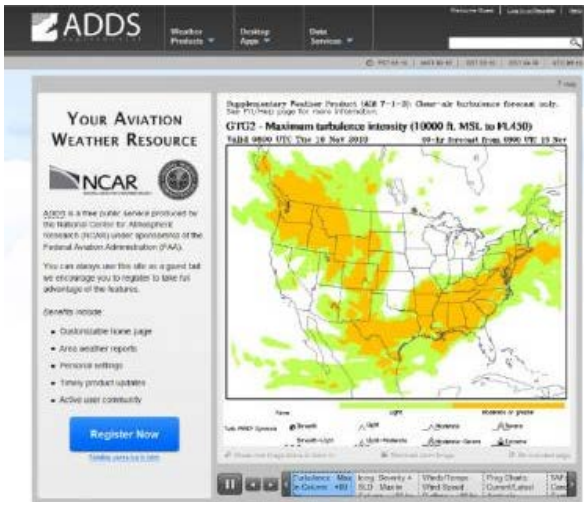
For the past few years RAL has been engaged in developing standards and technology for the NextGen Network Enabled Weather (NNEW) Program. NNEW is the FAA portion of a joint program between the FAA and NOAA to develop next generation technology and infrastructure for dissemination of weather data to US Government and other users. NNEW's goal is to enable ubiquitous access to aviation weather data anywhere an appropriate network connection is available.

NNEW achieves this goal by using a service oriented architecture (SOA) approach where existing internet technology is leveraged to build weather data directory and delivery services that conform to international standards. NNEW 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 where data sources and clients can be developed and modified independently but remain compatible while data latency and network bandwidth are optimized. RAL's participation in NNEW is sponsored by the FAA NNEW Program Office and collaborates with FAA WJHTC, MIT/LL, MITRE, NOAA GSD, NOAA MDL, NOAA AWC, and NOAA NSSL on development and implementation of NNEW.

FY2010 Accomplishments

RAL has built a WCS server reference implementation (WCSRI) for aviation weather data that the FAA is using as a prototype in the NNEW Program. The FAA is using the WCSRI to explore the best ways to combine it with existing FAA infrastructure programs for wide area networking, security, and system wide information management. The NNEW work in FY2010 culminated in a capability evaluation held at the FAA Technical Center where data from the FAA, MIT/LL, NCAR, and NOAA were brought together using NNEW technologies to form a multi-agency experimental four-dimensional weather data cube. The Capability Evaluation was very successful with more than 300 weather data sets made accessible through the experimental 4-d cube.

Aviation Digital Data Service (ADDS) Program



The new Experimental ADDS Web site.

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. 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.

FY2010 Accomplishments

Data display techniques and utilization of new web technologies have been prototyped on the Experimental ADDS web site. In FY2010, a major rework of the Experimental ADDS site occurred to provide more efficient access to the weather products. A new user registration process was introduced to allow returning users to customize the ADDS site to better meet their needs. After user testing and some refinement of the new Experimental ADDS web site, its underlying technology will be transferred to the NWS for use in Operational ADDS.

Weather Dissemination to the Flight Deck—Weather Technology in the Cockpit (WTIC) Program

One of the programs being 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 ATC system collaborative triad (the others being ATC/ATM and airline dispatch or flight operations control). Throughout 2010, 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. Certain SAE and RTCA/Eurocae document development work 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.

FY2010 Accomplishments

- A formal FAA-sponsored WTIC program was initiated at RAL to support the development of cockpit weather display and data link requirements and standards.

- Collateral benefit to this active RAL involvement is feedback to the RAL scientific R&D programs related to pilot and flight deck needs for advanced weather information in the future.
- The RTCA Special Committee 206/Eurocae Working Group 76 completed its Safety and Performance Requirements for Meteorological and Aeronautical Data Link.
- The SAE G-10 Working Group advanced progress of an Aeronautical Recommended Practices for the display of weather on integrated flight deck display systems.
- Initial planning began for an oceanic weather in-flight weather data link evaluation, with a focus on human-over-the-loop decision making and decision support.

FY2011 Plans

- RAL will continue 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 will include 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.
- Pending funding and direction from the FAA Aviation Weather Office WTIC Program, RAL will plan and conduct evaluations of human over the loop (HOTL) concepts and collateral benefits associated with weather updates to airline flights on trans-oceanic trips. The initial set of evaluations will be conducted in the *NextGen* Integration and Evaluation Capability (*NIEC*) flight simulator at the William J. Hughes Technical Center (WJHTC). Airline trips in both the South Atlantic and Pacific Oceans are the planned scenarios, using experienced airline pilots as test subjects. Updated convection and turbulence information will be simulated to better understand its impact on pilot decision making while operating in a remote/oceanic flight environment. Uplink of weather updates to actual airline trips will be the next step, possibly in FY11 or 12. It is hoped that these evaluations will further our understanding of the HOTL concept, and enhance the science of aviation weather diagnosis/forecasting in data-sparse regions.

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Oceanic Weather: Convection and Turbulence

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.

To address these needs, RAL scientists are 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 few years to detect and nowcast deep convection using satellite-based methodologies in combination with numerical model results. These methods have been implemented both regionally (i.e., the greater Gulf of Mexico/ Caribbean area), as well as globally. The detection of convection is accomplished with the Convective Diagnosis Oceanic (CDO) product while its nowcasts are accomplished with the Convective Nowcast Oceanic (CNO) product. Results from the CDO and CNO can be used alone to address needs related to deep convection or they can be used as input into other comprehensive systems such as the Global Turbulence Decision Support System (DSS) for Aviation. Accomplishments and plans related to these convection and turbulence weather products are discussed below. In addition, a related effort is discussed ("Storm Characteristics of Deep Convection") that examines relationships between reflectivity, cloud-to-ground lightning production and CIT.

Convective Diagnosis Oceanic System (CDO)

FY2010 Accomplishments:

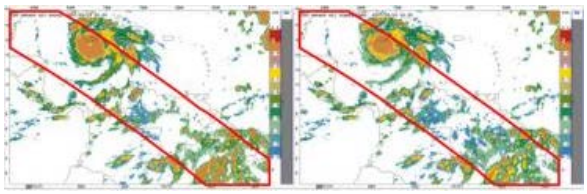

Figure 1. Output from the CDO on 19 August 2007 at 2220 UTC that shows a) the original CDO output and b) the modified CDO output that includes the TMI 37 GHz inferred lightning group as an input field. The swath of the TRMM is enclosed by the red shape. Hurricane Dean is present.

1) Using inferred lightning field within the CDO

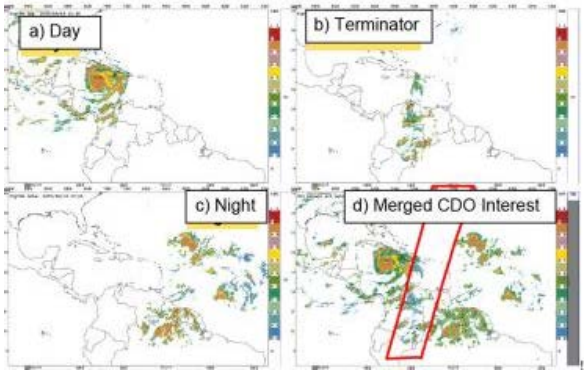

Figure 2. Computation of the CDO interest field based on time of day is shown for a) day time hours, b) during the terminator passage and c) night time hours. In d), results from the three partitions are combined into the final, merged CDO interest product.

Brightness temperatures and ice water path as derived from instruments onboard the Tropical Rainfall Measuring Mission (TRMM) are uniquely related to total lightning activity and have been tested as an additional input to enhance the CDO results. Using brightness temperature data from the 37 and 85 GHz channels of the TRMM Microwave Imager (TMI) and the Defense Meteorological Satellite Program (DMSP), the number of lightning groups are computed and used as an inferred indicator of storm severity. The inferred lighting groups are input as an interest field into the CDO to better define regions of hazardous convection. Preliminary results are promising; further refinements are needed. Figure 1 shows an example of the CDO interest field without and with the inferred lighting input. Validation of the results to ascertain performance improvements are needed and will be done in the next fiscal year.

2) Partitioning of the CDO interest field based on solar angle

The CDO algorithm is a data fusion of three satellite-based algorithms. One of the component algorithms has a significant difference in performance depending on whether it is day time, during the terminator passage or night time. To better account for this difference in skill, the solar angle is utilized to partition the computation of the CDO interest field by time of day. As shown in Figure 2, the CDO interest field is computed for each condition: a) day time, b) terminator and c) night time. Figure 2d shows the merger of the three partitions into one final CDO interest field. Preliminary validation with the Tropical Rainfall Measuring Mission (TRMM) satellite observations suggests the partitioned CDO has improved performance during the terminator passage.

FY2011 Plans:

This project ends in 2011. Efforts will focus on concluding the research and writing the final report.

Convective Nowcasting Oceanic System (CNO)

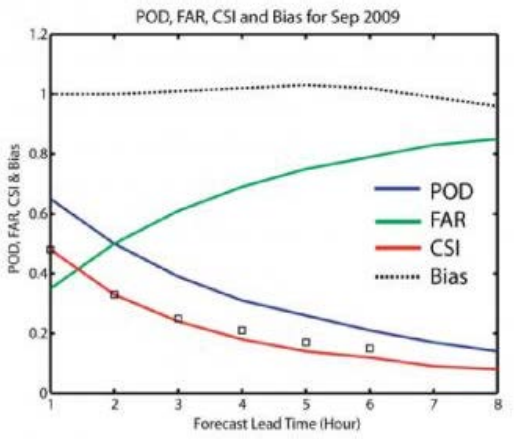

Figure 3. Performance skill scores versus forecast lead time (hours) of the CNO gridded nowcasts for a one month period from 1-30 September 2009 and within the greater Gulf of Mexico domain. Fields shown include the Probability of Detection (POD; blue line), the False Alarm Ratio (FAR; green line), the Critical Success Index (CSI; red line) and the bias (black dotted line). The black squares are from an earlier validation in August 2007 during Hurricane Dean and show the CSI scores.

FY2010 Accomplishments:

A comparison of three extrapolation techniques was undertaken that included the current CNO methodology of object tracking via the Thunderstorm Initiation, Tracking and Nowcasting (TITAN) software, a statistical technique called Random Forest that utilizes additional observational data sets and model results, and a gridded forecast system that merges model winds, TITAN storm vectors, and satellite-tracked winds. Results from a one-month validation show that the gridded forecast produces superior results at longer lead times (to 8 hrs) over the other two methods. This gridded nowcast methodology has been implemented over the greater Gulf of Mexico and global domains. Figure 3 shows performance skill scores for the gridded nowcast for a one month period in September 2009.

FY2011 Plans:

The current project ends in 2011. However, a new effort to blend satellite-derived observations with Global Forecast System (GFS) numerical results is underway. Fields that will be blended include precipitation rate and cloud top height. The domain of interest includes the greater Gulf of Mexico region.

Global Turbulence Decision Support System (DSS) for Aviation

FY2010 Accomplishments:

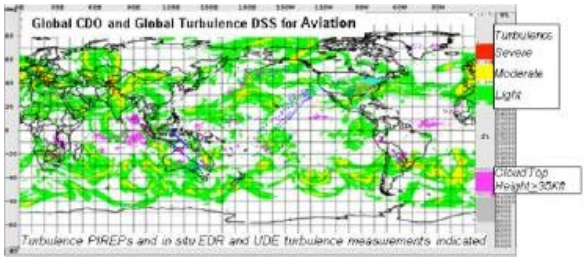

Figure 4. Display of the prototype Global Graphical Turbulence DSS forecast for 15 December 2007 at 1200 UTC showing predicted clear air turbulence intensity (green=light; yellow=moderate; red=severe) and the locations of cloud top heights ≥35kft (magenta) indicating possible convectively-induced turbulence locations. Validation data are shown by turbulence pilot reports (PIREP; where =null) and by in situ eddy dissipation rate$^{1/3}$ and UDE turbulence measurements (dark blue dots=null).

An initial prototype version of a Global Turbulence DSS for Aviation turbulence forecast ("Global GTG") product continued to run in real-time at NCAR/RAL in FY10. These forecasts use Global Forecast System (GFS) model data, which can be used to provide upper–level turbulence forecasts globally out to 36 hours. Additional GFS model fields were investigated to determine whether they could contribute to Global GTG performance, e.g., by helping to diagnose regions of possible convectively-induced turbulence, with promising results. Several satellite-derived turbulence prediction fields are being developed in conjunction with the University of Wisconsin-Madison and analyzed for possible inclusion in the short-range turbulence nowcast component of the system. These include the tropopause fold identification algorithm (TFA), objective identification of convective overshooting tops (OTs), and a downslope wind diagnosis intended to help determine likely mountain-wave turbulence (MWT) locations. The global product will also include rapid updates of satellite–derived convection diagnoses and nowcasts from the global CDO and CNO products described above.

Figure 4 shows an example of the current prototype Global GTG product with Global CDO and verification data overlaid.

FY2011 Plans:

The primary goal is to complete development of a comprehensive turbulence nowcast and forecast system that integrates CDO and CNO, satellite-derived turbulence diagnostics, and an enhanced version of Global GTG. The resulting turbulence nowcasts and forecasts will address clear-air, mountain-wave and convectively-induced turbulence sources in a unified fashion. An uplink demonstration of Global Turbulence DSS and convection fields to United Airlines aircraft is planned. NCAR researchers will continue to interface with the World Area Forecast Centers (WAFC) to advocate for the use of Global GTG as a replacement for the gridded turbulence product currently used by the Centers. (The gridded product is based only on the Ellrod Index, one of several components of Global GTG).

Storm Characteristics of Deep Convection

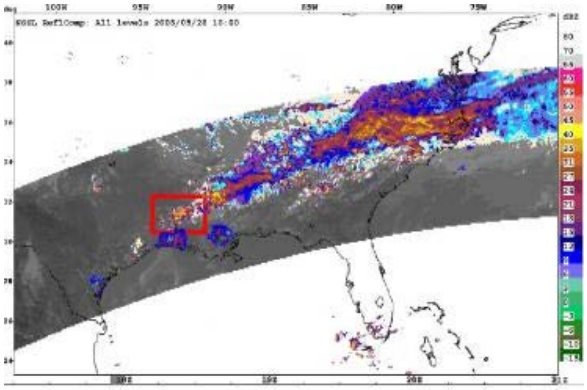

Figure 5. NEXRAD composite reflectivity (dBZ) mosaic is overlaid onto the TRMM VIRS 10.8 micron channel and shows the TRMM overpass region at 1800 UTC on 28 May 2008. The case study domain is indicated by the red box.

FY2010 Accomplishments:

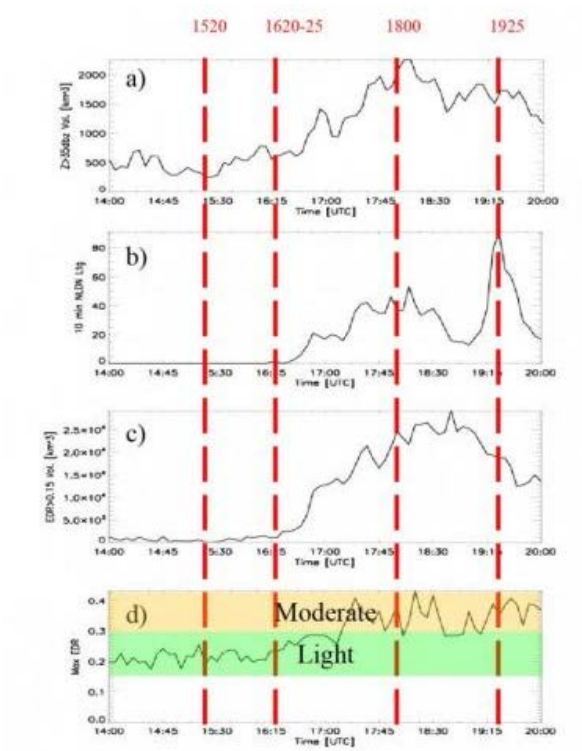

Figure 6. Time series plots from 1400 to 2000 UTC are shown for the domain indicated in Fig. 5. Fields plotted include a) the volume (km^3) of reflectivity ≥35 dBZ at and above the -10°C level, b) the number of cloud-to-ground lightning flashes measured by the NLDN, c) the volume (km^3) of NTDA $\varepsilon^{1/3}$ values ≥0.15 $m^{2/3}s^{-1}$ (light and greater turbulence) computed as a composite at and above the -10°C level and d) the maximum $\varepsilon^{1/3}$ value at and above the -10°C level within the domain.

The presence of lightning indicates that a storm has attained at least the minimum updraft strength to be an aviation hazard. Strong updrafts imply that aviation hazards such as turbulence, wind shear and icing may be present. Investigation into potential relationships between total and/or cloud-to-ground (CG) lightning measurements and convectively-induced turbulence (CIT) are being examined to determine their potential use for global aviation weather products.

Figure 5 shows the domain (red box) over which time series plots are computed on 28 May 2008 to examine relationships between reflectivity, CG lightning production and convectively-induced turbulence deduced from the NEXRAD Turbulence Detection Algorithm (NTDA; Fig. 6). The time series analysis shows that the volume of turbulence that is light or greater (Fig. 6c) increases as the storm reflectivity volume (Fig. 6a) and number of CG flashes (Fig. 6b) are also increasing (~1600-1800 UTC). During this storm growth period, the maximum $\varepsilon^{1/3}$ values increase to ≥0.3 $m^{2/3}$ s^{-1}, moderate turbulence (Fig. 6d) and remain near that level for the rest of the period. After 1800, the volume of $\varepsilon^{1/3}$ at values ≥0.15 $m^{2/3}$ s^{-1} follows the reduction in storm reflectivity volume. These preliminary results are encouraging for improving our understanding of turbulence production within convective storms, but additional cases must be examined.

FY2011 Plans:

This project ends in 2011. Efforts will focus on concluding the research and writing the final report.

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Avian Radar Performance Study

Background

The US Airways Flight 1549 accident on 15 January 2009 was the result of a collision with a flock of Canadian geese shortly after takeoff from New York City's La Guardia Airport. Upon failure of both engines and with insufficient time to return to the airport, the pilot was forced to ditch the aircraft in the Hudson River. Luckily, no lives were lost. The aircraft was damaged beyond repair. As this accident shows, bird strikes are a significant threat to flight safety as the impact can result in injuries and even fatalities for passengers and crew and substantial damage to airplanes. Since 1988, more than 219 people have been killed worldwide after their aircraft collided with birds. Bird and other wildlife strikes cost U.S. civil aviation more than $600 million per year. The United States Department of Agriculture (USDA) has the authority to regulate wildlife management at US civilian airports and has recently begun working with a commercial firm, DeTect, Inc., to modify a marine radar system to prevent to detect and track birds at airports. In FY2010, RAL scientists began working with the USDA/DeTect team to assess this radar system in an effort to prevent encounters between aircraft and birds.

Description

Figure 1. In 2004, a MERLIN Bird Radar System was installed on a landfill near the Louisville International Airport, Kentucky, to provide real-time monitoring and warning of hazardous bird activity. The Louisville airport is the the North American base for United Parcel Service and is the fourth largest freight airport in the US. The system was required by the Federal Aviation Administration (FAA) in order to expand the runway and is operated by bird control staff who use it to support bird control activities, alert the airport of elevated birdstrike risk and to document that bird levels on the landfill are maintained at or below area background levels. Photo provided courtesy of DeTect Inc.

In this study, a Merlin bird radar system, developed by DeTect, Inc., will be deployed at the NCAR Marshall Field Site and at the Plum Brook Station, Sandusky, OH, to assess the system's performance in identifying and/or tracking selected targets (i.e., birds of opportunity, unmanned aerial vehicles, and ballistic targets such as tennis balls). This comprehensive effort will explore the appropriate requirements and develop metrics against which the avian radar will be tested. These metrics will validate the radar's ability to identify and track specified targets using statistical performance measures and will validate the radar's level of performance within challenging environments that include weather and ground clutter targets.

A second effort will use a simulation study to further assess system performance by combining theoretical radar cross-sections of avian targets with Merlin scans containing ground clutter and weather. This simulation effort will assess system performance in a rigorous manner that can be difficult to achieve through field deployment alone.

Finally, the Merlin radar system characteristics will be evaluated and analyzed against the manufacturer's specifications.

FY2011 Goals

- Complete evaluation of Merlin radar system characteristics.
- Field deployment of the Merlin at Marshall Field site and at Plum Brook Station with data collection.
- Commence simulation study.

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New and Emerging Applications

Identify, explore, develop and implement advanced weather decision support systems for new and emerging user sectors.

- **Surface Transportation Weather**
- **Renewable Energy**
- **Weather Prediction Statistical Optimization**
- **Advanced Operational Aviation Weather System (AOAWS)**

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Surface Transportation Weather

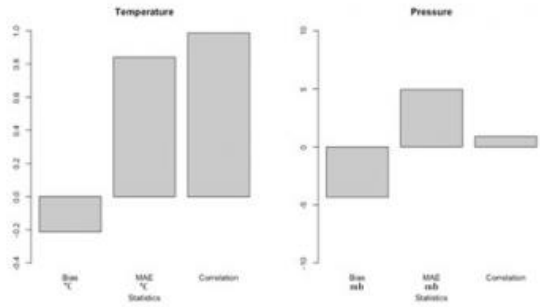
Background

RAL is a key contributor to the research and development of the weather component of the Federal Highway Administration's wireless vehicle technology program called **IntelliDrive[SM]**, and continues to support the adoption of the winter **Maintenance Decision Support System (MDSS)** technology across the nation. Plans are also being made to extend the MDSS technology 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. RAL is also working on improving the quality of the ***Clarus* System** observations and examining how the *Clarus* data can be used to increase safety and efficiency for summer road maintenance operations.

FY2010 Research & Development:

Vehicle Data Translator

The **IntelliDrive[SM]** program has three main goals, namely 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. 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 FY10 to continue developing the prototype 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 FY10 focused on two key areas: assessing vehicle probe data quality and refining the road and atmospheric hazard products.



	Temperature	Pressure
Bias	-0.21°C	-4.33hPa
MAE	0.84°C	4.95hPa
Correlation	0.99	0.91

Figure 1/Table 1: Overall statistics for vehicle temperature and pressure compared with the WXT-520.

Questions about data quality focused on determining the accuracy and bias of mobile temperature and pressure observations using data from 9 specially equipped cars NCAR operated within the Development Testbed Environment (DTE) near Detroit, Michigan. These cars sensed and recorded more than 260,000 temperature and pressure observations and several million other vehicle data elements — with an emphasis on collecting data during rain and snow conditions — over 19 days from January through April 2010. Overall, the quality-controlled vehicle temperature observations show similarity to the *in situ* temperatures recorded by a Vaisala WXT-520 (Figure 1 and Table 1). Pressure data are less robust, with larger errors, possibly due to the poor resolution of the pressure sensors (10mb). Stratification by environmental conditions,

Figure 2: Example display of the VDT display.

such as ambient temperature, wind speed, and rain rate, appear to have no affect on the accuracy or bias of the temperature or pressure data. Some vehicle conditions (e.g., speed) also do not influence the error statistics. There is some evidence to suggest variations in error statistics based on the vehicle though, indicating more robust studies, with more vehicles, are needed.

The same data were also used to develop new prototype VDT road and atmospheric hazard condition products. More details on the VDT concept and algorithms were presented in an Intelligent Transportation Society of America (**ITSA**) conference paper (**Drobot et al. 2009a**) and an ITS International article (**Drobot et al. 2009b**). Work in FY10 included adding ancillary data to the VDT as well, including NOAA Storm Prediction Center (SPC) storm reports, NWS 'Story of the Day', twitter feeds, and radar data. An example of the radar data and the SPC storm reports is shown in Figure 2._

Maintenance Decision Support System (MDSS)

Since 1999, RAL has led a team of national laboratories in the development of the Federal prototype winter Maintenance Decision Support System (MDSS), a unique decision support system that provides real-time snow and ice control guidance (e.g., treatment times, chemical choices, rates, and locations) for user-defined roadway segments.

In FY10, NCAR officially released **Version 6.0 of the MDSS software**. Additions in Release 6.0 include new data sets, such as Automated Vehicle Location (AVL) information, truck camera images, and webcam images from fixed locations, which can now be viewed on the display. The observation processing subsystem has also been enhanced to allow easier spin-up of forecast sites by using weather forecast elements as surrogates for missing Environmental Sensor Station (ESS) observation data. This allows new (and intermittently observing) sites to work more seamlessly within the requirements of the Model of the Environment and Temperature of Roads (**METRo**). An event playback capability has also been added to view previous weather forecasts and treatment recommendations. This capability requires that previous data be maintained on the MDSS server for an extended period of time. Work also began to transition the MDSS to operations in Spain.

Other highlights included continuing to work with Denver International Airport and supporting the FHWA's annual Road Weather Management Meeting.

Clarus Quality Checking (QCh)

The USDOT FHWA **Road Weather Management Program**, in conjunction with the Intelligent Transportation Systems (ITS) Joint Program Office, established the *Clarus* Initiative in 2004 to reduce the impact of adverse weather conditions on surface transportation users. The goal of the initiative is to create a robust data assimilation, quality checking (QCh), and data dissemination system that can provide near real-time atmospheric and pavement observations from the collective state's investments in road weather information systems.

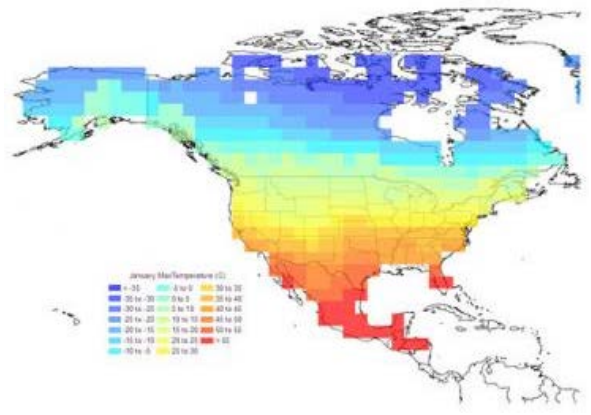


Figure 3: Pavement temperature climatological January maximums.

In FY10, RAL focused on improving several of the *Clarus* QCh algorithms. For the pavement surface and subsurface temperature, NCAR used the METRo model to create a climatology on a regular 2.5 by 2.5 degree longitude-latitude grid (the same as used for many **NCEP / NCAR Reanalysis** products); the climatology includes monthly expected maximum and minimum temperatures (e.g., Figure 3). NCAR also worked on a precipitation QCh. These QCh algorithms are being incorporated and tested in the ***Clarus* System**.

