COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

FY 2007 Annual Report
September 27, 2007

NOAA Cooperative Agreement #NA17RJ1229

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Cover photo by Paul Sperry

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Letter from the Director

Director's Welcome

We had another exiting year with numerous accomplishments, awards, recognitions of our faculty, researchers, and staff – too numerous to mention in detail here. Congratulations to all of CIRES. Research highlights are mentioned in detail in the Executive Summary of this report, and again, they were so numerous that it was hard to choose which to feature in the Summary.

We completed our University Program Review, a recurring event every seven years. I am proud to announce that we received high grades in the review process and CIRES was recognized as an important asset for the University of Colorado at Boulder (University). CIRES is a large and complex organization, which interacts in a variety of ways with academic departments and institutes at the University, as well as the many relevant NOAA laboratories and centers, located in the David Skaggs Research Center in Boulder. Despite this complexity, CIRES is working well and we are succeeding in meeting our missions and goals.

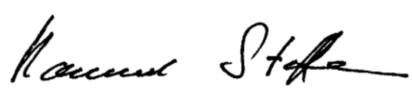
The Members' Council organized the second CIRES "Rendezvous Symposium" in spring. This highly successful endeavor was devoted to a full day of science presentations and discussions across all disciplines, engaging over 300 scientists, students, and staff. We have institutionalized the "Rendezvous Symposium" as an annual event.

CIRES continues to be the world leader in environmental sciences, as we are committed to identifying and pursuing innovative research in earth system science, and to fostering public awareness of this research. Our research budget continues to grow and has reached over $47 M, including the faculty support from the University for our CIRES faculty lines, supporting a total of 580 employees, graduate and undergraduate students. We have published over 880 papers in peer-reviewed science journals, participated in a number of news conferences, U.S. Congressional briefings, and outreach activities. The outcome and findings of our research is important in forming policies that are crucial for future generations.

We welcome one new CIRES tenure-track faculty researcher, Dr. Baylor Fox-Kemper, assistant professor in the Department of Atmospheric and Oceanic Sciences with expertise in experimental ocean modeling. In addition, the University authorized CIRES to search for a new director for our Center for the Study of Earth from Space, following the retirement of Professor Alex Goetz, and for a new director for our Center for Science and Technology Policy Research. With these new Graduate School faculty lines, CIRES will increase its faculty to a total of nineteen.

We also welcome our new Assistant Director for Science, Dr. Suzanne van Drunick who comes to us from the National Research Council in Washington, DC, where she was a Senior Program Officer for studies on environmental science and toxicology. Suzanne is already engaged in a number of activities, including this new CIRES annual report.

The annual report is a collaborative effort of a number of people in CIRES – researchers as well as administrative staff – and they all deserve credit for what you will find on the following pages. In particular, I would like to acknowledge the effort of Assistant Director Dr. Suzanne van Drunick who was instrumental in coordinating this effort. Enjoy your reading!



Executive Summary and Research Highlights

Since 1967, the Cooperative Institute for Research in Environmental Sciences (CIRES) has provided a dynamic setting for teaching and collaborative, interdisciplinary research in environmental sciences. CIRES is an organized research institute of the University of Colorado at Boulder (University), and is based on a cooperative agreement (Agreement) between the University and the National Oceanic and Atmospheric Administration (NOAA). CIRES' collaborative research is organized and aligned with NOAA's research by six scientific themes identified in the Agreement. These themes include advanced modeling and observing systems, climate system variability, geodynamics, planetary metabolism, regional processes, and integrating activities. Select research highlights from each of the scientific themes are presented below.

From July 30, 2006 to July 1, 2007 (FY07), CIRES supported 182 Research Scientists, 208 Associate Scientists, 18 Visiting Scientists, 14 postdoctoral researchers, 32 administrative staff, 80 graduate students, and 44 undergraduate students. In total, CIRES supported approximately 580 scientists, administrative staff, and students with an overall extramural research budget of $44,400,000, an increase of almost 3.5% compared to FY06. Including University faculty support, the total budget is almost $47,600,000, of which NOAA funds accounted for approximately $23,500,000 (49%).

CIRES received approval for one new faculty line and two reappointments for positions vacated by a retirement and departure of a CIRES faculty member. A new tenure-track faculty researcher, Dr. Baylor Fox-Kemper, was hired as an assistant professor in the Department of Atmospheric and Oceanic Sciences. Fox-Kemper's area of expertise is experimental modeling of oceanic eddies and ocean heat transport. Faculty searches are underway for a new director for the Center for Science and Technology Policy Research and a new director for the Center for the Study of Earth from Space. CIRES also hired a new Assistant Director for Science in December 2006. A part-time science news writer position was created to help convey CIRES' research findings to the news media and public. Communication of CIRES' mission and activities was further enhanced by the creation and broad dissemination of a new CIRES brochure.

In July 2006, the CIRES-NOAA FY 2007 and FY 2008 Scientific Workplan (Workplan) was completed and implemented. The Workplan describes collaborative research that integrates scientific projects conducted by CIRES under each of the six scientific themes. The Workplan accounts for Task III research of the Agreement, however, it integrates several scientific objectives of earth system science. These objectives are the drivers of the Workplan, which identifies goals and approaches for each objective, and incorporates milestones and impacts for each project. The new Workplan closely resembles the previous version, which NOAA and the Department of Commerce approved as a scientific roadmap with increased clarity and accountability.

The University's Program Review Panel (PRP) released its final report for CIRES in February 2007. The final report was based on a review of three separate reports. Those were (1) the CIRES Self-Study, which was prepared by a ten-member team comprised of the CIRES Associate Director, CIRES Fellows, Research Associates, graduate students, and administrative staff; (2) the report by the Internal Review Committee, which was comprised of non-CIRES faculty and graduate students; and (3) the report by the External Review Committee, which was comprised of two distinguished academics not affiliated with the University. The findings of the PRP final report included praise for the very high quality of the faculty engaged in CIRES, high degree of productivity among the Fellows, and effectiveness of administrative staff. CIRES' leadership was concluded to be very strong. The connections between CIRES and NOAA's Earth System Research Laboratory (ESRL) and other research organizations were credited with enhancing and strengthening CIRES research.

CIRES' Education and Outreach (E/O) program continued to strengthen the link between education and research related to science, technology, and math for the purpose of increasing public understanding of issues related to earth system science. To celebrate the launch of the International Polar Year, E/O organized a community-wide event, *Ice Fest*, which included a wide variety of activities focused on the cryosphere, polar research, and climate studies.

In addition, another exciting CIRES FY07 highlight was the announcement of a new CIRES-NOAA Exchange Fellowship Program. Guidelines are being developed to enable CIRES and ESRL researchers to exchange laboratory and field research roles.

Research Highlights and Accomplishments from CIRES-NOAA Partnership by Scientific Theme

Advanced Modeling and Observing Systems

This theme includes the optimization of modeling and observing systems for disciplines such as atmospheric chemistry, physical atmospheric and oceanic processes, cryospheric processes, space weather, non-linear systems applications, data centers, and data management. Research ranges from local to regional and global scales.

- Quantitative characterization of the response of the cavity ring-down single-particle aerosol instrument was performed. The completed instrument, containing improvements over the 2005 prototype, was successfully deployed aboard NOAA R/V *Ronald H. Brown* for the TexAQS 2006/GoMACCS field campaign from August to mid-September in the western Gulf of Mexico/Houston Ship Channel region; aerosol samples were collected.
- Two lidars were deployed during the 2006 Texas Air Quality Study to measure ozone and aerosol profiles. The TOPAZ airborne lidar, aboard a NOAA Twin Otter airplane, flew 22 missions during which it mapped out the three-dimensional distribution of ozone and aerosols over eastern Texas and the Gulf of Mexico. The OPAL ship-based lidar, aboard the NOAA R/V *Ronald H. Brown*, measured profiles of ozone and aerosol backscatter. Recent improvements to ship-based and aircraft-based lidar systems include more accurate photodetectors, a simpler optical receiver, and new aerosol data processing methods.
- A ship-based remote sensing lidar to measure wind and turbulence profiles was developed by making improvements to NOAA's High Resolution Doppler Lidar.
- A new ozone sensor for ship-based measurements of ozone flux was developed. The sensor system was deployed on the R/V *Ronald H. Brown* in the TexAQS field program in later summer 2006.
- During the Texas Air Quality Study, the TOPAZ airborne ozone lidar, and the ship-based ozone and Doppler lidars, collected data for comparison with model computations of ozone formation, transport, and mixing processes, to investigate the ability of models to represent important boundary layer parameters.
- Diurnal sampling and inter-satellite bias corrections were applied to the High-resolution Radiation Sounder satellite radiances.
- Enhancements to the Gridpoint Statistical Interpolation (GSI) code were incorporated to improve use of surface weather observations (METARs), and GSD-developed procedures were introduced into GSI to incorporate three-dimensional, high-frequency National Weather Service WSR-88D radar data in the initialization of cloud and precipitation hydrometeors.
- The Real-Time Verification System was re-designed by enhancing the functionality of the database, web-interface, and real-time processing modules of the system to support verification of aviation parameters, such as icing, turbulence, and convective weather.
- New verification techniques were developed for evaluating the accuracy of convective echo tops, high resolution automated convective probabilistic forecasts, and ceiling and visibility forecast lead times. Results from statistical evaluations of turbulence and convective weather forecasts were summarized in written reports.
- The GOES X-ray instrument was calibrated with selected solar observations and 2005 rocket underflight data.
- A fully operational version of the Coronal Mass Ejection (CME) Locator was developed based on white-light corona observations from the NASA STEREO mission. EUV dimming properties (intensity, solar location, and mass) were compared with associated CME properties as observed by the Extreme Ultraviolet Imaging Telescope.
- A ten-year study of the stability of the CUCF's reference UVB broadband radiometers and 50+ network UVB radiometers was published.

Climate System Variability

Climate variability affects all natural systems and human activities. Climate directly influences agriculture, water quality, and human health. Understanding and potentially predicting climate change is critical to the public interest, as well as to a broad array of decision makers within federal and state government, industry, resources management, and hazard mitigation.

- A newly updated ozone-profile database was assessed for trends and changes in trends, and validated against ozone products derived from remote and *in situ* measuring systems such as satellites and ozone sounding.

- The global impacts of the ENSO-related and ENSO-unrelated tropical sea surface temperature (SST) trends over the last 50 years were assessed using the NCAR/CAM3 and the NCEP/GFS atmospheric general circulation models (GCM), with particular emphasis on the impacts on precipitation trends over the Americas, western Africa, and Europe. Both GCMs indicate substantial precipitation trend responses in these regions to the tropical SST trends, which are generally in excellent mutual agreement, and with the observed precipitation trends. Both the ENSO-related and the ENSO-unrelated portions of the tropical SST trends are found to be important in this regard.
- The possibility of abrupt climate change over North America in the next several decades triggered by continued warming of the Indian Ocean was assessed. These runs suggest that the continued tropical ocean warming will gradually modify the atmospheric jet streams to the point where the ability of the jet streams to channel atmospheric disturbances along the upper tropospheric waveguide will undergo a relatively sudden shift sometime in the next century. This will cause relatively rapid shifts in the climates of North America and Europe.
- The impacts of coupled air-sea interactions, decadal ocean dynamics, land-surface feedbacks, and land-use changes on decadal atmospheric variability were assessed. It was concluded that the North Atlantic and European climate response to Indian Ocean warming might be considerably greater than hitherto judged from analyses of atmospheric model experiments alone.
- The Gulf of Mexico Atmospheric Composition and Climate Study was planned, and executed between July 1 and October 15, 2006, throughout Texas and the northwestern Gulf of Mexico. Three NOAA/ESRL and CIRES' platforms were deployed: a NOAA WP-3 aircraft, a NOAA Twin Otter, and the NOAA/ESRL R/V Ronald H. Brown. This intensive field study provided significant new information that is required to afford a better understanding of the sources, and atmospheric processes responsible for the formation and distribution, of ozone and aerosols in the atmosphere and the influence that these species have on the radiative forcing of climate regionally and globally, as well as their impact on human health and regional haze.
- Fire, fossil fuel, and ocean carbon modules were implemented with the ensemble Kalman filter system, commonly referred to as CarbonTracker: *http://www.esrl.noaa.gov/gmd/ccgg/carbontracker*.
- Two new tall-tower sites were established as part of the NOAA/GMD North America Carbon Observing System (Carbon America) during FY07: One near Boulder, CO, and the other near West Branch, IA. Continuous *in-situ* CO_2/CO mixing ratios and regular air samples are being used as part of the Carbon Tracker system mentioned above.
- A temperature/humidity/GPS system to augment current trace-gas vertical-profile measurements was developed and field-tested, allowing for automated measurements of the ambient temperature and humidity, and the position and altitude of each sample, in a vertical profile. The system was installed at five sites in the NOAA/GMD Carbon America aircraft network.
- A new index for assessing changes in the atmospheric burden of ozone-depleting gases was made available from the NOAA website. The Ozone Depleting Gas Index provides a summary of progress being made in the global effort to reduce the atmospheric burden of ozone-depleting gases.
- The representation of physical processes and the Madden-Julian Oscillation in the NCEP Global Forecasting System was investigated and improved by studying fourteen coupled general circulation models (CGCMs) used in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4). The results show that all current state-of-the-art CGCMs have significant problems in simulating tropical intra-seasonal variability.
- A study examining the double-ITCZ problem in CGCMs participating in the IPCC AR4 was completed. The results show that most of these CGCMs have a double-ITCZ problem.
- Images of 401 glacier photographs were posted online.
- A major paper was published in *Journal of Geophysical Research* synthesizing a variety of atmospheric and oceanic data to examine the large-scale energy budget of the Arctic. The seasonal cycles of vertically integrated atmospheric energy storage and the convergence of energy transport from ERA-40, as evaluated for the polar cap, compare well with realizations from the NCEP/NCAR reanalysis over the period 1979-2001.
- Development of seasonal forecast guidance tools for the U.S., based on the predictability of tropical SSTs several seasons in advance, and training these tools on the atmospheric responses to different types of anomalous tropical SSTs in large new sets of seasonal integrations made with the NCAR, GFDL, and NCEP GCMs, continued. Results indicate that, compared to the forecast tool currently being used in real-

time experimental seasonal forecasts, the new forecast tool has the potential to make improved forecasts of U.S. seasonal precipitation and surface temperature.

