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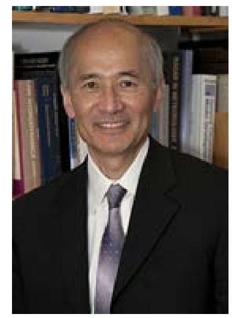
2011 Annual Report

A Message from the Director



Roger Wakimoto

This is the time of year where things slow down momentarily, giving me a chance to take a look back at the previous year's work, even as efforts for Fiscal Year 2012 move ahead. Both the community and NCAR continue making notable scientific achievements.

Critical to NCAR's efforts to serve the university community are our leaders. In 2011 two of our labs – the Earth Observing Laboratory (EOL) and the NCAR Earth System Laboratory (NESL) – both gained new directors, Vanda Grubišić and Jim Hurrell, respectively. In addition, Michael Thompson became the High Altitude Observatory's director in July 2010. After 23 years, Rick Anthes has stepped down from his role as president of the University Corporation for Atmospheric Research (UCAR). While Rick will continue in his scientific endeavors, I'd like to thank him for his years of effort on behalf of NCAR, UCAR, the National Science Foundation, and the university community. I would also like to welcome Tom Bogdan, who begins as UCAR president in early January 2012. I look forward to the years to come working with these new team members.

Other exciting news includes finalization of the NCAR-Wyoming Supercomputing Center (NWSC) construction and commissioning, completed in October 2011, on schedule and within the planned budget for the project. At the start of operations 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. With the last two missions flown this summer, the HIAPER Pole-to-Pole experiment comes to an end. This multi-university, multi-institution, multi-agency effort led by Harvard, generated an extraordinarily detailed mapping of the global distribution of greenhouse gases, black carbon and related chemical species in the atmosphere. Congratulations to all involved on the effort to create this rich set of observations.

Congratulations are also due to the EOL team led by Terry Hock, which received recognition from John Hickenlooper, Colorado's Governor, for innovative dropsonde technology created and refined over the past five years. The 2011 Colorado Governor's Award for High-Impact Research recognizes outstanding research that will change the quality of life for people here and all over the world. Also of note is work done by the Research Applications Laboratory's wind energy team, which worked with the National Renewable Energy Laboratory and Xcel Energy to provide highly detailed, localized weather forecasts to help Xcel's wind energy production. The forecasts enabled the utility to better integrate electricity generated from wind into the power grid, in particular by helping plant operators decide when to power down traditional coal and natural gas plants and rely on wind energy instead, in the process saving rate payers millions of dollars.

Continuing our focus on helping educate the next generation of scientists, the Integrated Science Program (ISP) ran a 2-week colloquium on African weather and climate. The colloquium brought together students and researchers working on climate and weather issues in Africa, with a focus on learning how to use remote sensing, numerical simulation and prediction, statistical data analysis, and visualization tools to address scientific questions. The Advanced Study Program's (ASP) *Statistical Assessment of Extreme Weather Phenomena under Climate Change* included 100 participants – including students, lecturers, and researchers – visited NCAR over a three-week period. Expanded from two weeks, the extra week allowed students more time to work on hands-on projects, and added a topical Research Colloquium during the middle week, in which researchers had a rare opportunity to engage in five days of discussion with other experts in the field of extreme value theory. The ASP also ran a student workshop that coincided with the Denver-based World Climate Research Programme's open science conference, which brought together for the first time ever its entire research community.

In addition to the news above, NCAR and our community participated in many other notable scientific efforts. Please 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. 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 2011 work.

With best wishes for 2012 and sincere thanks for your ongoing support, and the hard work of the past year, *Roger*

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NCAR Community 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 2011. Highlights run the gamut from gathering detailed atmospheric data over Antarctica to predicting hurricane formation in the Atlantic Basin. Also featured is a new, modular wind profiler that has the flexibility to meet a broad range of research needs, and a look at NCAR's Web 2.0 capabilities that keep our various audiences - the public, scientists, funders, etc. - up to date on the latest efforts going on within NCAR and the community.

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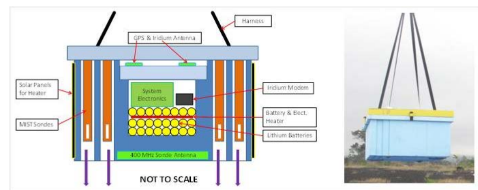
Up, Up, and Away: Concordiasi Driftsonde takes to Antarctica's Skies

Like salt in soup, research tools often go relatively unnoticed unless missing or malfunctioning. Lacking the right tools may result in scientific outcomes or understanding that is less impactful, and potentially more difficult to achieve. When tools work well, greater possibility exists for discovery, and in some cases the right tool may offer new or unlooked-for results. In the recent Concordiasi Project launched from McMurdo research station in Antarctica, Driftsonde technology provided the equivalent of not just the salt but the vegetables, protein and broth for the Météo-France-, National Science Foundation-funded field campaign.



This schematic shows the balloon-based Driftsonde concept. The Driftsonde releases dropsondes, which measure and relay information on wind, temperature, humidity and other meteorological characteristics as they descend through the atmosphere. These data get sent back to the Driftsonde. In turn, the Driftsonde transmits the data to satellites, such as the IRIDIUM Leo satellite, which provides critical information used in near-real time weather forecasting.

The Driftsonde System, developed by a team of mechanical, electrical and software engineers in NCAR's Earth Observing Laboratory (EOL) to provide a low-cost way of taking instant measurements along a vertical profile of atmosphere, looks something like a giant weather balloon – a weather balloon that offers oversized observing capabilities. Launched from the ground and able to stay aloft for up to several months, Driftsonde systems provide Concordiasi researchers with a sophisticated suite of tools.

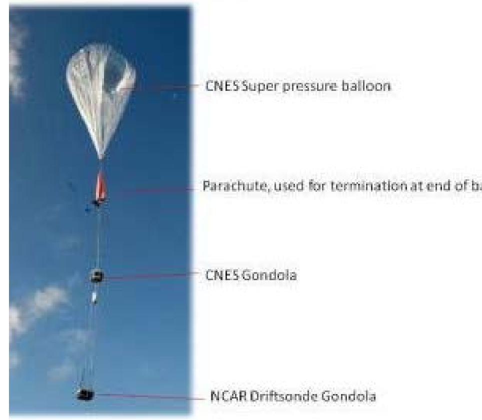
Fitted with dropsonde instrumentation, once launched Driftsondes collect the detailed atmospheric information transmitted back from dropsonde sensors to the Driftsonde gondola. Measurements include observed atmospheric characteristics such as wind, temperature, humidity, and pressure.

Operated remotely using a web-based interface, this design allowed dropsonde control and monitoring to occur from anywhere in the world with an internet connection. This proved helpful during Concordiasi's 24/7 operations, when Boulder- and France-based operators transitioned operations at the respective day's beginning and end in each country.

These capabilities also allowed dropsonde release to occur at desired points along the Driftsonde flight path. Points of interest included remote geographic areas and significant weather events, for example. Also, a main focus for Concordiasi scientists, the EOL team worked closely with Météo-France to ensure that some dropsonde releases coincided with satellite overpasses to facilitate validation of these remotely sensed data, says Steve Cohn, manager of EOL's In-situ Sensing Facility (ISF).

"We also kept an eye on areas that atmospheric models indicated were sensitive to new data, so if something particularly interesting was taking place or about to happen, atmospherically, a dropsonde could be launched," Cohn says. "The team worked closely with Antarctic modelers and forecasters to identify such events."

The Concordiasi Driftsondes were built and deployed by NCAR and flown on France's space agency (Centre National d'Etudes Spaciales) super pressure balloons and included as part of an International Polar Year research effort. With launches occurring in September and October 2010, some of the Driftsondes remained aloft into December.