Clarus Regional Demonstration

The USDOT FHWA **Road Weather Management Program** is conducting multi-state *Clarus* Regional Demonstrations to highlight progress in developing the ***Clarus* System**. These demonstrations encourage state agencies to contribute ESS data, show how *Clarus* facilitates better transportation system management, and enable the private sector to create improved road weather information business solutions. RAL is participating in one of the two regional demonstrations, focusing on a) assessing to what extent *Clarus* data improves numerical weather prediction modeling capabilities to

Figure 4: Reduction in error (°C) achieved when including Clarus data in the air temperature forecast.

support surface transportation weather; b) developing a non-winter maintenance and operations decision-support system; and c) contributing road and weather forecasts for a multi-state regional operational experiment. RAL is teamed with Mixon-Hill and State DOTs in Iowa, Indiana, and Illinois.

Research in FY10 centered on assessing to what extent inclusion of *Clarus* data improved forecast skill. Results showed that the *Clarus* data did lead to a measurable reduction in forecast error in certain cases, mainly for temperature over the 0-6 lead time, as shown in Figure 4.

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Renewable Energy

Background

Supporting the nation's transition to renewable energy was identified as a new research frontier in both the NCAR and RAL Strategic Plans (2009). In pursuing this goal, RAL staff collaborate with university researchers, other NCAR scientists, federal laboratories, and the private sector to develop methods to support the wind energy industry. These efforts have been largely focused on more accurately analyzing wind potential for siting wind farms and providing real-time wind forecasting to improve operations and the economics of incorporating wind energy into the power grid. It is anticipated that RAL's renewable energy research will expand to include the prediction of direct and indirect solar radiation and the impact of aerosols and jet contrails on insolation.

FY2010 Progress and Accomplishments: Xcel Energy Wind Prediction Project

In late December 2008, RAL began a collaborative project with **Xcel Energy Services, Inc**. to perform research and develop technologies to improve Xcel Energy's ability to increase the amount of wind energy in their energy generation portfolio. The agreement and scope of work was designed to provide highly detailed, localized wind energy forecasts to enable Xcel Energy to more efficiently integrate electricity generated from wind into the power grid. The wind prediction technologies help 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 its customers. The U.S. Department of Energy's National Renewable Energy Laboratory (**NREL**) is also collaborating by developing algorithms to calculate the amount of energy that the turbines generate by winds blowing at various speeds for a broad spectrum of wind facilities. The wind prediction technologies have been designed to cover Xcel Energy wind farms in Colorado, Minnesota, New Mexico, Texas, and Wyoming. It is anticipated that wind energy forecasting companies in the United States and overseas may adopt the developed technologies to help utilities that need more accurate wind predictions transition away from fossil fuels.

To generate wind energy forecasts, NCAR is incorporating observations of current atmospheric conditions from a variety of sources, including satellites, aircraft, weather radars, ground-based weather stations, and even sensors on the wind turbines. The information is utilized by five powerful NCAR-based tools:

- The Weather Research and Forecasting (WRF) computer model, which generates high resolution deterministic finely detailed simulations of future atmospheric conditions
- The Real-Time Four-Dimensional Data Assimilation System (**RTFDDA**), which continuously updates the WRF model simulations with the most recent observations
- The Dynamic Integrated Forecast System (**DICast®**), which statistically optimizes the forecasts based on current observations, climatological data, and real-time validation of the model predictions
- An Ensemble of numerical weather prediction forecasts based on both WRF and the MM5 (Penn State/NCAR) mesoscale models
- NCAR Four Dimensional Variational Doppler Radar Analysis System (VDRAS), which combines Doppler radar data with a cloud scale model to predict short term weather events

These models and analysis systems were originally developed for other applications, but have been combined to provide a comprehensive wind energy forecasting system. Real-time information from Xcel Energy's largest wind facilities is utilized by the wind energy system to refine the power curve calculations and tune the forecasts. Wind predictions are made for each wind turbine and a sophisticated post-processing algorithm converts the hub-height wind predictions into energy predictions. These turbine-based wind and energy predictions are then merged to create predictions of average wind, power generation, and expected error for each wind facility and connection node. The predictions are

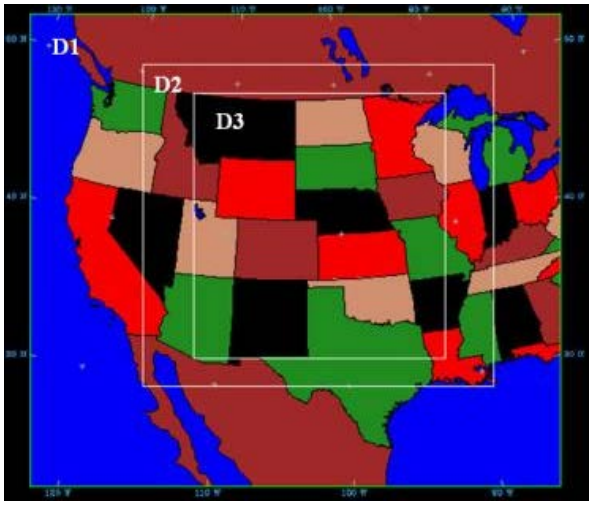

Figure 1: The grid spacings are as follows: D1=30km, D2=10km, and D3=3.3km.

subsequently provided to Xcel Energy using a dedicated real-time communication link.

In the first six months of the agreement, NCAR successfully developed the initial capabilities and began providing wind energy predictions. Since then RAL has been expanding the system capabilities and incorporating forecasts for additional wind farms as they are integrated in the Xcel system.

The Real-Time Four Dimensional Data Assimilation (RTFDDA) and forecasting system, developed by RAL to satisfy the meteorological needs of Army test ranges, has been adapted for wind-energy prediction. RAL implemented an operational RTFDDA system over the western and central states for supporting wind-power forecasting. This system contains three modeling domains with grid sizes of 30, 10 and 3.3 km (Figure 1). The 3.3 km domain covers the Rocky Mountains from New Mexico to Montana, the High Plains states, and most areas of the Central Plains. The system runs with a 3-hour cycle. In each cycle, it produces 24-hour forecasts for the innermost domain and 72-hour forecasts for the two coarser domains. The inner domain (3.3 km) generates output at 15-minute time steps.

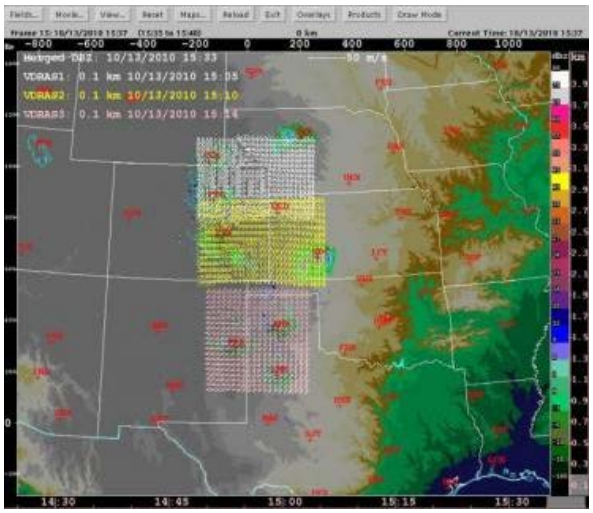

Figure 2: Diagram of the VDRAS domains used in the wind energy prediction system.

An ensemble wind energy prediction system has been added to the system in 2010. This system combines 15 WRF members with 15 MM5 members run on the 10 km grid. The mean of each model system is used in the **DICast®** system and also transmitted to the Xcel meteorologists for person-in-the-loop forecasting. This ensemble system also provides estimates of the uncertainty in the wind and resulting power forecasts. Calibration methods are being used to calibrate that uncertainty to reflect the actual expected error.

The Variational Doppler Radar Analysis System (VDRAS) enhances the wind energy forecasts through its independent monitoring of the evolving weather in the immediate vicinity of the targeted wind farms. This helps optimize the overall system by refining the short term forecasts by predicting the precise times that weather systems will impact the wind farms. The VDRAS domain for the Xcel project is depicted in Figure 2.

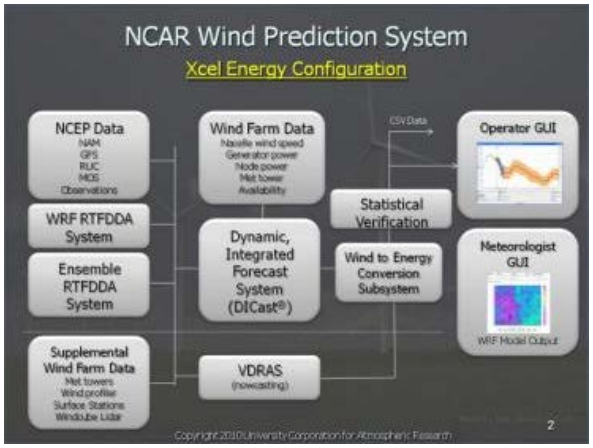

Figure 3: Conceptual diagram of the wind energy prediction technology components that will be incorporated into the final configuration.

A final conceptual diagram of all the technology components is provided in Figure 3. The components of the system culminate in a graphical user interface (GUI) display predicting wind power out to 72 hours from present. The meteorological model data is also made available to Xcel meteorologists.

FY2011 Plans:

RAL will work to:

- Expand the wind forecasting capability into additional areas, including mountainous and coastal sites
- Enhance the forecasting of wind power ramping events using statistical guidance techniques as well as the Variational Doppler Radar Analysis System (VDRAS)
- Downscale future climate scenarios for resource assessment
- Calibrate the uncertainty in wind forecasting systems
- Forecast cloud cover for solar energy sites
- Enhance very fine scale modeling capabilites with Large Eddy Simulations (LES)
- Study the effects of wakes on downwind turbine ingest
- Forecast conditions conducive to turbine icing
- Work with university collaborators on topics including:
    - assimilating mesoscale model data into fine-scale computational fluid dynamics models
    - studying the impact of shear across the turbine blade on power production
    - assessing icing conditions on rotating blades
    - coupling LES models with models of rotating blades using overset grid technology
    - assessing the feasibility of building integrating wind turbines
    - applying new artificial intelligence techniques to wind prediction problems

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Research Applications Laboratory | RAL
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Weather Prediction Statistical Optimization

Background

RAL has been 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 this 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.

FY2010 Accomplishments

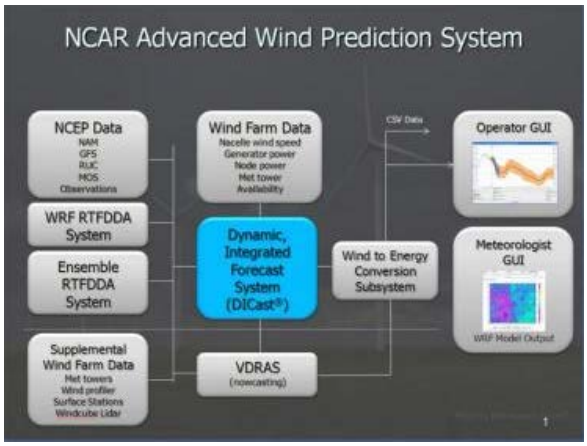

Figure 1: DICast is a key component of NCAR's Advanced Wind Prediction System

In 2010, short-term precipitation forecasts were integrated into the DICast and Logicast. These nowcast system, extrapolation-based, forecasts provide improved estimates of precipitation amount and probabilities out to 6 hours. Earlier versions of DICast and Logicast depended solely upon NWP model data for precipitation forecasts. While these forecasts are reasonable beyond 6 hours, they lack sufficient spatial resolution for short term forecasts. Since the models are often initialized up to 6 hours earlier, they may not match current conditions and not satisfy the “out-the-window” test. The incorporation of these radar-based extrapolations significantly improves these shortcomings.

While DICast has always worked globally, its forecasts can be improved by the incorporation of region-specific NWP models. To make improved European forecasts, several models specific to Europe have been integrated into DICast. This work has uncovered shortcomings in the system caused by differences in observational reporting practices in other parts of the world. Techniques have been developed to quality control input data and to handle sparse temporal reporting practices.

DICast has also been adapted to forecast wind speed at wind turbine hub heights. This has proved to lead to a more accurate wind energy forecast. For this application of DICast, the forecasts attempt to predict what the nacelle wind speed sensors mounted on the turbine hubs will report. As there is a strong relationship between nacelle wind speed and power generation, these wind speed forecasts can provide the basis for more accurate wind farm or connection node wind energy forecasts.

FY2011 Plans

The work to improve the quality and resolution of the short-term precipitation forecasts will be ongoing in 2011. To produce forecasts every 5 minutes out to two hours, a more complex computational infrastructure will need to be developed. Verification and tuning of the current and proposed systems will most likely lead to algorithmic improvements that improve the overall product.

Work will continue in the wind energy forecast arena. As more sites/regions are added and more forecasts are examined, we continue to learn and evolve our forecast techniques. This work is in its infancy.

Sophisticated customers can take advantage of probabilistic forecasts. These differ from the standard forecasts in that they provide a calibrated forecast of the potential forecast spread. For example, a forecast derived from such a system might say that “there is a 90% chance that the maximum temperature today will be below 38°C”. These types of forecasts are potentially valuable to the energy-load forecast industry and the wind energy trading industry. Existing and new techniques are being investigated to provide such forecasts.

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Advanced Operational Aviation Weather System (AOAWS)

Background

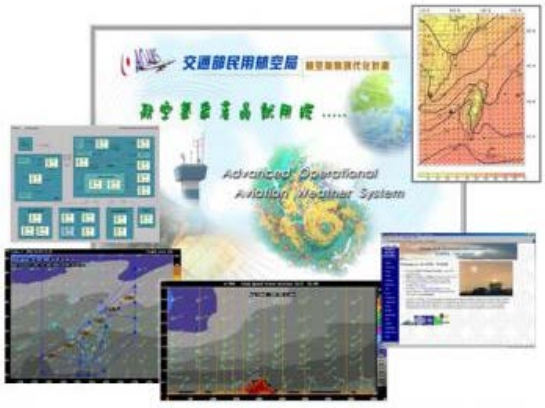

Figure 1: Composite image showing several AOAWS end-user display screens.

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 2009, NCAR's local Taiwan technology partner became InfoExplorer, Co., Ltd.

The AOAWS research and development project is currently focused on improving the WRF modeling system, advancing the WRF data assimilation system (WRF-VAR) to incorporate new data types (e.g., COSMIC GPS, and satellite radiance data, etc.), upgrading the in-flight icing and turbulence algorithms to incorporate the latest advancements developed as part of the FAA Aviation Weather Research Program, and developing and implementing new JAVA based display systems.

Major components of the AOAWS include: Low-Level Windshear Alert Systems (LLWAS Phase III) at Songshun and Taoyuan International Airport (formerly known as Cheng Kai Shek International); the WRF model which provides regularly-updated forecasts on three domains with grid spacing of 5km, 15km, and 45km; the Multi-dimensional Display System (MDS), which integrates all available real-time observational data and displays the information automatically to aviation forecasters and flight planning specialists; a JAVA based version of the MDS; 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.

1.2 FY2010 Accomplishments:

Figure 2: Illustration of the new WRF model domains and respective grid spacing used by the Central Weather Bureau (CWB) that also support the AOAWS. The Taipei Flight Information Region (FIR) is covered by the WRF 4-km domain.

Several system upgrades were accomplished in 2010 including upgrades to the WRF model and the WRF-VAR data assimilation system, display systems, and upgrades to the in-flight icing and turbulence products. As for WRF related research activities, testing of the Kain-Fritsch and Grell-Devenyi convective parameterizations continued. The KF scheme has been shown to produce the best typhoon track forecasts of all the WRF parameterizations. However, KF tends to over-deepen the storms. Comparisons between The Kain-Fritsch (KF) and Grell-Devenyi (GD) convective parameterizations show that KF produces excessive low-level heating when compared to GD. Detailed analyses of the warming behavior of the Kain-Fritsch convective scheme were reviewed and plans for additional diagnostic tests were conducted. The Central Weather Bureau's (CWB) and UCAR are working to identify the cause of this behavior and make necessary modifications to improve the KF behavior in tropical regions. The AOAWS team also worked with the CWB to incorporate COSMIC-based GPS data into the WRF system.

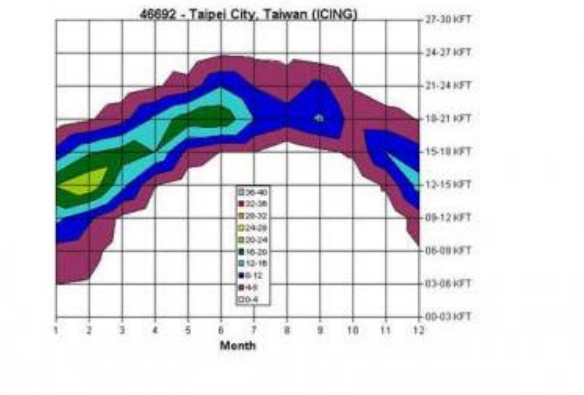

Figure 3: Illustration of the in-flight icing potential by month and flight level based on the in-flight icing algorithm when given Taipei soundings.(courtesy of Frank McDonough.

Research was also conducted to evaluate the performance of the in-flight icing and clear-air turbulence products operating on the new Taiwan WRF modeling system. In October 2010, the CWB WRF modeling system will be upgraded to include a new nested grid configuration. The new configuration will include a large 20 km grid over most of Asia with a 4 km nest over the Taipei Flight Information Region (FIR), which covers the entire Taiwan island. Both the Taiwan version of the Graphical Turbulence Guidance (GTG) and Forecast Icing Potential Product (FIP) were upgraded and tuned to the new configuration. Both algorithms were evaluated using a WRF model configuration similar to Taiwan, but run over the continental U.S. where sufficient pilot reports (PIREPS) were available to support the performance verification studies.

Display system improvements include the generation of graphical Terminal Aerodrome Forecasts (TAFs) and handling of new international data sets.

1.3 FY2011 Plans:

RAL will continue to upgrade the AOAWS system by making display system enhancements; evaluating the wind shear detection system; upgrading, testing and integrating the AOAWS data system infrastructure; and continuing to provide implementation support and maintenance services.

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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**
- **Understanding, Modeling and Forecasting Urban Atmospheres**
- **High Performance Computing for Operational Modeling**
- **Atmospheric Transport and Dispersion of Hazardous Materials**
- **Mesoscale Current-Climate Downscaling**
- **Mesoscale Ensemble Prediction**

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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. These systems and their products are tailored to each project to achieve the greatest 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. Numerous other domestic projects include supporting potential Space Shuttle landings at alternative sites, forecasting for wind farms, and exploring how urban development affects the weather. Recently, in collaboration with AirDat LLC, NSAP built a an operational forecasting system with a domain that spans the conterminous U. S. and uses observations from special AirDat weather instruments onboard regional commuter aircraft. In this section of the Annual Report, we describe our work in the following areas:

- Four-Dimensional Weather System (4DWX)
- MAGEN RTFDDA and 3DVAR Hybrid Forecasting System
- RTFDDA Forecasting System for Xcel Wind Energy
- AirDat 4-km CONUS RTFDDA Forecasting System
- DART-based Data Assimilation for Wind Prediction
- Assimilation of NEXRAD Observations to Support Dispersion Modeling
- Improving “Observation-Nudging” FDDA for Community WRF
- Advanced NWP Surface Bias Correction Scheme
- Next–Generation RTFDDA Forecasting System

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Understanding, Modeling and Forecasting Urban Atmospheres

Background

Atmospheric processes are influenced by urban complexes over a wide range of scales. The larger metropolitan area produces an aggregate effect on the mesoscale atmosphere, and RAL is developing improved urban–canopy parameterizations for representing the bulk dynamic and thermodynamic effects of buildings for use in the community WRF model for numerical weather prediction and regional climate simulations. On the smaller scales of neighborhoods, a variety of models and measurement systems have been used to define boundary–layer structure and better predict transport and dispersion in cities.

Developing integrated urban models for the community WRF model

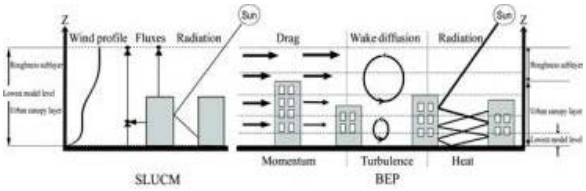
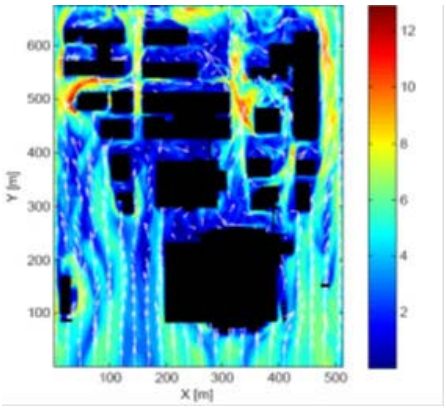


Figure 1. A schematic of the single-layer UCM (SLUCM, on the left-hand side), and the multi-layer (Building Effects Parameterization, BEP) models (on the right-hand side). From Chen et al. (2010).

As a result of an international collaborative effort undertaken in the last three years, an integrated, cross–scale urban modeling capability was released in the community WRF model V3.2 in April 2010. This new WRF/urban modeling system will help improve WRF weather forecasts for cities, enhance air–quality prediction, and provide fine-scale modeling tools for assessing the impacts of urbanization on the environment. The WRF urban–modeling system consists of:

- A suite of urban parameterization schemes with varying degrees of complexity
- A capability for incorporating in–situ and remote–sensing data about urban land use, building characteristics, and anthropogenic heating and moisture sources
- Companion fine–scale atmospheric and urbanized–land data assimilation systems
- The ability to couple WRF/urban to fine–scale urban T&D models and to chemistry models (Figure 1)

Accurate prediction of wind characteristics in an urban environment using the Immersed Boundary Method



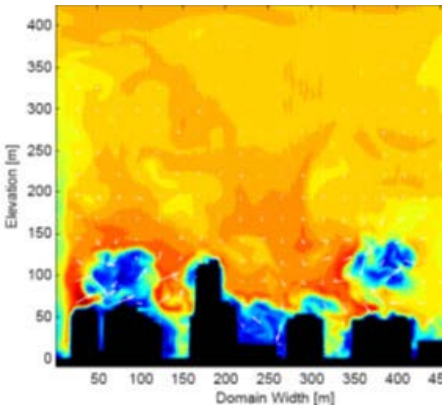


Figure 2. Example of WRF-IBM simulation of a flow over Oklahoma City corresponding to an Intensive Observational Period during Joint Urban 2003 field experiment (Lundquist, K. A., 2010, Ph. D. Thesis)

WRF includes a large-eddy capability for high-resolution simulations of processes in atmospheric boundary layers down to grid sizes of the order of one meter. To further enhance this capability for characterizing flows in complex terrain (e.g., urban environment), the WRF's large-eddy simulation capability has been recently extended by a team from the Lawrence Livermore National Laboratory (LLNL) to include 1) the immersed boundary method (IBM) for more flexible treatment of boundary conditions needed to simulate flows over complex terrain and 2) a state-of-the-science turbulence model. By combining three essential elements: the IBM, an advanced subgrid model for large-eddy simulations, and appropriate surface boundary conditions, our goal is to develop a capability for producing highly accurate, multi-scale simulations of flow and transport over complex urban environments (Figure 2). Validation of the new IBM-WRF multi-scale modeling capability will focus on characteristic features of atmospheric flows in complex terrain such as upslope and downslope flows, lee waves, wave breaking induced turbulence, flow channeling in urban canyons, flow separation in building wakes, etc., using various field observations such as T-REX, METCRAX, and Joint Urban 2003 experiments.

Urban transport and dispersion modeling for emergency response

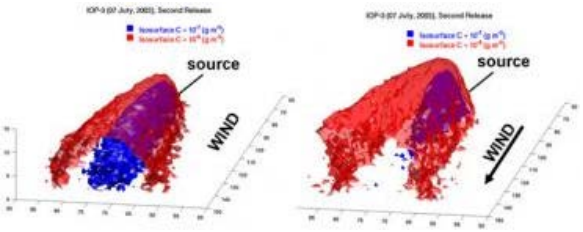


Figure 3. The 30-min average concentration isosurfaces (10^{-8} g m^{-3} in red and 10^{-7} g m^{-3} in blue) of the rural prediction, left panel, and the same isosurface from the urban run, right panel, for the second release of IOP3 (18:30 UTC / 13:30 local time, 7 July 2003). Model runs with 250 m grid increments. The wind is coming out of the figure plane. From Delle Monache et al. (2009).

A new urban parameterization for a fast-running dispersion prediction modeling system suitable for emergency response situations was developed, which includes five key parameters: the weighted grid-cell averaged building height, fractional frontal area of buildings, the roughness sub-layer depth, the surface roughness length, and the displacement height. It intends to represent the urban convective boundary layer in the dispersion prediction system developed by the National Atmospheric Release Advisory Center (NARAC) at Lawrence Livermore National Laboratory. The performance of the modeling system is evaluated against data from the field campaign Joint Urban 2003 (JU03), held in July 2003 in Oklahoma City, Oklahoma. The new parameterization considerably improves the performance of the original modeling system, by producing a better correspondence between predictions and observations (as measured by Taylor diagrams), and better captures directional effects resulting in plume predictions whose shape and size better resemble the observations (via the measure of effectiveness). Moreover, the new parameterization shows similar skills to urban modeling systems of similar or greater complexity.

As shown in Figure 3, when running the NARAC dispersion modeling system with this urban parameterization the plume is broader both horizontally and vertically, particularly near source region. This agrees better with a daytime release in urban environments where the presence of buildings is expected to enhance both vertical and lateral mixing when compared to a similar release in rural settings. The results show that the higher concentration region (dark blue isosurfaces) extends much further downwind for the run without than the run with the urban parameterization. The higher residence time in the run with the parameterization allows for greater diffusion of material outward or away from the plume centerline, thus creating a larger plume cross section.

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High Performance Computing for Operational Modeling

Computing

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.

Storage

RAL has achieved significant improvements in data storage management through the deployment of NAS (network attached storage) systems. The transition 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 scalability for future growth 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.

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Atmospheric Transport and Dispersion of Hazardous Materials

Background

Atmospheric releases of hazardous materials, either accidental or intentional, continue to pose a threat to both US citizens and troops abroad and at home. To counter this threat, RAL is actively supporting the research and development of novel techniques and systems which can be used to more accurately simulate the atmospheric evolution of the released material in both time and space, for planning, real-time response, and forensic analysis.