Geodynamics

The goal of geodynamics is to characterize the internal processes of the planet, including the properties of the core-mantle boundary, convection within the Earth's mantle, and the effects of convection on the surface of the planet.

- A global spherical-harmonic degree-720 model of the Earth's crustal magnetic field was created from a joint inversion of all available marine magnetic, aeromagnetic, and CHAMP satellite magnetic measurements. This model is the first step in the development of an Enhanced Magnetic Model needed for improved navigation by ships, aircraft, and near-Earth orbiting spacecraft.
- Bathymetric-topographic digital elevation models sufficient for tsunami propagation, run up and inundation prediction for 19 priority regions, defined by the U.S. tsunami community, were produced. This project is a priority for NOAA, has been presented to Congressional staffers, and featured on the NOAA website.
- Public access to the tsunami inundation DEMs has been provided at the "NGDC Tsunami Inundation Gridding Project" website (*http://www.ngdc.noaa.gov/mgg/inundation/*). On this site, visitors may download completed DEMs, with corresponding metadata and documentation.

Planetary Metabolism

Planetary metabolism is the complex web of biochemical and ecological processes and their interaction with the lithosphere, atmosphere and hydrosphere. Both natural and anthropogenic disturbances drive the structure and dynamics of natural systems, and a thorough understanding of these complex processes is essential to protect the biosphere from adverse effects due to pollution, destruction of natural landscapes, and inadvertent alteration of climate.

- Annual estimates of national and global gas flaring for the years 1995 through 2006 using low-light imaging data acquired by the Defense Meteorological Satellite Program (DMSP) spacecraft have been developed. In 2006, the gas flaring estimate of 168 billion cubic meters represented 27% of the natural gas consumption by the United States, with a potential market value of $69 billion. Global gas flaring adds more than 84 million metric tons of carbon to the atmosphere each year.
- A global poverty map with 30-arc second resolution, using a derived poverty index calculated by dividing population count by the brightness of satellite-observed nighttime lighting for the DMSP spacecraft, has been developed. The total estimate of the numbers of individuals living in poverty is 2.3 billion, slightly under the World Development Indicators' estimate of 2.6 billion. This significant work demonstrates a new technique for determining global poverty rates.

Regional Processes

Many of the research endeavors within CIRES and NOAA have a regional focus because they address a particular confluence of geography, demographics, or weather and climatic regimes. The effect of climate variability is often regionally focused, thus influencing very specific populations, economic systems, and ecosystems.

- A twelve-year (1993-2004) global oceanic data set of near-surface humidity has been developed using SSM/I and SSM/T-2 satellite sensors, and a seven-year (1999-2005) data set of both near-surface humidity and temperature has been developed combining AMSU-A and SSM/I satellite sensors.
- Daily ozone profile measurements at Trinidad Head, CA and Boulder, CO were performed during the intensive Measurements of Ozone over North America study in August 2006. The purpose was to determine the role of various sources to the tropospheric ozone budget over North America. A key finding of this intensive campaign was the important contribution to the upper tropospheric (6-11 km) ozone budget from lightning-produced nitrogen oxides.
- Research conducted by CIRES staff on data sets collected onboard the NOAA R/V *Ronald H. Brown* during the 2004 New England Air Quality Study has resulted in several successful research publications in peer-reviewed journals.
- Measurements obtained from the NOAA P-3 aircraft in the summer of 2004 during the International Consortium for Atmospheric Research on Transport and Transformation study have been used to examine the transport of pollutants from the United States over the Atlantic Ocean.
- The relative-humidity dependence of aerosol light extinction for surrogate atmospheric aerosol using cavity ring-down aerosol extinction spectroscopy was studied. Findings suggest that neglecting the water uptake

by the organic fraction of atmospheric particles could lead to significant underestimation of the cooling at the Earth's surface due to light scattering by aerosol.

Integrating Activities

CIRES engages in a wide range of integrating activities in research, education, and outreach that encompass each of the Institute's research themes and contribute to the overall mission of the Institute, University, and NOAA. The primary focus is on five overlapping categories that include (1) K-16 Interdisciplinary Education and Outreach, (2) Graduate and Post-Graduate Education, (3) Scientific Assessments, (4) Interdisciplinary Research, and (5) Science and Technology Policy Research.

- The final preparation of the World Meteorological Organization/United Nations Environment Programme 2006 scientific state-of-understanding assessment of the ozone layer for the Montreal Protocol was completed. CIRES scientists participated as coauthors, contributors, reviewers, and coordinating editor for the report.
- The many forces that impact water demand in a major Denver suburb, Aurora, with infrastructure requirements over the next ten years in excess of $1 billion, were investigated. How the recent drought, climate variables, demographics, pricing, irrigation technology, in-home water meters, and other variables affect demand were studied. A number of papers about water demand in the Denver area and a review paper on factors influencing residential water demand were published. Additionally, multiple presentations directed to these topics were delivered in Colorado and Arizona. A new website "Water Demand and Conservation" was created: *http://wwa.colorado.edu/resources/water_demand_and_conservation/*.
- Analysis of paleoclimatological streamflow reconstructions, future streamflow projections from models and other sources, and native streamflow reconstructions were synthesized to improve understanding of stream flows. A workshop held to assist the U.S. Bureau of Reclamation in assessing the state of climate change science in its Colorado River planning studies, led to the preparation of a peer-reviewed report, which may become an appendix in Reclamation's ongoing Environmental Impact Statement for the "shortage sharing" and combined operation of Lake Powell and Lake Mead. This is the first report of its kind by Reclamation anywhere in the U.S.

CIRES in 2006-2007

Administration and Funding

The Cooperative Institute for Research in Environmental Sciences (CIRES) is a joint institute established in 1967 between the University of Colorado and the National Oceanic and Atmospheric Administration (NOAA). The purpose of CIRES is to maintain an interdisciplinary environment for research on the geosphere, biosphere, atmosphere, hydrosphere and cryosphere. CIRES conducts basic research in support of NOAA's goals for application of environmental science to advance the public welfare. CIRES strengthens the scientific foundation upon which NOAA's many services depend. CIRES' connections with NOAA's Office of Oceanic and Atmospheric Research and sister Cooperative Institutes also provide an avenue for coordinated studies on a scale that could not be addressed by university research units on their own.

Vision and Mission
As a world leader in Environmental Sciences, CIRES is committed to identifying and pursuing innovative research in Earth System Science and fostering public awareness of these processes to ensure a sustainable future environment. CIRES is dedicated to fundamental and interdisciplinary research targeted at all aspects of Earth System Science and to communicating these findings to the global scientific community, to decision makers, and to the public.

CIRES' direction is provided through its Council of Fellows, its executive committee, and committees working on focused objectives such as maintaining excellence in computing facilities (Figure 1). Interdisciplinary science at CIRES is fostered through centers that cross traditional boundaries, and these include the Center for the Study of Earth from Space (CSES), the Center for Limnology, the National Snow and Ice Data Center (NSIDC), the Center for Science and Technology Policy Research (CSTPR), and the Climate Diagnostics Center (CDC). CIRES' campus affiliation provides NOAA labs and centers a breadth of connections in 11 university departments and programs (Figure 2). Communication is facilitated through a members' council, scientific retreats, research symposiums, regular town meetings, and outreach. Career progression and excellence are promoted through a career track and an outstanding employee recognition program. A vibrant academic and research environment is fostered through a graduate research fellowship program, a visiting faculty and postdoctoral program, an innovative research program, and a distinguished lecture series. Advanced research tools are provided through an instrument design group, machine shop, glassblowing, numerical climate models, and access to remote sensing and analytical instrumentation.

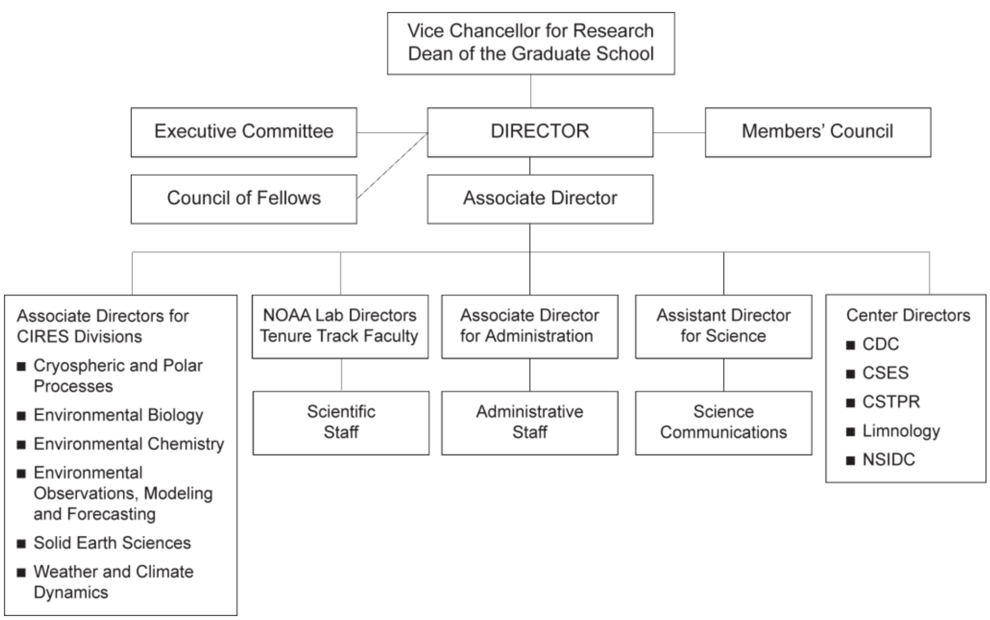


Figure 1. *Organization of CIRES.*

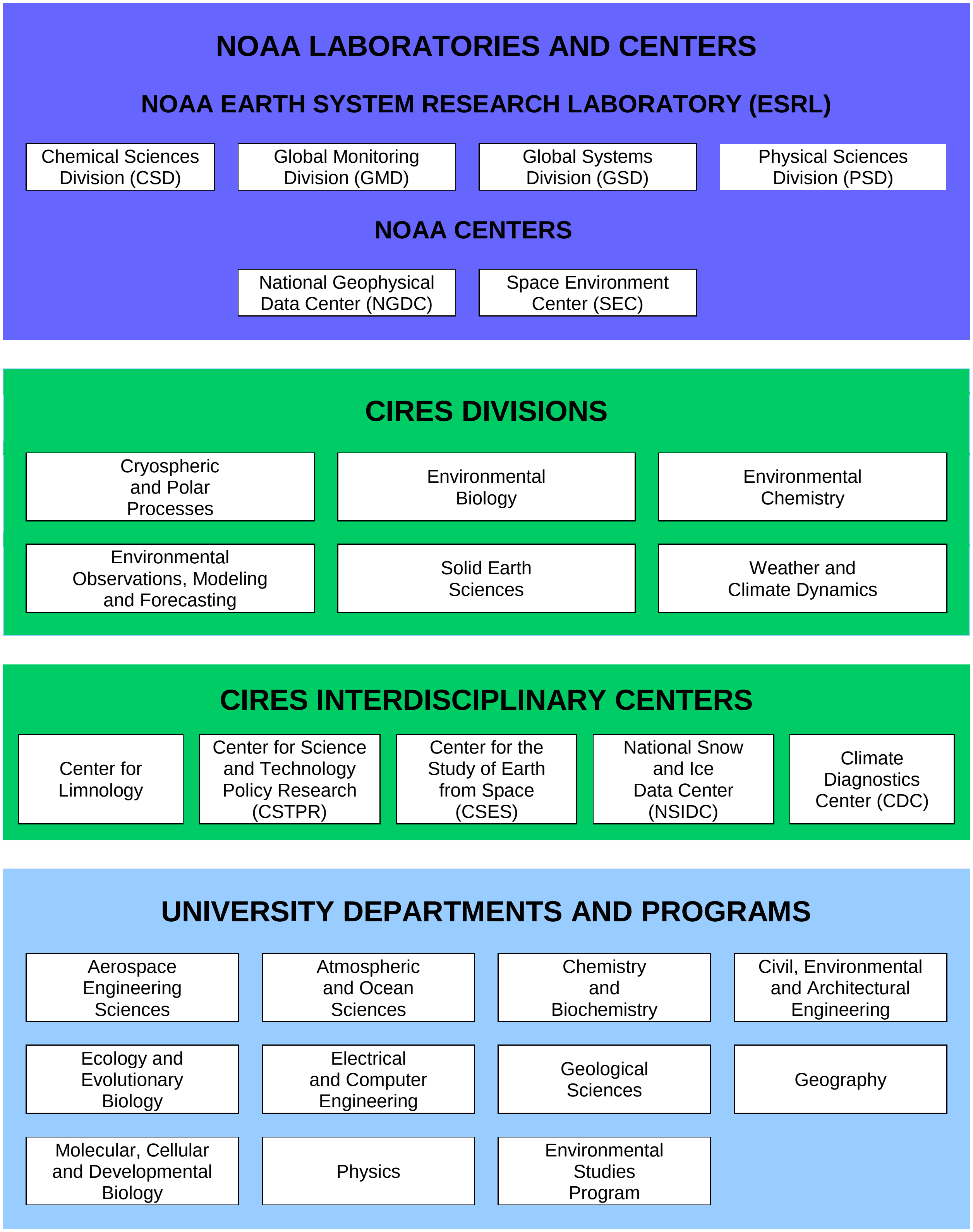


Figure 2. *CIRES' divisions, centers, and affiliated departments and programs; NOAA laboratories and centers.*

In recent years, CIRES has maintained modest and steady growth (Figure 3). The largest increment of CIRES' funding (49%) is provided by the Agreement with NOAA, of which expenditures have increased slightly faster than inflation over the past five years. The Agreement provides a financial foundation to help support CIRES faculty and research scientists in their active pursuit of funding from outside federal and non-federal contracts and grants. Their continued, collective success in obtaining external research awards has also regularly increased at a rate that slightly exceeds the rate of inflation. The University's monetary contribution to CIRES primarily covers faculty salaries, and varies slightly due to year-over-year changes in the CIRES-affiliated University faculty roster.