Flight train of Concordiasi balloon just after launch in Antarctica.

Météo-France initiated and led the Concordiasi project, which is named after France's Concordia research station located on the Antarctic Plateau and the IASI (Infrared Atmospheric Sounding Interferometer) satellite instrument; IASI is a key element of the METOP series of European meteorological polar-orbiting satellites. The campaign included researchers from around the world who looked to the Driftsonde observing systems to validate satellite data and obtain detailed information on the atmosphere in data-sensitive areas – areas where models indicated need for more information for validation, or very remote areas where data are rarely if ever collected. Other Concordiasi measurements focused on understanding the microphysics of polar stratospheric clouds.

Driftsonde Systems Help Validate Radiance Data and Offer Views on Cloud Microphysics

Polar-orbiting satellites over Antarctica collect radiance data. These snapshots of upwelling radiation coming from the surface or lower atmosphere can be translated into temperature data, providing insights on surface-level and atmospheric processes. Satellite-sensor precision varies, however, which can affect output from weather and climate models using the satellite-derived temperature data. Consequently, data validation becomes imperative. Dropsonde measurements of temperature will help achieve this end.

Equally important to Concoridasi scientists was broadening the depth of knowledge related to stratospheric clouds and small-scale physical processes. At the best of times, cloud formation and dispersal and the atmospheric characteristics affecting cloud dynamics are nuanced, but at such high altitude (18 km) and in one of the planet's most remote areas, this becomes even more of an issue. Importantly, the data collected during Concordiasi will increase **understanding of processes driving ozone-hole formation each** spring in the Southern Hemisphere.

Toward these ends, the fall 2010 Concordiasi program flew 13 Driftsondes from McMurdo, the main U.S. research base on Antarctica. Fitted with as many as 52 miniature dropsondes, the Driftsondes transmitted detailed atmospheric information via satellite to a ground-based station in real time. While such a capability may seem conventional, reliable real-time satellite data transfer has only recently become viable globally. Although the Driftsonde System was developed for the African Monsoon Multidisciplinary Analyses (AMMA) in 2006, Concordiasi offered an opportunity to enhance remote operations, real-time data download capabilities and quick-turn upload functionality that feeds operational weather models. The team also improved Driftsonde technology to allow the systems to function aloft over the span of several months.

During Concordiasi, operators on the ground vetted atmospheric data soon after Driftsonde transmittal, running the data through quality-control procedures before uploading it to the Global Telecommunications System (GTS); a World Meteorological Organization effort, the GTS facilitates *collection, exchange and distribution of weather observations and data*. Once in this system, Concoridasi data were used by operational models at research centers around the world responsible for creating near-real-time weather forecasts.

The 639 dropsonde profiles collected during Concoridiasi provide an unprecedented spatial data set over Antarctica. They offer valuable data for future atmospheric research in this region of the world.

In addition to providing new insights on Antarctic atmospheric characteristics, several spin-off developments have benefitted from this work. Among these is perfecting technology created by EOL engineers for a dropsonde system on NASA's Global Hawk, an unmanned aerial vehicle that, like the Driftsonde, flies at stratospheric altitudes, collecting data that would otherwise not be accessible to researchers. This technology also allows real-time dropsonde release and download of data from a ground station – Driftsonde technology development led to this capability. Additionally, EOL developed the Mini dropsonde specifically for the Driftsondes; these smaller dropsondes will prove useful for future research campaigns on manned aircraft. And, up next, a new dropsonde system is under development for use on the NSF/NCAR Gulfstream V (GV) research airplane. The new system will automate GV dropsonde launches; currently an operator manually launches the dropsondes.

"This upgrade is a huge step forward," explains Cohn. "Today, safety demands that during excessive turbulence operators remain in their seats on the GV – this means the sondes don't launch. Automating launch gives scientists and staff who operate the system greater control over dropsondes."

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New Wind Profiler Design Adds Research-Design Flexibility

One size fits all research equipment has advantages: scientists know what they're dealing with, this approach saves on costs, and can serve more than one project. But, despite the advantages, one-size-fits-all sometimes leaves a desire for something more tailored to meet research needs.

The prototype hexagonal antenna modules of EOL's new 449 MHz wind profiler radar undergoing testing at NCAR Foothills Lab in Boulder.

During T-REX (the Terrain-Induced Rotor Experiment), scientists studied atmospheric dynamics occurring leeward of mountain-ridge crests. Run in 2006 in California's Owens Valley, deployable, upward-looking 915 megahertz (MHz) wind profilers assisted with observations of the atmosphere. These Doppler radar provided details on atmospheric characteristics such as winds, turbulence, clouds, and precipitation. The wind profilers can measure winds upward to three kilometers at a resolution as high as 60 meters, with temperatures measurable up to about one kilometer. While glad to have the upward-looking, mobile radars, the scientists would have benefited from additional atmospheric detail.

"One size fits all doesn't offer much flexibility at times – it's like using one hammer to hit all kinds of nails," says William Brown, a project scientist at the National Center for Atmospheric Research's (NCAR) Earth Observing Laboratory (EOL), and leader for the lab's atmospheric profiling group. "For T-REX, we wanted to see the wide range of atmospheric dynamics, but only had enough wind profilers to set up at a few locations and didn't have flexibility, for example, to vary how deep we could look into the atmosphere."

Having talked about alternatives to the 915 MHz profiler during a number of projects, including renting or borrowing equipment, T-REX eventually led EOL's In-situ Facility (ISF) team to explore the option of building one themselves. Their engineering skills combined with EOL's Computing Data and Software (CDS) facility, made this entirely possible. They wanted a wind profiler that both better met researchers' needs and increased the equipment manageability factor – quick and easy to set up and lighter weight.

The team envisioned a modular design that would allow the option of lining a series of wind profilers along the expanse of a research site or combining a number of individual radars to create a single, more powerful wind profiler able to see beyond the 3-km atmospheric boundary layer. The other issue facing them: such a wind profiler would have to work within the narrow radio frequency range allocated by the U.S. federal government for scientific use. Many of the frequencies within the radio frequency spectrum are reserved for use by cell phones, and television and radio broadcasting.

Taking all of these needs and desires into consideration, ISF took the idea of creating a modular 449 MHz wind profiler for future research to EOL management, which funded the initial development effort in 2008.

The resulting modular 449 MHz wind profiler, as the IFS team envisioned it, offered an exciting advance in weather data collection, by providing a network of upward-looking radar, able to "see" a minimum of 4 km into the atmosphere at a range resolution of 50 meters and time resolution of a few minutes. Such a system would be able to provide detailed observations on the characteristics of the atmospheric boundary layer between the Earth's surface and the top of the troposphere where much of the weather that society experiences occurs.

The development is proceeding in stages. So far a prototype, three-module system has been built, and additional funding received from the NCAR directorate is enabling more modules to be constructed. Being modular and deployable, the system can be loaded onto a trailer and sited wherever research needs require. Once in the field, the 449's network of radar antenna modules can be assembled as a single-antenna unit, or multiple units that build on the cumulative capacity to look higher into the atmosphere. And, while weather balloons are equally mobile, it is expensive to deploy balloons in large numbers and they cannot provide the same level of continuous detailed focus on a selected area of study.

A field campaign, the Persistent Cold Air Pool Study (PCAPS), run by the University of Utah, Michigan State University and NCAR offered a first-test opportunity for the 449 MHz wind profiler in 2010. Many cities surrounded by mountains have issues with inversions in which overlying warm air traps cooler – often polluted – air in the underlying basin or valley, PCAPS observations will help with understanding weather conditions that contribute to these inversions. The study required continuous weather monitoring, which included launch of more than 150 weather balloons, as well as use of NCAR's 915 and 449 MHz wind-profiler radars to capture details of wind, temperature, precipitation and humidity along vertical columns of atmosphere above Salt Lake City.