Atmospheric Transport and Dispersion (AT&D) Meteorological Data Services

The ability to accurately simulate and predict downwind material dispersion is intimately tied to one's ability to characterize and forecast the atmospheric state. For real-time response and forecasting purposes, quick and efficient access to operational weather observations and numerical forecasts is paramount. Due to the complexities of obtaining real-time products from different production centers, RAL has developed a Meteorological Data Services (MDS) system specifically tailored for atmospheric transport and dispersion modeling needs. The system actively gathers a variety of global real time meteorological observations and numerical forecasts and makes these data available to a variety of operational transport and dispersion modeling systems, including the Hazard Prediction and Assessment Capability (HPAC), Integrated Weapons of Mass Destruction Toolset (IWMDT), and Joint Effects Model (JEM). Operational MDS systems have been installed at several Department of Defense (DoD) sites and have been providing uninterrupted 24/7 access since FY2006. In addition to developing the MDS systems, RAL has also developed customized MDS client interfaces, which more efficiently request/retrieve meteorological information for use with the modeling systems, listed above. The MDS client interface has been successfully integrated into these toolsets and continues to be adopted in other T&D applications. RAL continues to provide improvements/modifications to the operational MDS system and client interfaces. Specific accomplishments since the last reporting period and plans for next fiscal year are summarized below.

FY2010 Accomplishments

- Developed simplified system maintenance/operation/troubleshooting aspects of MDS that assist onsite MDS administrators' day-to-day support and make long-term code maintenance easier;
- Made access to applications more secure and compliant with the Defense Threat Reduction Agency (DTRA) sponsor's security requirements by providing required system patches/updates that meet agency requirements and enable final Authority To Operate (ATO) status to be granted to the MDS systems;
- Improved the performance with system/software enhancements that enable the system to handle high user-request volumes;
- Developed and deployed 3 new MDS releases to meet the above objectives, culminating in a 2.0 release that included a major operating system upgrade and improvements to the system-level failover software;
- Transitioned MDS from a developmental system to an operational system managed by the DTRA Operations and Maintenance group;
- Provided comprehensive documentation that aids the ongoing operation, maintenance, troubleshooting, and further development of the MDS system by DTRA staff;
- Developed training materials and held educational sessions that inform DTRA staff in detail on all aspects of MDS;
- Provided assistance to DTRA staff in handling operational issues and facilitating their achievement of increasing levels of independence;
- Contributed weather software feature enhancements and code improvements to the HPAC5 Maintenance Build;
- Developed, tested, and delivered new high priority features and fixes for the HPAC weather software;
- Provided software integration and support in HPAC for a new NCAR/RAL developed high resolution upper air climatological database.

FY2011 Plans

- Continued development, testing, and delivery of weather software for HPAC;
- Prioritized enhancement of MDS in conjunction with the DTRA Operations group;
- Investigation into new capabilities for MDS. The new research and development work will focus on validation and verification with a goal to provided automated selection of the forecast model that performs best for a specific geographic region under a particular weather regime.

Hazardous Material Source Term Estimation

In addition to requiring an accurate description of the atmospheric state (past, present, and future), AT&D modeling systems also require an accurate specification 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. Therefore, algorithms and techniques are being actively developed, within RAL, which can quickly reconstruct or estimate the material release source using these limited sensor observations. In particular, RAL has developed a tailored source term estimation (STE) and hazard refinement system, which is currently being integrated into the HPAC/JEM systems. The current STE system consists of 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 STE model are used to calculate a "first guess" source estimate based on the available chemical plume and meteorological observations. The LEPM and corresponding adjoint are then used to iteratively refine the SCIPUFF based STE and wind estimates using variational data assimilation techniques. Specific accomplishments since the last reporting period and plans for next fiscal year are summarized below.

FY2010 Accomplishments

- Transitioned the STE prototype system into a hardened and documented codebase, that can now be easily integrated into the HPAC/JEM systems. This involved recoding most of the system from matlab to java; rearchitecting the codebase into a more object oriented framework; and providing in line documentation, within the code, so that web based documentation reports can easily be generated using javadocs.
- Developed a comprehensive and automated testing framework, which tests the system at multiple testing levels, against the various field trial datasets.
- Added an initial capability to adjust the wind fields, in addition to the source parameters, to find the optimally minimized solution, and account for inherent wind-velocity errors.

FY2011 Plans

- Continue to investigate methodologies which better characterize the adjoint cost function, when assimilating sensor data with thresholds.

Virtual Atmospheric Dispersion Field Testing

In order to adequately test and evaluate the performance of these evolving STE systems, RAL is actively developing a Virtual Threat Response Emulation and Analysis Testbed (VTHREAT), which will enable simulation of physically realistic hazardous release scenarios, placement of material and meteorological sensors, and extraction of the resulting synthetic sensor readings. These synthetic observations can then be used to evaluate the STE systems' ability to accurately reconstruct the hazardous material release source specifications, under various atmospheric regimes and against various material release scenarios. The VTHREAT system uses high-fidelity atmospheric and transport and dispersion models to generate physically realistic "single realization" chemical-biological-material release data sets. The "single realization" data sets are then converted to observations through models that emulate the characteristics of the sensing platform. The sensor models typically include detailed information on sensor performance characteristics and can provide a mechanism to utilize information from development testing information during operational testing. Sensor output is produced with the format and fidelity of the sensor, enabling the evaluation of sensor platforms and corresponding modeling and information systems relative to the virtual "truth" data set from which they were derived. VTHREAT has undergone a preliminary evaluation, characterizing its ability to produce realistic virtual dispersion data sets, and has been used to support field programs and test future material sensor applications. Specific accomplishments since the last reporting period and plans for next fiscal year are summarized below.

FY2010 Accomplishments

- Completed initial validation of the VTHREAT atmospheric and dispersion modeling component, in cooperation with the Institute for Defense Analysis, against the FUSION Field Trial 2007 datasets, particularly Trial 54.
- Developed a new graphical user interface, utilizing NASA's World Wind Visualization package
- Added an initial capability to model particle gravitational settling effects.
- Developed a prototype capability to emulate an aerosol backscatter LIDAR, modeled after the NCAR Raman-shifted Eye-safe Aerosol LIDAR (REAL).

FY2011 Plans

- Add additional particle dynamic effects, including dry/wet deposition and wet particle effects, to the system
- Continue research into adding an aerosol background interferent capability.
- Plan to add new sensor emulation model capabilities, including the Joint Biological Point Detection System (JBPDS), Joint Services Lightweight Standoff Chemical Detection System (JSLSCAD), Joint Biological Standoff Detection System (JBSDS), and Joint Chemical Agent Detector (JCAD).

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Mesoscale Current-Climate Downscaling

Background

To provide high–resolution current–climate information in data–sparse regions for a variety of decision makers, RAL has developed the Climate Four Dimensional Data Assimilation (CFDDA) system. This capability was originally based upon the MM5 model, and now has been transitioned to WRF. CFDDA uses global–scale data from long term reanalyses (such as the NCEP/NCAR Reanalysis, or the European Center for Medium Range Weather Forecasting Reanalysis); standard surface and upper–air observations; and satellite–derived estimates of winds, temperature, and humidity to downscale the global climate to the local region, while fully accounting for topographic variations and surface characteristics. Several applications of the CFDDA system are described in this Annual Report:

- A Global Downscaled Climatography Project
- Modeling Plague in Uganda
- SHOM Climate Four-Dimensional Data Assimilation Project
- National Ground Intelligence Center Project

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Mesoscale Ensemble Prediction

Background

The chaotic nature of the atmosphere and the imperfections of weather models mean that probabilistic forecasting is necessary to deal with unavoidable numerical weather prediction uncertainties. The decisions made by RAL sponsors, based on mesoscale numerical model forecasts, can certainly be improved through the availability of probabilistic information. To better provide this information, new mesoscale ensemble prediction systems are being developed, and real-time systems that incorporate ensemble models are moving into operational use. A challenging and exciting aspect of this effort is working with forecast users to help them better incorporate stochastic information into their decisions. This work is being conducted through the sponsorship of the Army Test and Evaluation Command and Xcel Energy projects, whose broader objectives and progress are discussed elsewhere in this annual report.

FY2010 Accomplishments:

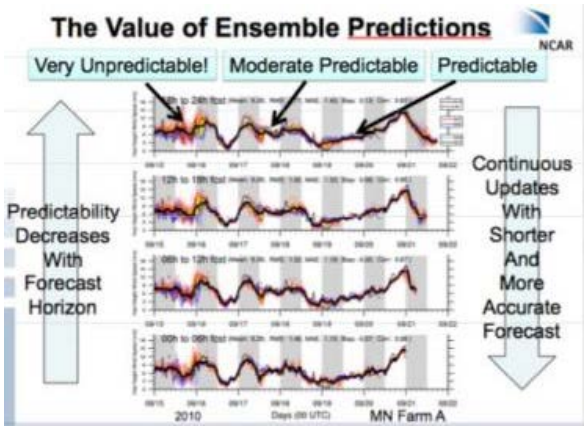

Figure 1. An example of real-time wind prediction at a wind farm in Southwest Minnesota. The dashed black lines are observed winds. The red and blue lines are individual ensemble member forecasts and the solid thick black lines represent the ensemble mean forecasts.

The Ensemble RTFDDA (E-RTFDDA) analysis and forecasting system is one of the most important new capabilities recently added to the RAL Real–Time Four Dimensional Data Assimilation (RTFDDA) and forecasting system. Unlike most other mesoscale ensemble systems, E-RTFDDA is a multi–model, multi–scale, and cycling data assimilation and prediction system. The continuous cycling mechanism of the E-RTFDDA allows the model to produce accurate nowcasts and short-term forecasts. In FY10, a 30–member E-RTFDDA system has been continuously operated at the US Army Dugway Proving Ground, supporting routine tests and decision–making for test planning. In addition, a second 30-member E-RTFDDA system was also implemented to provide wind energy forecasting to support Xcel Energy Inc's. operation in wind integration, load balance planning and energy trading. The Initial Operating Capability products of this E-RTFDDA system have been released for Xcel's real-time use in June 2010. The ensemble wind forecasts at the Xcel wind farms located in Colorado, Minnesota, Texas and New Mexico, have been extracted from the real-time E-RTFDDA forecasts and provided to the RAL statistical wind-power conversion module to produce probabilistic wind power forecasts.

The scientific research on E–RTFDDA includes ensemble–member refinement, statistical verification, and ensemble–forecast calibration. Refinements of E–RTFDDA members include improving individual member forecasts and enhancing ensemble member perturbations. E–RTFDDA is built upon WRF and MM5. To incorporate the advances associated with the evolution of the community WRF model, the E-RTFDDA WRF members have been upgraded in accordance with each community WRF release. In addition, modifications have been put into the WRF YSU and MYJ PBL schemes to improve the PBL modeling. New WRF physical–process parameterization schemes include three TKE-based PBL schemes that have been introduced in the community WRF release - these have been incorporated in the E–RTFDDA physics–perturbation member pools. Operational E–RTFDDA systems are tuned to the perturbation members that provide the best modeling of seasonally evolving weather regimes. For example, extra PBL and land surface model perturbations were added for cold air damming modeling in the wintertime over the eastern states, and for wintertime cold air pooling in the mid–western and inter–mountain areas. Extra perturbation members for modeling moist convection were included for summer weather prediction.

In the area of engineering development, three important items are described here. First, the WRF adaptive time step has been refined and adjusted to accommodate data assimilation algorithm of RTFDDA. Implementation of this capability in the operational E-RTFDDA systems for DPG and Xcel

speeds up the ensemble forecasting of the system by more than 25% and thus effectively extends the DPG system from 40 hour forecasts per forecast cycle to 48 hours. Second, to cope with the needs of high-frequency forecast for wind energy prediction, both WRF and MM5 member models were revised to be able to effectively output at 10 – 15 minute intervals for sub-domain areas. And third, a new post-processing dataflow has been designed and implemented for effective extraction and presentation of the huge amount of real-time ensemble output. An example of real-time wind forecasts at a Northern Colorado Wind farm are shown in Fig. 1.

Statistical post-processing of E–RTFDDA is a critical procedure to enhance the value of ensemble forecasts. Two post-processing areas are studied; one is the ensemble forecast verification and the other is ensemble forecast calibration. Real-time E-RTFDDA forecasts for both ATEC and Xcel systems have been archived and processed for verification and calibration. Ensemble verification aims at assessing the reliability and resolution of the ensemble predictions, while ensemble calibration translates the uncertainties of the ensemble forecasts into probabilistic forecasts by correcting the first (mean) and second moment (spread) bias. The improvements of the statistical post–processing approaches are to be measured by reliability diagrams, rank histograms, etc. Furthermore, calibration allows for statistically transferring/downscaling model forecasts (1st and 2nd moments) from the raw grid–box–mean model forecasts to station–specific properties. The calibration developed for E–RTFDDA is based on the Quantile Regression (QR) approach. Specifically, the scheme computes a weighted ensemble mean derived by weighting each ensemble–model based on its error variance. Two years of E–RTFDDA hourly forecasts for 30 individual ensemble members were processed using the Dugway Proving Ground SAMS (Surface Automatic Meteorological Station) observations. These model data and the corresponding observation records at each station are processed and fitted to quantiles using QR conditioned on the ensemble mean, median, spread, and persistence. For a given forecast, the scheme segregates model forecasts into differing ranges of ensemble dispersion, refits the models, and thus achieves calibrated forecasts. In 2010, initial ensemble calibration forecasts and verification maps at selected sites at DPG have been provided in real-time to end-users.

Finally, E-RTFDDA provides a scientific and technical cradle for development of an advanced next-generation 4DWX system with ensemble-based data assimilation (EDA) and the ensemble prediction system (EPS) paradigm. During 2010, significant progress has been made in this area. The core engine of this system is the integration of the NCAR DART (Data Assimilation Research Testbed) ensemble Kalman filter (EnKF) tool with E–RTFDDA. With this approach, EnKF takes advantages of E-RTFDDA by deriving error covariance using the multiple-perturbation E-RTFDDA forecasts and then it feeds E-RTFDDA forecast with the EnKF mean updates and a subset of EnKF perturbation members. The preliminary result showed that this innovative seamless EPS and EDA formulation produces more accurate initial conditions and better perturbations that improve the sampling of the uncertainties in the initial conditions. Implementation and evaluation for operational forecast for the Army DPG E-RTFDDA system will be the focus study for FY11.

FY2011 Plans:

The ensemble research and development at RAL will focus on three main areas:

1. Implement and test the NCAR DART ensemble Kalman filter (EnKF) tools with the Army DPG E-4DWX modeling system. DART-EnKF will be used to create the perturbed initial conditions using the current E-4DWX forecasts from both MM5 and WRF members. These initial conditions will be integrated to construct the member perturbations of E-4DWX. This research will represent a first step toward the next-generation seamless EDA-EPS system development, where EnKF-based EDA is loosely coupled to the current E-4DWX EPS system.
2. Continue to develop and validate the ensemble forecast verification and calibration algorithms for the locations of surface stations of the ATEC DPG E-4DWX system and the lower PBL hub-height wind forecasts of the Xcel E-RTFDDA system. Inter-comparison with other advanced ensemble calibration schemes, such as the Bayesian Averaging Model approach, will also be conducted. Furthermore, a new ensemble post-processing approach, which combines a model bias correction scheme using an analog-based Kalman filter scheme, can be applied independently to correct each individual ensemble member (bias of the first moment). And, the ensemble QR and BMA calibration (bias of the second moment) with the bias corrected member forecasts, is planned. It is expected that an improved probability calibration outcome will be achieved through this two-step model-error correction algorithm. These ensemble calibration schemes will be applied for deriving end-user probabilistic application products for both ATEC and Xcel operational ensemble forecasting systems.
3. Design, prototype and implement the RAL next-generation seamless EDA and EPS weather modeling system. This next-generation modeling system, called the 4DREKF (Four-Dimensional Relaxation Kalman Filter) data assimilation and forecasting system, is an ensemble data assimilation and forecasting paradigm that improves upon the successful 4DWX FDDA relaxation scheme and the cutting-edge ensemble Kalman filter based data assimilation weighting scheme. In FY2011, the 4DREKF model system framework and basic functions will be formulated, and tests will be conducted for evaluation of the system capabilities for real-case simulation with case studies and OSSEs (Observation System Simulation Experiments).

In summary, the FY2011 mesoscale ensemble research will aim for incremental upgrades to the existing operational ensemble systems adding more capabilities and functions, and will make a major step forward in the development of the RAL next-generation seamless EDA and EPS weather modeling system. In addition, RAL will continue to explore advanced technologies for extracting, processing, and displaying probabilistic forecast information, based on the huge amount of real-time ensemble output, for both novice and sophisticated users.

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Research Applications Laboratory | RAL

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Numerical Systems Testing & Evaluation

Maintain and expand a central collaborative function within NCAR and a distributive network of collaborators for developing, testing, and validating numerical forecast systems important to operational decision makers and the international research community.

- **Weather Research and Forecasting (WRF) Developmental Testbed Center (DTC)**
- **Advanced Verification Techniques and Tools**
- **Data Assimilation Testbed**
- **Tropical Cyclone Modeling Testbed**
- **Application of NASA "A-Train" Satellite Observations to Enhance Numerical Weather Prediction Products**

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Weather Research and Forecasting (WRF) Developmental Testbed Center (DTC)

Background

The WRF Developmental Testbed Center (http://www.dtcenter.org/), which is a distributed facility with components in the Joint Numerical Testbed (JNT) (www.ral.ucar.edu/jnt/) at NCAR's Research Applications Laboratory (RAL) and the Global Systems Division (GSD) of NOAA's Earth Systems 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. The goal of these activities is to accelerate the rate at which new technology is infused into operational weather forecasting. The WRF 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.

FY2010 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 2010, the DTC supported the following software packages to the community:

- Weather Research and Forecasting (WRF; http://wrf-model.org/index.php) – 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/index.php) – 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 the operational systems. Testing and evaluation undertaken by the developers of new NWP techniques from the research community is generally focused on case studies. Extensive testing and evaluation must be performed to ensure that these new techniques 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 either be generated by the DTC or provided by external modeling groups. The DTC's evaluation includes standard verification techniques, as well as new verification techniques when appropriate. All verification statistics also undergo statistical significance assessment. During 2010, the DTC performed evaluations for a variety of testing activities, each of which are briefly described below:

Reference Configurations

WRF can be viewed as a state-of-the-art model with many options, which is highly configurable and suitable for a broad range of weather applications. With the numerous options available in the WRF end-to-end system, it is extremely difficult to test all possible option combinations.

In order to establish widely publicized verification results for a variety of well-tested configurations of the WRF model, the DTC has implemented the WRF Reference Configuration (RC) concept. By conducting carefully controlled, rigorous testing, including the generation of verification metrics, and distribution of these baseline results, RCs will provide the operational community guidance for selecting configurations with potential value for

operational implementation. RCs will also provide the research community with baselines against which the impacts of new techniques can be evaluated and may aid researchers in selecting a configuration to use for their projects.

Over the past year, work toward designating several DTC RCs has been completed based on recent and previous testing and evaluation activities the DTC has conducted. A website has also been established from which all RCs can be accessed (http://www.dtcenter.org/config/). Information distributed on the website for each RC includes a description of the 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.

NOAA Hazardous Weather Testbed Spring Experiment

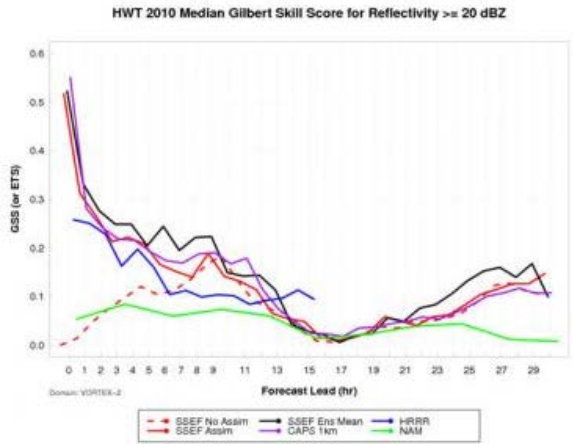

Figure 1. Median Gilbert Skill Score for 00 UTC runs of CAPS 4-km SSEF ensemble mean (black), SSEF ARW control member with assimilation (red solid), SSEF ARW control member without assimilation (red dashed), CAPS 1-km deterministic (purple), 3-km HRRR (blue), and 12-km NAM (green). Scores were aggregated over runs from 17 May – 18 June 2010.

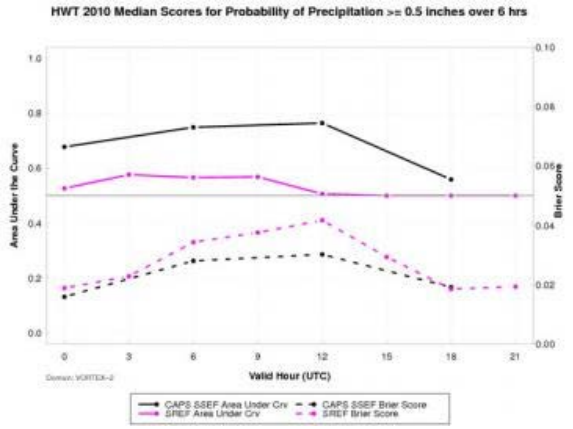

Figure 2. Median Area Under ROC curve (left axis – solid lines) and Brier Score (right axis – dashed lines) for CAPS SSEF (black) and SREF (pink) probability of exceeding 0.5 inches of precipitation over 6 hours. Scores were aggregated over runs from 17 May – 18 June 2010. No skill for Area Under Curve is denoted by grey line at 0.5.

The main focus of recent NOAA Hazardous Weather Testbed (HWT) Experimental Forecast Program (EFP) Spring Experiments (SE) has been to gain an understanding of how to better use the output of storm-scale configurations of numerical models to predict convective storms. The purpose of the DTC collaboration with this project is to help evaluate the performance of experimental real–time runs by computing objective verification statistics using MET while fostering connections between research and operations through demonstrating the utility of MET-based objective evaluation in an operational forecast setting.

To support the SE 2010, the DTC 1) evaluated an entire storm-scale ensemble plus baseline models, 2) assessed radar assimilation impacts on forecast skill 3) evaluated the skill of storm-scale models on select variables important to aviation hazard prediction and 4) evaluated ensemble probabilistic fields for flood forecasting. Traditional and probabilistic verification metrics, along with an advanced spatial verification technique called the Method for Object-based Diagnostic Evaluation (MODE), were applied. Evaluation statistics were provided on the HWT-DTC collaboration website (http://verif.rap.ucar.edu/eval/hwt/2010/) within 6-12 hours of the valid time.

The University of Oklahoma's Center for Analysis and Prediction of Storms (CAPS) provided the 4-km Storm Scale Ensemble Forecast (SSEF) and a 1-km deterministic forecast. In addition, several operational baseline forecasts were assessed, including the 12-km NCEP North American Mesoscale model (NAM) and the 3-km NOAA High Resolution Rapid Refresh (HRRR). The Gilbert Skill Score (GSS) for composite reflectivity greater than 20 dBZ is shown in Figure 1. Impacts of radar assimilation on convection-allowing model forecast skill are assessed using the two CAPS SSEF control members. The member with no assimilation (red dashed line) starts with no skill at time zero and exhibits increasing skill as the model develops convection. Conversely, the member with radar and synoptic-scale observation assimilation (solid red line) exhibits one of the highest skill scores at time zero, however, then drops off rapidly and the scores between the two control members become similar beyond the first 6 hours. Due to a limited sample size (25 cases), statistical significance cannot be ascertained, though these trends are consistent with results presented in Kain et. al (2010). Additionally,

the 4-km ensemble mean (black) was produced using 15 members with radar assimilation for initial conditions. It exhibits slightly higher skill compared to the radar assimilation control run throughout most lead times. The CAPS 1-km deterministic run (purple) and HRRR (blue) also exhibit greater skill than the no-assimilation control member, as well as the courser resolution NAM. The difference in skill scores between the CAPS runs and the HRRR during the 0-6 hour lead times may reflect the gain in skill from assimilation of synoptic observations only. Due to the fact that the synoptic observations are usually not available until 01 UTC, synoptic observation assimilation is not included in the 00 UTC HRRR runs performed in real-time, but is included in the CAPS runs that typically begin with a 5-hour latency. Further investigation is needed to confirm this hypothesis.

Probabilistic forecasts of precipitation exceeding 0.5, 1.0, and 2.0 inches over 6 hours were also evaluated. Figure 2 shows median Area Under the Receiver Operator Characteristic (ROC) Curve (solid lines) and Brier score (dashed lines) for the CAPS SSEF and NCEP's operational Short Range Ensemble Forecast (SREF) probability of exceeding 0.5 inch over 6 hours. The optimal Area Under Curve value is one while optimal Brier Score is zero. Both scores suggest the CAPS ensemble mean demonstrates greater skill than operational baseline SREF for accumulated precipitation probabilistic forecasts over the HWT time period. Once again, sample size is small and, therefore, statistical significance was unable to be determined.

Hydrometeorological Testbed

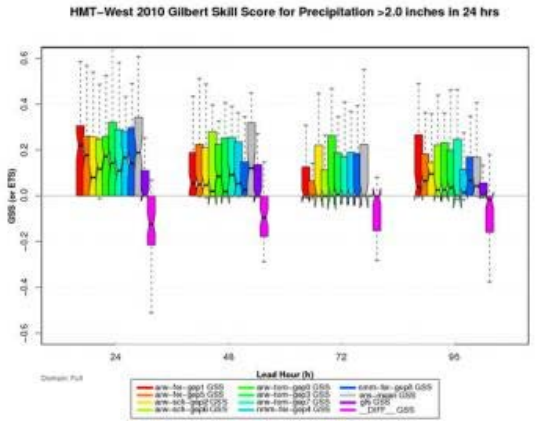

Figure 3. Box and whisker plot of GSS aggregated over the entire 2010 HMT-West Winter Exercise (85 samples). The boxes correspond to: ensemble members - red, orange, yellow, green and blue boxes with [core]-[microphysics]-[GEFS ensemble member for initial conditions] as naming convention; ensemble mean – gray; GFS - purple. Pairwise difference between the GFS and the ensemble mean is denoted by the magenta boxes.

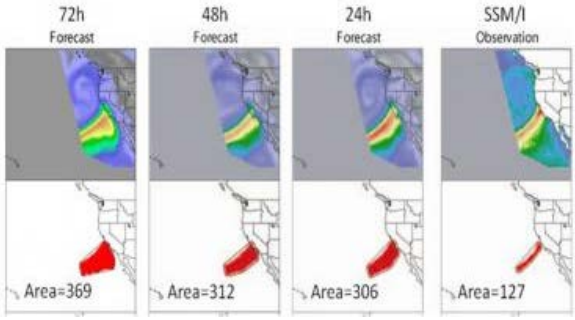

Figure 4. Top: 72-, 48-, and 24-hour GFS precipitable water forecasts (3 left panels) and composite SSM/I integrated water field (right panel) of Atmospheric River event valid between 12 UTC-00 UTC 25 February, 2004. Bottom: Objects identified in MODE with areas denoted.