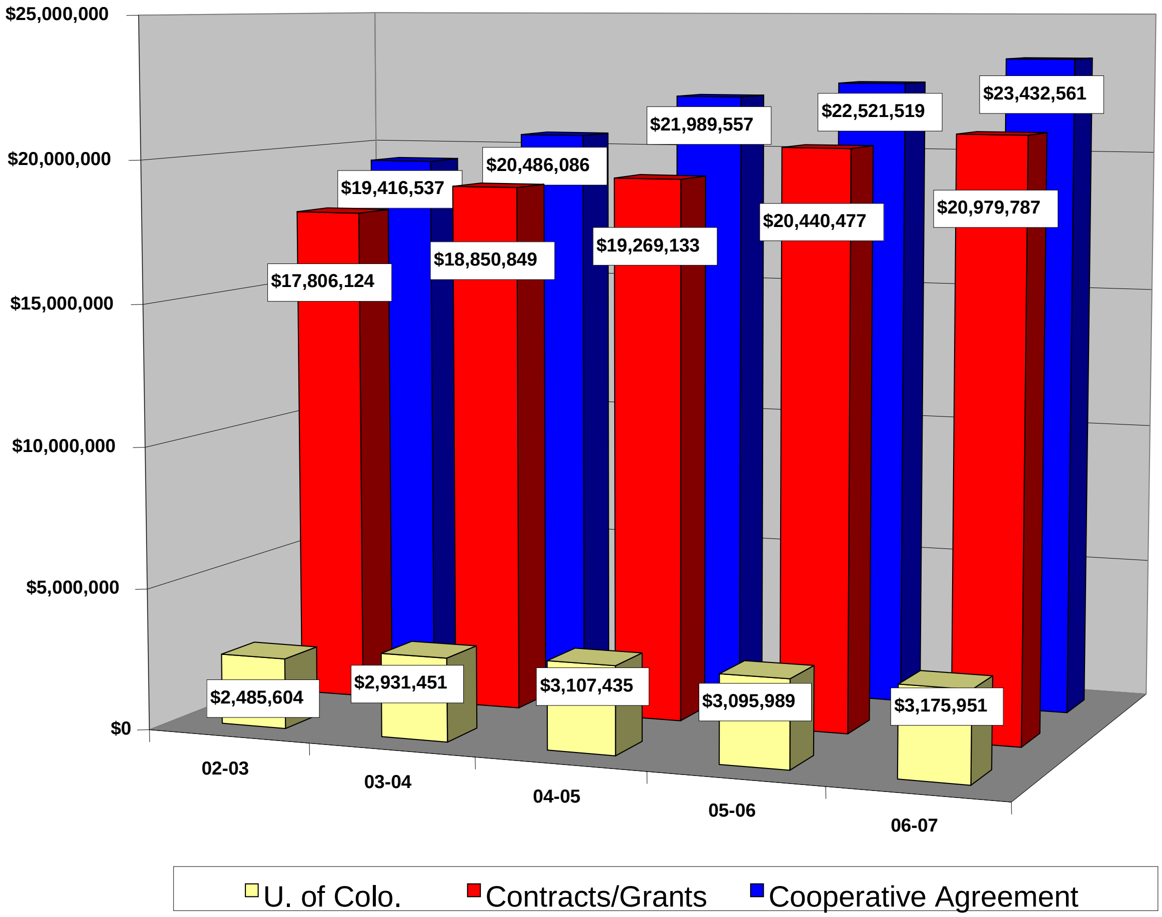


***Figure 3**. CIRES expenditures 2003 – 2007. Continued growth over five years in University-sponsored funding, individual federal and non-federal contracts and grants, and NOAA Cooperative Agreement research support.*

Agreement expenditures by task for FY07 are shown in Figure 4. Task I expenditures include CIRES administration and internal scientific programs such as the Visiting Fellows program. Task II provides partial funding for the National Snow and Ice Data Center, the largest of CIRES' five interdisciplinary scientific centers. Task III funds CIRES' collaboration with NOAA's Earth System Research Laboratory, National Geophysical Data Center, and Space Environment Center. Task IV was created to serve as an efficient administrative mechanism for directing NOAA research grants and awards, which would otherwise be stand-alone grants and awards outside the Agreement, to University researchers in fields allied with CIRES' mission. Water in the West is a CIRES' program to provide water research and decision support to policy makers throughout the western U.S.

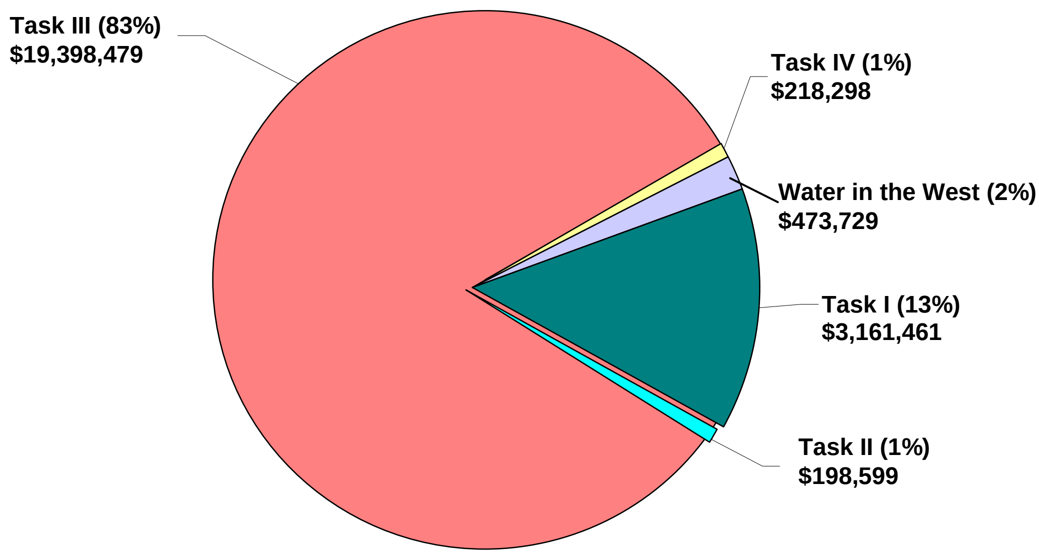


Figure 4. *Cooperative Agreement expenses by task for FY07.*

The largest share (43%) of Task I supports CIRES administration, primarily salaries and benefits for the administrative staff (Figure 5). The Visiting Fellows program receives the second largest share (31%) of Task I expenditures and is supported by other funding as well. Task I also provides partial support of CIRES' Education and Outreach program, other research, and the physical plant facilities.

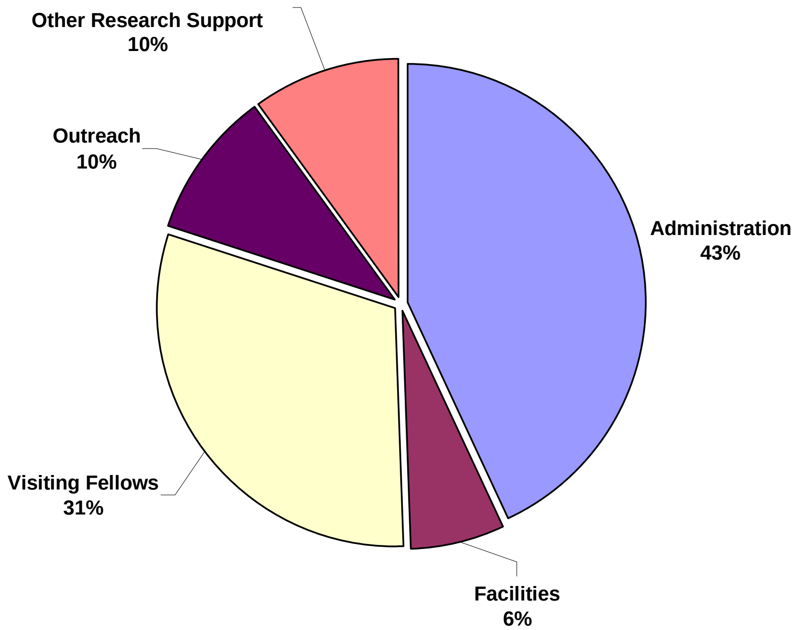


Figure 5. *CIRES Task I base fund expenditures for FY07.*

Task I funding is supplemented by CIRES' portion of the University's indirect cost recovery (ICR), which is distributed annually to academic units as a proportion of indirect costs funded through University researchers' grants and awards (Figure 6).

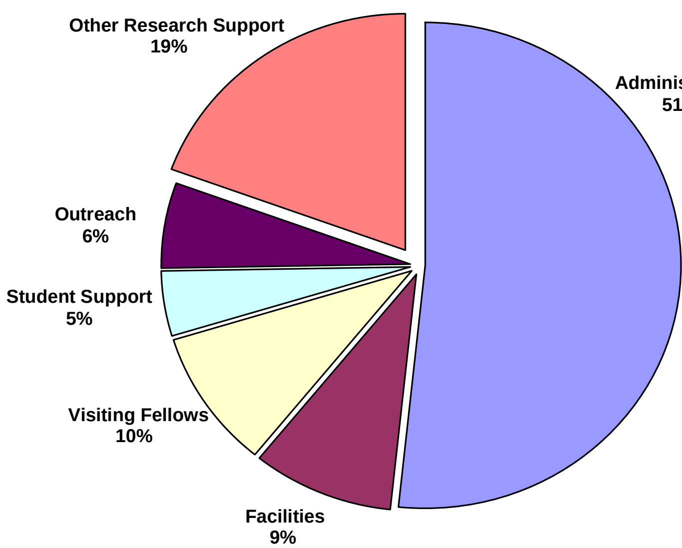


Figure 6. *CIRES Task I base fund plus ICR return expenditures for FY07.*

Contributions to NOAA's Strategic Vision

Cross-cutting, interdisciplinary research priorities within CIRES complement NOAA's current Five-Year Research Plan priorities, which aim to enhance the understanding and prediction the of Earth's environment. The Five-Year Research Plan reflects NOAA's response to some of the nation's most challenging environmental needs, as identified in the 20-Year Research Vision, and supports the four mission goal areas identified in the NOAA Strategic Plan – Ecosystems, Climate, Weather and Water, and Commerce and Transportation. The following are examples of CIRES research that supports NOAA's mission goals.

Ecosystem Mission Goal: Protect, restore, and manage the use of coastal and ocean resources through ecosystem based management.

CIRES contributes to the ecosystem mission goal through observations and research on habitat, ecosystems, and extreme events. Toward this goal, CIRES is a valuable contributor to research on ocean temperature and climate. CIRES researchers are diagnosing impacts of changes in tropical sea surface temperature over the last 50 years, and determining sensitivity to past and future temperature changes in different parts of the tropical oceans. Using a satellite retrieval method recently developed by ESRL researchers, CIRES is creating a multi-year global oceanic data set of near-surface temperatures and humidity. Crossing disciplines, CIRES is evaluating data on ocean warming to assess the possibility of abrupt climate change over North America, and using global chemistry/dynamics models to examine the effect of future ship traffic in the Arctic northern passages on Arctic pollution.

Ecosystem management includes the assessment of potential hazards based on the collection and interpretation of environmental data. CIRES is developing a U.S. Tsunami Hazard Assessment that will describe tsunami sources and estimate tsunami frequency based on historical and geological tsunami data.

Climate Mission Goal: Understand climate variability and change to enhance society's ability to plan and respond.

CIRES is a respected leader in areas of climate science research relevant to NOAA's climate mission goal. Researchers at CIRES have contributed substantially towards climate observations, analysis, and predictions; climate forcing; and climate effects on ecosystems across various spatial and temporal scales. Basic research at CIRES has advanced our understanding of observed long-term climate variations and recent unexpected changes, especially in the polar regions. Spatially, CIRES' vast research spans from the sea surface, land, and ice to the lower and upper atmospheres and space environment.