"PCAPS offered a chance for side-by-side testing of the 915 and 449 MHz wind profilers, as well as the opportunity to fiddle with and fine-tune the 449's 3-antenna prototype – with good results," says Steve Cohn, manager of EOL's In-situ Sensing Facility.

PCAPS relied on the three-module wind profiler, however future visions include stringing together multiple antenna modules to suit the required research need – whether looking at the mid- or upper troposphere, or as far as the lower stratosphere. A 7-module network configuration is now being built that will allow the radar to look at the mid-troposphere; this configuration will be tested in summer 2012.

Further down the road, scientists and engineers in EOL hope to make observations of the lower stratosphere by stringing together 19 antenna modules that will provide information on the atmosphere's characteristics spanning from 300 meters to 15 kilometers from the Earth's surface, at a resolution as fine as 100 meters.

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Web 2.0 at NCAR

Communications teams within the National Center for Atmospheric Research (NCAR) have fully embraced social networking technology. The HIPPO (HIAPER Pole-to-Pole) flights in 2009 set the stage for the initial introduction of Web 2.0 into NCAR. At the start of this study to collect observations within the global troposphere to better understand the global carbon cycle, interested viewers could watch the progress of the National Science Foundation/NCAR Gulfstream V (GV) as it flew across the globe, from pole to pole, using the Google Earth tracking tool. In recent years, EOL broadened its capabilities in this area by hiring a public education and outreach coordinator, Alison Rockwell, to help publicize its many field campaigns and field-research-support efforts. In doing so, new functionality including video, Facebook, and Twitter got added to the mix.

EOL has provided a site that breaks the variety of project foci up for easier viewing; among these are severe weather, climate processes, atmospheric patterns, ocean processes, and air chemistry, **www.eol.ucar.edu/field_projects/project-categories/ocean-systems**. Here, readers can find links with user-friendly, digestible views on the details of EOL projects under way or recently completed.

A view of NCAR-Wyoming Super Computing Center visitors' center while under construction and upon completion.

For example, under the Ocean Dynamics section, DYNAMO (run in 2011), HIPPO (run from 2009-2011), and VOCALS (run in 2008; VAMOS (Variability of the American Monsoon Season) Ocean-Cloud-Atmosphere-Land Study) are among the featured research projects. Project pages contain YouTube videos, as well as the series of Twitter and Facebook feeds created during the project lifetime.

"The beauty of this system is that after creating a Facebook entry, the entry gets fed to Twitter automatically, so a single notice of events is generated simultaneously onto different sites looked at by different audiences," says Rockwell.

In addition, YouTube is a highly utilized feature at EOL, with videos taken during campaign preparation, while the campaign is in action, and post-flight to fully capture a "day in the life" for those who haven't experienced a typical day in the field.

EOL is not alone in its social media efforts. The Computational and Information Systems Laboratory (CISL) has targeted the NCAR-Wyoming Supercomputing Center (NWSC) as the path to leaping into the Web 2.0 foray, covering development of the building that will soon house NCAR's supercomputers, as well as providing project background, and other details on the effort. A construction web-cam set up at the site lets virtual visitors see the latest developments in the NWSC structural build, nwsc.ucar.edu/. For those having missed earlier building phases, a time-lapse video shows the facility's construction from the ground up, with glimpses provided of the changes in weather and seasons throughout the effort an added viewing bonus.

Not to be left behind in the realm of Facebook and Twitter, the NWSC team maintains updates to both sites that give notice of project milestones, a heads up on talks going on at conferences and meetings, and other relevant information. Images from weekly reports written to keep NCAR and Wyoming project managers and NWSC personnel updated are multi-purposed, with relevant images and captions uploaded to Facebook and Twitter, in addition to a variety of photos that document project progress.

The High Altitude Observatory also has a Facebook page – perhaps no surprise given the number of graduate students and postdocs associated with the Observatory, says HAO's Associate Director, Michael Thompson.

"Our Facebook pages helps connect existing postdocs and graduate students with former students – so far, we've got 260 followers, which seems pretty good given that we only recently made the site available," continues Thompson.

In addition to NCAR's efforts, the University Corporation for Atmospheric Research (UCAR), NCAR's managing body, provides a variety of Web 2.0 capabilities, http://www2.ucar.edu/news/social-networking-ncar-ucar. These include Facebook and Twitter, as well as a number of blogs and YouTube channels highlighting NCAR and UCAR research, and Flickr, which features images from a digital image library and COMET, a science-education program.

For more information see: **www.nwsc.ucar.edu** and **https://www.eol.ucar.edu/field_projects**

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PREDICTing Hurricane Formation in the Atlantic Basin

Some tropical weather systems originating over Africa end up forming hurricanes upon reaching the central or western Atlantic ocean. Forecasts of the movement of hurricanes, once formed, have improved markedly during the past three decades, however a major challenge remains to predict the formation of hurricanes. By understanding the formation stages of hurricanes, scientists hope to improve numerical forecasts and provide additional forecast guidance tools so that accurate forecasts can be made farther in advance. They anticipate improving hurricane forecasts out to as much as seven days – today, fairly accurate hurricane forecasts can be achieved three to five days in advance of storms. This longer lead time may further reduce societal and infrastructure losses.

Thus far, observations of hurricane formation – tropical cyclogenesis – have been limited because hurricane development typically happens over vast expanses of ocean. Typically the only observations are made by satellites, and while vital to forecasting, satellite measurements can't observe everything needed to make accurate forecasts. Using the NSF/NCAR Gulfstream V (GV) aircraft in the Atlantic basin as part of the PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT) field experiment, scientists gained a wealth of new observations captured during flights over the basin during hurricane season. In particular, they wanted to observe wave-like disturbances whose characteristics are theorized to provide clues about the likelihood of hurricane formation.

PREDICT Research Flight number 4, August 21, 2010.

"During PREDICT, we located storm systems early, and followed them over several days before they developed," explains Chris Davis, one of the project's principle investigators. "Having double crews allowed us to follow storms, gaining detailed information on formation processes."

Two of three well-sampled storms became tropical storms, says Davis, one did not. All three provided insights of hurricane genesis, as well as on factors contributing to lack of development.

"Because the project focused on tropical cyclogenesis, we looked at weak, early stage storms forming in the tropics. Having an opportunity to see a system *not* turn into a tropical storm is as important as seeing storm formation," Davis says.

One of the desired project outcomes was to gain a set of cyclogenesis-prediction conditions that could help determine whether something would or would not happen, hurricane-wise, with the goal of taking some of the element of surprise out of the forecasting mix. As a result, perhaps the most exciting outcome of the effort was in finding that consistency exists between real-life storm formation and theories of what might happen. This, says Davis, offered a case of theoretical analysis matching up with real-life dynamics. PREDICT provided an opportunity to observe and document such outcomes.

Operating during the 2010 hurricane season from August through September, the National Science Foundation-sponsored PREDICT team was not alone in its efforts to study hurricanes in the Caribbean. NOAA and NASA also ran programs during this timeframe. The fortuitous timing led to collaborations when aircraft from each agency could observe the same weather system. Data and analysis outcomes will be shared between the three agency teams.

Together, the teams have gathered a wealth of data, and expect much to be gained upon further study. Basic data analysis is underway, which includes identifying areas that would benefit from further, future investigation. PREDICT has also resulted in advances from a practical research perspective. These include real-time monitoring and mission refinements. Since PREDICT's end, subsequent research missions using the GV have benefitted from the ability developed during PREDICT to stream information in real time about the best locations to send the plane to gather required or desired information. Moreover, PREDICT efforts have assisted in refining data archival and retrieval techniques via the web, which speeds analysis capabilities. Data archived at EOL in the field catalog are more readily retrievable, and the ability to look at data has improved. All of this, in combination, says Davis, leads to improved future campaigns and has enhanced PREDICT's contribution to the research community.