The Hydrometeorological Testbed (HMT) has the goal of accelerating the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service (NWS) and its River Forecast Centers (RFCs). The DTC and HMT collaboration during 2010 was focused on forecast verification. The evaluation was conducted in order to make use of current MET capabilities to provide meaningful verification information for HMT applications.

An important aspect of MET in the HMT-DTC collaboration is ensemble prediction. Initial efforts were undertaken this year to develop the verification tools to evaluate the HMT-West ensemble provided by NOAA GSD. Objective evaluation was performed using MODE on the HMT-West ensemble QPF fields and compared with an operational baseline, the Global Forecast System (GFS). A second area of interest is the innovative use of object-based verification techniques that key on pattern characteristics of gridded fields such as shape, size, average intensity, etc. MODE utilities were adapted to demonstrate the feasibility of identifying and verifying Atmospheric River features and precipitation fields in the HMT West region.

Quantitative Precipitation Forecasts (QPF) were evaluated for accumulations over 6- and 24-hours. For 6-hour accumulations, Stage IV Quantitative Precipitation Estimates (QPE) were used for evaluation. For 24-hour accumulations, both Stage IV and gauge data were used. GSS calculated for 24-hour accumulations exceeding 2 inches is shown in Figure 3. The pairwise difference (magenta boxes) between the ensemble mean (grey boxes) and the GFS (purple boxes) QPF are also displayed. If the notch about the median on the difference box does not encompass zero, the difference is considered to be statistically significant. Based on Figure 3, which represents an aggregation over 85 samples, the ensemble mean has statistically significant higher skill over the operational baseline, GFS, at lead times of 24- and 48-hours.

GFS precipitable water forecasts for four Atmospheric River cases and two null-cases were used to demonstrate the utility of object-oriented verification techniques for use with Atmospheric Rivers. Figure 4 show the results of the 25 February 2004 case study. Subjectively, the GFS appears to have a southerly bias in the positioning of the ARs landfall and a general over-forecast of the areal extent of the vapor field. A case study from 5-9 January 2010

(not shown here) supports the subjective impression drawn from comparing the fields. It indicated the median distance between the MODE object centroids for a 96-hour forecast was 250 km and 100 km for 24-hour forecast. The direction of centroid offset has not yet been explored. In addition, the area ratio of forecast to observed objects for smaller IWV fields was 1.5, indicating a high areal bias from the forecast.

DTC Ensemble Testbed

As operational centers move toward ensemble-based probabilistic forecasting, the DTC has been asked to expand its efforts into providing a testbed platform to serve as a bridge between research and operations. Hence, during 2010, the DTC has established the DTC Ensemble Testbed (DET). The goal of DET is to provide an environment in which extensive testing and evaluation of ensemble-related techniques can be conducted such that the results are immediately relevant to the operational centers (e.g., NCEP/EMC, AFWA).

This effort was initiated with a National Workshop on Mesoscale Probabilistic Prediction, which took place in Boulder in September 2009 (see http://www.dtcenter.org/events/past_events.php). This workshop, which included numerous experts on ensemble prediction as well as community members from NOAA, universities, military organizations, and operational centers, provided a context in which DET plans are being developed.

FY2011 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. Several new model tests will be undertaken in context of RCs, WRF for hurricanes, and DET ensemble configurations. Collaborations with other NOAA testbeds will continue. The DTC will also help organize and support tutorials on WRF, MET, GSI, and hurricane models.

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Log in

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 the forecasts, or that can be helpful for making decisions (e.g., forecasting). Moreover, it is possible for high quality forecasts– such as high-resolution forecasts – to have very poor scores when evaluated by 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 and other approaches (e.g., distribution–based) that can provide more meaningful information – for forecast developers as well as forecast users – about forecast performance; and the development and application of methods (e.g., confidence intervals) to estimate the uncertainty associated with verification measures. 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.

FY2010 Accomplishments

Spatial verification method inter–comparison project

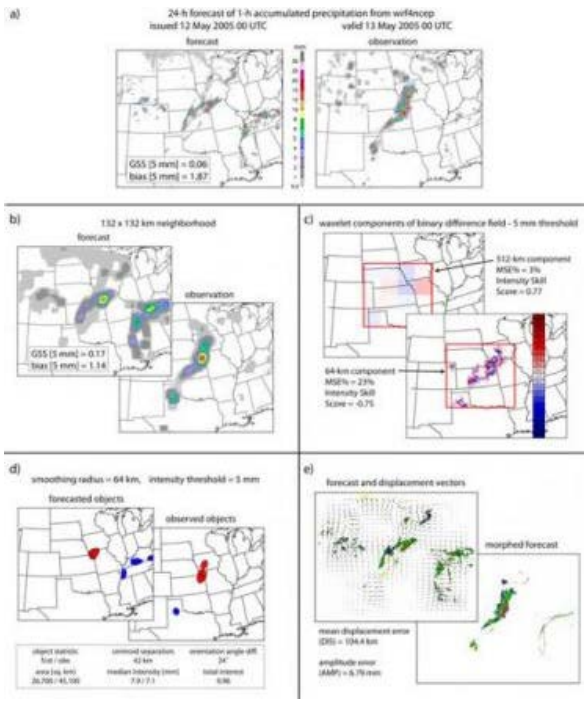

Figure 1: Third figure from the ICP BAMS article. Panel (a) shows the real ICP test case valid on 13 May 2005 at 00 UTC. Remaining panels demonstrate four categories of new methods applied to this case. Panel (b) shows upscaled versions of the fields from panel (a), where traditional scores are subsequently applied. This method belongs to the neighborhood category (a filtering approach), and the smoothing (in this case upscaling) is applied to multiple neighborhood sizes so that scales of useful skill can be established. Similar to panel (b), panel (c) shows a scale separation method (another class of filtering approaches), where a wavelet decomposition has been performed enabling one to look at possibly physically meaningful scales. Panels (d) and (e) demonstrate displacement methods (features-based and field deformation, resp.).

The Spatial Forecast Verification Methods Inter–Comparison Project (ICP; (http://www.ral.ucar.edu/projects/icp) was initiated in February 2007 to help clarify the capabilities, as well as similarities and differences of new approaches for verification and evaluation of spatial forecasts (e.g., for fields like precipitation that are characterized by identifiable coherent features). Many of the researchers who had proposed new methods have participated in the project and have applied their techniques to a common set of test cases. A special collection of papers for the *Weather and Forecasting* journal has come to its completion with all papers being published (predominantly in volume 24). One further piece of the collection will be published in the October issue of the *Bulletin of the AMS*. This last paper, and the collection to which it belongs, constitute the end of the first phase of the ICP, which focused on evaluating the methods on precipitation fields (Figure 1 summarizes the four categories of methods, and is used to help illustrate them in the BAMS article). Currently, we are in the process of finding alternative test cases for different types of fields. The continuation of the project will rely largely on continued voluntary participation by the community. This will be a challenge as many participants have moved on to other jobs and topics. However, some new researchers have joined the project, and as some of the techniques become available in MET, it will be more feasible for fewer researchers to apply them to new fields. Most participants who still plan to be involved have expressed desires to look into wind fields, so that is the primary avenue we are now exploring. Eric Gilleland (RAL), Barb Brown (RAL), and Beth Ebert (Bureau of Meteorology, Australia) jointly lead the project.

Method for Object–based Diagnostic Evaluation (MODE)

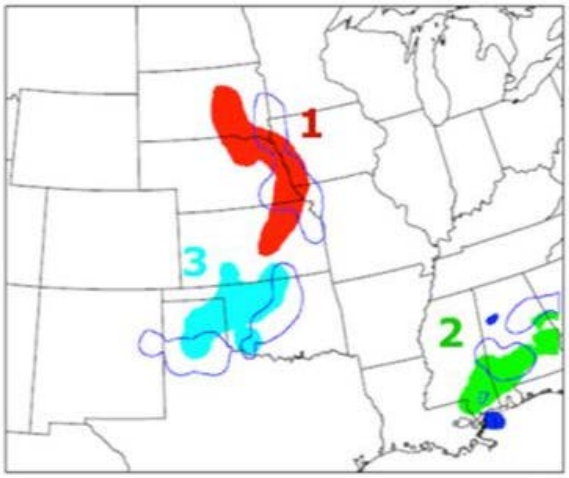

Figure 2: MODE applied to the ICP real test case valid 1 June 2005 at 00 UTC. Numbers and colors indicate identified features in the forecast field, and blue outlines represent corresponding features identified in the associated analysis field. Dark blue represents features in the forecast field that were not matched to any feature(s) in the analysis field.

One of the cornerstones of verification technique development in the RAL Verification Group is the Method for Object–based Diagnostic Evaluation (MODE). This object–based spatial verification method was one of the methods included in the ICP (see above). Development of MODE has been supported by the STEP project. Figure 2 shows an example of identified features from one of the ICP test cases.

The extension of object–based verification approaches is in progress and will continue into the next fiscal year. Fields other than precipitation have been examined with promising results. Atmospheric rivers, derived wind fields, radar reflectivity and echo top, and ensembles all appear to lend themselves to verification with object based methods. Further research will be completed to confirm these initial impressions. Extension of spatial methods to CloudSat vertical curtains is currently underway and will continue into the next fiscal year.

Model Evaluation Tools

Version 3.0 of the Model Evaluation Tools (MET) http://www.dtcenter.org/met/users/, developed by Developmental Testbed Center (DTC) staff in the JNT/RAL, was released to the community in September. This updated set of model evaluation tools includes traditional verification methods as well as new methods that have been developed for spatial forecasts. The new version includes methods for ensemble forecasts, new data formats, and cloud verification approaches. MET can now verify models from both of the model postprocessors, rather than just the wrfpost. A new ensemble tool can create ensemble mean or probability forecasts from a set of deterministic forecasts. Then appropriate statistics, such as rank histograms and ranked probability scores, can be used to verify these forecasts. Cloud verification is accommodated with both the implementation of new methods a new tool to handle cloud observation data. Multi-category contingency tables are now supported in MET, and allow users to verify several categories of cloud cover. Further, the world wide merged cloud analysis product (WWMCA), produced by the Air Force Weather Agency, can be read and plotted in MET. This allows our users to verify their forecasts with the WWMCA cloud observation product.

Image Warping for Forecast Verification

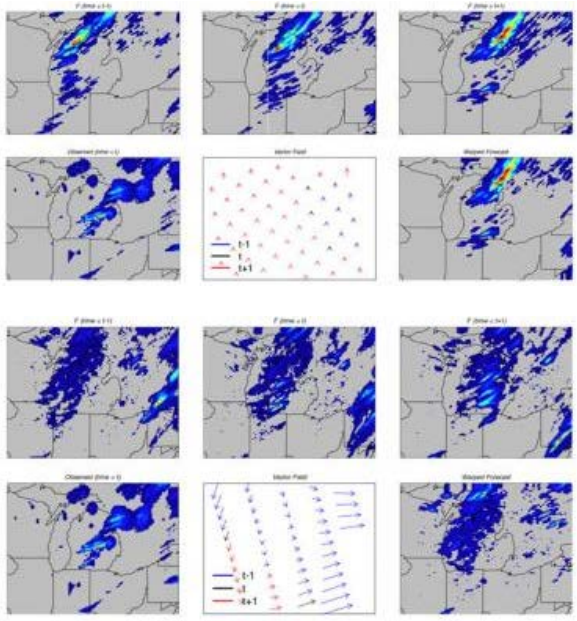

Figure 3: Space-time image warping applied to a case from the 2005 NSSL/SPC Spring Program. Stage II analysis for 26 April 2005 at 20 UTC is compared against NCAR (top six panels) and NCEP (bottom six panels) WRF forecasts valid at 19, 20 and 21 hours UTC on 26 April 2005 (all initialized at 00 UTC).

Where MODE is a features-based displacement method, image warping is a field deformation displacement method. Both approaches can give similar results, and it may prove useful to apply image warping to the individual features of MODE, or other features-based approaches. Each type of method has advantages and disadvantages. Image warping, and similar procedures, were among the first to be proposed for verification of spatial fields. However, these techniques were not widely picked up, perhaps largely because they were not very thoroughly investigated, and require a high amount of spin-up to perform. With help from Swedish collaborators, via a large travel grant from the Swedish Foundation for International Co- operation in Research and Higher Education (STINT), the image warping technique has been much more thoroughly studied. A recent paper (Gilleland, Lindström, and Lindgren, 2010, *Wea. Forecasting*, **25** (4): 1249—1262, henceforth, GLL) presents a fairly comprehensive investigation of the approach. Several main drawbacks of the early attempts were obviated in the study, including: (i) it was shown that it is not necessary to identify features to use as landmarks, or as in GLL control points, (ii) thin-plate splines used for the warping function enable efficiencies in code that allow one to make complex deformations in operationally suitable times, (ii) where many early papers merely suggested how one might go about the problem, GLL showed how to do it, and (iv) a new summary statistic that allows for comparison of multiple forecasts was proposed, and shown to work well with the ICP test cases.

Additionally, Eric Gilleland presented the problem of adding a temporal dimension to the spatial warp to determine the feasibility of distinguishing timing errors from displacement errors to a group of mathematics and statistics graduate students at the Statistical and Applied Mathematical Sciences Institute (SAMSI) Industrial Mathematical and Statistical Modeling workshop in Raleigh, North Carolina. In the course of ten days, the students were able to adapt the work of GLL to include the temporal dimension. While much work is still needed, they demonstrated that it can be done, and that it gives reasonable results. Figure 3 shows their early results for the great lakes region (see caption for details). The (grid-point to grid-point) RMSE applied to the forecasts valid at 20 hours UTC (i.e., valid for the same time as the Stage II analysis shown) is 2.67 and 2.24 for NCAR and NCEP WRF models, resp. After deformation, however, the RMSE's reduce to 0.73 and 1.51. This amounts to a reduction of 56.5% for NCAR's WRF model configuration for this case, and 32.4% for NCEP's. While it is not appropriate to go by the percent reduction alone, investigation of the deformation vector fields (lower middle panel in each set of six panels) indicates that considerably greater displacement energy is required for NCEP's model than NCAR's (for this case), and a much lower RMSE results. This is most likely because the NCEP model has a large bias of small intensity scatter here. This is only for a single instance of a small region, and should not be construed as a telling result generally for the two models. However, it demonstrates that the approach is potentially very powerful, and worth further study.

FY2011 Plans

The annual release of MET for 2011 will include enhanced cloud and ensemble verification methods. Capability to handle CloudSat observations will be made operational. Further research on appropriate methods for verifying wind forecasts and verifying forecasts through time will be conducted, and included into the software release if appropriate. The annual workshop will be conducted, and the recommendations relayed to the verification advisory group as guidance for future MET development.

MODE will be applied to CloudSat vertical slices, to determine if object based verification is appropriate. Further, the object time tracking extension to MODE will be made operational and released with the next version of MET. Experimental use of MODE on fields other than precipitation will continue.

We hope to determine some good test cases for the ICP that differ wildly from precipitation fields. Most likely, this will involve wind fields. The plan is to obtain some new test cases, and have participants apply their methods to them before the next International Verification Meeting (to be held in Australia in 2012), so that we can have the next ICP meeting as part of that meeting. This is because the better part of the international verification community will be in attendance, and much good input could be given.

Further work on the image warping technique will depend on several factors. One of the primary Swedish collaborators is once again able to work on this

project, so that will help greatly. At a minimum, we plan to write R code to do image warping so that it is more freely available to the community.

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Research Applications Laboratory | RAL
2010 ANNUAL REPORT

Data Assimilation Testbed Center

Background

The goals of the Data Assimilation Team (DAT) are to provide a pathway between data assimilation research and operational capability, a framework for distributed development of new capabilities & advances in data assimilation, an environment for the objective testing and evaluation of state-of-the-art data assimilation techniques, and a rational basis for enhancement of data assimilation techniques and systems and, eventually, numerical weather forecast systems for operational centers and the research community

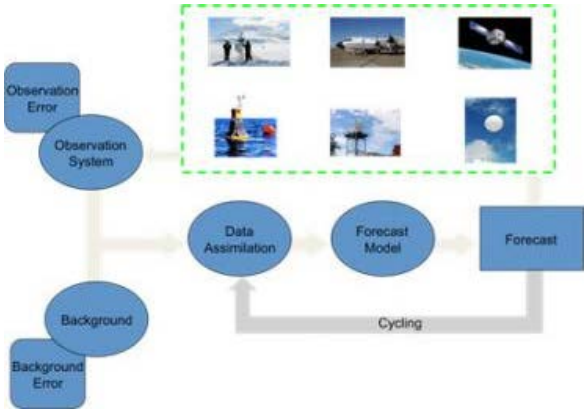
FY2010 Accomplishments

Community Support

The DAT currently maintains and supports a version of the Gridpoint Statistical Interpolation (GSI) 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, including the North American Mesoscale (NAM) Forecast System, the Global Forecast System (GFS), the Real-time Mesoscale Analysis (RTMA) System, and the Hurricane Weather Research and Forecasting Model (HWRF) at NOAA/NCEP, the Goddard GMAO Global Forecast System at NASA, the Rapid Refresh (RR) System at NOAA, and regional applications at the Air Force Weather Agency (AFWA). The DAT is working with these operational and research centers to coordinate the distributed development via a GSI Review Committee hosted by the DTC. The GSI Review Committee is the core of the GSI collaborative effort responsible for coordinating and code review of the GSI code. The first planning meeting for the committee was held in June 2010 and the first Review Committee meeting was held in September 2010.

The DAT has maintained and updated the Boulder community GSI repository, synced with the NCEP GSI developmental code, performed multiple platform tests, improved the code portability and developed utilities and tools for GSI applications and diagnostics. Working with the GSI developers, the DTC has provided user support to the research community since 2009, including annual public code and documentation releases, annual community GSI tutorials, online tutorials and documentation, and answering of users' questions via the GSI helpesk (gsi_help@ucar.edu). Currently, the testing and support of this GSI system by the DAT focuses on limited area numerical weather prediction (NWP) applications coupled with the Weather Research and Forecasting (WRF) Model. There are more than 200 users who have registered through the GSI website since last year. The DTC released version 2.0 of the GSI code in April 2010 and hosted the first Community GSI Tutorial in June 2010.

Testing and Evaluation



The Data Assimilation Team (DAT) assessed various data assimilation techniques and systems in regional applications within an end-to-end system.

The DAT continued to assess various data assimilation techniques and systems in regional applications. Such tests were performed within an end-to-end system (Fig. 1) in a near operational environment, including data pre-processing, data assimilation, forecasting and data-post processing. Some of the activities that were undertaken include the following:

Collaborating with NCAR/MMM, the DAT tested a three-dimension variational (3D-Var) data assimilation system and an ensemble data assimilation

system with a focus on surface observation assimilations. The conventional observations and the surface observations from the National Weather Service (NWS) surface network were assimilated using the WRF 3D-Var (WRF–Var) system and the NCAR Data Assimilation Research Testbed (DART) ensemble system at high resolution over a month–long period for winter and summer. The results generated by the two systems were evaluated and reported to the AFWA.

The DAT performed configuration tests and observation impact studies using two different versions of the GSI code, including the community release version 2.0 and the latest GSI developmental version. The latter one is the candidate code for the next global data assimilation system update in Spring 2011 at NOAA. The experiments are being conducted in a Caribbean domain for the period of August 15 – September 15, 2007. The capability and robustness of the WRF–ARW and GSI system in regional applications with different configurations and the forecast impacts of the radiance data, surface data, and Global Positioning System (GPS) radio-occultation observations were evaluated. The impact of the background errors on the data analysis and forecasts were also tested.

FY2011 Plans

The DAT will continue to work with other partners on providing community support for data assimilation systems and techniques. The DAT will also continue to conduct test and evaluation (T&E) activities to assess the latest development of the data assimilation systems and techniques and evaluate observation impacts on short-range weather forecasts.

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Tropical Cyclone Modeling Team

Background

The focus of the Tropical Cyclone Modeling Testbed (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) which works to improve the accuracy and reliability of hurricane forecasts; to extend 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 model systems, and expanded forecast applications based on the high resolution and ensemble-based numerical prediction systems. HFIP's modeling efforts are organized into three development paths. Stream 1 refers to the yearly upgrades made to operational numerical weather prediction capabilities, Stream 2 refers to efforts taking multiple years to enhance operations, and Stream 1.5 refers to improved models and/or techniques that the National Hurricane Center, based on prior assessments, wants to access in real-time during a particular hurricane season that cannot be made available by the operational modeling centers in conventional production mode. Each hurricane season, HFIP conducts an experiment, referred to as the Demonstration (Demo) System, which attempts to demonstrate model capabilities that go well beyond the current capability of the operational global and regional models.

FY 2010 Accomplishments

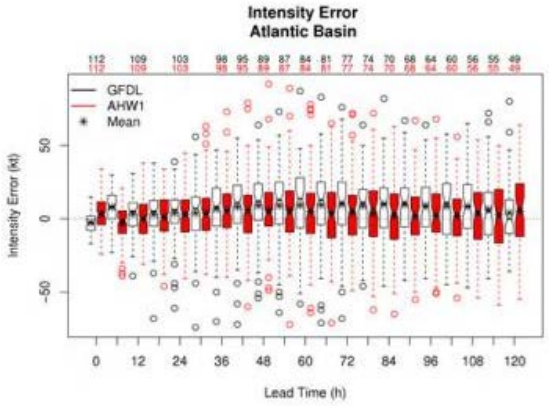

Figure 1: Intensity error distributions with respect to lead time for operational GFDL and AHW for 2008 and 2009 retrospective Atlantic Basin cases over land and water.

During 2010, the TCMT contributed to HFIP by evaluating experimental models run during the HFIP 2009 Demo (http://www.ral.ucar.edu/projects/hfip/d2009/); contributing to retrospective test plans and evaluating retrospective forecasts provided by Stream 1.5 candidates (http://www.ral.ucar.edu/projects/hfip/h2010/); collecting data from modeling groups participating in the HFIP 2010 Demo (http://www.ral.ucar.edu/projects/hfip/d2010/); developing a prototype data service; and investigating the application of ensemble verification methods to tropical cyclones. The model evaluations undertaken by the TCMT employ standard statistical techniques to assess the performance of each model with respect track and intensity. The team employs methods that require a homogeneous sample, assessment of statistical significance and pair-wise differences when appropriate, and the overall distribution of the errors, rather than simply considering the mean or median of the distributions. The TCMT's evaluation of the Stream 1.5 candidates led to the selection of two experimental model configurations for Stream 1.5 status during the HFIP 2010 Demo: an experimental version of GFDL hurricane model and a configuration of the Advanced Hurricane WRF (AHW). Figure 1 shows one of the error distributions produced for the retrospective forecasts submitted for evaluation.

All data files collected for the annual HFIP Demos and the retrospective tests will be made available to the HFIP community via the TCMT's web-based data service. These data, which include both ASCII files containing basic storm parameters and GRIB files containing gridded data, will be used for diagnostic studies directed at determining the source of errors in the numerical models, which in turn, should lead to improvements in the operational numerical guidance.

FY2011 Plans

In 2011, tropical cyclone track and intensity forecasts collected during the HFIP 2010 Demo will be evaluated using consistent tools and approaches for all models, as well as the retrospective forecasts provided by Stream 1.5 candidates for the 2011 Demo. Statistical approaches will also be developed and implemented for the evaluation of other relevant attributes of tropical cyclone forecasts. The development of the HFIP data service will continue with the expansion of other features such as interactive visualization for quick-look browsing.

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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**
- **Coupled Surface Hydrometeorological Processes and Regional Climate**
- **Aerosols and Precipitation**
- **Winter Weather**
- **Colorado Headwaters Project**
- **Water Resources and Climate**

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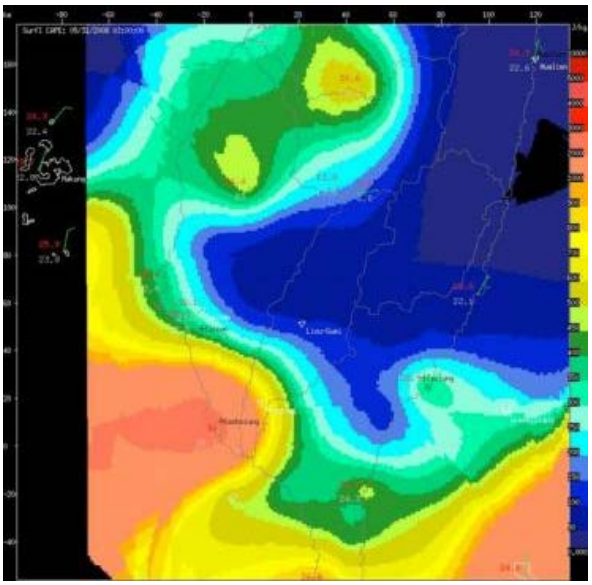
Short-Term Explicit Prediction (STEP) Program

Background

The Short Term Explicit Prediction (STEP) program (**http://www.mmm.ucar.edu/STEP**) is an NCAR multi–NCAR Laboratory activity to improve the short–term forecasting of high–impact weather such as severe thunderstorms and hurricanes. The STEP program is being stimulated by significant scientific advancements in the ability to observe the four–dimensional structure of the atmosphere, the development of new data assimilation techniques, and the continuing development of numerical modeling systems and automated nowcasting systems. STEP includes research into basic understanding of high–impact weather systems, development of forecast techniques, real–time testing of forecast systems, verification, and interaction with users. This collaborative effort includes national and international scientists, engineers, and operational personnel from universities, government institutions and the private sector.

In the FY10 and FY11 funding cycle, RAL was awarded six projects out of the total of 11 funded proposals. These RAL projects were primarily focused on the study of terrain-induced precipitation using TiMREX data over Taiwan and radar data over the Rocky Mountain Front Range. The RAL effort includes observation analysis, nowcasting development, data assimilation, modeling, and verification. The major accomplishments from these RAL projects are summarized below.