CIRES develops methods and processes for integrating multiple types of climate research data, and making the data more streamlined and accessible to facilitate interoperability within the scientific community for the purpose of knowledge extraction, data quality control and validation, and trend detection. Tools are also being created for the public and policy makers to increase access to climate science information and forecast products.

Weather and Water Mission Goal: Serve society's needs for weather and water information.

CIRES contributes to NOAA's mission to provide essential information on weather, which critically influences regional air quality, through its research on new approaches and instrumentation to conduct atmospheric observations. CIRES researchers analyze pollutant ozone and fine particles, and their intercontinental transport, to better understand how they affect overall air quality and its impacts on public health. CIRES participates in the Texas and New England Air Quality Studies and undertakes research that contributes to enhanced regional air quality prediction and to improved regional-scale weather forecasts, including forecasts of severe weather events.

CIRES contributes to the need for state-of-the-art information on water through its investigations on novel approaches for streamflow reconstructions and future streamflow projections. Efforts are also ongoing to provide support activities for the National Integrated Drought Information System and to provide input to the Climate Prediction Center to assist in the planning of water operations during droughts, as well as to develop guidelines for estimating the economic costs of drought in Western states.

Commerce and Transportation Mission Goal: Support the nation's commerce with information for safe, efficient, and environmentally sound transportation.

CIRES contributes to the transportation goal primarily in relation to aviation. Enhancing database and web-interface functionality and improving real-time processing modules supports verification of aviation parameters, such as icing, turbulence, and convective weather. These new tools and verification approaches provide information about the quality of aviation forecasts to aviation decision makers.

Creating a Dynamic Research Environment

CIRES has created a number of programs and initiatives to stimulate interdisciplinary collaborations between CIRES, NOAA and University Departments. The following paragraphs summarize our main programs. Detailed descriptions and specific research outcomes can be found in the Complementary Research section of this report.

CIRES' Outstanding Performance Awards Program

The CIRES Awards Committee, comprised of CIRES' Members' Council representatives, annually reviews the nominations and recommends awards for outstanding professional achievement. Five awards of $2,000 each were given this year, three in the science and engineering category and two in the service category. The awards were presented to each individual or research team at the CIRES' Members' Council Rendezvous symposium (see below). This year, CIRES recognized **Joost de Gouw** (CSD), **David Stone** and **Kelvin Fedrick** (SEC), and **Jonathan Kofler** (GMD) for outstanding performance in Science and Engineering, and **Allaina Howard** (NSIDC), and **John Maurer** (NSIDC) for outstanding achievements in Service.

In 2006, NOAA presented its 2006 Bronze Award to NOAA employees for demonstrating the usefulness of unmanned aircraft systems in accomplishing NOAA's mission, including operational and research goals. Several CIRES members were integral members of this stellar team, and in April 2007, CIRES presented them each with plaques recognizing their contributions. These CIRES members are **Dale Hurst** (GMD), **Fred Moore** (GMD), **Geoffrey Dutton** (GMD) **David Nance** (GMD), **Brian Vasel** (GMD), **Marian Klein** (formerly PSD) **Vladimir Leuski** (formerly PSD), and **Eric Ray** (CSD).

Visiting Fellows Program

CIRES annually conducts a competitive Visiting Fellows program that promotes collaborative research at the forefront of scientific knowledge. One-year fellowships are made to Ph.D. scholars and university faculty planning sabbatical leave to continue their education in research positions that may foster interdisciplinary training and exposure to scientific assessments and policy research. Since 1967, CIRES has awarded more than 220 Visiting and Sabbatical Fellowships. Recipients have included previous CIRES Director, Susan Avery, and current Director, Konrad Steffen. Selections are based in part on the likelihood of stimulating academic interactions and the degree to which both parties will benefit from the exchange of new ideas. To further this goal, the competition is open to scientists from all countries, and priority is given to candidates with research experience at institutions outside the Boulder scientific community.

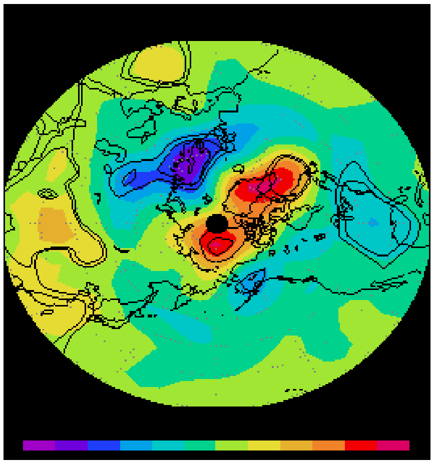
Fellowships are offered to scientists with research interests in the following areas:

- Physics, chemistry, and dynamics of the Earth system (atmosphere, biosphere, hydrosphere, lithosphere, cryosphere)
- Global and regional environmental change
- Climate system monitoring, diagnostics, and modeling
- Remote sensing and *in situ* measurement techniques for the Earth system
- Interdisciplinary research themes

Graduate Research Fellowship Program

CIRES has long supported a Graduate Research Fellowship program to promote student scholarship and research excellence. The program embraces a dual approach by (1) attracting the outstanding students at the outset of their graduate careers, and (2) enabling current students to place a greater emphasis on completing and publishing their research results. Support ranges from a summer stipend to tuition, stipend and partial health insurance for one year (12 months). Fellowships are restricted to Ph.D. students advised by a CIRES Fellow or any prospective or current graduate student who might be advised by a CIRES Fellow. Evaluations by a committee of CIRES Fellows are based on the candidate's University application, accomplishments, and the likelihood of their contribution to environmental science. Independence, passion for science, and ability to communicate are also considered. This year, CIRES awarded fellowships to seven students, five of whom were new recruits, to explore topics ranging from climate change and the mass balance of the Greenland ice sheet to natural carbon storage in ecosystems and the role of organic haze in the early Earth's atmosphere.

Innovative Research Program (IRP)



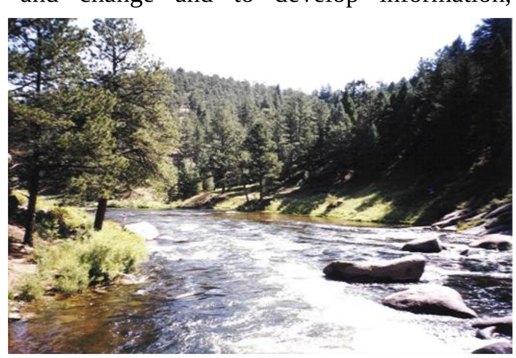
The purpose of the CIRES-wide competitive Innovative Research Program is to stimulate a creative research environment within CIRES and encourage synergy between disciplines and research colleagues. The program encourages novel, unconventional and/or fundamental research that may quickly provide concept viability or rule out further consideration. Activities are not tightly restricted and can range from instrument development, lab testing, and field observations to model advancement. Funded projects are inventive, often opportunistic, and do not necessarily have an immediate practical application or guarantee of success. Each year, an interdisciplinary team selects the award recipients, and the results of their research are presented the following year at a poster reception. The winners of the ninth annual Innovative Research Program competition include projects to improve hurricane forecasting and explore the use of bacteria in cleaning up and converting toxins found in crude oil and tar.

Education and Outreach (EO)

The CIRES' Education and Outreach program provides science education opportunities for educators, students and scientists. Their work emphasizes scientific inquiry, links with current research, and understanding of foundational concepts in geoscience. Examples of programs for educators include Earthworks, a week-long Earth System Science retreat for science teachers, and the Northeast Front Range Math and Science Partnership summer institutes. Programs designed for students include the National Ocean Sciences Bowl and the EVE-MESA high school course for English Language Learners. Programs supporting scientists include the Resources for Scientists in Partnerships with Education (ReSciPE) workshops and collaboration with scientists preparing geoscience research proposals to include educational components. While EO does work across the breadth of CIRES research topics, the group has developed a suite of work in climate sciences, including video products and mechanisms to help climate scientists communicate about their research to the public.

Western Water Assessment (WWA)

The Western Water Assessment is CIRES' signature integrating activity that involves personnel from the Climate Diagnostics Center, the Center for Science and Technology Policy Research, the Center for Limnology, the National Climatic Data Center, the Natural Resources Law Center, the Institute for Behavioral Studies, and the Institute for Arctic and Alpine Research. Its mission is to identify and characterize regional vulnerabilities to climate variability and change and to develop information, products and processes to assist water-resource decision makers throughout the Intermountain West. WWA is responsive to NOAA's mission, strategic goals, and cross-cutting priorities, as well as other congressional NOAA mandates, including the U.S. Global Change Research Act and the Climate Change Strategic Program. WWA is funded by the NOAA Office of Global Programs as part of their Regional Integrated Sciences and Assessments program.



Rendezvous! CIRES' Members' Council Symposium

The CIRES' Members' Council held its second annual research symposium on April 10, 2007. Mirroring the purpose of the old west's gathering of tribes, traders and settlers for an exchange of goods, information and good will, the meeting was dubbed "Rendezvous." This one-day symposium featured presentations by Director Konrad Steffen, the six associate directors, the directors of the Center for Science and Technology Policy Research and the Education Outreach Program, and brief introductions by the presenters of approximately 80 posters. CIRES took advantage of the occasion to honor the winners of the 2007 Outstanding Performance Awards. Two poster sessions and a luncheon rounded out the successful day. CIRES was pleased to host not only its own members, but also several visitors from the University and NOAA. Organized by the Members' Council, this symposium continued the tradition that began last year of bringing together CIRES members, Fellows, and students to highlight the depth and breadth of science and to foster scientific exchange in a stimulating setting.

Distinguished Lecture Series

CIRES promotes global perspectives by sponsoring notable speakers whose work crosses disciplinary boundaries. The Distinguished Lecture Series features outstanding scientists, science policy makers, and science journalists who take imaginative positions on environmental issues and can establish enduring connections after their departure.

John M. "Mike" Wallace, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle
"Year-to-year Variability and Long-term Trends in the Circulation over High Latitudes"

Prasad Gogineni, Center for Remote Sensing of Ice Sheets, University of Kansas, Lawrence
"Synthetic Aperture Radar Imaging of Ice-bed Interface and Radar Sounding of Fast-Flowing Glaciers"

Stefan Hastenrath, Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison
"Variations of East African Climate, Glaciers and Lakes over the Past Two Centuries"

Amanda Lynch, School of Geography and Environmental Science, Monash University, Australia
"A Factorial Analysis of Storm Surge Flooding in Barrow, Alaska: An Adaptation Study"

Symposia and Conferences

Listed below are events sponsored, organized, or hosted by CIRES.

- Northeast Front Range Math/Science Partnership: Earth & Space Science (7/06)
- Director's town meetings (7/06, 8/06, 9/06)
- ESRL Dedication (8/06)
- Northeast Front Range Math/Science Partnership: Algebra in Middle Level Mathematics Teaching (9/06, 10/06, 11/06)
- Public Lecture by Astronaut Harrison "Jack" Schmitt (9/06)
- Innovative Research Program poster session (9/06)
- Panel Discussion on *An Inconvenient Truth*: Assessing the Science and Policy Implications (9/06)
- Water, Drought and Wyoming's Climate (10/06)
- Climate Change and Variability in the San Juan Mountains (10/06)
- Climate Diagnostics and Prediction workshop (10/06).
- Climate Change for Water Resource Managers workshop (11/06)
- ReSciPE Inquiry workshop at University of Colorado (11/06)
- ReSciPE Inquiry workshop at Colorado Science convention (11/06)
- Energy Initiative symposium (10/06)
- NSIDC 30th Anniversary seminar (10/06)
- Sierra Nevada workshop (10/06)
- Consortium of Resonance and Rayleigh Lidars meeting (11/06)
- Visiting and Graduate Fellowships poster session (11/06)
- The Climate and Cryosphere Scientific Steering Group meeting (12/06)
- North American Carbon Program Investigators meeting (1/07)
- Joint Canada/Mexico/USA Carbon Program Planning meeting (1/07)
- Climate and Tourism Workshop: Identifying links between climate variability and change and tourism industries on the Colorado Plateau (01/07)
- National Ocean Science Bowl Regional Competition: Mountain Mariner Challenge (2/07)
- Climate Change Activities at CU, Climate Change Network brown bag lunch (2/07)
- North American Volcanic and intrusive rock DATabase (NAVDAT) meeting (3/07)
- Ice Fest, Celebrating the Launch of IPY (3/07)
- Boulder Labs Diversity Council meeting: Building Tomorrow's Workplace in 2007 (3/07)
- The Web and the West: Comparing Two Frontiers (3/07)
- NOAA Coastal Services Project Design and Evaluation workshop (3/07)
- CIRES' Members' Council Rendezvous Science symposium (4/07)
- National Seasonal Assessment Workshop for Wildfire Potential in the Western States and Alaska (04/07)
- ReSciPE Inquiry workshop at Challenger Learning Center, Maine (11/06)
- Introduction to Inorganic Isotope Ratio Mass Spectrometry (6/07)
- Earthworks workshop for Secondary Science Teachers (6/07)
- Northeast Front Range Math/Science Partnership: Integrating Earth & Space Science with Physical Science (6/07)