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Forecasting Tool Optimizes Integration of Wind Energy into the Electricity Grid

Many in our research community rely on NCAR for providing research tools that are critical to helping find answers to scientific and societally relevant questions. Among these tools and capabilities are the Earth System Grid, which assists with efficient delivery of scientific data to new and existing users, a new coronagraph that facilitates detecting and tracking solar activity, and forecasting capabilities that improve integration of wind-generated electricity into the utility grid.

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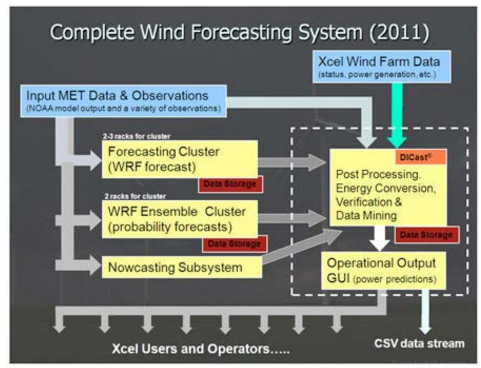
Forecasting Tool Optimizes Integration of Wind Energy into the Electricity Grid

Wind as an energy source has captured the attention of energy and utility industries. However, when it comes to wind-energy generation, accurate forecasts are crucial for efficient planning and resource management. Knowing when the wind will blow and when it won't has been a major impediment to ensuring wind power meets its full potential. But as wind forecasts improve this may become less of an issue. The Research Applications Laboratory (RAL) at the National Center for Atmospheric Research (NCAR) is contributing to this greater level of reliability. Working with Xcel Energy, the nation's leading utility in wind energy, and the National Renewable Energy Laboratory (NREL), scientists and engineers have developed and deployed an advanced wind power prediction system – the NCAR/RAL Wind Power Forecasting System.



Conceptual diagram of the wind energy prediction technology components that will be incorporated into the final configuration.

With 3.4 million electric customers, Xcel Energy is the fifth largest combined electric and gas utility in the United States. It boasts the largest wind energy capacity in the continental U.S. with more than 50 wind farms, 2972 turbines, and 4062 MW of wind power. The company knew that to expand their renewable capacity from 10% to 30% to meet the State of Colorado's renewable energy requirement, they needed a significant improvement in wind prediction. In addition, accurate wind forecasts and uncertainty information are necessary both for day-ahead trading and real-time decision making regarding power levels of back-up energy generation units and transmission. Until recently, the commercial marketplace lacked access to wind-power forecasting capabilities that provided the needed level of accuracy.

As the wind capacity of a utility grows, it becomes more difficult to effectively integrate this variable resource into the power mix. Accurate wind power forecasts significantly improve integration by reducing uncertainty of wind generation, and in doing so lead to cost reductions as reliability of output improves. In addition, reliable day-ahead forecasts enable more efficient energy trading between utilities that lead to more economic power dispatch.

RAL's wind power forecasting system substantially advances the state-of-the-science of wind power forecasting through integrating advanced modeling capabilities, real-time data assimilation, nowcasting, and statistical post-processing technologies. The system utilizes both publically available model data and weather observations and wind forecasts produced from a customized NCAR-developed wind forecasting model that also incorporates real-time data (e.g., wind speed, power, availability, etc.) from 2972 wind turbines. The observations and model forecast data are combined using NCAR's Dynamic, Integrated, Forecast System (DICast) technology, which automatically calibrates and adjusts the predictions based on real-time feedback from the wind generators.

The forecasting system enables utilities to integrate large amounts of wind energy into the power grid by providing comprehensive forecasts of wind-power generation on both short-term time scales of 15 minutes to three hours, and at scales that allow longer term planning – on an hourly basis up to 168 hours (7 days) in advance. Implementation of the system has resulted in a 40% reduction in wind energy prediction error, which has improved integration of wind power into the electric grid. In 2010 alone, the increased accuracy saved Xcel Energy rate payers $6 million.

This wind energy forecasting system is widely considered, nationally and internationally, to be the most advanced system of its kind with the details of the system configuration and component technologies freely shared with the meteorological and energy communities, says William Mahoney, the NCAR scientist who conceived the project and provided project oversight.

"Never has so much real-time [meteorological and power system] data been leveraged in an operational wind energy forecasting system. This was truly ground-breaking work," says Eric Pierce, Xcel Energy's Managing Director of Energy Trading and Commercial Operations. "Xcel as seen return of investment through cost reductions due to greater operational efficiencies."

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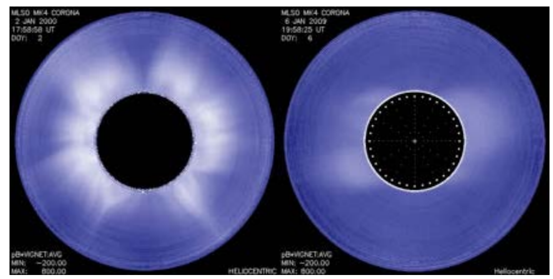
New Coronagraph Assists in Detecting and Tracking Solar Activity

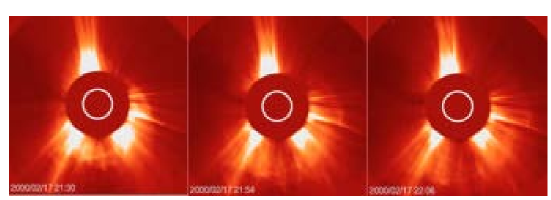


Comparison of coronal brightness between solar activity maximum (left) and activity minimum (right). Images were acquired with the MK4 Mauna Loa K-coronameter on Jan 2, 2000 during solar maximum and on Jan 6, 2009 during solar minimum. Brighter regions are locations where the Sun's magnetic field contains the plasma creating high density regions; dark regions are where the magnetic field is open, allowing the plasma and embedded magnetic field to escape to form the solar wind. Images have the same scaling and color table to illustrate solar cycle variations.

Streams of charged ions, radiation, and other matter are routinely ejected from the Sun's atmosphere outward into the solar system. When directed Earthward and depending on their strength, effects of these mass ejections from the solar corona can increase radiation levels in the Earth's upper atmosphere, posing hazards to astronauts, and to a lesser extent for high altitude airplane flights particularly over the north and south poles. In addition, generation of strong electrical currents from these storms may affect functioning of electrical transmission lines and the dependent power grids, and interfere with radio and satellite signals, which can affect air transportation and day-to-day activity of society. Helping to provide a better view and warning of such space weather phenomena, scientists rely on a variety of instruments including coronagraphs. These telescopes are designed with disks that block – occult – the bright light of the Sun's surface to provide a view on the fainter outer solar atmosphere known as the corona. Scientists study this region because the most energetic forms of solar activity, such as coronal mass ejections (CMEs) and flares, originate in the corona.

NCAR's new K-coronagraph will soon be deployed to the Mauna Loa observatory in Hawaii, replacing the existing MK4 coronagraph. Like the MK4, the new coronagraph will measure the polarized white light emitted from the corona. Like all coronagraphs, the K-coronagraph effectively replicates a solar eclipse artificially. An occulting disk located inside the telescope blocks the bright light emitted from the Sun's surface, overpowering the corona, which is a million times dimmer. Using the K-coronagraph, scientists expect to be able to observe CME dynamics at early formation stages, which will allow researchers to better understand how they form and providing time to prepare for resulting space weather effects.