Nowcasting Convective Precipitation over Complex Terrain



Taiwan is extremely vulnerable to flash floods resulting from heavy rain produced by local thunderstorms and by a spectrum of large-scale synoptically forced weather. Taiwan Central Weather Bureau (CWB) forecasters are being tasked in the coming years to issue frequently updated, short-term forecasts of heavy precipitation. The Terrain-influenced Monsoon Rainfall Experiment (TiMREX) conducted in 2008 during Taiwan's warm season gathered high resolution dual-polarization radar, surface, sounding and special vertical profiling measurements prior to and during heavy rainfall events. These high resolution observations are being used to examine storm formation and evolution, identify critical nowcast predictor fields, and develop real-time applications for nowcasting heavy rainfall over complex terrain. Until the NWP models can provide specific, highly reliable, accurate forecasts of precipitation occurrence on 1-5 km scale and on the 0-2 hr nowcast timescale, the approach taken here is to use a heuristic nowcast system that employs fuzzy logic to combine all available observations with selected numerical model output fields and high resolution wind and thermodynamic fields from the 4D-Variational Doppler Radar Analysis System (VDRAS) to provide location-specific forecasts of heavy rain. Preliminary efforts are underway to identify predictor fields for the Taiwan heavy rainfall nowcasting system.

Two applications are being tested for their applicability in detecting changes in atmospheric stability over time and producing more frequently updated fields in comparison to what is currently available from the NWP models. First, CAPE and CIN fields are now being generated within VDRAS. The

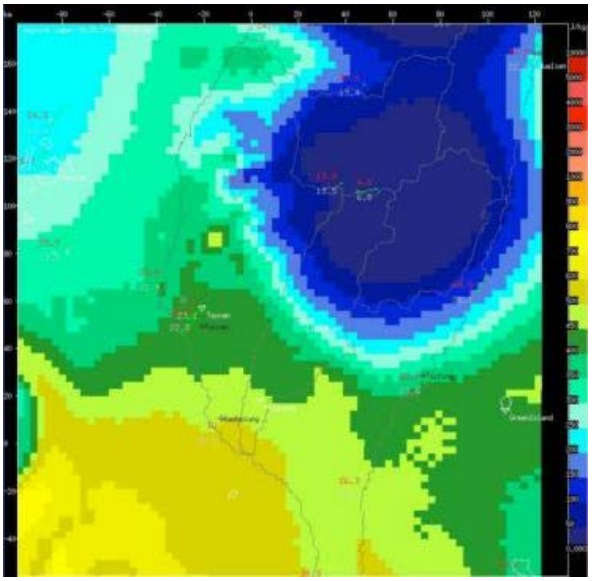


Figure 1. CAPE fields for 31 May 2008 at 0300 UTC (1100 LT) over southern Taiwan. Left panel: CAPE produced from the metarCapeCin algorithm. Right panel: CAPE produced from VDRAS.

second application is a software algorithm called metarCapeCin that uses hourly surface station data to update the surface temperature and dewpoint values in the sounding that were launched every 3 h during TiMREX. The algorithm then makes new calculations of CAPE and CIN and produces hourly, gridded fields of CAPE and CIN over the Taiwan domain. CAPE and CIN fields produced by VDRAS and metarCapeCin are shown in Fig. 1 at 0300 UTC (1100 LT). The overall pattern of the instability is similar between the two sets of fields. The regions of larger instability are concentrated mostly in southern Taiwan along the west and east coasts where there is plenty of available moisture at all levels (e.g. at Tainan). The magnitudes of CAPE from the metarCapeCin algorithm are higher than the VDRAS CAPE values and correspond to the magnitudes computed for the unmodified 3 hr soundings.

The lack of observations over the complex terrain (i.e, the Central Mountain Range that runs N-S through Taiwan) is problematic for both stability field applications and for the NWP-derived CAPE field as well. A surface station analysis algorithm called SERP is being run on the TiMREX data that has been designed specifically for interpolating surface station data (in regions of complex terrain) directly to the grid points to retain the specific attributes of the atmosphere in those regions in contrast to the smoothed values that are produced with a Barnes analysis interpolation. It is envisioned that analyses from SERP will provide more representative information for use in downstream algorithms like VDRAS and metarCapeCin. Preliminary examination shows that the SERP algorithm more accurately represents the extreme values often observed over the higher terrain of Taiwan. Also, mesoscale features that are lost due to smoothing in the Barnes analysis are retained in the SERP output. Lastly, circular artifacts in the Barnes analysis, a result of using a fixed radius of influence, are not present in the SERP output.

Observation analysis study is also been pursued to better understand terrain-induced precipitation processes. Twenty non-synoptically forced days with convective storms during TiMREX have been identified. For each of these days the S-Pol data are being examined for the initiation time and location of cells exceeding 35 dBZ. The 3D wind velocity as observed by the radiosondes, profiler and surface stations is being examined for correlations with the storm initiation locations.

Low-Level Wind Analysis over Complex Terrain using Radar Data, Surface Data, and Numerical Model Data

Wind direction relative to mountain slope plays a critical role in predicting terrain-induced precipitation. In order to provide better low-level wind for ANC, VDRAS was implemented at CWB of Taiwan to obtain more accurate low-level wind analysis for improved nowcasting of convection over the complex terrain in Taiwan. Preliminary case studies using TiMREX data demonstrated that VDRAS was able to analyze the southwesterly flow more accurately than mesoscale models, which is often a precursor for geographical precipitation forecast in southern Taiwan. Data impact study was conducted by comparing analysis with and without the NCAR's S-Pol radar to examine whether the current CWB radar network is sufficient for capturing the southwesterly flow that impinges the mountain slope. The results indicate that observations from NCAR's S-Pol had a significant influence on successfully analyzing the southwesterly flow due to the location of the radar and its better clear-air observation capability.

Evaluation of Nowcasting Performance during the Beijing 2008 FDP

A paper discussing the accuracy of nowcasts made during the Beijing 2008 Forecast Demonstration Project (FDP) (which included the period of the 2008 Olympic Summer Games) has been accepted for publication in *Weather and Forecasting*. Twelve nowcast systems were available from China, Australia, Canada and the U.S.. The nowcasting systems were a mix of radar echo extrapolation

methods, numerical models (three used 3DVAR) , techniques that blended numerical model and extrapolation methods and systems incorporating forecaster input.

The skill of the numerical models were inconsistent from hour-to-hour and day-to-day and it was speculated that without assimilation of real-time radar reflectivity and Doppler velocity fields to support model initialization, particularly for weakly forced convective events, it will be very difficult for models to provide accurate forecasts on the nowcasting time and space scales. Automated blending techniques tended to be no more skillful then extrapolation since they depended heavily on models to provide storm initiation, growth and dissipation. However, even with the cited limitations among individual nowcasting systems, the Chinese Olympic forecasters considered the B08FDP human consensus forecasts to be accurate and useful. Key to the success of the human forecasts was the development of nowcasting rules predicated on the character of Beijing convective weather realized over the previous two summers.

Impacts of land–surface/atmospheric interactions on summer convection

The land surface modeling work led by Fei Chen examined effects of surface and PBL (Planetary Boundary Layer) processes on warm season precipitation and their impacts on WRF precipitation forecasts. The primary focus during FY10 is on the effects of surface exchange processes including the detailed specification of vegetation in WRF and land–atmospheric coupling strength on 0-24 h prediction of convective precipitation during the 10–16 June STEP IHOP retrospective period. Model simulations reveals that the timing of convection initiation and QPF amounts are sensitive to the land–atmospheric coupling, especially to the surface coupling strength. For instance, the WRF simulation with strong surface coupling overforecast the spatial extent of a heavy precipitation event occurred on 11 June 2002, which resultes in a lower late afternoon and evening (t = 12 – 16 h) precipitation-forecast skill (Fig. 2).

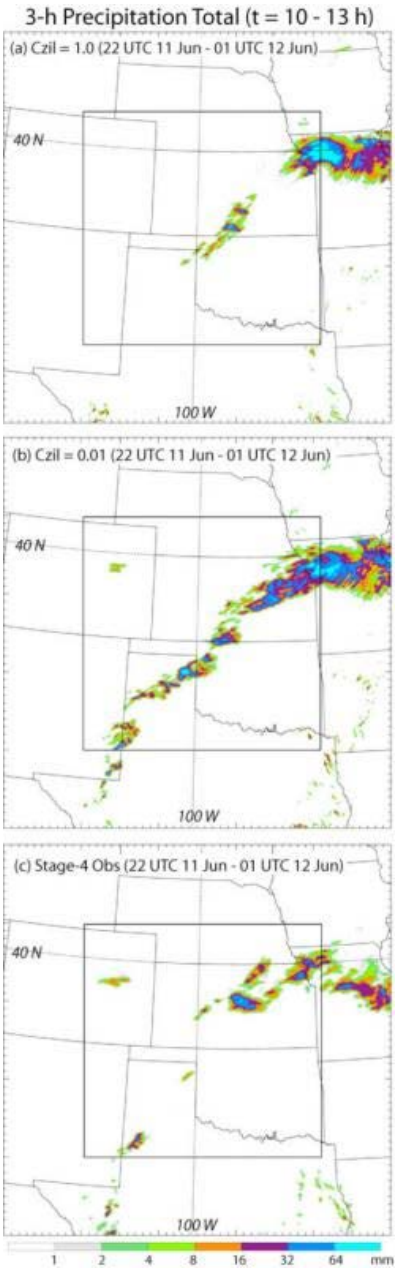


Fig. 2. Three-hour precipitation amounts for WRF simulations with (a) weak and (b) strong surface exchange during t = 10-13 h , and (c) observed (Stage-4) precipitation amounts for the same period. From Trier et al. 2010 (Wea. & Forecasting).

For FY11, we will continue this work to extend this modeling work to the BAMEX_2003 field observation period and to specifically focus on how the surface exchange processes and related daytime PBL evolution would affect the transition from daytime surface based to elevated nocturnal convection.

Improving and verifying model microphysics with observations

This work is motivated by Weather Research and Forecasting Research Applications Board recommendations calling for the development of multi-species microphysics schemes with accurate particle size distribution models and/or multiple moment schemes that are refined and verified with observations. Polarimetric radar and disdrometer measurements are being used to examine particle size distributions, rain rates, freezing-level heights, and hydrometeor types (e.g., hail location/size) in a

summertime convective squall line (Fig. 3).

Disdrometer measurements from two two-dimensional video disdrometers have been analyzed for this squall line, including the determination of DSD parameters, rain rates, and liquid water contents. Three-dimensional idealized WRF simulations of this squall line case have also been run using both the Morrison and Thompson microphysical schemes. Polarimetric radar data from the KOUN radar is currently being processed for this case, and thus analysis is currently underway to compare these simulation results with the radar and disdrometer observations.

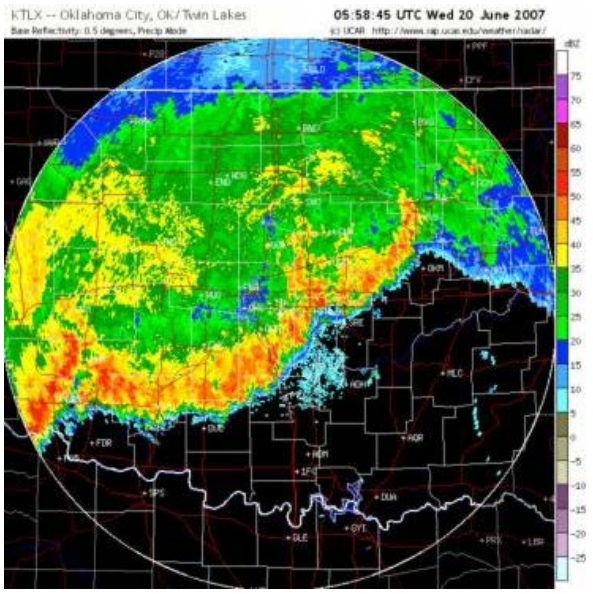


Figure 3. NEXRAD radar reflectivity image from 20 June 2007.

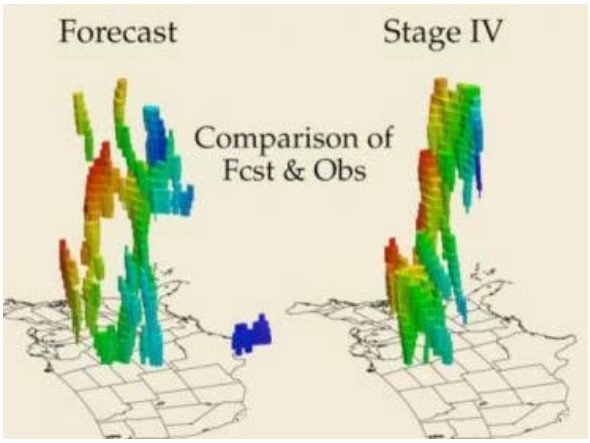
Method for Object-Based Verification (MODE)

In 2010 MODE was extended to apply to a number of types of variables in addition to precipitation. For example, MODE has been applied to variables related to winds (e.g., convergence, vorticity, speed). MODE also has been applied to several different cloud variables, including the World Wide Merged Cloud Analysis (WWMCA).

Evaluation of temporal errors in the development and movement of convective systems is a high priority for nowcasting researchers; thus, much of the MODE development over the last year continued to focus on development of the time domain version of MODE (MTD). Significant progress was made in this effort, and the time-domain capability is on schedule to be incorporated in a future version of the Model Evaluation Tools (MET) verification software package. Several new behaviors of the MODE object detection and resolution techniques are apparent when one of the dimensions is non-spatial, and making sense of these behaviors has required some research and investigation. For example, in addition to the object matching and merging steps included in the traditional MODE application, object partitioning and reassembly are new aspects of the MODE application, which require additional fuzzy logic engines. These new requirements create new complexities, which are difficult to resolve satisfactorily; methods for coping with these aspects of MTD are still being investigated. Image analysis algorithms and their generalization to three dimensions have been evaluated and will contribute to solving the problems associated with these new methods. The results will be shown at the upcoming AMS conference in January 2011.

Application of MODE to data from the Beijing Olympics and to hurricane precipitation data were also considered. Other forms of satellite data were investigated for use with a vertical swath version of MODE. These efforts leverage data and funding from other projects. Some of the results of these efforts will be presented at the next AMS conference.

World Weather Mesoscale Cloud Analysis cloud data mapped over the Earth.



Comparison of forecast and observation objects using the Time Domain version of MODE

FY2011 Plans

- The effort to improve understanding and forecasting of orographical convection will continue with data collected during TiMREX used to further study the life cycle and characteristics of terrain–induced convection. The Rocky Mountain Front–Range will be another focus region for the study.
- Three WRF–ARW data assimilation systems including 3DVar, RTFDDA (Real–Time Four–Dimensional Data Assimilation and Forecasting), and WRF/DART (Data Assimilation Research Testbed) will be demonstrated using data collected in the region.
- The TiMREX data will also be used for the further development of NCAR's Auto–Nowcasting system.
- Another focus in FY11 will be elevated convection and the transition between elevated convection and surface-based convection.
- For the microphysics study, the emphasis will be on the implementation of new observation–based parameterization schemes within WRF–ARW. Model simulated microphysics will be compared with observations to develop relations of particle size distribution.
- Development of MODE-TD will continue and the tool will be utilized to evaluate new datasets. MODE will be applied to other STEP datasets in collaboration with other STEP researchers.

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Coupled Surface Meteorological Processes and Regional Climate

Background

RAL scientists are involved in a variety of projects related to hydrometeorological processes at the land–atmosphere interface including evapotranspiration, runoff (flash floods and river discharge), infiltration, snowmelt and soil moisture. With collaborators from the university and federal agency communities, RAL scientists lead and participate in field observational studies as well as model development and model assessment activities. The major goal of these efforts is to improve our understanding and predictive capabilities of land–atmospheric interactions spanning a variety of time and space scales (weather to climate). Field research activities broadly center on improving understanding and prediction of the factors controlling land-atmosphere exchanges with increasing emphases on complex terrain, forested and seasonally snow-covered regions. Model activities include development of the community Noah land–surface model and coupled WRF/Noah regional climate models, development of probabilistic precipitation estimates and forecasts, and deployment of multi-model, or 'ensemble' prediction systems.

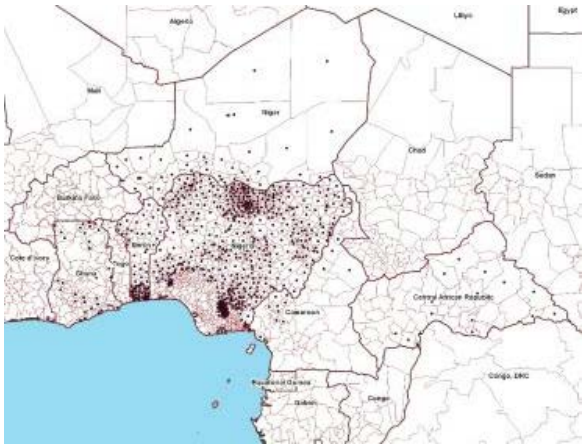

Figure 1. World Health Organization (WHO) districts for which we have meningitis reports allowing us to develop a disease forecasting model relying on weather forecast information (polygons with dots); from this model, we plan on providing meningitis outbreak forecasts for the majority of districts shown (polygons).

Current field research projects being conducted by RAL scientists include boundary layer evolution studies over the Rocky Mountain foothill regions, precipitation hydrometeor characterization studies for quantitative precipitation estimation (QPE), studies on the impacts of insect-driven forest mortality on land-atmosphere exchanges of energy, water and volatile organic compounds (VOCs), and snow energy-water balance studies.

Model development and evaluation studies engage a broader suite of topics including flash flood prediction, research on the North American Monsoon climate system, investigating land–atmospheric feedback in semi–arid regions in the US and China, ten–year reanalysis of land–surface component for arctic region, medium range and climate forecasting applications in Bangladesh and California, enhancement of land surface models (Noah and CLM) for disturbed (fire and beetle infestation) land surfaces, and improving the Water Evaluation And Planning (WEAP) model used by water managers to assess the impact of future climate predicted precipitation on the operation of reservoirs, diversions, power production and irrigation.

Key tools for these process and prediction studies include radars, satellites, surface observational networks, the WRF mesoscale model with the Noah land surface model for both weather and regional climate, ensemble forecast systems, a distributed version of the Noah land surface model that allows for overland, channel and subsurface flows, and the WEAP water evaluation and planning tool. The community models, including the Noah-distributed and WRF/Noah regional climate models continue to serve as frameworks from which increasingly deep interactions with the hydrological community occurs. Each of the activities in which RAL scientists engage is aimed at advancing the science of coupled land-atmosphere exchange processes while also helping forecasting agencies, water managers and the emergency response sectors to more effectively plan for and mitigate high impact weather and climate events.

FY2009-2010 Accomplishments

- Updated the time-varying albedo characteristics of snowpack in the Noah land surface model
- Improved the estimation of the surface exchange coefficient in Noah
- Expanded functionality of the Noah-distributed model for coupled, regional climate-hydrology applications
- Conducted climate change impacts studies for the Colorado Front Range, State of California, and the country of

Peru with WEAP
- Collected and quality-controlled boundary layer/land-surface/hydrometorological data from non-infested/beetle-infested and non-burned/burned forests
- Collected and quality controlled spatially-distributed rainfall and hydrometeor data across the Colorado Front Range in support of dual polarimetric radar QPE validation and nowcasting studies
- Continued improvements of operational real-time calibration of NWP ensemble forecasts of weather variables over Dugway Proving Grounds
- Quantified important errors in numerical approximations effecting multi-facted aspects of hydrological model behavior and accuracy
- Initiated implementation of a post-processing algorithm for calibrating NWP wind speed over wind farms of the Xcel wind energy project
- Produced operational flood forecasts for the Brahmaputra and Ganges Rivers as they enter into Bangladesh, and forecasts of the Surma and Meghna Rivers in the Northeast Highlands region of this country
- Designed a framework for quantifying contributions of multi-physics parameterizations in hydrological models
- Initiated new deployment of the coupled WRF/Noah-distributed model in continuously-running regional climate mode over the northern Alps region of Bavaria, Germany

FY2010-2011 Plans

- Develop an operational meningitis vaccine decision support tool utilizing ensemble weather forecast information for susceptible, developing regions of Africa (Figure 1)
- Complete development of a set of observational-based Noah model land surface parameters for beetle-infested and burned areas
- Develop and evaluate a new version of the Noah-Multi-Physics (Noah-MP) land surface model
- Intercompare the performance of four land-surface models (Noah-CLM, LEAF, Noah-MP) over the Colorado Headwater region
- Contrast impacts of land-atmosphere interactions on precipitation in IHOP-02 with those of the BAMEX-04 field campaigns
- Continue to make improvements of flood forecasting algorithms utilizing Thorpex-Tigge forecast data and possible new regional applications
- Develop improving post-processing algorithms and applications, including the CBRFC
- Complete testing and evaluation of dual-polarimtric radar-based precipitation and flash flood nowcasting system for the Colorado Front Range (Figure 2)
- Initiate new intra-seasonal forecasting project aimed at quantifying the impacts of land surface forcing on warm-season medium range precipitation forecasts in the southwest U.S. and northwest Mexico
- Complete a climate change impacts study for Peruvian water development project
- Expand observational and modeling activities into snowpack energy-water exchange studies in forested and un-forested environments

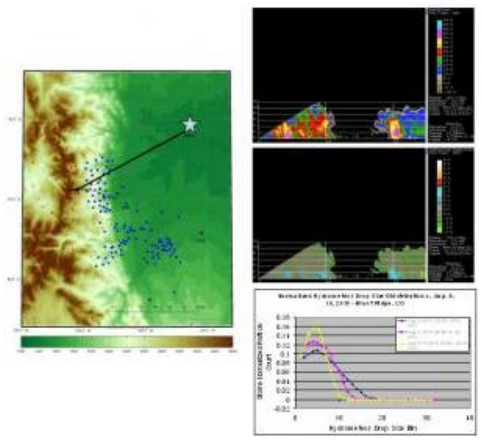

Figure 2. Map on left shows the location of the Col. State CHILL radar (blue star) and the ground observing network of rain gauges (blue and red squares) and other intensive ground observing sites. Panels on right show range-height indicator (RHI) plots of radar reflectivity (top), differential reflectivity (middle) and surface disdrometer measured hydrometeor drop size distributions (bottom) for a heavy rainfall event observed at the Niwot Ridge study site on Aug. 9, 2010.

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Aerosols and Precipitation

Background

The growing scarcity of fresh water has prompted governments around the world to consider the possibility of augmenting rainfall by cloud seeding. The potential for man-made increases in rainfall is strongly dependent on the natural microphysics (i.e., the size and concentration of water droplets and ice particles inside clouds) and dynamics (i.e., the forces affecting air motions in and around the clouds) of the clouds to be seeded. The microphysics are in turn dependent on background aerosol levels, because it is the aerosol particles that attract water vapor to form cloud droplets, and in cold clouds, ice particles. Furthermore, the types and concentrations of aerosol particles can be influenced by trace gases (i.e., air pollution). Given these dependencies, the microphysics of clouds can differ significantly from one geographical region to another, and even between seasons in the same region. In some instances, clouds may not be suitable for seeding, or the frequency of occurrence of suitable clouds may be too low to warrant the investment in a cloud seeding program.

Sound scientific studies on atmospheric aerosols, pollution levels, and cloud microphysics and dynamics in a given area should therefore be undertaken before cloud seeding efforts begin. RAL scientists have been conducting such studies around the world for the last fifteen years. Current efforts are focused in Queensland, Australia; the Kingdom of Saudi Arabia; the U.S. and Latin America. A program to determine whether winter seeding can increase snowfall in the mountains of Wyoming is described in the "Winter Weather" section of this Annual Report.

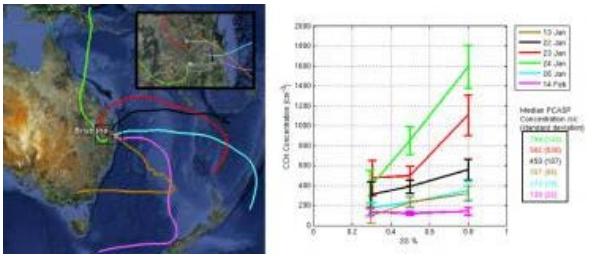


Figure 1. Map of 120 hour HYSPLIT back trajectories (left) for each of the six aerosol filter sampling days (Jan 13, 22, 23, 24, 26, and Feb 14) and associated color-coded CCN concentration measurements at three supersaturations (0.3, 0.5, 0.8%) with whiskers indicating plus/minus one standard deviation for each filter sampling measurement (right; see legend). The median (and standard deviation in parentheses) PCASP aerosol concentration for each filter sampling measurement are also noted by color for each day.

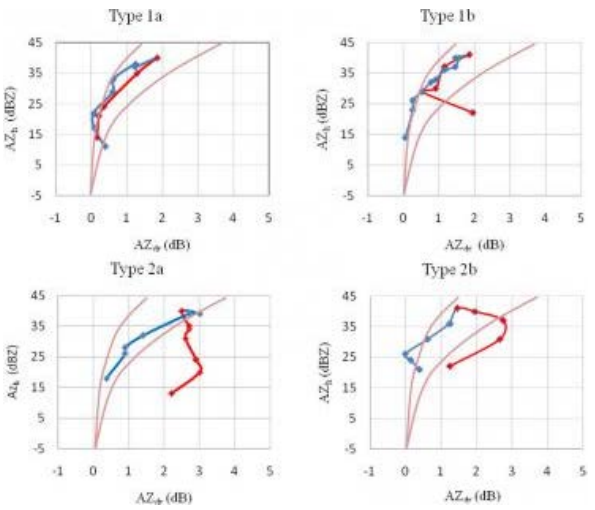


Figure 2. Examples of four types of rain drop size evolution observed in Queensland with the CP2 dual-polarization radar. The data in these figures show the time evolution of area reflectivity (AZ_h) versus area differential reflectivity (AZ_{dr}) for sweeps at approximately 1.5 km MSL, which roughly equals 0.5 to 1 km above cloud base. The line connecting the individual points shows time evolution in a given cloud, with red colors the growing phase and blue the dissipation.

Queensland Program

From 2007-2009 RAL led a cloud seeding research program field campaign in southeast Queensland, Australia. During this time, field measurements from two wet seasons were collected, utilizing dual-polarization and dual-Doppler radar and in situ microphysical (aircraft-borne) observational platforms. A randomized hygroscopic cloud seeding experiment was also conducted.

FY2010 Accomplishments

In 2010, the final report was submitted to the program sponsor and analyses from the program were submitted for publication in the form of several research and conference paper (Tessendorf et al.

2010a, Tessendorf et al. 2010b, Tessendorf et al. 2010c, and Wilson et al. 2010). The statistical randomized seeding results indicated that clouds seeded with hygroscopic flares typically were longer in duration, although the sample size of the randomized experiment was still too small to make robust claims. Other analysis efforts aimed to understand the *physical* effects of aerosol and cloud seeding on precipitation. These studies showed that there was considerable natural variability in southeast Queensland clouds and this natural variability must first be understood before any further studies on the effects of cloud seeding could be done. Thus, analyses were performed to characterize the natural variability, and included characterizing the synoptic weather regimes as related to rainfall production, aerosol regimes that may influence cloud microphysics, and rain formation processes as observed by dual-polarization radar.