Presentations by Other Guest Speakers

- Frank Laird *Fighting Evolution, Controlling Education: Controversy over Intelligent Design* (9/06)
- Jana Milford *Dealing with Uncertainty in Regulatory Applications of Air Quality Models* (9/06)
- Sarah Krakoff *Climate Change, Morality and Law* (10/06)
- Carl Koval *CU's New Energy Initiative* (10/06)
- Michael Zimmerman *Outline of an Integral Ecology* (11/06)
- Juan Bautista Bengoetxea *Science and Technology Studies in Spain* (11/06)
- Lisa Keränen *Public and Technical Argument in Science-Based Controversies* (12/06)
- Katinka Waelbers *Philosophy of Science, Technology & Society: Master program at the University of Twente* (1/07)
- Paul Komor *Meeting Colorado's Future Electricity Needs: One Question, Many Answers* (1/07)

- Brad Udall *All Institute Seminar - Western Water Management at a Tipping Point: Recent Activities of the CIRES' Western Water Assessment* (2/07)
- Juan Lucena *What the Field of Engineering Studies has to Contribute to CSTPR* (2/07)
- Juan Lucena *Engaging Engineers in Policymaking: From Problem Solvers to Problem Definers* (2/07)
- Martin Hoerling *Past Peak Water in the West* (2/07)
- Björn-Ola Linnér *Who Gets What, How and When: Historical Responsibility & Emissions Trade in Climate Policy* (2/07)
- Jennifer Kuzma *Emerging Technologies & the Environment: Case Studies for Science & Technology Policy* (3/07)
- Jennifer Kuzma *Oversight for Nanotechnology: No Small Matter* (3/07)
- Mark Squillace *The Future of Federal Wetlands Regulation* (3/07)
- Krister Andersson *Decentralized Governance & Environmental Change* (4/07)
- Wayne Ambler *How Should We Introduce Engineering Undergraduates to STS and Policy Issues?* (4/07)

Theme Reports

Scientific Theme: ADVANCED MODELING AND OBSERVING SYSTEMS

AMOS-01: Instrumentation Design, Prototyping and Analysis
- CSD01: Instrumentation for Atmospheric Observation and Analysis
- CET01: Remote Hydrologic Sensing
- PSD08: Sensor and Technique Development

AMOS-02: Data Management, Projects and Infrastructure Systems
- NGDC01: Geospatial Technology for Global Integrated Observing and Data Management Systems
- NGDC02: Marine Geophysics Data Stewardship
- SEC03: Information Technology and Data Systems
- SEC04: Space Environment Data Algorithm and Product Development

AMOS-03: Prediction, Model Development and Evaluation
- CSD02: Chemical Transport Model Research
- PSD09: Environmental Monitoring and Prediction
- GSD01: Regional Numerical Weather Prediction
- GSD03: Verification Techniques for the Evaluation of Aviation Weather Forecasts
- NGDC03: Space Weather
- SEC01: Solar Disturbances in the Geospace Environment
- SEC02: Modeling the Upper Atmosphere

AMOS-04: Observing Facilities, Campaigns and Networks
- GMD01: Central Ultraviolet Calibration Facility
- GMD02: Surface Radiation Network

AMOS-01: Instrumentation Design, Prototyping and Analysis

CSD01: Instrumentation for Atmospheric Observation and Analysis

GOALS:
Design and evaluate new approaches and instrumentation to make atmospheric observations of hard-to-measure species that are important players in the chemistry of the troposphere and stratosphere.

> ***MILESTONE CSD01.1:***
> Report airborne observations of gas-phase ammonia (NH_3) that were made aboard the NOAA WP-3D by a newly chemical ionization mass spectrometry (CIMS) technique during the New England Air Quality Study–Intercontinental Transport and Chemical Transformation (NEAQS–ITCT).

ACCOMPLISHMENTS FOR CSD01.1:
Ammonia (NH_3) is the dominant gas-phase base in the troposphere. As a consequence, NH_3 abundance influences aerosol nucleation and composition and affects regional air quality, atmospheric visibility, and acid deposition patterns. Major sources of NH_3 in the troposphere include biomass burning and anthropogenic emissions from livestock waste, large-scale application of fertilizer, and automobile emissions. Despite its importance, there are few observations of NH_3 above the planetary boundary layer. Some of the earliest were by filter or denuder techniques that required sampling times (>15 min) that are not well suited to aircraft traveling at speeds of 100 m s^{-1} or greater. NH_3 mixing ratios in concentrated plumes from biomass burning sources have been reported at greater than 10 parts-per-billion by volume (ppbv). However, NH_3 mixing ratios as low as 0.1 ppbv have been hypothesized to influence important atmospheric processes, such as new particle formation. To further understand the distribution of NH_3 throughout the atmosphere, its role in atmospheric processes such as aerosol formation, and the impact of

anthropogenic and agricultural NH_3 sources on regional air quality, fast-time resolution, sub-ppbv airborne observations are needed.

To address this need, a Chemical Ionization Mass Spectrometer (CIMS) instrument for measuring NH_3 from an airborne platform was developed. The newly developed technique utilized a protonated acetone dimer detection scheme to selectively and sensitively measure NH_3 aboard the NOAA WP-3D aircraft during the New England Air Quality Study – Intercontinental Transport and Chemical Transformation (NEAQS–ITCT) field campaign. The average sensitivity determined from in-flight standard addition calibrations ranged from 2.6 to 5 ion counts per second (Hz)/parts-per-trillion by volume (pptv) for 1 MHz of reagent ion and could be adjusted by varying the flow tube residence time. The average 1-σ variation in sensitivity for a given flight was 20%-25%. A heated/thermostated PFA Teflon inlet was used for sampling ambient air. The instrument time response was determined in-flight from the NH_3 signal decay after removal of a standard addition calibration. The 2 e-folding signal decay time for all calibration curves analyzed ranged from 4 sec to 10 sec and on average was 5 sec. This suggested the instrument time response was on the order of 5 sec. The background signal was determined routinely in-flight by scrubbing NH_3 from the ambient sample and ranged from 0.5 to 1.3 ppbv. For a 5-sec measurement, the uncertainty in an individual background measurement varied from 20 to 60 pptv. The difference in consecutive background measurements ranged from 50 pptv to 100 pptv. Total uncertainty for the 5-sec data was estimated at no worse than ± (30% + 125 pptv), though for certain individual flights, it was less. The accuracy and precision of the airborne instrument was similar to previous ground instruments. However, the time response of the airborne instrument was faster and it was more sensitive than these instruments, primarily due to improvements in the ion transmission, inlet construction, and cleaner mass spectra due to use of a collisional dissociation chamber.

The 5-sec data obtained during NEAQS–ITCT enabled the observation of NH_3 from a variety of sources including biomass burning plumes, urban areas, and an agricultural source. NH_3 enhancements of 1 to 5 ppbv were observed on many flights in biomass burning plumes 8-10 days old with no enhancement observed in aged (~14 days old) biomass burning plumes. In the biomass burning plumes, NH_3 was well correlated with carbon monoxide (CO), a biomass burning tracer, with slopes ranging from 0.007 to 0.015 ppbv. During the 25 July flight, enhancements in NH_3 mixing ratios were coincident with enhancements in CO, the sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) mixing ratios downwind of New York City. NH_3 mixing ratios ranged from 0.4 to 1 ppbv in the New York City emission plume and were <0.15 ppbv outside of it. During the August 15 flight, NH_3 mixing ratios were enhanced directly downwind from an agricultural area northeast of Atlanta, GA. Here NH_3 mixing ratios ranged from 0.5 to 0.65 ppbv. In the urban and agricultural source cases, NH_3 mixing ratios decreased rapidly from the source. Whether this is due to surface deposition, loss to particles or clouds, or dilution due to plume dispersion has not been determined. However, given the number of sinks that can affect NH_3 mixing ratios, it is clear that more observational data are needed to understand NH_3 transport and the regional impact of these sources. These results demonstrate that the airborne NH_3 CIMS instrument described here is selective, sensitive, and fast enough for use from aircraft platforms to help understand the transport and subsequent regional impact of NH_3 emissions from a variety of sources.

> ***MILESTONE CSD01.2:***
> Develop instrumentation to make fast-response, airborne measurements of ethylene, an important precursor for ozone formation in Texas.

ACCOMPLISHMENTS FOR CSD01.2:

A laser-photo-acoustic spectroscopy (LPAS) instrument for fast-response measurements of ethene was developed and used onboard the NOAA WP-3D research aircraft during an air quality study in Houston, Texas, in September and October of 2006. Previous work had indicated that ethene and propene from petrochemical emissions were much larger than emissions databases indicated, and played a key role in the formation of ozone in the area.

Airborne data for ethene obtained with the LPAS instrument were compared with gas chromatographic analyses of whole air samples collected in flight. The two measurements agreed within the combined measurement uncertainties, and from the comparison researchers estimated the detection limit of the LPAS instrument to range between 200 and 1000 pptv depending on the turbulence encountered during the flights.

Analysis of the LPAS data focused on two different issues. First, it was immediately evident from the results that the peak values of ethene were not as high as during a previous mission in 2000. This observation led to a careful statistical analysis of ethene observations between the two years. It was found that ethene was on average 40% lower in 2006 than in 2000. Even though the meteorology was also very different between the two years, it was concluded that the difference was more likely due to a reduction in ethene emissions, because (1) other trace gases did not show a decrease between 2000 and 2006, and (2) formaldehyde, an atmospheric oxidation product of ethene, showed a similar 40% decrease.

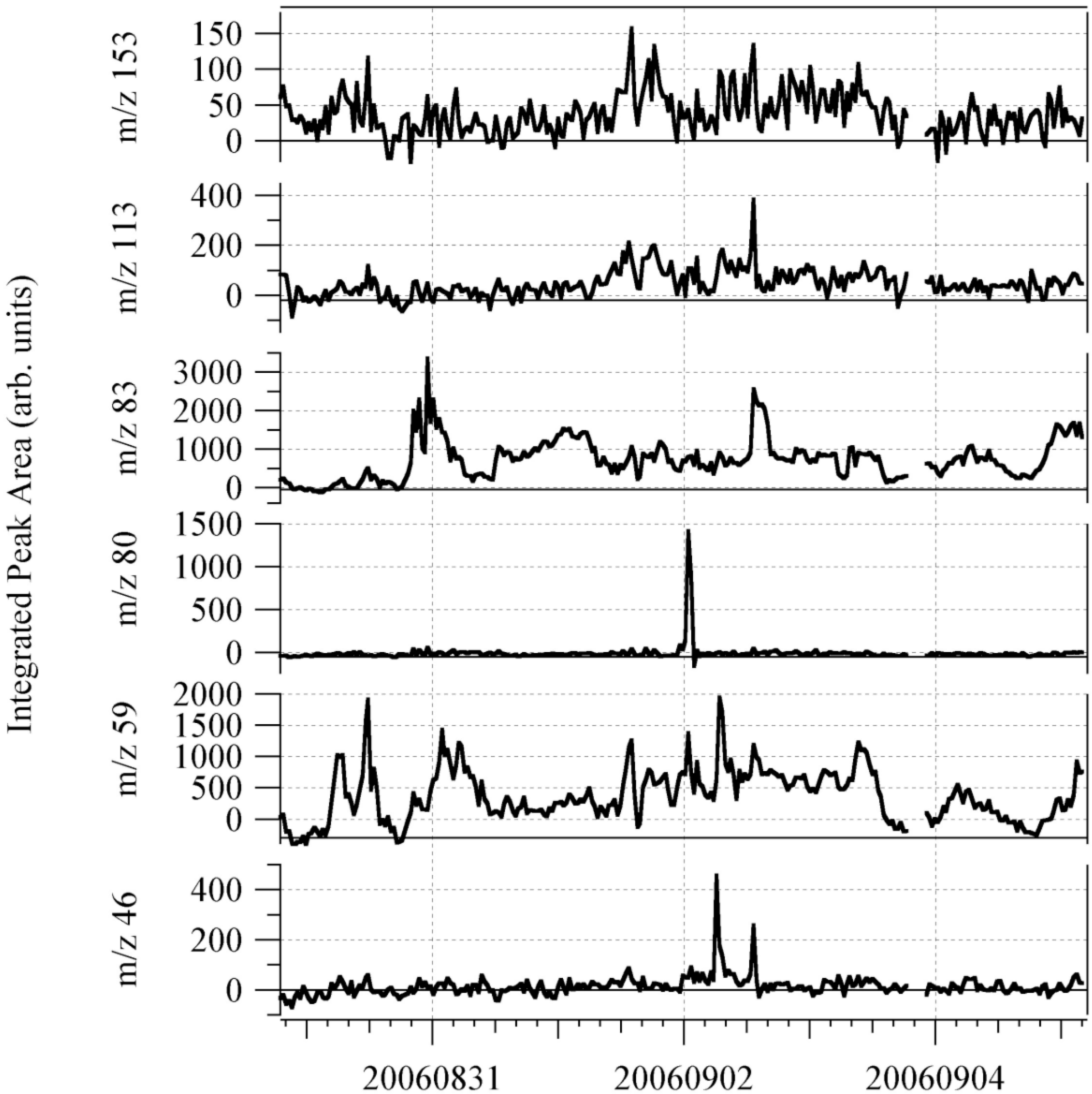
The other issue that analyses have focused on is a quantification of ethene emission sources. By integrating across the width of an industrial plume, and by taking the wind speed and direction into account, the emission flux can be estimated assuming a homogeneous distribution across the height of the boundary layer. This method of estimating emissions was compared to results from a solar occultation flux (SOF) measurement operated by Chalmers University (Gothenburg, Sweden) onboard a mobile laboratory. The SOF measurement determines column ethene using absorption of solar IR radiation, and thus provides a completely independent estimate of the ethene fluxes in the Houston area. The results from the two methods generally agreed within a factor of 2 without systematic biases. A comparison of the results with flux estimates represented in an emissions database revealed that the actual fluxes are 10-40 times higher than those used in the modeling. This is very important information for air-quality managers in Texas to take into account in their efforts to understand and model ozone formation in the area.