CMEs form enormous, magnetically charged loops of coronal material, with larger CMEs propelling billions of tons of material toward Earth at roughly 1.5 million kilometers per hour (~900,000 miles per hour) with the fastest ones traveling more than 10 million kilometers per hour (seven million miles per hour). The number of CMEs that form varies with the sunspot cycle. During solar minimum, when solar activity is low, one CME may be generated each week. During the other extreme of the Sun's cycle, the solar maximum when solar activity is much higher, several CMEs may be generated daily. CMEs, explains Joan Burkepile a project scientist in NCAR's High Altitude Observatory, may also play an important role in reversing the direction of the Sun's magnetic field that happens each sunspot cycle.



Large Angle and Spectrometric Coronagraph (LASCO) halo coronal mass ejection (CME) of February 17, 2000. The portion of the halo directly over the south pole was recorded by the MK4. This is one of the brighter halos recorded by LASCO.

"HAO scientist B.C. Low has theorized that CMEs may play a critical role in removing twisted coronal magnetic flux. The cumulative effects of many CMEs over the sunspot cycle removes the old cycle magnetic flux from the corona, enabling the reversal of the Sun's magnetic field, and making way for the next sunspot cycle," says Burkepile.

The K-coronagraph will assist in detecting and tracking CME activities, aiding prediction of geomagnetic storms. Among its capabilities is a low signal-to-noise ratio, which means it has the capacity to provide research with extremely high quality images of the very low corona in white light. The K-coronagraph will acquire images every 15 seconds across a field of view that ranges from 1.05 to 3 solar radii – approximately 20,000 to 800,000 miles above the solar surface. While enormous from the perspective of a view on Earth, the resulting relatively narrow, detailed images allow scientists to more readily identify CME speeds and acceleration rates over time; such perspective is critical for understanding processes related to CME generation and dynamics. Currently, a variety of theories exist about the details of CME formation. Improved observations will assist in refining these ideas.

Like its predecessors, the K-coronagraph will also be used in conjunction with space-based coronagraph observations. Ground-based versions complement satellite sensors by providing coronal views that are lower, or closer, to the coronal regions located nearest to the Sun's surface. Ground-based coronagraphs – and the K-coronagraph in particular – have advantages over satellite coronagraphs in that they are more accessible in the event of modifications or upgrades being needed. Also, data transmission costs are less, and facilities are more easily maintained over sustained periods of time. Ideally, the K-coronagraph will become part of an international network of similar telescopes, useful for supporting solar research as well as cultivating future generations of instrumentation scientists.

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A History of the Earth System Grid and Gateways

Approximately every five years, the Intergovernmental Panel on Climate Change (IPCC) issues a report providing the world with an updated assessment of the risks of human-induced climate change. This report relies on information produced by physical and social scientists from around the globe based on research done in the years leading up to publication. For the climate model runs alone, significant amounts of data have to be delivered from researchers to a data clearing house where it is stored and served on-demand to meet user requests for the information. According to the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National Laboratory, which hosted all of the climate model data for the IPCC Fourth Assessment Report (AR4), more than 35 terabytes (TB) of climate model output from 17 modeling centers worldwide were made available to the science community. Twelve hundred registered users had downloaded more than 337 TB of data as of January 2007, the month before AR4 publication. As of late 2011, nearly 600 peer-reviewed publications had been written that used the IPCC AR4 model output archived at PCMDI.

The IPCC assessment offers only one example of the need for data center staff and tools capable of providing large volumes of data seamlessly. Adding to this challenge is the increasing number of scientific endeavors that demand raw data to begin the research process and the related increase in data users, many of whom have limited experience working with large computing systems to access the available information. The open availability of such large volumes of data to the global user community, comprised not just of research scientists but also the general public, students, policymakers, economists, urban planners, and other analysts, requires specialized resources and staff. The skills of computer scientists and software engineers, and data managers and data scientists, plus the computing hardware and software needed, are all necessary to enable easy access to these data.

"As demand for data increases from users with varied computing expertise, the scientific community and NCAR needed to find a means of delivering data in a more streamlined fashion," explains Gary Strand, a software engineer at the National Center for Atmospheric Research (NCAR) who specializes in climate model data management.

NCAR – and Strand – has long served climate model data to its user community. But as user numbers grew, they recognized a need for improved protocols for serving these data to new and existing users. In the late 1990s, says Strand, the U.S. Department of Energy (DOE) began a project called "the Earth System Grid" (ESG) as a means of transferring large volumes (10 TB or more) of data between the DOE laboratories distributed across the United States.

"DOE funded the Earth System Grid to find a way to efficiently move data between Argonne National Laboratory in Illinois and Lawrence Livermore National Laboratory in California, and other DOE labs," explains Strand. "The ESG project success led Warren Washington, an NCAR senior scientist, to consider the resulting approach as useful for delivery of NCAR climate data, both from the perspective of NCAR data users and for those on the data delivery side."

NCAR become involved in the Earth System Grid (ESG) in the early 2000s. NCAR was the first "gateway" of the ESG, using the new technology to deliver the DOE-funded Parallel Computer Model (PCM) climate data to the wider user community.

Working with the DOE labs and PCMDI, NCAR researchers and their DOE colleagues met weekly to discuss hardware and software needs for the system, as well as figuring out a way to distribute data via the Web in response to the growing variety of users and user needs. By 2004, the group had a solid prototype for Web-based data delivery that allowed both experienced and less expert users broader data access, and streamlined the work required behind the scenes. Between 2004 and 2006, Strand says that just for NCAR, the number of users requesting and being served PCM data grew from dozens to hundreds. Around this same time, the newly developed Community Climate System Model version 3 (CCSM3) working groups also sought to use the ESG Gateway to deliver CCSM3 data.

"ESG has been incredibly successful. In 2005, PCMDI become that second ESG Gateway for the AR4 data – and these data are still actively mined by users. With the IPCC Fifth Assessment Report now under way, ESG data distribution gateways have expanded to centers around the world, and this redundancy of data availability and delivery benefits all, and indicates buy-in for the ESG by the global scientific community," Strand says.

Side Bar: Updates on the Community Earth System Model

In June 2010, NCAR researchers delivered climate data from the Community Earth System Model (CESM) to the global climate community. Completion of CESM 1.03 earlier this year includes the capability for modelers to run Coupled Model Intercomparison Project 5 (CMIP5) and Representative Concentration Path (RCP) simulations. In addition, CESM has a new Scientific Steering Committee Chairperson and Project Lead in Marika Holland.

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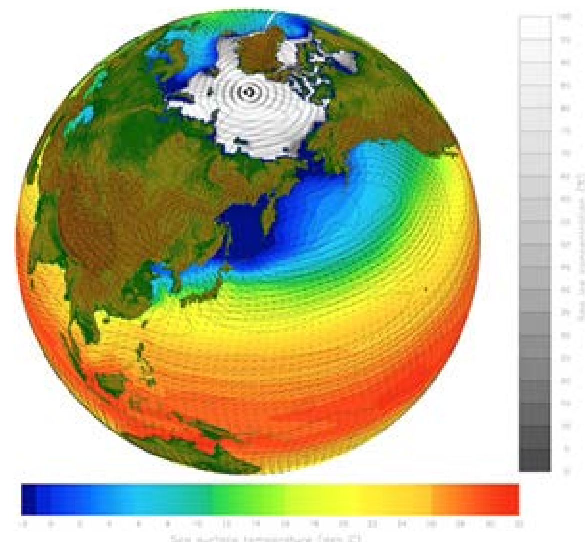
Cyberinfrastructure for data-enabled science



The figure depicts a single month from a simulation of the 20th century from the Community Earth System Model (CESM), a coupled model that integrates atmosphere, ocean, land, and ice components. The figure shows wind vectors (arrows) from the lowest atmosphere layer and contours of sea level pressure. The ocean model surface temperatures are shown in orange to blue colors (see color key at bottom), and sea ice is shown in grayscale (see key at right).