Examples of the variability of aerosol and cloud condensation nuclei (CCN) measurements are shown in Figure 1, along with back trajectories from each measurement. The aerosol and CCN measurements were characterized based on these back trajectories; measurements with lower aerosol and CCN concentrations typically originated in air masses over the ocean (referred to as the maritime regime), while the highest aerosol concentrations came from trajectories that spent a lot of time over land (continental regime). Various raindrop size evolution types were also observed with dual-polarization radar (Fig. 2). These raindrop size evolution types also tended to correspond with the maritime or continental regime characterization (Type 1's were maritime and Type 2's continental; not shown). These results suggest that rain formation processes in Queensland are impacted by the varying air mass influences experienced in the coastal region, and that this needs to be taken into account in cloud seeding feasibility studies.

At this time, there are no plans to continue the program.

Citations:

Tessendorf, S.A., R.Bruintjes, C. Weeks, M. Dixon, M. Pocernich, J. Wilson, R. Roberts, E. Brandes, K. Ikeda, C. Knight, L. Wilson, J. Peter, N. Torosin, 2010a: Overview of the Queensland cloud seeding research program. *J. Wea. Modification,* **42**, 33–48.

Tessendorf, S.A., and co-authors, 2010b: The Queensland Cloud Seeding Research Program. *Bull. Amer. Meteor. Soc.,* in review.

Tessendorf, S.A., C. Weeks, D. R. T. Bruintjes, D. and Axisa, 2010c: Aerosol characteristics observed in southeast Queensland and implications for cloud microphysics. Proceedings 13th Conference on Cloud Physics, JP3.7, Amer. Meteor. Soc., Portland, OR.

Wilson, J.W., C. Knight, S.A. Tessendorf, and C. Weeks, 2010: Polarimetric radar analysis of rain drop size variability in maritime and continental clouds. *J. Appl. Meteor. Clim*., in review.

Saudi Arabia -- Assessment of Rainfall Augmentation

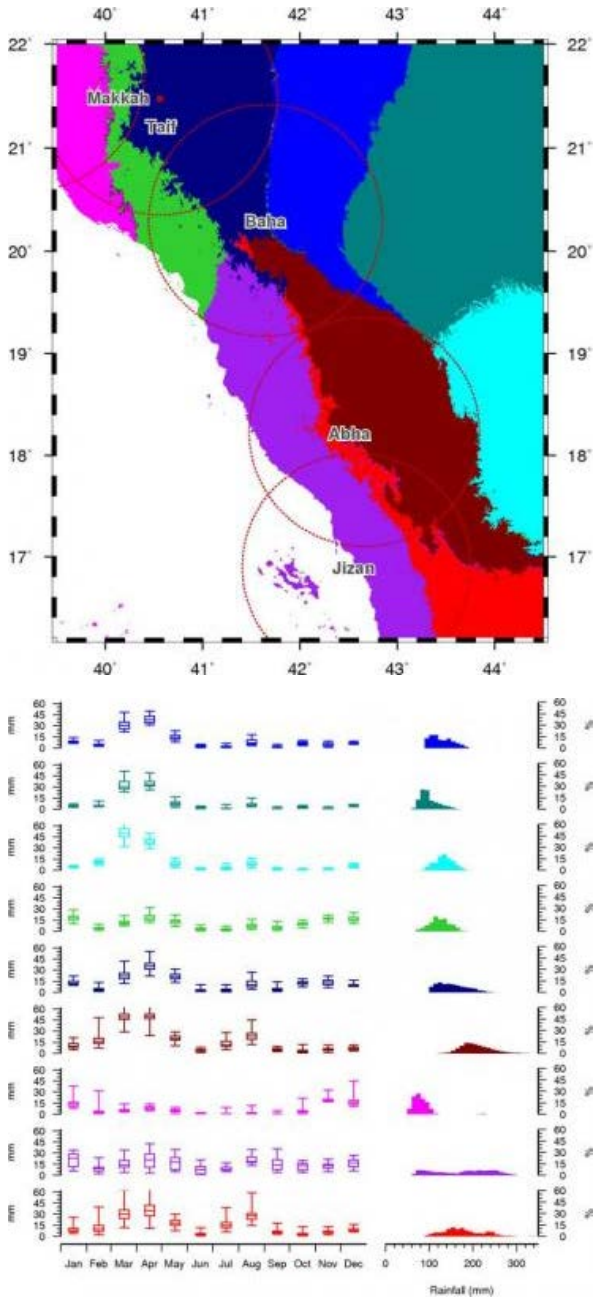


Fig 3: Results of precipitation regional analysis in the southwest region of Saudi Arabia. Panel (a) shows the spatial distribution of the nine regions identified in the analysis. Panel (b) shows the seasonal distribution of rainfall based on the categorization.

http://www.ral.ucar.edu/projects/saudi/

During the summers of 2008 and 2009, RAL scientists conducted a rainfall assessment program in the southwest region of Saudi Arabia. Data was collected from both radars and intensive airborne observations. The goal of the study was to examine summertime convection over the mountainous region (often referred to as the "escarpment") that is adjacent to the Red Sea. The escarpment provides a focus for orographic precipitation as a result of complex interactions with the sea breeze and upper level thermodynamics.

FY2010 Accomplishments

Analyses of the data are on-going. An interesting result of the study shows seasonal precipitation has two distinct peaks in this region: March-April and August. Figure 3 shows our regional analysis of the different precipitation zones. The regions near or on top of the escarpment clearly show two distinct precipitation peaks. Evaluation of radar observations during these two peaks indicates the area has distinct characteristics in terms of the diurnal cycle and cell structure. Climatological evaluation indicates there are several distinct precipitation zones in the southwest region. We observe a large annual variability in precipitation in the southwest region of Saudi Arabia. Figure 4 shows analysis of the diurnal cycle for the three different seasons. The results indicate large variability between years for a given season and between seasons (e.g., spring and summer).

Based on our analysis, we have developed a conceptual model that summarizes the mechanisms for summer precipitation formation in the southwest region. Observations indicate that convective cells tend to be short-lived with complicated microphysics; the presence and concentration of large cloud droplets suggest that GCCN broaden the cloud droplet spectrum; and ice-phase microphysics is important and seems to be efficient. Figure 5 shows an illustration of the conceptual model design based on the two years of field observations.

FY2011 Plans

Future field work will include the design of a randomized cloud seeding experiment to help determine and quantify seeding effects along the escarpment. The randomized program would include airborne studies to examine the precipitation growth processes in both seeded and unseeded clouds. All the cloud and precipitation studies would be supported by aerosol properties and atmospheric

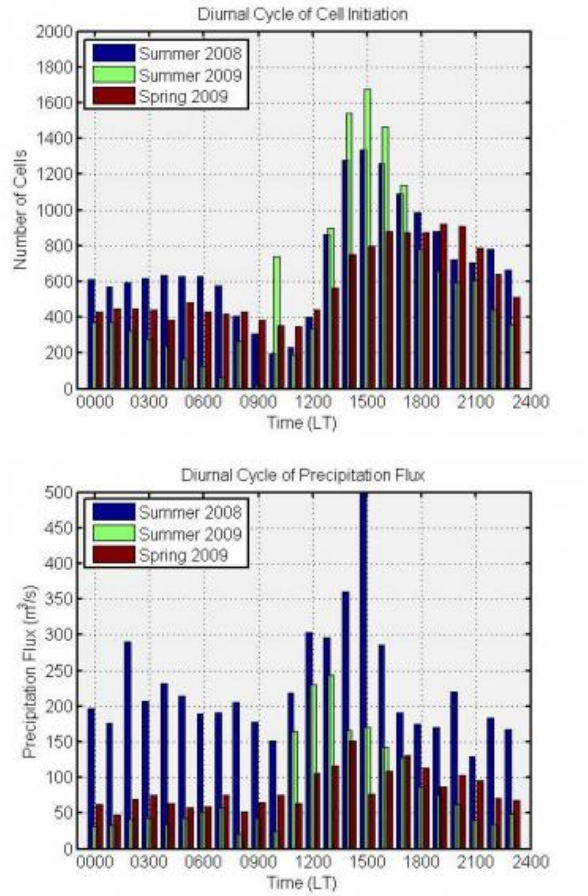


Fig. 4: Diurnal cycle of (a) storm cell count and (b) precipitation flux in the southwest region of Saudi Arabia for the summer 2008 (blue), summer 2009 (green), and spring 2009 (red).

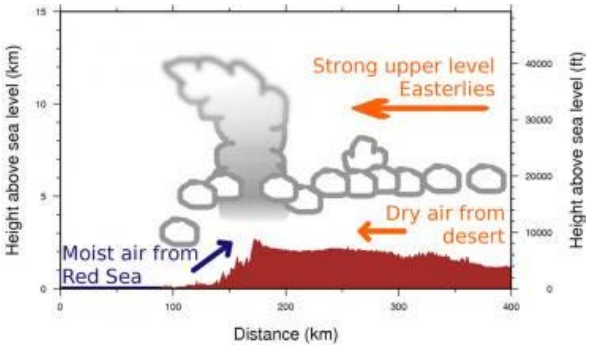


Fig. 5: Conceptual model for conditions leading to convective development over the southwest region of Saudi Arabia during the summer.

observations to better understand the dynamic and thermodynamic conditions influencing clouds and precipitation generation in Saudi Arabia.

Polarimetric Radar Analysis of Convective Clouds (POLCAST)

http://www.ral.ucar.edu/projects/polcast2/

The 3rd observational period of Polarimetric Cloud Analysis and Seeding Test (POLCAST3) field experiment was conducted from 21 June through 23 July 2010 in eastern North Dakota. POLCAST3 was a continuation of the original field program that was conducted in the summer of 2006 and the second field program (POLCAST2) in the summer of 2008. During POLCAST3, the focus was on collecting randomized seeded cases using the University of North Dakota (UND) polarimetric Doppler weather radar (NorthPOL) and *in situ* sampling from airborne observations using the Weather Modification Incorporated (WMIs) instrumented Cessna 340 seeding aircraft and the UND Citation II research aircraft. POLCAST3 was supported through the North Dakota Atmospheric Resource Board (NDARB) and was a collaborative effort between the National Center for Atmospheric Research, NDARB, UND, and WMI.

POLCAST3 (and all the previous POLCAST studies) have been designed to better understand the effects of hygroscopic cloud seeding at cloud base on convective clouds in North Dakota. More specifically, the program aims to determine identifiable signatures of hygroscopic seeding in polarimetric observables or derived fields; to characterize hygroscopic seeding effects stratified by aerosol and CCN concentrations; and characterize the cloud droplet size distributions for seeded and non-seeded clouds.

FY2010 Accomplishments

All the cases were randomized to characterize cloud droplet distributions above cloud base for seeded and non-seeded clouds to confirm inferences observed in the polarimetric Doppler weather radar fields. During POLCAST2, we obtained 13 randomized cases and another 14 randomized cases from POLCAST3, giving us a total of 27 cases for analysis.

Figure 6 shows an example of one of the randomized cases. Using the polarimetric fields from NorthPOL, the NCAR hydrometeor identification (HID) algorithm was applied to infer the different particle types observed in the storm. Figure 7 shows an example of the hydrometeor retrieval using the NCAR HID. The examples shown are from elevation angles of 2.4° (low level example) and 8.0° (upper level example). The retrievals indicate that the storm had a mixture of light to heavy rain outside the convective core,

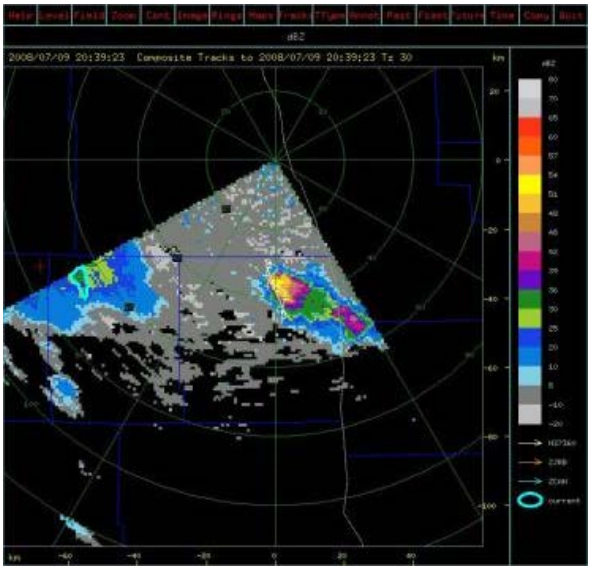


Fig. 6: TITAN image of a case targeted on 9 July 2008. The targeted stormed is located within the white box.

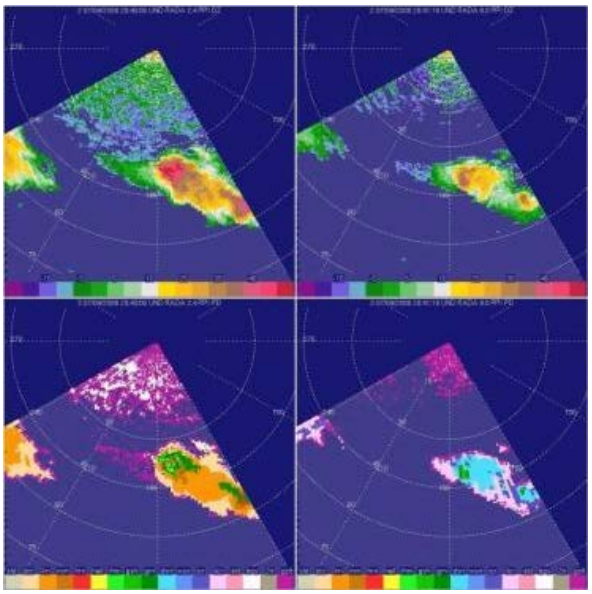


Fig. 7: Reflectivity (top panels) and hydrometeor retrieval (bottom panels) PPI images for elevation tilt of 2.4° (left panels) and 8.0° (right panels) for storm observed around 2040 UTC 09 July 2008.

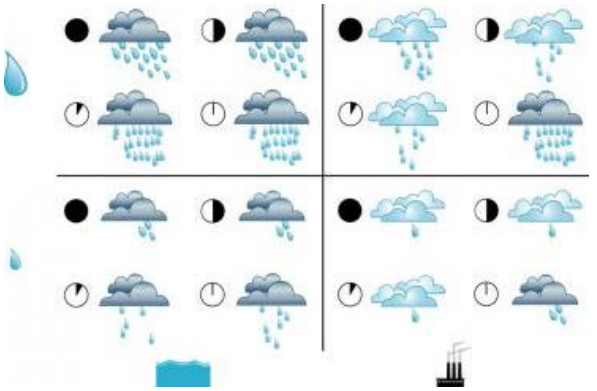


Figure 8: Schematics of aerosol solubility effects on clouds and precipitation. Top and bottom quadrants indicate wet and dry conditions, respectively, left and right quadrants respectively indicate the clean and polluted backgrounds. Circles represent aerosol solubility of 100%, 50%, 10%, and 1%, with the black area indicating the soluble portion of the aerosol. Clean clouds are indicated by dark clouds and polluted clouds by light ones.

with a rain/graupel/hail mix inside the convective core at low levels. At upper levels, the HID algorithm indicated the particles were mostly dry snow with some orientated ice crystals at outer edges of the anvil. These data in combination with the aircraft observations are being used to determine if a hygroscopic seeding signature can be detected by radar and aircraft measurements.

FY2011 Plans

We have completed the initial analysis of the radar data quality and assessment of the randomized cases. The next step will focus on extracting the data for each randomized case (with echo) and performing the traditional randomized seeding analysis (similar to those conducted in other studies in South Africa and Mexico). The polarimetric fields from events observed in POLCAST3 will be processed using the NCAR HID and added to the events observed in POLCAST2. The first step requires careful tuning to the atmospheric conditions (e.g., thermodynamic profile) for each day. Afterwards, the HID will be applied to the randomized cases. The HID statistics will be separated into Seed/No Seed cases and evaluated. The cases will be evaluated to determine if we can make any inferences to the effects of hygroscopic seeding on the targeted cases. The final step is to integrate the radar observation results with the aircraft observations to provide a more complete picture of the observed cloud events.

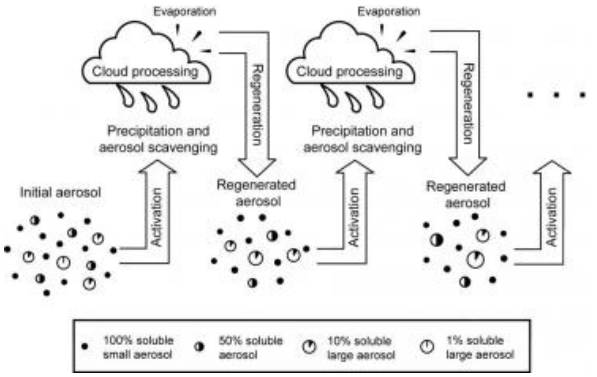


Figure 9: Schematics of aerosol-cloud-precipitation interactions.

NASA Tropical Composition, Cloud and Climate Coupling (TC4) Experiment

http://www.ral.ucar.edu/projects/tc4

During July and August 2007, NASA sponsored a field campaign called the Tropical Composition, Cloud and Climate Coupling (TC4) experiment. The experiment was conducted over Costa Rica, Panama and the surrounding oceanic region and was aimed at examining the characteristics of convection over the southern peninsula of Panama and adjacent Gulf of Panama. Observations from the NASA 10-cm polarimetric Doppler weather radar (NPOL) formed the primary dataset used in analysis. Also, rainfall measurements obtained from a high resolution rain gauge network were used to evaluate the precipitation characteristics.

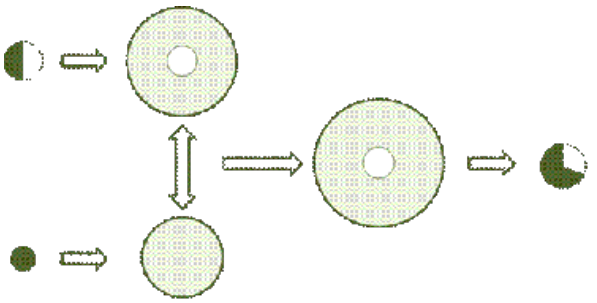
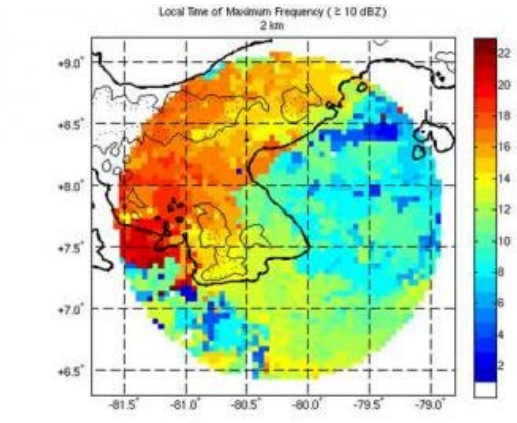


Figure 10: Schematics of cloud processing of internally mixed aerosol particles. Small circles represent aerosol particles with dark area indicating soluble portion. Light green large circles indicate cloud droplets with white area indicating insoluble aerosol core inside.

FY2010 Accomplishments

A variety of events were observed during TC4, ranging from short-lived unorganized convection to



Local time of maximum frequency.

long-lived mesoscale convective systems (MCSs). Results of the data analysis (see diurnal cycle map shown in Fig. 1.) show that organized systems often developed and intensified over the Gulf of Panama in the late evening before weakening and dissipating before reaching land in the mid-morning hours. A secondary peak in convection as result of strong diurnal heating was observed over the mountainous region of Panama during mid-afternoon. Figure 2 shows the analysis of the vertical structure of storms. The results indicate there was nearly the same vertical structure of storms for evening and morning with slightly more deep convection in late afternoon. The results of this observational study are the starting point of an ongoing mesoscale modeling study.

FY2011 Plans

This project is currently in the final stages of analysis. Two manuscripts are being generated and should be submitted for publication. The first study focuses on documenting the observed convection and associated atmospheric conditions observed during TC4. The second study is a modeling effort in an effort to represent the convection observed in the Gulf of Panama.

Numerical Studies of the Effects of Aerosol Solubility and Regeneration on Orographic Clouds and Precipitation

Warm-phase and mixed-phase numerical sensitivity studies have been conducted by RAL scientists using a detailed bin microphysical scheme coupled with the WRF model. The theoretical studies on aerosol solubility and regeneration effects on orographic clouds and precipitation in 2010 confirmed that incorporation of the aerosol regeneration process into the numerical model is necessary. Further, studies found that:

- Cloud properties and precipitation features are very sensitive to aerosol chemical compositions or solubility (Figure 8) and this effect is more prominent for polluted clouds than clean clouds.
- Aerosol regeneration decreases the precipitation by 2%-80% under various conditions and regenerated aerosols replenish 1/3 to 2/3 of the missing particles when regeneration is not considered.
- Cloud processed aerosols affect cloud and precipitation properties.
- Riming of snow is not sensitive to aerosol concentration and chemical compositions but riming of graupel is very sensitive to both properties.
- The sensitivity of mixed-phase clouds and precipitation to aerosol solubility and regeneration is lower than that of warm-phase clouds.
- The quantitative sensitivity of mixed-phase clouds to aerosol is not changed by ice initialization parameterizations.

Studies of the effects of aerosol solubility and regeneration on orographic clouds and precipitation presented a scenario of aerosol-cloud-precipitation interactions as illustrated in figure 9. The initial aerosol will be processed by cloud and their size distribution and chemical compositions will be modified. The new processed aerosol can activated new clouds and will be processed again. Enlightened by the question of how aerosols processed by clouds in details and how they impact clouds and precipitation, some preliminary theoretical studies using a new aerosol-microphysics scheme have been carried out. The mechanism of cloud processing of aerosol is illustrated in figure 10.

The preliminary results showed that 1) the solubility of large aerosols decides the aerosol bulk solubility after cloud processing; 2) cloud processing generates larger aerosols, equilibrates the aerosol size distribution and smoothes the aerosol solubility distribution; 3) cloud-processed aerosols have complicated effects on clouds and precipitation. Please see **http://ams.confex.com/ams/13CldPhy13AtRad/techprogram/paper_170624.htm** for details.

FY2011 Plans

Work in 2011 will focus on understanding how the freshly emitted externally mixed aerosol particles become internally mixed by cloud processing.

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Winter Weather

Background

Winter weather efforts include a number of programs funded by state and federal agencies to develop and test new instruments, systems and techniques for measuring winter precipitation. Work on behalf of the Federal Aviation Administration to support ground deicing operations is described in the aviation chapter of this report. Here we focus on three programs: weather modification efforts related to winter snowpack enhancement in Wyoming; the move of NOAA's Climate Reference Network test facility to our Marshall Field Site; and a new project sponsored by the National Weather Service to conduct winter testing of future ASOS sensors such as the All Weather Precipitation Accumulation Gauge, also at our Marshall site.

Wyoming Weather Modification Program

The Wyoming Weather Modification Five-Year Pilot Program (WWMPP) is funded by the State of Wyoming through the Wyoming Water Development Commission (WWDC), and is unique among state-sponsored programs in that it includes a substantial evaluation component. The main purposes of the WWMPP are to establish an winter orographic cloud seeding program in three target areas (the Medicine Bow Range, Sierra Madre Range and Wind River Range) and evaluate the feasibility and effectiveness of the cloud seeding. 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).

Map of Wyoming with coarse representation of topography and land use. Red outlined areas denote the three mountain ranges selected for cloud seeding operations: Medicine Bow, Sierra Madre, and Wind River. The randomized seeding experiment involves only the two southern ranges, the Medicine Bows and Sierra Madres.

Natural precipitation in winter storms develops and falls out when clouds: a) contain supercooled liquid water (SLW); b) exist in a temperature range for efficient ice nuclei (IN) activation and crystal growth; c) form in conditions conducive to snow development (riming or aggregation); and d) have sufficient time for ice particles to develop, grow, and fall onto the barrier (or target area in this case). Many storms are thought to be naturally inefficient in producing snowfall because they lack a sufficient number of IN active at the cloud temperatures where significant SLW is found. Such clouds may possibly be made more efficient by supplying additional IN in these regions of SLW – the essence of cloud seeding.

Orographic clouds over the Medicine Bow range.

Attempts 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 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, it is generally believed that no single

analysis can be convincing regarding the effect of seeding. Rather, it is necessary to build multiple layers of evidence, both statistical and physical, to provide a consistent picture of the effect of cloud seeding.

Two general approaches are guiding the evaluation of the WWMPP: a) a randomized experiment that builds distributions of seeded and control (unseeded) cases, and b) exploratory studies to investigate a wide variety of ideas on detecting seeding effects, including physical studies to document the precipitation formation events hypothesized to be important to snowfall production in orographic storms. Collaborations with other researchers, particularly those at the University of Wyoming and the Desert Research Institute, have led to "piggy-back" studies applicable to the assessment of seeding impacts on precipitation formation and eventually on streamflows.

Initial Studies

The first two winter seasons of the program (2005-06, 2006-07) were needed for performing exploratory studies to develop the evaluation plan, permitting activities, installing equipment, and peer review of the scientific experimental design. Initial assessments were necessary to: 1) determine the suitability of current snow measurements (i.e., the NRCS SNOTEL network) for detecting the potentially small effects of cloud seeding; 2) specifically identify target areas; 3) define adequate seeding periods; 4) optimally locate ground-based seeding generators; 5) determine the frequency and locations of potential seeding conditions; and 6) investigate a number of other requirements for seeding operations (e.g., the role of numerical models, potential use of airborne seeding, deployment of instruments, etc.).

Winter weather instruments

During the same time as the initial assessments were being performed, permitting requirements needed to progress so that the ground-based seeding generators and other instruments could be installed on federal lands without undue delay. Specific sites needed to be chosen and then surveyed for environmental impacts, and more generally, potential impacts of seeding on federal lands needed to be addressed. A baseline study on silver concentrations (determined through sampling watersheds and snowpack) found that even in the worst-case scenario, no significant rise in baseline silver concentrations would occur under the proposed seeding, due to the extremely low concentrations of silver iodide used for seeding and the high natural background levels of silver in soil and water.

At the end of 2007, the two southern ranges were established as targets for the randomized seeding experiment to be conducted using ground-based seeding (with updated generator locations) from 15 November through 15 April. High-resolution precipitation gauges were deployed for the snowfall measurement, along with auxiliary instruments to assist in determining seeding conditions. Seeding in the Wind River Range would occur on a non-randomized basis, with somewhat less-than-ideal generator locations, and evaluated using current instrumentation (e.g., SNOTEL data) and numerical modeling output.