The results of this work have been presented at two workshops in Austin, Texas, to colleagues involved in the study, officials from the Texas Commission on Environmental Quality (TCEQ) and other interested parties. A publication about this work is in preparation for the *Journal of Geophysical Research*.

MILESTONE CSD01.3:
(i) Characterize quantitatively the response of the cavity ring-down single particle aerosol instrument, and plan use of it on actual air-flows brought into the laboratory. (ii) Deploy the organic aerosol collector on the NOAA R/V *Ronald H. Brown* and use suitable mass spectrometry to analyze the samples.

ACCOMPLISHMENTS FOR CSD01.3:
(i) The development of a cavity ring-down instrument to measure the albedos and optical sizes of individual aerosol particles was completed, and characterization of the instrument performance was carried out. During the instrument characterization, it was determined that obtaining the particle extinction, which is necessary for the albedo measurement, by measuring the depletion in the cavity laser intensity, provides a more robust measurement than the ring-down method. The depletion method provided less spread in the measured albedo values for a collection of particles of known sizes and optical properties than those derived from the ring-down time measurements. The depletion method also avoids some technical difficulties associated with operating the instrument in the cavity ring-down mode. The instrument operating in the depletion mode is able to optically size the diameters of laboratory-generated particles to within 50 nm. Currently, the instrument can measure the albedo and size of particles down to diameters of around 300 nm and an upper size limit above a micron in diameter. Changes in albedo of greater than 10-15% were observable using partially absorbing dyed laboratory particles. Final modifications are being made to the instrument to provide a higher vacuum necessary for the introduction of particles from ambient air into the instrument. Currently, a manuscript is in preparation that describes the instrument and its capabilities. Plans are being made for field measurements in the near future.

(ii) After evaluation of the performance of the prototype aerosol speciation instrument during the fall of 2005, a field-deployable instrument incorporating several additional improvements was constructed during the winter and spring of 2006. The completed instrument was successfully deployed aboard NOAA R/V *Ronald H. Brown* for the TexAQS 2006/GoMACCS field campaign from August to mid-September in the western Gulf of Mexico/Houston Ship Channel region. Proton-transfer-reaction chemical ionization mass spectra of thermally-desorbed aerosol samples showed significant variations in the composition of the organic fraction of atmospheric aerosol on hourly-to-daily timescales. Data from the field campaign were reduced during fall 2006-winter 2007. First-look results were presented at a mass spectrometry conference in January 2007. Laboratory studies to assist with understanding the data acquired during the field campaign and to characterize further the performance of the instrument were begun during spring 2007 and are continuing. A manuscript describing the instrument and its performance is in preparation.



Time series of several masses observed by the AOS-PTR-ITMS during its initial deployment aboard R/V Ronald H. Brown during the summer 2006 TexAQS/GoMACSS campaign.

MILESTONE CSD01.4:
Develop ship-based and aircraft-based lidar systems to measure ozone and aerosol profiles.

ACCOMPLISHMENTS FOR CSD01.4:
Two lidars were deployed during the 2006 Texas Air Quality Study (TexAQS II) to measure ozone and aerosol profiles. The TOPAZ airborne ozone-profiling lidar was built the previous year and saw its first deployment at TexAQS II. TOPAZ is a compact and lightweight airborne ozone lidar based on an innovative, all solid-state, wavelength-tunable UV laser transmitter. During TexAQS II, TOPAZ flew 22 missions totaling approximately 120 hours aboard a NOAA Twin Otter airplane during which it mapped out the three-dimensional distribution of ozone and aerosols over eastern Texas and the Gulf of Mexico. In addition to ozone mixing ratio and aerosol backscatter profiles, TOPAZ also provided highly resolved information on the spatial distribution of mixed layer height. First

results show that the data gathered with TOPAZ will be crucial to address important science questions regarding the local buildup and regional transport of ozone in eastern Texas.

During TexAQS II, the OPAL lidar measured profiles of ozone and aerosol backscatter from aboard the NOAA R/V *Ronald H. Brown*. Recent lidar improvements included more accurate photodetectors, a simpler optical receiver, and new aerosol data processing methods. In addition to ozone concentration, derived profiles include total uncalibrated backscatter, calibrated aerosol backscatter and aerosol extinction at 355 nm. Other products are cloud heights, and aerosol layer heights (e.g. mixed-layer and residual layer heights) which are important for understanding pollution concentrations. The ozone profiles will be used to help explain the daily evolution of tropospheric ozone, especially to better define which situations develop into high ozone events. The aerosol data will be used for studies of aerosol hygroscopic growth factor, *f*(RH) (relating scattering at high relative humidity to that at low relative humidity) and visibility, evaluation of air quality model predictions of aerosol, closure studies on aerosol optical and microphysical properties, and case studies of horizontal transport and vertical mixing.

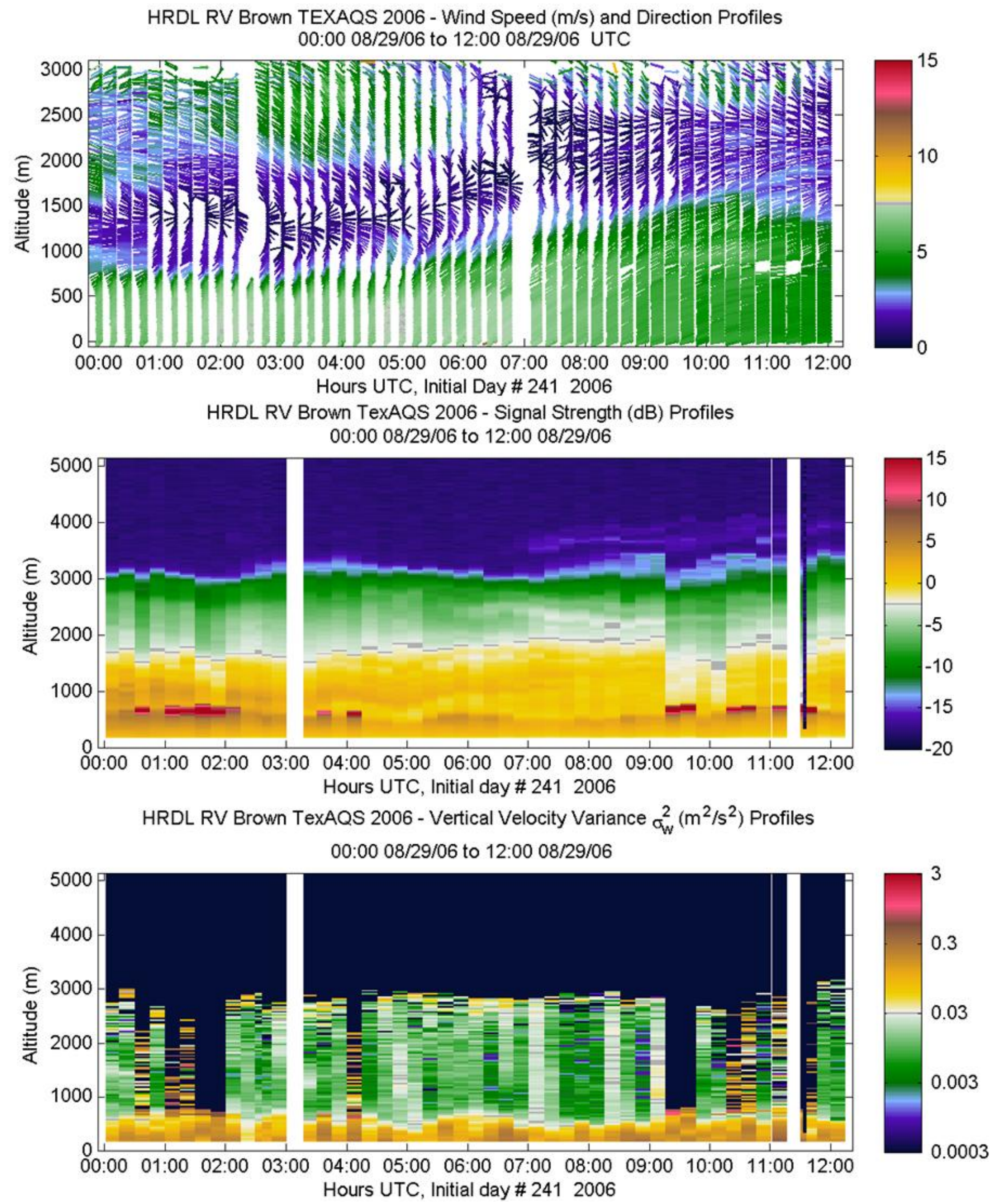
MILESTONE CSD01.5:
Develop a ship-based remote sensing lidar to measure wind and turbulence profiles.

ACCOMPLISHMENTS FOR CSD01.5:

Understanding boundary layer dynamics, including mixed-layer heights, mean wind profiles, and mixing strength, are important for estimating pollutant concentration and transport in air quality studies. In order to make measurements of such atmospheric dynamics, NOAA's High Resolution Doppler Lidar (HRDL) has been updated in the following ways: The main laser has been updated to run at a higher output power by integrating new pump diodes, new optical systems to couple pump light into the laser cavity, and an improved thermal control system for the laser crystal itself. The motion compensation and scanning system has also been updated to incorporate automatically zenith stare files into a 15-minute scan pattern. Such zenith stare data provide new profiles of vertical velocity and vertical velocity variance (i.e. vertical mixing) that are used, along with horizontal mean winds derived from other scans, to understand pollutant dispersion, mixing, and concentration. In addition, scientists have created new processing algorithms that enabled the wind and mixing profiles to be automatically generated and posted to ship-based and land-based servers once every 15 minutes, thus allowing researchers near-real-time access to information about wind and mixing conditions for contextual and forecasting applications.

Existing and forthcoming information derived from this data set include:

- Profiles of horizontal mean wind speed and direction
- Profiles of relative aerosol strength and aerosol layering
- Vertical winds and profiles of vertical mixing/turbulence statistics
- Horizontal (near surface) mixing/turbulence statistics
- Aerosol and mixed layer (i.e., boundary layer) heights
- Profiles of wind speed and directional shear
- Boundary layer dynamic features: rolls, surface streaks, thunderstorm outflows, etc,
- Ship/oil-platform plume detection.



CET01: Remote Hydrologic Sensing

GOALS:

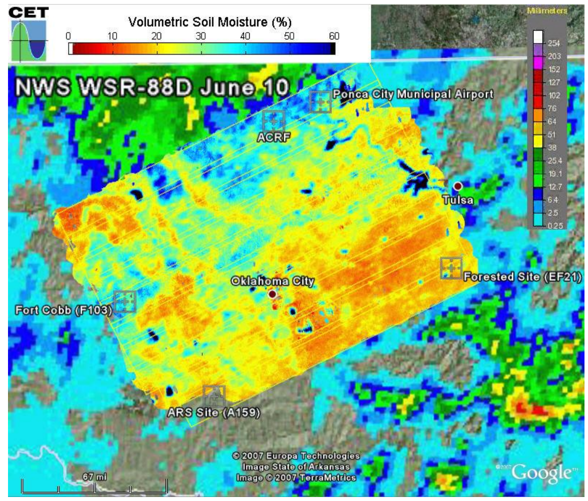
Develop microwave remote sensing capabilities to facilitate NOAA measurements of key hydrological variables.

MILESTONE CET01.1:

Develop a new microwave sensing capability to enable NOAA measurements of soil moisture and/or snow water equivalent.

ACCOMPLISHMENTS FOR CET01.1:

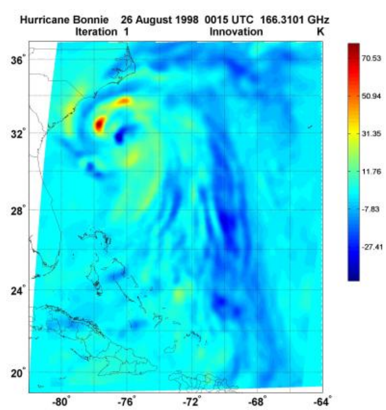
During FY2007, the CET operated the PSR/CXI soil moisture (SM) imaging radiometer as part of the DoE Cloud and LAnd Surface Interaction Campaign (CLASIC). The mission took place during June in Oklahoma, and resulted in eight successful mapping sorties during which the PSR mapped SM within the topmost 5 cm over a region of size ~255 x 190 km with ~1.5 km resolution. Mapping occurred during the wettest month of June in Oklahoma history, thus providing unique conditions under which to test C-band SM mapping capabilities under near-saturation. For the first time a self-contained algorithm was demonstrated for retrieval of SM with geo-registered overlap product delivered consistently within 24 hours of imaging and estimated accuracy of ~5-10%, depending on vegetation overburden. The mission included the first-ever use of airborne SM mapping technology to assist in real-time flood risk assessment over deluged areas of central Texas.