In FY2011 climate scientists using CCSM and CESM intensified their program of extremely ambitious climate change simulations for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). This work follows the experimental design of the Fifth Coupled Model Intercomparison Project (CMIP5). CMIP5 describes a set of coordinated climate model experiments designed to address questions about climate change that arose from the IPCC's previous assessment report (AR4). CMIP5 is a five-year experimental design, but the new data infrastructure developed in NCAR's Computational and Information Systems Laboratory (CISL) improved the efficiency of the workflows for these critical simulations and reduced their time to completion. Further, algorithms developed in CISL were used to assimilate the observed global temperature and ocean salinity as initial conditions for the IPCC's ensemble decadal predictions. Developing this capability with the Data Assimilation Research Testbed (DART) required use of CISL's Climate Simulation Lab (CSL) resources to complete the long-term simulations in time for AR5.

NCAR's CISL recently deployed the Globally Accessible Data Environment (GLADE) that makes data workflows more efficient and simplifies data access and usage. Researchers can now structure their workflows to use stored data directly without first needing to copy it to and from systems for supercomputing and data analysis and visualization (DAV). GLADE's centralized high-performance file systems span supercomputing, data post-processing, DAV, and HPC-based data transfer services. This data architecture increases the efficiency of modeling workflows and significantly improves the speed at which researchers can run, analyze, and visualize their simulations. CISL's data infrastructure improved the productivity of CMIP5 climate modeling experiments and helped them be completed in time for inclusion in IPCC AR5.

IPCC simulations rely on data delivered via the Earth System Grid (ESG), a science gateway to climate data collections that are hosted at eight sites around the globe including NCAR. This federated system serves thousands of IPCC AR5 researchers and forms the primary data access facility for the challenging petascale CMIP5 activity. The Earth System Grid Center for Enabling Technologies (ESG-CET) is a long-term initiative that develops a globally distributed petascale data management environment for CMIP5/IPCC-AR5 and U.S. climate science. CISL leads this gateway development effort and focused FY2011 ESG development on data management priorities for the CMIP5 IPCC work. To expand ESG support for CMIP5 metadata, CISL's ESG developers delivered enhanced security, federation, data versioning, and replication capabilities, along with more sophisticated and scalable services for data analysis and data products.

In FY2011, CMIP5 experiments created more than 1 PB of data. In addition to making CISL's HPSS archival system available to store this data, CISL dedicated 500 TB of GLADE disk to ESG, and 400 TB of that was consumed by CMIP5 efforts. As this data was created and stored at NCAR, the GLADE architecture expedited its archival, analysis, visualization, and distribution around the world via ESG. CISL continues its community leadership role to develop data services that can address the future challenges of data growth, preservation, and management. CISL's disk and tape storage systems provide an efficient, safe, reliable environment for hosting datasets, and CISL's data services continue to be further streamlined, improved, and expanded through the new data-centric design facilitated by GLADE.

Only a small number of institutions, such as NCAR, have the resources necessary to conduct high-end climate research, model development, and campaigns such as the IPCC assessments. The technical requirements of scientific applications such as climate system models are highly specialized: a discipline-specific approach to supercomputing allows CISL to tailor system design and services for these requirements. It also ensures that model development and research in Earth System processes can occur in a controlled yet responsive environment where researchers can prepare complex models and perform the computationally demanding tests required to validate them. To refine predictions of future climate change, CISL prepares for more sophisticated coupled atmosphere-ocean-ice-land models by developing and operating science gateways and other Grid-based technologies that handle massive data flows. Science gateways provide a specific community with some level of integrated, web-based data and knowledge management, secure data access, simulation capability, plus the ability to perform data analysis and visualization. CISL develops and operates science gateways to improve scientific communities' access to shared resources.

CISL's 11 science gateway projects and initiatives share cyberinfrastructure and span climate science, regional climate change, Arctic science, solar science, digital preservation, and international efforts to develop knowledge infrastructure. Many of these efforts are tied to major interagency, national, and international initiatives, including, for example, the World Meteorological Organization (WMO), the Intergovernmental Panel on Climate Change (IPCC), the World Climate Research Program (WCRP), the International Polar Year (IPY), and the Library of Congress' National Digital Information and Infrastructure Preservation Program (NDIIPP). Most of these projects use open source, web portal infrastructure called the Science Gateway Framework (SGF).

CISL develops the SGF as shared cyberinfrastructure to support a wide range of community activities. The SGF serves as a foundation for the Earth System Grid (ESG) and many other national and international science efforts including the WCRP Coupled Model Intercomparison Project (CMIP), the IPCC Fifth Assessment Report (AR5), the Community Earth System Model (CESM), and many more. The SGF-based ESG is currently running at NCAR, several Department of Energy facilities including Lawrence Livermore National Laboratory/Program for Climate Model Diagnosis and Intercomparison (PCMDI), Oak Ridge National Laboratory, Lawrence Berkeley National Laboratories/ National Energy Research Scientific Computing Center (NERSC), as well as at NASA's Jet Propulsion Laboratory, the British Atmospheric Data Centre, the German Climate Computing Center, and Australia's National Computational Infrastructure; all support CMIP5 activity and other projects. The ESG is a complex software package with many stakeholders and is easily deployable at sites anywhere in the world. This petascale system is a critical community resource for CCSM, CESM, and CMIP5/IPCC.

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NCAR Annual Report 2011

Research 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 2011 is a look at new insights on the solar cycle, an update on climate and weather model capabilities that allow scientists to more easily model across varying scales of interest, finding the "missing energy" in the global energy budget, an exploration of chemical weather issues affecting society and ways of managing these issues through science, as well as an introduction to a several new NCAR leaders.

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NCAR’s New Leadership Line-up

Jim Hurrell, associate director of the NCAR Earth System Laboratory (NESL), Michael Thompson, associate director of the High Altitude Observatory (HAO), and Vanda Grubišić, associate director of the Earth Observing Laboratory (EOL).

Three new leaders have recently taken the helm at the National Center for Atmospheric Research (NCAR). The center has also gained a new president at the University Corporation for Atmospheric Science (UCAR), NCAR's managing body. All are well known to NCAR and its scientific community. They are Michael Thompson, associate director of the High Altitude Observatory (HAO), Vanda Grubišić, associate director of the Earth Observing Laboratory (EOL), Jim Hurrell of the NCAR Earth System Laboratory (NESL), and Thomas Bogdan who becomes UCAR president in January 2012.

While the details of NCAR's leaders' agendas differ, Michael, Vanda and Jim all have research and program plans aimed at better serving the scientific community and pushing forward research being done in their respective organization's area of expertise.

Of the three, Michael is, relatively speaking, a veteran director at this point. Taking up the baton on July 1, 2010, Michael has visited Boulder annually since completing a postdoctoral visiting-scientist appointment with HAO in 1988-89; he became an NCAR affiliate scientist in 2003. Michael comes to NCAR from the University of Sheffield in England where he had a dual role as the head of the School of Mathematics and Statistics and professor of applied math and solar physics. His research there focused on helioseismology, asteroseismology, solar physics, and inverse problems. With luck and some juggling, he intends to continue his research along with his duties as HAO Director. Michael takes over from Michael Knölker, who held the director position since 1994.

Vanda comes to NCAR from the University of Vienna. There, she was hired as the first female full professor of any geoscience discipline in the University's 640-year history to lead the Chair of Theoretical Meteorology, the position once held by Felix Maria Exner. Vanda first visited NCAR in 1991 as a Yale graduate student, then returned as an ASP post-doc in 1995-1997, becoming head of EOL on July 11, 2011. Also, like Michael, she spent time at NCAR after her postdoc, working closely with scientists in NESL's Mesoscale and Microscale Meteorology (MMM) division studying mesoscale atmospheric dynamics, before leaving NCAR for the Desert Research Institute for 10 years; she became NCAR affiliate scientist in 2008. Her research has always included strong observational and modeling components. Vanda succeeds Roger Wakimoto, who took on the role of NCAR Director.