Design of the Randomized Experiment

The final experimental design includes the following elements: 1) target areas near the crests of the Medicine Bow Mountains (near the Brooklyn Lake SNOTEL) and the Sierra Madre Mountains (near the Old Battle SNOTEL); 2) a cross-over design in which one range is randomly chosen for seeding and the other becomes the control, resulting in paired cases; 3) a seeding period of four hours with a "buffer" period of four hours to clear the areas of seeding material; 4) high-resolution precipitation gauge data for determining the seeding response, averaged over two sites within each target area; 5) two control gauge sites (unaffected by seeding) in each range to help describe the natural variability in precipitation between target areas and between snowfall events;

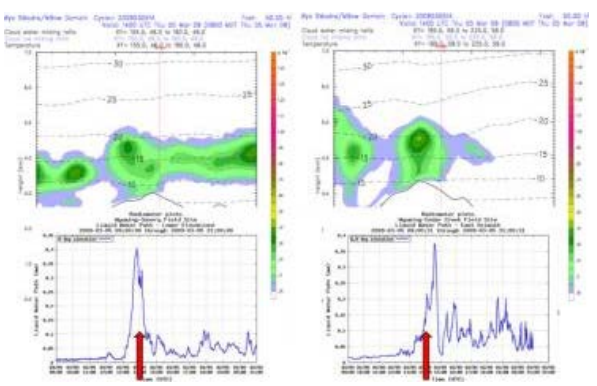
Precipitation measurement site in the Wyoming Medicine Bow mountain range

6) seeding conditions occurring in each range simultaneously (i.e., cold enough temperatures for the seeding material to work, wind flow of the right direction for the seeding generators to affect snowfall in the target areas, and the presence of SLW); and 7) enough cases to provide statistical significance of the results.

Resources used for carrying out the experimental design include 16 ground-based seeding generators (8 in each range), 20 precipitation gauges at 8 sites (with redundancy at each site and some experimental gauges), 12 weather stations (at each gauge site and four at generator sites), two microwave radiometers for detecting SLW, a radiosonde unit ("weather balloon" for measuring temperature, moisture, and winds at cloud heights), and a numerical forecast model – WRF RT-FDDA – cycling every three hours with updated observations. The seeding generators, radiosonde unit, and one radiometer are operated by WMI, and the precipitation gauge network, one radiometer, and forecast model are operated by RAL/NCAR.

FY2010 Accomplishments

The Weather Research and Forecasting (WRF) model and the Real Time Four Dimensional Data Assimilation (RT-FDDA) system are used in operations to guide forecasters on expected conditions specific to seeding criteria, particularly when super-cooled liquid water might be expected and for estimating plume trajectories from individual seeding generators into the target regions. Several display features (maps, cross-sections, etc.) have been customized to the WWMPP, and a separate website is dedicated to providing the model output. Comparisons with radiometer data (liquid water path as a proxy for cloud water) have shown good agreement under most scenarios but with a slight bias toward larger values of cloud water in the WRF model. A number of numerical experiments are being pursued, testing different parameterizations.



Cross-sections of WRF-derived cloud water over the Serra Madres and the Medicine Bows with time series plots of radiometer-measured liquid water path indicated below. The red arrows show the time of the cross-sections.

A total of 69 cases have been called over two seeding seasons under the final experimental design conditions. While the initial studies relied on historic data to estimate the number of cases likely to be gathered in a season and the total number of cases needed for statistical significance (given some assumptions), data collected during actual cases have begun to refine those original estimates. Two key variables that directly affect the number of cases needed for the experiment are measurement variance (i.e., the variations of snow amounts that fell during cases) and correlation between ranges (i.e., how closely snowfall amounts in each range track each other for the cases). Because of the more tightly controlled conditions in which cases are called (versus the general nature of historic data), the variance from the collected cases is nearly half of what was originally estimated. Similarly, the correlation between ranges is about 20% higher than previously assumed. The lower variance and the higher correlation together decrease the estimated total number of cases needed by almost half. Although the number of cases eligible in a season is less than expected, it appears that five years of seeding (on a randomized basis) will sample enough cases to provide an acceptable level of confidence in the results. This is still in line with expectations when the program was originally funded, even though those expectations were based on very coarse estimates and assumptions. The stability of the results, including the precipitation variance and the correlation between ranges, should improve as more cases are collected.

FY2011 Plans

The continuation of randomized experiment is the highest priority for the next two seasons. Along with the precipitation measurements required to assess the WWMPP, additional instruments are being deployed to better understand and document the physical chain of events hypothesized to be affected by cloud seeding. These include additional surface-based instruments at the GLEES site, such as a hotplate sensor (for high-precision snow rates) and a disdrometer (for measuring particle-size spectra). Addition funds have been requested from agencies in the lower Colorado River basin to better forecast and document seeding conditions. The request is to deploy a ceilometer upwind of the Sierra Madres (for documenting cloud base development and height/temperature, and to further complement the assessment of seeding criteria) and to deploy a fixed-beam K-band cloud radar aimed over the Sierra Madres (to provide long-term and consistent documentation of cloud conditions during all precipitation events). Analysis of the data collected from these additional, complementary instruments will continue over the next two seasons. The goals are to document any changes due to seeding and to optimize and extend potential seeding opportunities.

Climate Reference Network Testing at Marshall

Background

The Climate Reference Network (CRN) test facility has been in operation for the past two years at NCAR's Marshall Field Site. The primary purpose of the CRN test facility is to support the testing of new precipitation gauges and gauge shielding for measuring liquid equivalent snowfall amounts. This measurement effort is viewed as an important element in the CRN's goal of monitoring climate change at sites across the U.S. The current CRN sites use GEONOR precipitation gauges inside a 2/3-scale Double Fenced Intercomparison Reference (DFIR) shield. These shields require large areas for installation since they are over 25 feet in diameter, which can lead to difficulty in finding sites large enough to accommodate the installations. They also require significant resources and manpower to maintain. CRN is interested in testing the possibility of changing these shields to a smaller double or single Alter-style shield to help reduce the costs and siting issues associated with the larger shields. Before this can be done though, extensive testing of smaller shields needs to be completed and transfer functions developed to ensure that the impact of the smaller shield design on snowfall collection efficiency is minimized and/or eliminated.

In addition to gauge measurements of snowfall amounts, recent technological advances with snow depth sensors are also of interest to the group and preliminary testing of the new laser snow depth sensors are also being undertaken at the Marshall test site.

FY2010 Accomplishments

In addition to maintaining the site, troubleshooting hardware and software problems and collecting and archiving the data, NCAR/RAL hosts a yearly Solid Precipitation Workshop in September which gives NCAR and CRN participants an opportunity to present their latest findings, as well as ideas and plans for the upcoming winter. This year, Environment Canada also sent several representatives to participate in the workshop and results from their field studies were presented and discussed. Previous years' results, new ideas, technologies and advances in gauge upgrades and shielding were all discussed, including the new Belfort-style single and double Alter shields.

At the 2010 workshop we learned that the Marshall Field Site had been selected as the U.S. test site for a new Solid Precipitation Intercomparison Study being proposed by the World Meteorological Organization (WMO). This study will include participants from countries around the world including Canada, Japan, China, Russia, Norway and Switzerland. The purpose of the study will be to determine a reference gauge and shield for liquid equivalent snowfall measurements using automated precipitation gauges.

FY2011 Plans

Efforts in FY11 will focus on more intensive testing of the new Belfort gauges and shields as well as the testing of the new laser snow depth sensors at the Marshall Field Site. Preparations to support the upcoming WMO Solid Intercomparison Study will also be undertaken including some preliminary testing of gauge/shield combinations for presentation at further meetings with the other participants in the study.

National Weather Service (NWS) – All Weather Precipitation Accumulation Gauge (AWPAG) Testing at Marshall Field Site

Background

The NWS has recently converted all of its Automated Surface Observing System (ASOS) sites from a tipping bucket gauge to an all-weather weighing gauge. While the tipping bucket gauges work well in rain, problems associated with heating and ice buildup during winter precipitation (primarily snow) make it a poor gauge to use during winter conditions. The OTT Pluvio gauge was selected as the replacement for the tipping bucket and was installed at the ASOS sites with a Tretyakov-style shield. Further studies have shown that, while the collection efficiency is improved significantly from the tipping buckets, the gauge shielding is still inadequate during winter precipitation events and the gauges are still prone to under-catch problems in high wind (> 3 m/s) events. To address this, the NWS added an eight-foot alter-style shield around the Tretyakov to help increase the snowfall collection efficiency. Because the Double Fenced Intercomparison Reference (DFIR) shield is accepted as the current standard for measuring snowfall, the NWS was interested in testing the new gauge/shield combination at sites where DFIR shields were readily available. The Marshall Field Site was selected as a test site by the NWS and three OTT gauges were installed in October of 2009; one in a DFIR shield, one in a standard Tretyakov shield and one in the new Tretyakov/Alter shield.

FY2010 Accomplishments

Data was automatically collected from each of the gauges throughout the winter and made available to the NWS through the Marshall webpage. Though NCAR/RALs involvement was mainly to support the gauges and associated hardware, some funds were used to compare the accumulations from the difference gauges. While the Tretyakov/Alter shield combination did increase the snowfall collection efficiency of the gauge, the amounts collected were still lower than the accumulation from the gauge in the DFIR shield. A preliminary transfer function was developed for the Tretyakov and Tretyakov/Alter shields in comparison to the DFIR shield to correct the measurements for wind speed errors. These transfer functions were then applied to the raw data from the Tretyakov-shield and Tretyakov/Alter-shielded gauges to correct the accumulations. These transfer functions are still being tested on the data collected from the 2009/10 season.

FY2011 Plans

The NWS concluded that it had collected sufficient data during the winter of 2009/10, and has therefore ended this

study. The gauges have been returned to the NWS, and no future testing is planned at this time.

Support for the 2010 Winter Olympics in Vancouver, Canada

Background

RAL scientists supported Environment Canada during the Vancouver Winter Olympics and the Para-Olympics in February-March 2010, providing nowcasts and forecasts for both the airport and a variety of Olympic venues. Andy Gaydos deployed RAL's Weather Support to Deicing Decision Making (WSDDM) winter weather nowcasting system via the web. Olympic forecasters came to rely on this system for their primary information on real-time weather evolution for the two main Olympic venues at Whistler Mountain and Cypress (near Vancouver). A video disdrometer was deployed by Paul Kucera at the top of Whistler Mountain to provide documentation of the snow size distribution. Roy Rasmussen participated as Research Support Desk nowcaster for the WMO project on winter nowcasting during the Olympics (SNOWV10) and interacted with the main Olympic forecasters during briefings and hourly during events. Julie Theriault took snow observations on the slopes of Whistler Mountain between the main Olympics and the Para-Olympics in support of a study of the impacts of melting snow on the cooling of the air and the precipitation type. Roy Rasmussen provided an evaluation of the performance of the Olympic snowgauges to the Olympic forecasters.

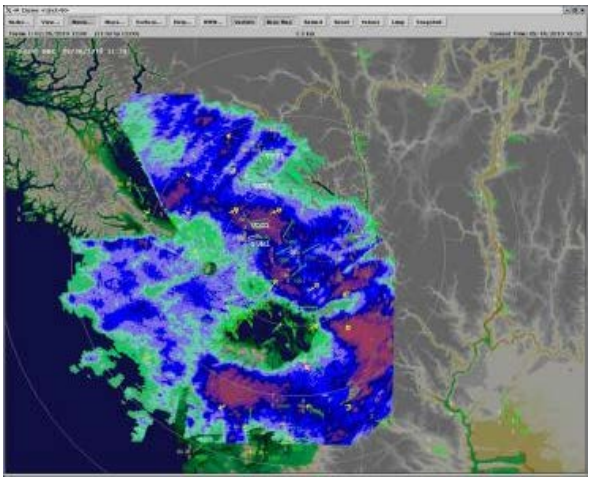


Image from the WSDDM web page of the radar reflectivity associated with a winter storm impacting the two main Vancouver Olympic venue sites at Whistler mountain (TFT) and Cypress mountain (VOG) Note the high values of reflectivity over the Olympic mountains (lower part of the display) and the hole in the reflectivity just to the northeast of the Olympics (lee of the mountain in this case). Also shown are surface winds and precipitation type.

FY2010 Accomplishments

A case study of the impacts of melting snow on the determination of the precipitation phase (rain or snow) has been initiated in conjunction with Trevor Smith, the lead Olympic forecaster, and George Isaac, Paul Joe, and Jason Milbrandt of Environment Canada. Julie Theriault and Roy Rasmussen are the NCAR participants. Results have been presented at a conference and are currently being written up for publication.

FY2011 Plans

RAL will participate in planning meetings for a forecast demonstration project to be held in conjunction with the next Winter Olympics in 2014 in Russia.

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Colorado Headwaters Project

Background

The Colorado Headwaters effort was initiated in the Spring of 2008 as a project within the RAL/Integrated Science Program Water System program. It is focused on assessing the impact of climate change on winter precipitation, snowpack and runoff processes in Colorado's headwater basins using a very high resolution fully coupled atmospheric–hydrologic model (WRF coupled with the NOAH land surface model). This work is collaborative with NCAR/MMM and researchers from the University of Vienna, George Mason University, and the University of Texas.

Methodology

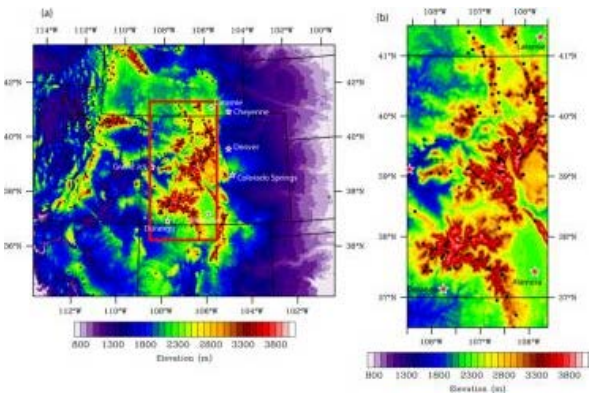


Figure 1: The WRF model domain and location of SNOTEL sites (black dots). (a) The full model domain. (b) Sub–domain focused on the 112 SNOTEL sites in the Colorado Headwaters region.

The project was awarded 500,000 computer GAUs through an Accelerated Science Discovery competition in the spring of 2008. Using these resources, the Advanced Research WRF (ARW) model was applied to conduct high–resolution regional climate simulations of cold–season snowfall, snowpack, evapotranspiration and runoff in the Colorado Headwaters region. The domain of the high-resolution model is shown in Figure 1a, and the SNOwpack TELemetry (SNOTEL; **http://www.wcc.nrcs.usda.gov/snow/**) observation sites used to evaluation the simulations in Figure 1b as the black dots. The specific simulations performed were as follows: i) five 6–month (1 November to 1 May), 2–km–resolution simulations of present–day climate using the North American Regional Reanalysis (NARR) data, covering two cold seasons (i.e., year 2004–2005, and year 2005–2006) of normal (i.e., approximately multi–year mean) precipitation and snowpack, one cold season (i.e., year 2007–2008) of anomalously high snowfall and snowpack, one cold season (i.e., year 2002–2003) of anomalously low snowfall and snowpack, and the 2008 warm season; ii) a few coarse-resolution simulations of the 2007–2008 cold season with grid spacings of 6 km, 18 km and 36 km; iii) four 6–month, 2–km–resolution simulation of snowfall and snowpack in response to a pseudo climate warming, in which the initial and boundary conditions were derived from the combination of the 3–hourly NARR data from the four retrospective cold seasons listed in (*i*) with the climate perturbations representing the differences between the present (i.e., 10–year averages from 1995–2005) climate and the future (i.e., 10–year averages from 2045–2055) climate projected by CCSM; and iv) two future climate simulations at grid spacings of 6km and 18 km for the 2052–2053 cold season using the 6–hourly CCSM output for the IPCC SRES A1B scenario. During the FY2010, Pseudo Global Warming (PGW) simulations were performed for the 2007-2008 cold season on a 36 km in order to study the impact of simulated climate signal on model resolution.

FY2010 Accomplishments

FY2010 activities focused on (i) model verification, (ii) a model sensitivity study on various WRF physics parameterization, (iv) various diagnostic analysis of the PGW simulations, (v) a comparison study on statistical vs dynamical downscaling using the Colorado Headwaters simulations, and (vi) development of an improved snowpack physics in the Noah Land Surface model. Verifications of the WRF simulations on four retrospective 6-month simulation

of cold season precipitation showed that the model reproduced observed SNOTEL precipitation amounts within 10-15% of observations from 112 SNOTEL sites. Spatial pattern of precipitation from the high resolution model simulation also showed excellent agreement with the SNOTEL observations. Snowfall amount from the coarser model resolution simulations (6, 18, and 36 km grid spacings) underestimated the observed season-total snowfall amount by 20-25 % due to terrain smoothing and associated weaker vertical motions. The strong dependence of simulated snowfall and snowpack on grid resolutions clearly indicates the importance and usefulness of high–resolution models in improving the future climate projections by global climate models. Model sensitivity tests on various WRF physics parameterizations, including seven microphysics parameterizations, three LSMs, five PBL parameterizations and two radiative transfer models, have shown that the model was most sensitive to microphysics parameterization. The agreement with the SNOTEL observations was the best with the Thompson et al. 2008 and Morrison et al. 2009 schemes.

Journal papers that have resulted from the Colorado Headwaters project in FY2010 include:

Ikeda, K., R. Rasmussen, C. Liu, D. Gochis, D. Yates, F. Chen, M. Tewari, M. Barlage, J. Dudhia, K. Miller, K. Arsenault*, V. Grubišić*, G. Thompson, E. Guttman, 2010: Simulation of seasonal snowfall over Colorado. *Atmos. Research*, **97,** 462-477.

Barlage. M., F. Chen, M. Tewari, K. Ikeda, D. Gochis, J. Dudhia, R. Rasmussen, B. Livneh, M. Ek, and K. Mitchell, 2010: Noah Land Surface model modifications to improve snowpack prediction in the Colorado Rocky Mountains. *In Press. J. Geophy. Reseach.*

Rasmussen, R., C. Liu, K. Ikeda, D. Gochis, D. Yates, F. Chen, M. Tewari, M. Barlage, J. Dudhia, W. Yu, K. Miller, K. Arsenault*, V. Grubišić,G*. Thompson, E. Gutmann, 2010: High resolution coupled climate-runoff simulations of seasonal snowfall over Colorado: a process study of current and warmer climate. *Accepted to J. Climate.*

Gutmann, E. D., R. M. Rasmussen, C. Liu, K. Ikeda, J. Gochis, M. P. Clark, J. Dudhia, G. Thompson, 2010: A comparison of statistical and dynamical downscaling of winter precipitation over complex terrain. *Submitted to J. Climate.*

FY2011 Plans

A number of detailed studies using the high resolution simulation data are underway. In addition, an 8-year continuous WRF model simulation at 4-km resolution using the PGW approach over the domain in Figure 1a will be performed. The model setup will include improved snow physics in the Noah Land

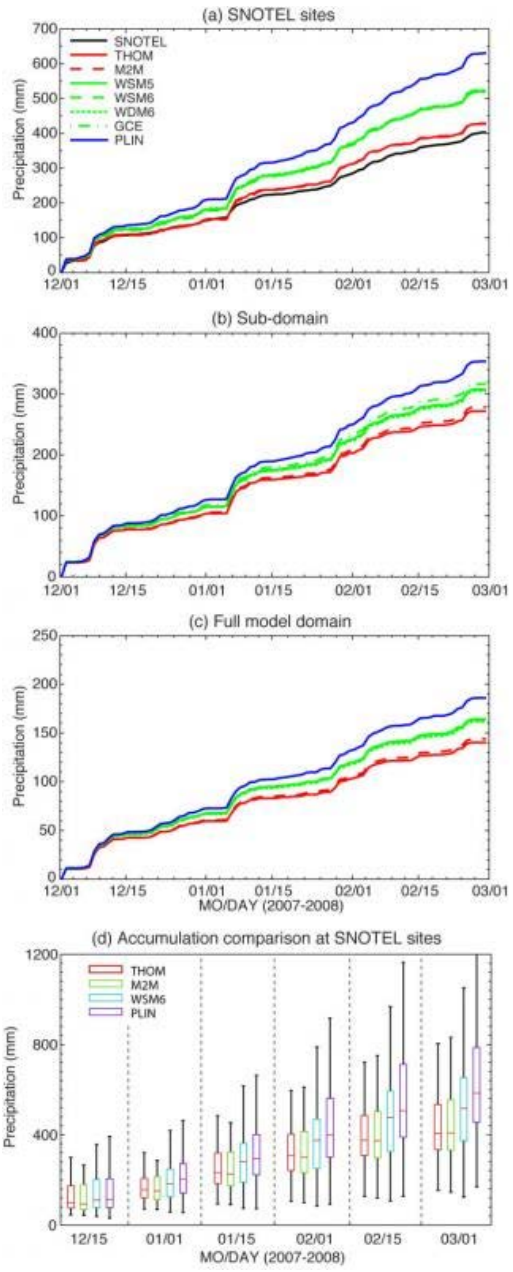
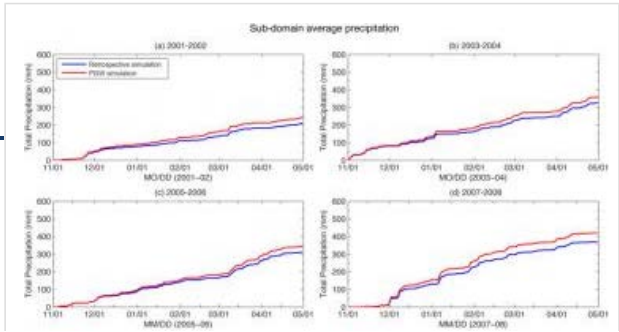


Figure 2: Precipitation accumulation from high-resolution WRF simulations using various microphysics parameterizations. [THOMP: Thompson 2-moment, M2M: Morrison 2-moment, WSM5: WSM 5-class, WSM6: WSM 6-class, WDM6: WRF double moment, GCE: Goddard GCE, PLIN: Purdue Lin] (a) Average model values at 112 SNOTEL sites with the mean SNOTEL observation overlaid, (b) the sub-domain average, and (c) the full-domain average. (d) Box plots showing distributions of the model precipitation at SNOTEL sites from THOM, M2M, WSM6, and PLIN microphysical schemes.



Surface model (Barlage et al. 2010). The simulation data will be used to study climate change impact on runoff, snowpack and precipitation in all seasons. Future work also includes conducting nested regional climate runs.

Figure 3: Sub-domain average precipitation accumulation from the 2-km WRF model simulation using retrospective NARR data (blue line) and perturbed NARR data (PGW simulation; red line). The results are from the 6-month period from (a) 2001-2002, (b) 2003-2004, (c) 2005-2006, and (d) 2007-2008.

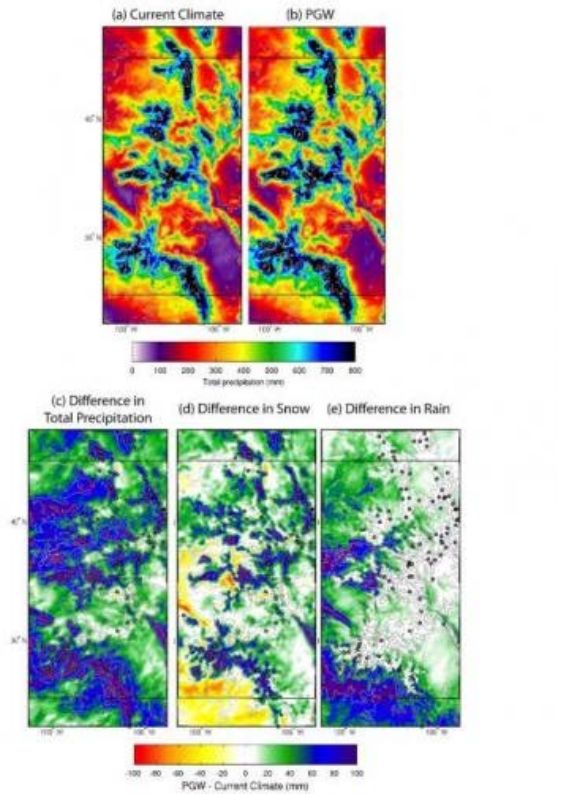


Figure 4: The 6-month total precipitation simulated by the 2-km WRF model in the sub-domain using (a) the 2007-2008 NARR data and (b) perturbed NARR data (PGW simulation). Bottom panels show difference in (c) total precipitation, (d) accumulated snow, and (e) accumulated rain between the PGW and retrospective simulation.

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Water Resources Planning and Management

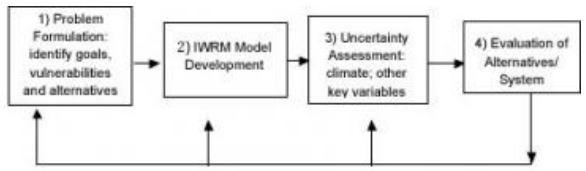
Background

As water planners and managers become increasingly aware of global climate change and its possible impacts on water resources, they are seeking climate change information pertinent to their planning needs. To address these needs, RAL scientists, supported by the Water Research Foundation and NCAR's Assessment Program have developed climate change educational materials for the water resources community. Despite the pressing need, many water utility managers remain unsure if or how they should adapt to climate change. They correctly note that many uncertainties remain. In particular, reliable projections of local-scale changes in precipitation are not yet possible.

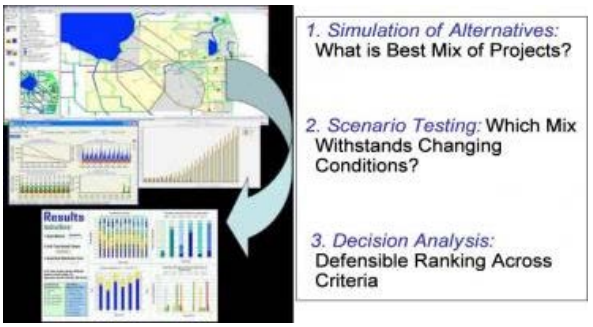
This uncertainty arises partly from fact that precipitation is inherently much more variable over time and space than is temperature. It also arises from the inability of coarse-resolution climate models to adequately simulate the fine-scale processes that determine where and when precipitation occurs. Statistical and dynamical downscaling techniques and higher-resolution climate models, made possible by more powerful computers, can help to increase the reliability of regional climate projections, but they won't eliminate all sources of uncertainty. In short, we know that climate change is likely to affect water resource availability and quality but we also know that we have a limited ability to foresee the full details of those changes, especially at local scales relevant to water planning.