MILESTONE CET01.2:

Develop an improved version of the DOTLRT radiative transfer model with radiance assimilation capabilities.

ACCOMPLISHMENTS FOR CET01.2:



The DOTLRT radiative transfer model was improved in two major capacities during FY2007: 1) a fast Henyey-Greenstein Mie lookup library was created to improve execution speed, and 2) a fully-polarimetric surface emission model based on WindSat satellite data and the OSU two-scale radiative transfer model was developed. These models have been delivered to the NOAA-NASA-DoD Joint Center for Satellite Data Assimilation, and are expected to be used with the JCSDA Community Radiative Transfer Model (CRTM). In addition, the DOTLRT Jacobian capabilities were incorporated within a precipitation-locking all-weather radiance assimilation algorithm to demonstrate for the first time all-weather microwave-radiance assimilation over precipitation. Results of running the locking algorithm over first frames of data indicate reasonable convergence of the radiance innovation field. The locking algorithm is being applied to the simulation of the short-term QPF performance of a geostationary microwave sounder.

MILESTONE CET01.3:

Demonstrate the potential for geostationary microwave imaging of precipitation using simulation experiments.

ACCOMPLISHMENTS FOR CET01.3:

Precise system simulations of the GEostationary Microwave (GEM) imager/sounder and the GeoSTAR synthetic thinned-aperture imaging radiometer have been studied within the context of the NOAA Geostationary Microwave Pathway study. The simulations use extensive 6-km MM5 simulations of Hurricane Bonnie at landfall, and include five-phase precipitation microphysics and full scattering-based Jacobian calculations. The data illustrate – more accurately than any other simulation to date – what will be observed from the future GEM and GeoSTAR sensors. The results of the study have been presented at the World Meteorological Organization's IGeoLab series of workshops.

PSD08: Sensor and Technique Development

GOALS:
Design, develop, enhance and evaluate remote and in situ *sensing systems for use from surface and other platforms of opportunity in order to measure critical atmospheric, surface, and oceanic parameters.*

> ***MILESTONE PSD08.1:***
> Continue construction of a roving calibration standard for ship flux measurements.

ACCOMPLISHMENTS FOR PSD08.1:
Considerable progress was made on developing the portable flux standard and implementing ship and buoy inter-comparisons for quality assurance.

Production of the roving flux standard is nearly complete. Researchers have upgraded one of the existing ESRL flux systems to create the portable standard (i.e., rather than build an entire new system from scratch). The upgrade features: 1) conversion from a network cabled sensors to wireless transmission and 2) improved radiative flux and navigational measurements.

Dr. Frank Bradley of CSIRO Canberra, Australia visited ESRL for a month in the spring of 2006 to work on the flux measurement handbook. Considerable progress was made and a draft was circulated among coauthors. The handbook has now been published as a NOAA Technical Memorandum (*ftp://ftp.etl.noaa.gov/user/cfairall/wcrp_wgsf/flux_handbook/*).

A mostly complete prototype system was assembled and exhibited at the INMARTECH Symposium (Woods Hole Oceanographic Institution) in October 2006. A presentation was also made ("The NOAA Portable Seagoing Air-Sea Flux Standard," C.W. Fairall, S. Pezoa, L. Bariteau, and D.E. Wolfe). A complete seatainer-based system has now been assembled and is undergoing testing in Boulder.

> ***MILESTONE PSD08.2:***
> Field test fast ozone sensor on Houston A/Q field program for ship-based ozone flux measurements.

ACCOMPLISHMENTS FOR PSD08.2:
A new ozone sensor was been built at INSTAAR (Detlev Helmig is leading the project). The system was deployed on the R/V *Ronald H. Brown* in the TexAQS field program in later summer 2006.

AMOS-02: Data Management, Projects and Infrastructure Systems

NGDC01: Geospatial Technology for Global Integrated Observing and Data Management Systems

GOALS:
Develop methods and processes for integrating multiple types of observations (e.g., gridded satellite products, and in-situ *measurements) using new Geographic Information System (GIS) data management and access tools; develop methods and processes for partnering with scientists to facilitate interoperability by producing metadata for scientific observations that are compliant with national FGDC (Federal Geographic Data Committee) and international ISO (International Standards Organization) standards; and create tools that allow the mining of vast environmental archives for the purpose of knowledge extraction, data quality control and trend detection.*

> ***MILESTONE NGDC01.1:***
> Increase access to environmental observations from Internet applications (Internet Mapping, Google Earth, etc.) using Open Geospatial Consortium standards and spatial databases.

ACCOMPLISHMENTS FOR NGDC01.1:
NGDC is serving information about NOAA Observing Systems using the Open Geospatial Consortium Web Map Service. Between July 2006 and June 2007, the number of requests served grew by a factor of ten, to roughly 60,000 requests/month. These data are also being served to Google Earth using static and dynamic KML.

MILESTONE NGDC01.2:
Integrate satellite granule metadata into spatial databases and Geographic Information Systems.

ACCOMPLISHMENTS FOR NGDC01.2:
During the last year, NGDC created tools for calculating and ingesting metadata for gridded NOAA Sea Surface Temperature data at three resolutions (14, 50, and 100 km) and tools for integrating NOAA satellite observations with *in-situ* observations. The second system involves roughly 1,000,000-point SST observations/day that are ingested into a spatial database and served on the web with a number of GIS tools.

NGDC02: Marine Geophysics Data Stewardship

GOALS:
Contribute to a streamlined, more fully automated, accessible, and web-based management and stewardship process for Marine Geophysical data in support of seafloor research at CIRES and throughout the environmental science community.

MILESTONE NGDC02.1:
Add a generic set of Federal Geographic Data Committee (FGDC)–compliant metadata files for each survey in the Multibeam Bathymetric Data Base (MBBDB) at *http://map.ngdc.noaa.gov/website/mgg/multibeam/viewer.htm*, thereby improving the infrastructure for search and access of these data.

ACCOMPLISHMENTS FOR NGDC02.1:
FGDC compliant metadata files have been generated for most surveys in the NGDC MultiBeam Bathymetric Data Base (MBBDB). Users can access these metadata files directly from the search page or, if the data are downloaded, the metadata file is packaged automatically in the compressed delivery file. The MBBDB System is accessed through the web page: *http://map.ngdc.noaa.gov/website/mgg/multibeam/viewer.htm*.

MILESTONE NGDC02.2:
Search, target, and acquire multibeam data from the larger, worldwide oceanographic community.

ACCOMPLISHMENTS FOR NGDC02.2:
Researchers retrieved multibeam sonar survey data from various institutions. Data are assessed for quality, archived for long-term storage, and disseminated to the public through NGDC's MultiBeam Bathymetric Data Base (MBBDB).

Lamont Doherty Earth Observatory	26
University of New Hampshire CCOM	7
University of South Florida	5
Woods Hole Oceanographic Institution	3
Scripps Institution of Oceanography	1
U.S. Naval Oceanographic Office	15
NOAA National Marine Fisheries Service	8
NOAA Pacific Marine Environmental Laboratory	3
Germany (Bundesamt fur Seeschiffahrt und Hydrographie	11
Russia (University of Rhode Island edited)	2
TOTAL	81

Surveys received and placed on line between July 1, 2006 and June 30, 2007 by contributing institutions.

MILESTONE NGDC02.3:
Implement an effective on-line, web-based data submission interface for multibeam bathymetry by which even a casual user will be able to submit data into the Multibeam Bathymetric Data Base (MBDDB).

ACCOMPLISHMENTS FOR NGDC02.3:
An online data submittal protocol and active web-link was developed (*http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam/MB_access.html*) for user contributions of multibeam sonar data to the MBBDB. The system sends automated email notices after the metadata form is completed and then again after the data have been uploaded. This product has been used in test mode for most of the calendar year but went live on the MBBDB website in June. It has been used for external submission fewer than 10 times. Evaluation of ease of use, effectiveness, and desirability by clientele and colleagues will have to follow more extensive usage.

SEC03: Information Technology and Data Systems

GOALS:
Determine the necessary research data systems and infrastructure required to implement successfully the empirical and physical scientific models of the space environment such as those envisioned in SEC01 and SEC02 with fast and efficient access to appropriate data sources.

MILESTONE SEC03.1:
Realign SEC data processing systems for better security and reliability. Identify and partition off National Critical Systems (NCS) from the rest of the IT infrastructure.

ACCOMPLISHMENTS FOR SEC03.1:
Project suspended indefinitely due to funding and priority changes.

MILESTONE SEC03.2:
Complete the phase-I migration of older and non-supported computing platforms to newer platforms. Complete and deploy SEC programmatic data subscription service. Complete and deploy next generation SEC status monitor and develop a project plan for integrating existing applications to the new status monitor. Complete the next version of the data bridge server and clients, in order to provide aggregate and atomic domain-name based data-retrieval, and auto-switching between main and warehouse data stores.

ACCOMPLISHMENTS FOR SEC03.2:
Phase-I completed, with first version of next generation SEC status monitor. Big Brother software used by the National Weather Service was used to anchor the new status monitor system, which now monitors all NCS systems for process health, network availability and up time. The Data Subscription Service project and next version of data bridge server and client projects were put on hold, and formally removed for the Phase-I effort.

MILESTONE SEC03.3:
Develop and deploy a secure and reliable data ingest, storage, processing and dissemination system for space weather data streams. Revise several existing applications to reduce complexity and increase reliability by integrating them with the new SEC shared services.

ACCOMPLISHMENTS FOR SEC03.3:
Development, testing and documentation for operational deployment of the NOAA/Boulder (TMO) Magnetometer Data Processor were completed. This process replaces an unreliable legacy system, and takes better advantage of new SEC shared services. Additionally, DMS to SWDS data set mapping were completed in an effort to migrate further from older DMS data storage system. Lastly, software utilities were developed to extract and transport daily GOES files from SWDS, and to identify data discrepancies. These utilities help to automate a largely manual and error prone set of processes.

MILESTONE SEC03.4:
Complete development of the GOES-N ground data systems IT infrastructure needed for post-launch test. Provide analysis and technical support to algorithm development, instrument checkout and data verification.

ACCOMPLISHMENTS FOR SEC03.4:
Implementation of MRS&S clients, Network Data Bridges, Telemetry Archivers, SEM & SXI Preprocessors and prototype framework for Level-1 image processing was completed in time for a post-launch test. Several improvements to the preprocessors were made in response to analysis of early post-launch test products. Finally, replay capabilities were implemented, allowing scientists to replay telemetry through enhanced processing algorithms, as they further developed their models.

SEC04: Space Environment Data Algorithm and Product Development

GOALS:
Explore new techniques for analyzing and modeling GOES space environment data, and develop and validate new algorithms and products.

MILESTONE SEC04.1:
Assemble proxy data sets for the GOES-R instruments.

ACCOMPLISHMENTS FOR SEC04.1:
Proxy data for some of the GOES-R instruments have been created. The SEISS, MAG and XRS data sets are complete. Since there have been difficulties with the GOES-13 SXI and EUVS instruments, those data sets have not been collected. However, the use of other satellite data sets is being considered. Also, work is being done to make the GOES-13 data sets suitable for operational use as well as for test data sets for GOES-R.

AMOS-03: Prediction, Model Development and Evaluation

CSD02: Chemical Transport Model Research

GOALS:
Undertake research that contributes to the ability to forecast regional air quality and improves the understanding of the budget of ozone in the upper troposphere.

MILESTONE CSD02.1:
Use the forecast capabilities of current chemical transport models for the planning of the deployment of the R/V *Ronald H. Brown*, the WP-3, and other aircraft during the 2006 Texas Air Quality Study /Gulf of Mexico Atmospheric Composition and Climate Study experiment.

ACCOMPLISHMENTS FOR CSD02.1:
During the 2006 Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study experiment (TexAQS/GoMACCS), the FLEXPART particle dispersion model was run in forecast mode to provide pollutant tracer forecasts to guide the WP-3D aircraft and the R/V *Ronald H. Brown* into pollution plumes. The model was updated four times per day and utilized the 1×1 degree resolution windfields of NOAA NCEP's Global Forecast System model to yield five-day forecasts of CO, SO_2 and NOx emissions from all North American anthropogenic sources. Special Houston-region tracers were also provided at higher resolution. In addition, a biomass-burning tracer, emitted from fire hotspots and sensed in near-real-time by MODIS, was calculated four times per day. The forecasts were made available to the mission planners in two on-line formats (*http://www.esrl.noaa.gov/csd/metproducts/flexpart/index.html*). The first format consisted of static GIF images of the tracers at various altitudes, with fixed map projections to provide a quick overview of the plume evolution over the following five days. The second, more useful format allowed the user to access an interactive web page and create custom images and image loops of the various tracers for any location and any altitude. This forecast package provided accurate, timely, and easily accessible pollution-plume forecasts for the full duration of the

TexAQS/GoMACCS experiment, and can be easily modified to provide forecasts for future NOAA/CIRES field studies.

> ***MILESTONE CSD02.2:***
> Gather remote-sensing observations during the 2006 Texas field study to investigate the capability of models to represent important boundary layer parameters.