Newest laboratory head of the three, Jim took the reins of NESL on September 1, 2011, taking over from Greg Holland who acted as interim head, filling in the gap between former AD Guy Brasseur's departure from the position and identification of Jim as NESL's new leader. Working in the Climate and Global Dynamics division (CGD) since graduating with his doctorate degree in atmospheric science from Purdue, Jim arrived at NCAR to work with Warren Washington in the Climate Analysis Section of CGD. A post-doc for nine months, Jim was hired as a ladder-track scientist in 1991 when an opening occurred. His career includes leadership of CGD, and Chief Scientist of the Community Climate Projects, among other roles; he is currently Co-Chair of the World Climate Research Programme on Climate Variability and Predictability (CLIVAR).

Michael Thompson

Both his experience at NCAR and HAO's international reputation were draws for Michael to the director position.

"HAO has reputation of being one of the greatest solar physics institutes in the world, it measures far above its budgetary weight in terms of new research output and instrumentation," says Michael. "Observatory research capabilities and focus recently have been extended to include Earth's magnetosphere – so HAO expertise ranges from the Earth's upper atmosphere to the solar core."

HAO has one of the strongest visitor programs at NCAR; programs range from postdoc positions that extend for up to two years to visiting graduate students who have co-advisors at HAO to affiliate scientists, as well as short- and long-term visitors. The student-based and postdoctoral programs, Michael explains, give HAO greater access to graduate students, who provide a source of new ideas and growth for HAO, and let HAO offer the community a service in terms of training future researchers in solar-terrestrial physics. Since Michael's arrival, focus on affiliate scientists has increased, with greater visibility of these visitors to HAO, NCAR, and the scientific and solar physics community. Among the methods to achieve this end is a dedicated section on HAO's web site introducing each of these scientists.

Both HAO and visitors benefit, says Michael, from the intellectual ties and technical skills, opportunities to work one-on-one on a given research problem, and sharing insights and expertise on HAO's community models and data sets. Strategically speaking, visitors' know-how has an added benefit in that it can help deliver on the Imperatives and new Frontiers in HAO's plan cost effectively.

COSMO – the Coronal Solar Magnetism Observatory – features as a big part of Michael's vision for HAO, with plans for COSMO to be built, and three cutting-edge instruments to be housed at the Mauna Loa Solar Observatory (MLSO) in Hawaii. Among the instruments will be a new K-coronagraph, a white light telescope that detects the evolution of white light reflected from the solar corona, and a chromosphere and prominence magnetometer that will be used to take disk and limb measurements of magnetic fields in the chromosphere and solar prominences, which can be precursors to coronal mass ejections. COSMO's centerpiece will be a large coronagraph, comprising a 1.5-meter lens feeding light to a larger, more light-sensitive version of the Coronal Multi-channel Polarimeter (CoMP); this will provide information on magnetic fields and oscillations (Alfvén waves) in the Sun's corona. Each of these instruments will provide new insights on solar coronal dynamics, which can affect space weather that, in turn, affects the Earth.

Vanda Grubišić

Vanda's affiliation with NCAR and EOL extends back to her graduate-school days at Yale when as a first-year student she worked on the Hawaiian Rainband Experiment (HARP) project, which focused on investigating formation and dynamical and microphysical structure of rainbands offshore of Hawaii's Big Island. Flying on the NSF/NCAR Electra offered a rocky introduction to airborne atmospheric research. Summed up as a five-hour encounter with virtually non-stop boundary-layer turbulence, Vanda describes it as one of the most miserable flights ever.

"Everyone on board was green. The late Joachim Kuettner, a veteran field project manager and researcher who was a science observer on the same mission, leaned over to assure me the flight would be over soon," Vanda recalls.

Not remaining on terra firma for long, Vanda hopped back on the research plane at the earliest possible moment, and thus a career of field campaigns and research commenced.

One among many reasons for her return to NCAR is a passion for EOL's mission. EOL provides end-to-end support for observational science that is unmatched elsewhere, says Vanda. Lab staff designs and builds new sensors and instruments, integrates them onto existing and new platforms, offers support in field mission design, on-the-ground mission support and coordination, data collection, data quality control, as well as data tools and services.

The service EOL provides has given a considerable boost and sustained support to observational science for the NSF-funded atmospheric science university community we primarily serve, explains Vanda.

"All services benefit through being informed by the science done at NCAR and EOL, and by EOL scientists working closely with the members of the community. The science is complex, and a lot is done by EOL staff behind the scenes that is easy to miss even by the experienced user – I have always had a great appreciation of EOL staff and all of EOL's efforts and accomplishments," she explains.

Vanda notes that EOL closely watches the direction in which the science evolves given that the lab has to be able to anticipate where the new frontiers will be in order to provide service in the future. In the process, EOL scientists and engineers reflect on how the science will be done and how new observations and related tools might help these efforts. Since becoming EOL's director, Vanda says she has gained new appreciation of the lab – especially on the development side. As a university user, she has been aware of EOL's deployment and data capabilities and expertise. Since taking on her new role, she has immersed herself in learning first-hand the full extent of the development activities and how they interplay with the rest of the activities within the lab.

As an observationalist and a modeler, her knowledge and skills bring new perspective to EOL. She sees her job as bridging the two research approaches, assisting with ensuring communications and closer interactions between the modeling and observational communities. For science to advance, a close interplay between these two areas is needed – Vanda says that EOL is and will increasingly be more engaged in this realm. In the process, strengthening the collaboration with NCAR's other labs will continue to be a focus.

Her vision for EOL is to start from its existing position of strength – advanced observational science and technology. This includes a suite of ground-based and airborne instruments and platforms suitable for physical process studies. Historically the focus for EOL has been on mesoscale and microscale phenomena. Given the current direction of science focused on climate and Earth system science, as well as the new capabilities provided by the long-range high-altitude NSF/NCAR Gulfstream V (HIAPER) aircraft and its state-of-the art instrumentation, Vanda sees EOL's challenge in extending observational science support to climate-related process studies. Part of that challenge lies in strengthening the ties to the climate community, in particular the climate-modeling community, both within and outside of NCAR. On bringing these two traditionally disparate communities together within NCAR, Vanda plans to work with Jim Hurrell to ensure the needs and talents of both groups are met and the science frontier moved forward.

Jim Hurrell

Skilled at sports, but considering odds slim of either making the Major League baseball cuts or earning a living in the U.S. Professional Golfers' Association, Jim looked to other career options in college. Synoptic meteorology proved hard to ignore, having grown up with Indiana's tornadoes and a father fascinated by the daily weather forecasts; his dad regularly tuned in to NOAA's National Weather Service (NWS) forecasts, and flipped through all three local news channels' forecasts every evening.

His father's influence and interest in meteorology followed Jim to college where, as a freshman, he signed up for the same introductory atmospheric science class his dad had taken at the University of Indianapolis several years earlier for fun. His atmospheric science professor – who also taught Jim's dad – had ties to the local NWS station in Indianapolis, where he helped Jim get a job as an announcer, reporting on the weather to help pay for college. This added fuel to the academic fire because here Jim had a chance to learn meteorology from veterans working in the field. Then, as a graduate student at Purdue, Jim's interest shifted to climate as a way to understand the dynamics driving synoptic weather patterns, and ultimately led him to NCAR as a postdoc to work with Warren, and soon after to the Climate Analysis section, where he took on a ladder-track scientist position.