Uncertainty is not a new phenomenon for water planners. Substantial uncertainties have long surrounded projections of future population growth, changes in water use habits, and construction costs. Uncertainty surrounding future climate projections is not fundamentally different from these more familiar uncertainties, except in degree and in the length of the time horizon. Effective planning can proceed, despite such uncertainties, by adopting a risk-management approach that considers a range of plausible projections for the most relevant, but uncertain variables.

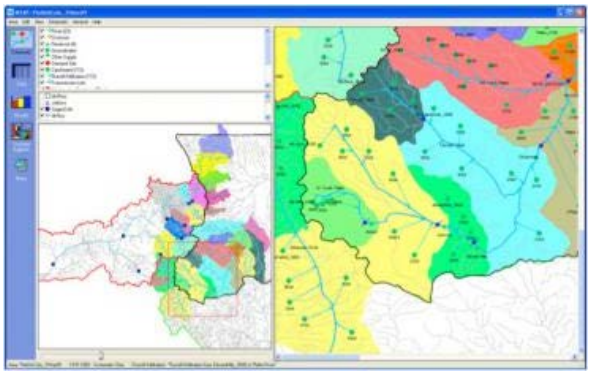
Over the past few years, we have engaged with a select set of municipal water providers and related regional coordinating bodies in the development of a decision support process to facilitate assessments of water utility vulnerabilities and response options to prospective climate changes. These projects focused, in particular, on the problem of planning in the



Decision Analytic Process used to helped water agencies consider climate change.

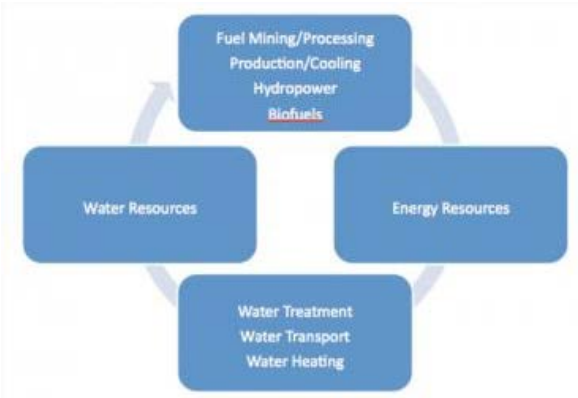


Process diagram for Palm Beach Count Water Decision Support Process.



A screen-shot showing the Upper Colorado, Platte, and Arkansas Basins within the Water Evaluation and Planning (WEA) decision support model.

context of uncertainties surrounding the local-scale hydrologic changes that will result from global climate change. This has resulted in several reports, including *Climate Change in Water Utility Planning: Decision Analytic Approaches.* The projects have developed and demonstrated a structured assessment process to help the drinking water industry conduct scientifically sound and cost-effective assessments of utility vulnerabilities and adaptation options in the context of climate variability and change.



Simplified Water-Energy Nexus

FY2010 Accomplishments

In 2010, we finished and/or contributed to a number of projects dealing with climate change and water planning. Below we summarize several of these efforts:

Global Climate Change Screening Analysis for the St. John's River Water Supply Impacts Study

The St. Johns River Water Management District in Florida is evaluating the potential effects of withdrawing water from the St. Johns River and the Ocklawaha River to help meet the projected growth in water demand for public use under the Alternative Water Supply (AWS) initiative. As part of this evaluation, the District would like to incorporate how potential climate change and variability might influence this analysis. A key challenge for water managers is how to incorporate highly uncertain information about potential climate change from global climate models (GCMs) into local and regional-scale water management models and tools to support local planning. Exploratory in nature, the resulting climate scenarios generated by this project represent a first-step by the District to explicitly consider possible future climate conditions in their AWS analysis.

Climate Change in Water Utility Planning: Decision Analytic Approaches (with the Water Research Foundation- Project 3132).

This project developed a formal decision analytic process to help water utilities incorporate climate change into their planning process. The figure below summarizes the sequence of four main activities likely to be followed in the development and use of such a decision-support process. In the case of the partnering utilities that participated in Project 3132, each of these steps was fairly well defined, beginning with a set of simple questions: Do you have a decision or question that is climate sensitive, and what are the objectives and variables that need to be considered to make the decision? (Problem Formulation); Do you have a model or need for a model that can help understand that question? (Model Development); Given future climate and other uncertainties, would you like to consider those uncertainties, and if so how?; (Uncertainty Assessment); What measures would you like to use to assess your decision and how do they relate to your objectives? (Evaluation of Alternatives or System); and finally, What additional interests and concerns need to be recognized and addressed, and what additional decision options should be evaluated to better inform the decision? (Iteration).

A Dynamic Decision Support System: Linking Water Resource Simulation and Decision Analysis

The research offers water utilities examples of new concepts in decision analysis and methods of dealing with future uncertainty using scenario-based planning. The approach links these methods into a platform for exploring and ranking supply and demand management alternatives, including

1. Linking the Water Evaluation and Planning (WEAP) model with interactive multi-criteria decision analysis (MCDA) methods;
2. Using scenario-based planning methods to evaluate select alternatives under different combinations of future population, demand, and climate projections; and
3. Collaborative modeling and consensus building with a diverse stakeholder group.

Joint Front Range Climate Change Vulnerability Study

The Joint Front Range Climate Change Vulnerability Study has been a collaborative effort between water utilities along Colorado's Front Range, the Colorado Water Conservation Board, the Western Water Assessment, the Principal Investigators, and the Water Research Foundation. It focused on developing and applying procedures for combining the results of the latest climate science with the best available hydrologic simulation capabilities to gain insight into future streamflow trends that could be expected under a changing climate. An educational component was included and has been essential to developing the methodology, interpreting the results, and understanding needs for future research and investigation. David Yates deployed the Water Evaluation and Planning (WEAP) to conduct this study, developing detailed models of the Platte, Arkansas and Colorado River Basins

FY 2011 Plans

A new NOAA funded project will focus on the links between water and energy. The project, "New resources and methodologies for exploring the water-energy nexus in California in the face of climate change and other uncertainties", will explore the coupling of two advanced water and energy decision support tools. The Water Evaluation and Planning

(WEAP) and Long-range Energy Alternatives Planning (LEAP) systems offer a unique, integrating platform to explore water and energy interactions and feedbacks. There is arguably no better place to explore this inter-relationship than in the State of California, where it is estimated that nearly 20% of all energy is associated with moving, lifting, treating, and using water. We have partnered with three key water and energy organizations in the State of California to more rigorously explore the water-energy nexus. The State's Department of Water Resources is responsible for guiding California's water future, done so through the Water Plan Update and other activities; the California Energy Commission (CEC) is the coordinating agency to addresses climate change with the responsibility of achieving reductions in greenhouse emissions; and the Pacific Gas and Electric Company (PG&E), provides natural gas and electric service to millions in northern and central California. We will link water management options, such as reuse, reservoir re-operation, demand-side management, land use changes, etc., as represented in the WEAP portion of the tool, to models of the electric utility serving the water utilities, as represented in LEAP. In addition to a new decision support tool, the results of this case study will be used to develop a final report on the Northern California's Water Future and its Implications for Energy Demands to serve both the State's Water Plan, and the missions of the CEC and PG&E.

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Climate, Weather & 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**
- **Governance and Adaptation: Water and Fisheries**
- **Resilient and Sustainable Cities**
- **Weather, Climate and Health**
- **Geographic Information System (GIS) Program**

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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 provide any number of societal enhancements, including improved personal safety, reduced property damage, and increased economic efficiency, as well as saving multiple lives and millions of dollars annually. To realize the potential benefits associated with improved weather forecasts, researchers, industry, and policy makers must better understand how individuals and socioeconomic sectors currently – and potentially could – use different types of weather information.

Few assessments of the benefits of weather information have been performed, and much of the knowledge available on the use and value of weather information is difficult to locate and utilize. To address this need, NCAR, with funding from NSF and NOAA's U.S. Weather Research Program, established the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information (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 following efforts were collaborative with researchers from the Mesoscale and Microscale Meteorology Division of NCAR's Earth System Laboratory.

FY2010 Accomplishments

Information Resources

The Societal Impacts Program continues to develop and support a suite of information and capacity building resources to further the integration of social sciences and meteorology. These include:

- *Weather and Society Watch* is a free quarterly newsletter published in January, April, July and October, containing research articles, news of interest, editorials, and job and conference announcements.
- *Extreme Weather Sourcebook*, a database providing data on economic and other societal impacts of hurricanes, floods, tornadoes, lightning, and other U.S. weather phenomena.
- *Societal Impacts Program Discussion Board* – an online open discussion forum on the societal impacts of weather and weather forecasts with over 300 participants.

WAS*IS

In August 2010, SIP conducted the 8th Weather and Society * Integrated Studies (WAS*IS) Workshop in San Juan, Puerto Rico. Also known as WAS*IS-Caribbean, this workshop was supported with funding from RAL's Diversity Fund and the National Weather Service International Activities Office. The 9th Weather and Society * Integrated Studies (WAS*IS) Workshop was held in Boulder, Colorado in August 2010 with funding from the National Weather Service and NCAR's Integrated Science Program (ISP). The vision of WAS*IS is to change the weather enterprise by comprehensively and sustainably integrating social science into meteorological research and practice. A total of nearly 250 individuals have participated in WAS*IS workshops to date.

Fig. 1 The 23 invited participants of the 2010 WAS*IS Caribbean Workshop and the WAS*IS organizers and external advisory committee members. Photo taken in San Juan, Puerto Rico on June 8, 2010.

National Household Survey on Use of Weather Forecast Information

Data collected from a national survey designed to assess how the public interprets weather forecasts and probability information is being analyzed to understand how the public obtains, understands, and uses weather forecast information, including uncertainty information, in decision making. This works is integrating theory and methods from meteorology, economics, communication, and psychology to develop a truly multidisciplinary approach.

Assessment of Hurricane and Flash Flood Warnings

Work continues on an NSF funded research effort examining decision processes employed by institutions, organizations, and individuals in analyzing, disseminating, and interpreting warnings of two important weather hazards: hurricanes and flash floods. This project represents the first effort by a balanced research team representing the fields of meteorology, sociology, economics, public policy analysis, and decision sciences to look at warning processes and systems holistically.

Improving the NWS Public Forecasts through Integration of Social Science

This interdisciplinary research project is evaluating certain National Weather Service websites to characterize the key limitations of the public forecast information currently being provided, identify primary areas for improvement, assess users' interpretations of, uses of, and preferences for the public forecast information, and identify and implement experimental changes to the public forecast information resulting from the research, and assess public feedback.

Assessing Current Storm Surge Information from the Public Perspective

Using focus groups, in-depth interviews, and literature reviews, work began to explore the public's awareness and understanding, or lack thereof, concerning storm surge and currently available storm surge information, and assessing 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.

FY2011 Plans

In addition to planning for a 2nd WAS*IS Caribbean workshop and a Summer 2011 Boulder WAS*IS Workshop, work will continue on four related projects on communication, understanding and use of warning information particularly with respect to flash flood warnings and hurricane warnings. These NSF and NOAA funded projects will continue over the next one to three years.

The first project is developing an integrated understanding of warning systems and processes with a focus on hurricanes in Miami, Florida, and flash floods in Boulder, Colorado by:

- Addressing the role of uncertainty throughout the warning process, including information dissemination and decision making
- 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

In a closely related effort, a second project advances the communication of hurricane forecast advisories and warnings by examining:

- The process through which advisories and warnings are developed, and the resulting content
- The communication channels used by various actors in this process
- How at–risk coastal residents, including more vulnerable populations, comprehend and react to specific components of advisories and warnings

A third project is designed to meet the socio–economic research needs of the Hurricane Forecast Improvement Project through an assessment of emergency managers' information needs and a survey of the value households place on HFIP improvements.

The fourth project is developing and implementing a survey of hurricane-vulnerable populations to assess their awareness and understanding of storm surge and storm surge information and the potential need for new information provision approaches.

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Governance and Adaptation: Water and Fisheries

Background

Natural resources that support economic activities, the healthy functioning of ecological systems and the well-being of human populations often require some form of public regulation and management. The governance arrangements that define the role and scope for public involvement in natural resource management have important impacts on the vulnerability of coupled human-natural systems to climate-related disruption and their capacity to adapt to evolving risks posed by climate change. These arrangements determine who makes which decisions, how those decisions are made and enforced, and mechanisms for resolving disputes. In FY 2010 CSAP research focused on analysis of governance and adaptive capacity in two types of natural resource systems: water resources and marine fisheries.

Each of these systems is characterized by large numbers of independent resource users, whose activities are regulated either well or poorly by a variety of public authorities – often in different agencies and/or different jurisdictions. In addition, there are inherent interconnections and spillover effects among individual resource use activities, as well as across the impacts of regulatory actions taken by different authorities or jurisdictions. This interconnectedness must be acknowledged and taken into account in any policy evaluation. The extent to which governance arrangements facilitate effective coordination across multiple layers of decision making will determine the quality of resource management outcomes and the ability of these socio-ecological systems to adapt readily and effectively to climate variability and change. Our research goals in this area include exploring and documenting the complexity of natural resource management decision environments, and the effects of alternative sets of governance arrangements on the capacity to respond effectively to climatic impacts on the resource system.

FY2010 Accomplishments: Water Resources

Work focused on the role of water law in facilitating or impeding adaptation to changing conditions, including the possible effects of climate change on patterns of water availability. A paper entitled: “Grappling with Uncertainty: Water Planning and Policy in a Changing Climate” was prepared and presented at the University of Houston’s Symposium on Climate Change, Water and Adaptive Law. In response to comment, the paper was revised and submitted for publication in *Environmental & Energy Law & Policy Journal*. Key issues are the need to create flexibility to change how, where and when water is used while also protecting aquatic environments and the interests of water users who are not parties to the decision at hand. These issues also provided the basis for presentations for the Pacific Disaster Center’s Workshop on Climate Variability and Water; the World Wildlife Fund 2009 Kathryn Fuller Science for Nature Symposium; and Princeton Environment Institute’s Seminar series.

Other work focused on developing a multi-criteria approach for water sector adaptation planning in developing countries. This work highlights governance as one of several key aspects of an effective and well-integrated program to improve the robustness, resilience and flexibility of water management in the face of changing climate conditions.

FY2010 Accomplishments: 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 2010 CSAP’s Dr. Miller led an international team of social, biological and physical scientists in writing a paper entitled “Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science”(to be published in the Dec. 2010 issue of *Progress in Oceanography*). This paper describes the shortcomings of marine-system management advice coming from uncoordinated individual disciplinary research efforts, and calls for a transition to an “integrative-science” process that would entail ongoing engagement of resource managers, users and an interdisciplinary scientific team in developing and adjusting management measures in response to evolving information on the state of the resource system.

Another project developed and applied models of strategic optimizing behavior to evaluate the long-term consequences of alternative approaches that the Western and Central Pacific Fisheries Commission is considering for managing

multinational tuna harvests. This problem involves fishery stocks that migrate freely across the high seas as well as the Exclusive Economic Zones (EEZ's) of several Pacific island nations, and that are harvested primarily by large industrial fleets based in countries outside the region. Model results demonstrate that the impacts of ENSO on the movement of fish stocks could disrupt efforts to maintain cooperation on harvest management, but that appropriate policy design can stabilize incentives to cooperate. In addition, the model shows that overall economic returns and the division of fishery benefits between island nations and multinational fleets can vary significantly depending on the choice of policy instruments (e.g. limiting capacity-weighted number of vessels versus limiting capacity-weighted allowable days of fishing). A paper describing the model and demonstrating these results was presented at the 2010 meeting of the International Institute for Fisheries Economics and Trade (IIFET) and has been published in the conference proceedings.

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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, Del Monache, Hopson, Monaghan, Wilhelmi), with other laboratories in NCAR (Morss MMM, Oleson – CGD, Sain - Image), UCAR (Pandya), with university partners (CSU, CU, KU, U of Veracruz), federal agencies (CDC, NASA, Environment Canada), and state and local agencies (AZ Department of Health Services, Maricopa County Health Department and Houston Department of Health) the research will focus on:

- investigating the complex relationships among weather, climate, human health and ecosystems
- researching population vulnerability to human health threats
- determining appropriate adaptation and mitigation strategies to tackle these issues
- educating the next generation of scientists in these complex, yet interconnected areas

FY2010 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. Analysis and write-up are currently underway of data that have been collected from a pilot household survey in Phoenix, AZ to further our understanding of societal vulnerability to extreme heat. A framework for how to assess this vulnerability based on our Phoenix study was published in 2010:

Wilhelmi OV and Hayden MH. (2010) **Connecting people and place: a new framework for reducing urban vulnerability to extreme heat**. *Environ. Res. Lett.* 5 014021. doi: **10.1088/1748-9326/5/1/014021**

A new program was funded by NASA to develop a System for Integrated Modeling of Metropolitan heat Risk (SIMMER). The project will focus on understanding population vulnerability to extreme heat in Houston, TX.

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. Research conducted along the Arizona-Sonora border was published in 2010:

Hayden MH, Uejio C, Walker K, Ramberg F, Moreno-Sanchez R, Rosales C, Gameros M, Mearns LO, Zielinski-Gutierrez E and Janes CR. (2010) Microclimate and Human Ecological Factors in the Divergent Ecology of *Aedes aegypti* along the Arizona, U.S./Sonora, MX Border. *EcoHealth* 7 (1): 64-77. doi: 0.1007/s10393-010-0288-z

Additionally, we have received funding from NSF to conduct a new program to address this world-wide human health threat. The program, The vector mosquito *Aedes aegypti* at the margins: sensitivity of a coupled natural and human system to climate change, will investigate and model dengue fever risk along an altitudinal gradient from Veracruz to Puebla, Mexico, in FY2011-13.

A prototype Earth–gauging System Integrating Weather and Health Data to Manage Meningitis

This project supported by the Google Foundation aims to build and implement a prototype decision–support system that integrates two–to 14–day weather forecasts and epidemiological data to provide actionable information that can be used to contain the spread of meningitis epidemics. In 2010

Conducting a survey in Navrongo, Ghana

we continued to build our local partnerships in Ghana, undertook a site visit to field test a survey on knowledge, attitudes and practices (KAP) and cost of illness (COI) regarding meningitis in the Navrongo region of Ghana which will be conducted in early 2010 and 2011. Work is ongoing to demonstrate weather–meningitis links, and develop and verify ensemble–derived forecasts for meningitis management.

Integrating the Social and Physical Sciences toward Reducing Incidence of Plague in Rural Uganda

This project, sponsored by the Centers for Disease Control and Prevention, 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 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.

Traditional Healer in Rural Uganda

CDC-NCAR Postdoctoral Fellowship

Two new postdoctoral fellows have begun at NCAR this fall. They will be trained in aspects of climate modeling in the first year at NCAR and in epidemiology in the second year at the Centers for Disease Control and Prevention in Fort Collins, CO and Atlanta, GA. 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.

FY 2011 Plans

Work will continue on the meningitis and plague projects with funding through FY 2011 from Google and the Centers for Disease Control and Prevention (CDC) respectively.

Additionally, we have initiated work on our projects which have recently been funded by NSF and NASA by holding kick-off meetings. Our SIMMER project meeting in July 2010 included our collaborators from KU, Houston Dept. of Health, Environment Canada, and Toronto Dept. of Health. Work has also begun in Mexico with a recent visit to the region to meet with collaborators from the University of Veracruz and local and state officials in Veracruz, Xalapa, and Puebla, MX.

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Geographic Information System (GIS) Program

Background

The Geographic Information System (GIS) program at the National Center for Atmospheric Research (NCAR) is an interdisciplinary effort to foster collaborative science, spatial data interoperability, and knowledge sharing using GIS. Working toward the definition, standards and interoperability of atmospheric information for usable science, the GIS program is: 1) conducting research integrating the Earth system and social sciences through spatial analysis and interoperability of geo-referenced information; 2) supporting the use of GIS as both an analysis and an infrastructure tool in atmospheric research; 3) improving usable science and knowledge sharing between science groups, educators and stakeholders; and 4) addressing broader issues of spatial data management, interoperability, and geoinformatics within the geosciences. Research progress in integration of geographic and atmospheric information allows GIS staff to conduct and support a variety of research projects at NCAR, where spatial analysis and accurate georeferenced data are critical to answering complex scientific questions. With more than one hundred GIS users throughout NCAR, research projects range from atmospheric chemistry to societal impacts of climate change to homeland security.

Current research activities in the GIS program fit under the following two themes:

- Coupling social and natural sciences through integration of quantitative and qualitative data in a GIS and
- Improving spatial accuracy and usability of atmospheric models for terrestrial and societal applications.

FY2010 Accomplishments

RAL scientists contributed to a number of GIS-related projects in FY2010:

Integration of quantitative and qualitative data for spatial assessment of local level vulnerability and adaptive capacity to extreme heat.

Project participants: O. Wilhelmi, M. Hayden, H. Brenkert-Smith (NCAR), S. Harlan (ASU), and K. Komatsu (AZ Dept of Health). The study is focused on theoretical and methodological advancements for assessing local level vulnerability and adaptive capacity to extreme heat. A framework for assessing extreme heat vulnerability has been developed by Wilhelmi and Hayden (ERL, 2010). The framework explores linkages between quantitative and qualitative data for a more comprehensive understanding of local level vulnerability and adaptive capacity to extreme heat events. Statistical and spatial analyses are currently underway using data that have been collected from a pilot household survey in Phoenix, AZ to further our understanding of societal vulnerability to extreme heat.

System for Integrated Modeling of Metropolitan heat Risk (SIMMER).

Project participants: O. Wilhelmi, A. Monaghan, M. Hayden, S. Sain (IMAGe), Keith Oleson (CGD), Michael Barlage, C. Uejio, J. Boenhert, K. Sampson (NCAR), Johannes J. Feddema and Nathaniel Brunsell (Department of Geography, University of Kansas), Deborah Banerjee and Adebowale Awosika-Olumo (Houston Department of Health and Human Services), Marshall Shepherd (University of Georgia), Eric Fetzer (NASA JPL), Alex de Sherbinin (CIESIN, Columbia University), Robert Harriss (HARC), Claus Rinner (Ryerson University), Ugis Bickis and Abderrahmane Yagouti (Climate Change and Health Office, Health Canada HQ, Ottawa), Monica Campbell and Stephanie Gower (Environmental Protection Office, Toronto Public Health), Ciara De Jong (Toronto Environment Office, City of Toronto). This NASA-funded project (2010-2013) addresses the critical need for information at regional to local scales that are pertinent to public health decision-making in the context of global change. The primary goals are to: 1) advance the methodology for assessing current and future urban vulnerability from heat waves through integration of physical and social science models, research results, and NASA data; and 2) develop a System for Integrated Modeling of Metropolitan Extreme Heat Risk (SIMMER) for building local capacity for heat hazard mitigation and climate change adaptation in the public health sector. One of the strengths of this project is the emphasis on the validation of the SIMMER methodology. Collaboration with a research team in Toronto, Canada will ensure that the methodology developed for Houston, TX is transferrable and can be directly applied in public health decision-making.

Global assessment of urban heat island effect and future heat waves: GIS applications in urban climate modeling.

Project participants: O. Wilhelmi, J. Boehnert, K. Oleson (CGD), and J. Feddema (U. Kansas) - CCSM outputs from global coupled simulations of present-day climate and future climate are being analyzed in a GIS with respect to the

urban heat island effect, future heat waves and their impacts on urban population. This project involves development of geoprocessing techniques for working with the netCDF model outputs in a GIS; spatial analysis of projected heat waves intensity and spatial extent, and analysis of potential impacts of combined effect of urban heat island and future heat waves on urban population. A journal article is currently in preparation.

NCAR models in GIS applications.

Project participants: O. Wilhelmi, J. Boehnert, K. Sampson, N. Wilhelmi (CISL/TDD) - GIS program staff are assisting climate- and weather-related policy and decision making, which depend heavily on easy-to-use, easily accessible Earth system science output and data, by providing GIS-compatible user access to CCSM AR4 global and downscaled U.S. simulations. To-date, more than 3500 users from 133 countries have accessed the CCSM-3 climate predictions through the GIS data portal. Climate change analysis products (e.g., seasonal and annual averages, climate anomalies) have been generated by the GIS program and will be added for distribution through the GIS portal in 2011. Other efforts in this realm include development of a WRF-GIS Web interface to explore the use of Web services and Web GIS technologies to distribute WRF model outputs in the context of societal impacts of weather.

Analysis of the UCRB water demand: characteristics, spatial patterns and assessment of potential vulnerabilities.

Project participants: O. Wilhelmi, K. Sampson, J. Boehnert, and K. Miller) - This NOAA-funded project is an NCAR contribution to the NIDIS Upper Colorado River Basin (UCRB) Pilot project within Assessment of Gaps in Drought Monitoring. Specific activities conducted in FY10 included: 1) Identifying spatial, temporal and qualitative data gaps in water demand in the Upper Colorado River Basin; 2) Developing a NIDIS pilot data GIS data model for estimation of water demand and vulnerability to drought; 3) Building a geodatabase and the analysis tools to support topological relationships among water users and their respective source or sources of water supply. The data and data analysis methodology will be available in a GIS format for integration with other NIDIS products to be used in drought preparedness, early warning and future research.

GIS-focused education and training

26 selected participants from 12 countries in the Americas participated in the two-week IAI-NCAR colloquium on “Knowledge Innovation at the Science-Policy Interface” in April, 2010 at the University for International Cooperation in San José, Costa Rica. Topics covered in the colloquium included: 1) Science of risk and vulnerability to natural hazards and global environmental change; 2) Integration of scientific data and knowledge for risk assessment, mapping and decision-making; 3) Strategies and tools for practical communication of scientific data to non-scientific audience and decision-makers using GIS. Through presentations, hands-on GIS training and development of risk-assessment group projects and policy briefs, the colloquium participants learned about interdisciplinary science of global change and risk assessments, acquired GIS skills, and gained experience with science communication. Other efforts in GIS education and training included several NCAR-hosted GIS training sessions for staff, visitors and collaborators.

In addition, a paper was published:

Wilhelmi O.V. and Hayden M.H. (2010) **Connecting people and place: a new framework for reducing urban vulnerability to extreme heat**. *Environ. Res. Lett.* 5 014021. doi: **10.1088/1748-9326/5/1/014021**

FY 2011 Plans

Work will continue on improving the accessibility of NCAR models. A new version of the climate change portal is expected to be released in FY11. Web-based educational resources that link GIS, climate science and societal impacts are currently being developed. We will continue geospatial research associated with the heat and health projects. We have initiated work on the SIMMER project. In FY11 we also expect to submit journal articles for the Phoenix heat stress and global heat waves projects.

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