Jim's research focuses on regional climate change, global warming, atmospheric patterns such as the North Atlantic Oscillation (NAO), and computer modeling of climate. He is particularly interested in understanding the interaction between human-induced global warming and natural climate patterns such as El Niño and the NAO.

His 20-year tenure at NCAR and leadership roles within the climate community have led to strong relationships across NESL's divisions, NCAR and the wider research community. This history and experience also feeds his vision for NESL. His knowledge of NESL scientists' deep expertise in the realm of weather, climate and chemistry, combined with the tools and technologies (models, instruments, observing platforms) developed with community input, offers synergistic opportunities for researchers, both at NCAR and within the broader community, to gain further understanding of fundamental Earth processes. This knowledge will be critical for informing society and decision makers about environmental issues that humans will have to manage now and into the future.

"Supporting the cross-pollination of scientific expertise across fields is an ongoing increase in computing power," Jim says. "Together, the potential exists for NESL and the community to develop the predictive capability needed to answer pressing societal questions related to extreme weather and climate, among other questions, on national, regional and local scales."

At this point, he explains, climate change is unavoidable, however the magnitude depends on what society decides to do about the problem. This reality is driving a need for local and regional information, attribution and prediction with lead times of hours, days, and years into the future. This is where Jim sees NESL stepping in. Bringing together and integrating expertise from across the laboratory will be critical to understanding future climate regimes and extreme weather.

Thomas Bogdan

Tom takes over the leadership of UCAR early next year. Currently, he is the director of the National Oceanic and Atmospheric Administration's Space Weather Prediction Center (SWPC). Prior to joining the SWPC in 2006, Tom was a senior scientist at NCAR, where he began work as a postdoctoral scientist in 1983, researching solar magnetic activity. Richard Anthes, who has led UCAR since 1988, and was previous to that NCAR's director, will hand the baton on to Tom on January 9, 2012.

Tom earned his Ph.D. (1984) and master's degree (1981) in physics at the University of Chicago and his bachelor's in mathematics and physics from the University at Buffalo, the State University of New York, in 1979. He has authored or co-authored more than 100 papers in solar-terrestrial research. He is a fellow of the American Meteorological Society and serves on its Council of the Members. Tom also works closely with the World Meteorological Organization as the U.S. point of contact for space weather issues. He has chaired and served on numerous National Science Foundation, NASA, and National Research Council committees and panels that provide advice to federal agencies and policymakers, and serves on the Advisory Council for the College of Arts and Sciences at the University at Buffalo.

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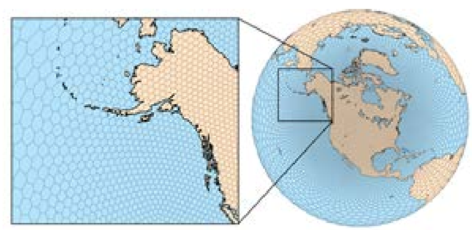
Developing the Model for Prediction Across Scales



The Voronoi-tessallation grid, shown above, uses nominally hexagonal cells to cover the Earth to form the basis for the algorithms used in the computer model. The grid above shows an 8-times grid magnification over Alaska and western Canada - note how the mesh varies smoothly from the coarse to fine region. This hexagonal mesh offers advantages over latitude-longitude mesh because each cell is of similar size and shape to the ones next to it, no matter the global location; the cells look the same anywhere on the globe, and this uniformity simplifies and speeds processors' calculations.

Meteorological centers providing real-time forecasts to society rely heavily on computer models for these predictions. All the computer models have algorithms responsible for solving the basic equations representing how the atmosphere and other geophysical components evolve. Most models use a latitude-longitude (lat-lon) mesh to decompose the Earth into discrete cells. This mesh wraps around the modeled globe; in polar regions, the narrow lat-lon cells require special mathematical filtering techniques to stabilize the computer models. Because these polar filters make computations more complex, processing speeds slow. If using machines capable of massively parallel processing – that is, supercomputers that have the ability to run at peta-flops speeds (1015 operations per second) – the need for filters slows down computational speeds and greatly constrains the ability to run the increasingly complex models that scientists require to understand and predict complex Earth-system processes.

As a result, since the late 2000s, scientists in the Mesoscale and Microscale Meteorology (MMM) division of the National Center for Atmospheric Research (NCAR) have looked for model-solver constructions that would eliminate the need for the polar filters. Working with a number of partners, including scientists at Los Alamos National Laboratory, Exeter University, Florida State University, and University of South Carolina, the team considered a variety of options before selecting a Voronoi-tessallation, which uses nominally hexagonal cells to cover the Earth, to form the basis for the algorithms used in the computer model. The hexagonal mesh offers advantages over latitude-longitude mesh because each cell is of similar size and shape to the ones next to it, no matter the global location; the cells look the same anywhere on the globe, and this uniformity simplifies and speeds processors' calculations.

"We turned to collaborators both within and outside of NCAR who had expertise in global weather and climate modeling, as well as familiarity with hexagonal meshes, to create the Model for Prediction Across Scales (MPAS)," says Bill Skamarock, a senior scientist in MMM.

Finding a good uniform mesh for the globe is only the first step of the process. Scientists also wanted the capability to maintain a global view but, as needed, have the ability to zoom in and get a better, more refined view over select regions, while not slowing down the processing by making the entire mesh fine-scale. For instance, over mountainous areas, higher resolution assists in more accurately replicating the details of atmospheric dynamics over complex terrain. At lower resolution, these nuances are frequently muddied and often lost. The Voronoi mesh can be varied between high and low resolution in a smooth and continuous manner. The variable resolution mesh, however, looks like a uniform mesh to the processors hence the same solution algorithm developed by the NCAR scientists and their collaborators are used on both uniform and variable resolution meshes and computational speed is maintained.

For the atmospheric component of MPAS, the NCAR team worked on combining the methods used on the Voronoi mesh with those used on NCAR's Weather and Research Forecasting (WRF) model. This allows the sharing of much software between the two models, and the models are similarly robust. The WRF model provides users with a well-tested weather and research forecasting standard that many in the scientific community have come to depend upon. MPAS is envisioned as the WRF next-generation model for global forecasting and regional climate applications, and by making the capabilities of the two models uniform to the greatest degree possible, the eventual model transition will become more seamless.

This initial work has focused on solving equations for cloud-permitting resolutions. Accurately modeling clouds (which vary on scales of millimeters to kilometers), and cloud processes related to formation, and dissipation, have long been the stumbling block for comparison with real-world observations and model projections of climate and weather effects on Earth. Gaining the ability to model cloud dynamics accurately is one of the driving forces for modern climate modeling, and a lynchpin in moving model outputs closer to matching observations. WRF represents the state-of-the-art in cloud permitting weather and regional climate simulation. MPAS is as accurate as WRF, but it does not suffer from the polar filtering issues of WRF and similar models, and it incorporates local refinement seamlessly in contrast to the abrupt change in refinement associated with the traditional grid nesting used in WRF. Thus MPAS is a major advancement in our simulation technology that, in concert with the introduction of the latest petaflop supercomputers, will allow scientists both inside and outside NCAR to address critical problems in numerical weather prediction, climate and regional climate.

In addition, MPAS outputs will be a critical part of NCAR's regional climate research program, which Greg Holland leads out of the NCAR Earth System Laboratory. MPAS analytical tools will be developed to allow scientists to consider more easily facets of climate change that have direct public impacts.

"Statistical and analytical tools will be developed that facilitate addressing questions society is interested in," says Holland. "For example, MPAS will enable improved application of a hurricane damage index that can be used to predict damage both in current and future storms in current dollars – information critical to the insurance and reinsurance industries, as well as other businesses, but that will also benefit decision makers and the interested public."

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