ACCOMPLISHMENTS FOR CSD02.2:

Optical remote sensors were employed to gather information on ozone, aerosol, winds, turbulence and mixing during a six-week period in August and September as part of the Texas study. The TOPAZ airborne ozone lidar characterized ozone and aerosol distributions in the Houston and Dallas areas on 20 days during the period; data were obtained during approximately 70 flight hours. From the lidar measurements, boundary-layer background-ozone concentrations, mixing-layer depths over different land surfaces and water, and ozone flux in plumes downwind of Houston and Dallas were computed. Data from flights along the east Texas border were used to estimate ozone imported into Texas from Louisiana and its effect on pollution levels. Initial analysis indicates no obvious correlation between mixing-layer depths and ozone concentrations. Estimates of flux showed that the ozone exported from the Dallas-Fort Worth area was about one-third that observed downwind of Houston.

During the same period, ozone and Doppler lidars were operated continuously from the R/V *Ronald H. Brown* in the Gulf of Mexico, Galveston Bay, and the Houston ship channel. The Doppler lidar provided high resolution profiles of horizontal wind speed and direction and vertical velocity speed and variance. From the vertical wind measurements, estimates of mixing strength and mixing-layer depth were computed and compared with *in situ* chemical and aerosol measurements on the ship as well as with the lidar-measured vertical profiles of ozone. Results indicate that several events characterized by downward mixing of upper-level aerosol were observed. Additionally, while in the ship channel, the lidar observed strong nocturnal low-level jet events that were associated with an observed absence of elevated pollution levels on subsequent days. The composite lidar observational set from the three instruments provide excellent data for comparison with model computations of ozone formation, transport, and mixing processes in the southeastern Texas region.

PSD09: Environmental Monitoring and Prediction

GOALS:

Improve numerical model performance through development of new data streams that directly impact forecast ability and through focused observational campaigns supporting geophysical process studies.

> ***MILESTONE PSD09.1:***
> Develop inter-satellite bias correction and apply both diurnal sampling and inter-satellite bias corrections to the High-Resolution Radiation Sounder (HIRS) satellite radiances. Determine the impact these corrections have on the radiances by comparing with HIRS simulated radiances from the GFDL climate model.

ACCOMPLISHMENTS FOR PSD09.1:

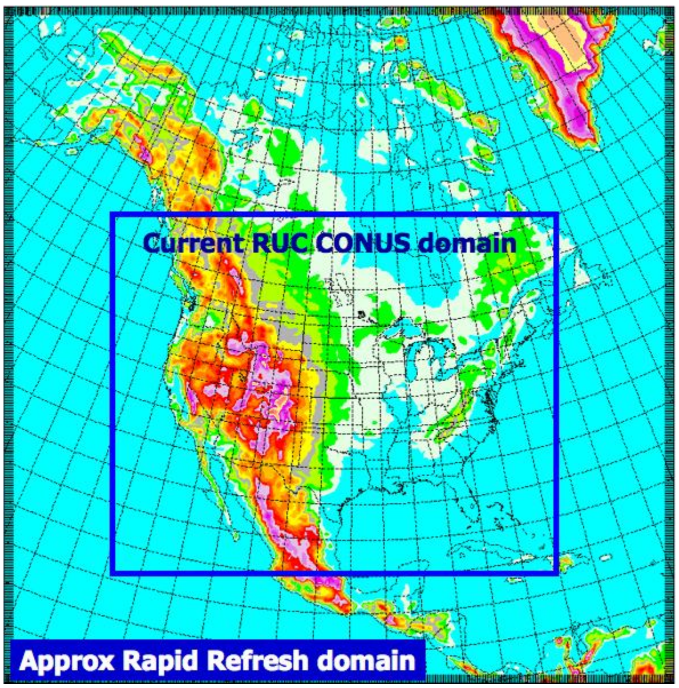
Corrections to the HIRS/2 satellite observations were developed to eliminate sampling errors due to orbital drift, diurnal differences between satellites, and instrument bias inherent to each satellite. Climate model simulations of HIRS observations were used to predict and correct the local time drift of HIRS observations for all of the satellites. Diurnal differences between satellite observations were corrected to have all ascending orbits to a 1930 LST observation, and all descending orbits were corrected to a 0730 LST observation time. Inter-satellite biases due to instrument bias for HIRS brightness temperatures for channels 2 through 12 were corrected to NOAA-10 HIRS observations. A final set of corrected HIRS clear-sky brightness temperature data has been compiled over a 26-year period (1979-2004) and is now being used to compare trends in clear-sky greenhouse gas trapping in climate model simulations. Other studies planned for these data include comparing trends between climate model OLR and HIRS-derived OLR and spatial trends in CO_2.

GSD01: Numerical Weather Prediction

GOAL:
Design and evaluate new approaches for improving regional-scale numerical weather forecasts, including forecasts of severe weather events.

> ***MILESTONE GSD01.1:***
> Begin one-hour cycling of initial version of the North American Rapid Refresh using GSI and the chosen configuration of the WRF model.

ACCOMPLISHMENTS FOR GSD01.1:
The current Rapid Update Cycle model and assimilation system, covering the coterminous United States and adjacent areas of Canada, Mexico and the Pacific and Atlantic Oceans as well as the Gulf of Mexico and a portion of the Caribbean Sea (see figure below), is scheduled to be replaced by the so-called "Rapid Refresh" in 2009. The purpose of the Rapid Refresh is the same as the RUC, to provide a "situation awareness" framework for forecasters by providing very frequently updated analyses and very short-range numerical model forecasts. The figure also shows the domain of the Rapid Refresh, which is about 2.6 times larger than the RUC domain and covers nearly all of North America, including mainland Alaska, as well as most of the Caribbean Sea.



In addition to the larger domain, the hydrostatic hybrid-isentropic coordinate RUC model will be replaced by a version of the WRF model, and the present RUC 3dVAR analysis scheme will be replaced by the Gridpoint Statistical Interpolation (GSI) 3dVAR analysis scheme, which is under continued development by NCEP and NASA Goddard.

Work toward a cycling prototype Rapid Refresh (RR) was an important focus of activity during the 2006-2007 period, particularly after the completion of the RR Core Test in August. Due to a several-month delay in availability of ESRL's new supercomputer, and the need for ongoing testing of important upgrades to the Rapid Update Cycle, researchers had to make some compromises to the scope of the efforts toward the Rapid Refresh to accommodate the available computing resources. This was done initially by instituting twelve-hour cycling of the WRF-ARW using GSI on the CONUS RR Core-Test domain, slightly smaller than the present operational RUC CONUS domain shown in the figure. However, the version of GSI used in this cycling has been without RUC enhancements to GSI, which are considered desirable for effective hourly cycling, including special treatment of surface observations to spread surface information vertically when the one-hour forecast background has an identifiable surface-based mixed layer. In order to begin to get experience running on the whole North American RR domain with GSI and WRF, a run covering this whole domain was set up with 13-km grid spacing on ESRL's older computer, and cycling was once per twelve hours. This has been running for several months now. Although results have been acceptable, they are far inferior to those that could be achieved using one-hour cycling. Once the new computer became available in early 2007, continued problems with its file system, which were revealed by the GSI code when it attempted to write to multiple nodes in parallel, slowed progress further while those problems were diagnosed and fixed. Although the pieces are now mostly in place for one-hour cycling over the full RR domain, this cycling had not yet begun as of June 2007.

A further requirement for running a WRF-based Rapid-Refresh one-hour cycle is to have a capability for digital filter initialization in the WRF model. This is necessary to reduce fast-mode noise in the one-hour WRF forecast used as background by the GSI 3dVAR analysis. However, the developers of WRF did not explicitly provide for running the model backwards in time, as is required for the DFI, so considerable development effort has been necessary. Such a capability was, in fact, developed in 2005 for WRF v2.1. Work to extend this capability to WRF v2.2 has turned out to be decidedly nontrivial, but it is progressing.

> ***MILESTONE GSD01.2:***
> Incorporate enhancements to Gridpoint Statistical Interpolation (GSI) code to improve use of surface weather observations (METARs) and introduce GSD-developed procedures into GSI to incorporate three-dimensional, high-frequency National Weather Service WSR-88D radar data in the initialization of cloud and precipitation hydrometeors.

ACCOMPLISHMENTS FOR GSD01.2:

Work on GSI at GSD was begun in 2005. After some very basic code adjustments, work started to concentrate on features important for RR applications, particularly those required for one-hour cycling and assimilation of hydrometeors. (GSI has heretofore been used only with models cycling every six hours and without assimilation of hydrometeor information.) The two most important of these features are usage of surface observations, including ceiling height and present weather, and analysis of hydrometeors.

One of the strengths of the present Rapid Update Cycle (RUC) is the handling of surface data in the RUC analysis. The difference between the surface observation of virtual potential temperature, water-vapor mixing ratio and horizontal wind components and the one-hour background forecast of these quantities is spread vertically through the mixed-layer (but only if there is such a mixed-layer) in the one-hour background forecast by generating “pseudo-observations” within the mixed-layer, but not above. For the time being, a different approach is taken in the GSI, using anisotropic background error covariance information in an adaptive way. The premise is to apply the PBL depth of the background forecast as computed in the present RUC and use this to constrain the scale of vertical correlation in the background error. This approach is combined with a model for anisotropic background error developed and implemented in GSI by NCEP. The present code employs the background virtual potential temperature when computing the vertical correlation of background error. Present work is directed toward introduction and intense testing of this approach in the real-time one-hour RR cycle soon to begin on the new ESRL supercomputer (see Milestone GSD01.1).

The existing operational RUC cloud analysis is done outside the variational framework of the RUC 3dVAR. It uses NESDIS cloud products (cloud top pressure and temperature) and METARs to decide the location of cloud top and clear area and then adds a thin layer of cloud under the cloud top and clears the column above cloud top. (The whole column is cleared of hydrometeors if the column is identified as being clear by the RUC cloud analysis.)

Versions of GSI released by NCEP have yet to incorporate any cloud analysis procedures. Therefore, an enhanced version of the existing RUC cloud-analysis procedure within the GSI software framework was incorporated, but as with RUC, outside the variational parts of the code. A systematic approach toward introducing the RUC cloud analysis into GSI has been pursued, including a) building onto the GSI framework to accommodate the cloud analysis, b) ingesting cloud observations, c) building the cloud analysis driver, and d) incorporating RUC cloud analysis into GSI. All the programming work has been finished including parallelization of the cloud-analysis code. Preliminary results show successful performance. The code will be further tested in the real time RR cycle.

A new procedure for assimilation of three-dimensional high-frequency National Weather Service WSR-88D radar data is being tested in real-time RUC cycles at GSD. Briefly summarized, this procedure uses the 1-km Q2 Mosaic radar-reflectivity product developed at the National Severe Storms Lab of NOAA, plus some additional quality control, to identify volumes of the atmosphere having radar reflectivity due to hydrometeors. In areas where radar data are absent, lightning is used to identify volumes likely to possess hydrometeors. The procedure also identifies areas where the one-hour background forecast has hydrometeors that do not exist in reality. In order to render the initial mass and momentum fields more consistent with these implied hydrometeor fields, the diabatic digital filter initialization is employed. After the initial adiabatic backward stage of the DFI, there follows the diabatic forward step. During this forward step, the potential temperature tendencies from the microphysics and convection parameterization schemes are replaced by tendencies specified based on the mixing ratios of the hydrometeors. In this way an initial divergent component of the wind field is introduced that has some measure of consistency with the hydrometeor fields and allows a much improved forecast of precipitation through the first three to six hours of the model forecast. Introduction of this procedure into the RR cycling later this year is planned, once a version of

WRF with a diabatic digital filter initialization is developed. This will thus be implemented, at least initially, outside the GSI framework.

GSD03: Verification Techniques for the Evaluation of Aviation Weather Forecasts

GOAL:
Design and evaluate new verification approaches and tools that will provide information about the quality of aviation forecasts and their value to aviation decision makers.

> ***MILESTONE GSD03.1:***
> Participate in the redesign of the Real-Time Verification System (RTVS) by enhancing the functionality of the database, web-interface, and real-time processing modules of the system to support verification of aviation parameters, such as icing, turbulence, and convective weather.

ACCOMPLISHMENTS FOR GSD03.1:
Upgrades to the turbulence and icing verification modules were added to the RTVS operations, and researchers participated in the development of the conceptual design for the reengineered RTVS.

> ***MILESTONE GSD03.2:***
> Investigate and develop new verification techniques for evaluating the accuracy of convective echo tops, high resolution automated convective probabilistic forecasts, and ceiling and visibility forecast lead times.

ACCOMPLISHMENTS FOR GSD03.2:
A Terminal Aerodrome Forecast (TAF) lead-time metric and a prototype web interface for access to the TAF lead-time metric statistics and diagnostic analysis capabilities were developed. These capabilities were demonstrated to NWS HQ staff.

The capability to evaluate convective echo top forecasts was added to the RTVS. Statistics are being used this season to evaluate forecast accuracy.

An "audit trail" verification capability was developed within RTVS to track the forecast quality of operationally significant convective weather forecasts.

A user-based verification technique for evaluating convective forecasts was developed. This technique incorporates strategic decision points, operational flight sectors, and high-impact weather events.

> ***MILESTONE GSD03.3:***
> Summarize results from statistical evaluations of turbulence and convective weather forecasts in written reports.

ACCOMPLISHMENTS FOR GSD03.3:
The statistical generation, analysis of results, and writing of the following reports were developed:

- Forecast Icing Product (FIP) Calibration study
- Graphical Turbulence Guidance version 2 supplemental report
- Monthly summary report for the Collaborative Convective Forecast Product.

Analysis of results for the National Ceiling and Visibility Analysis product was also completed.

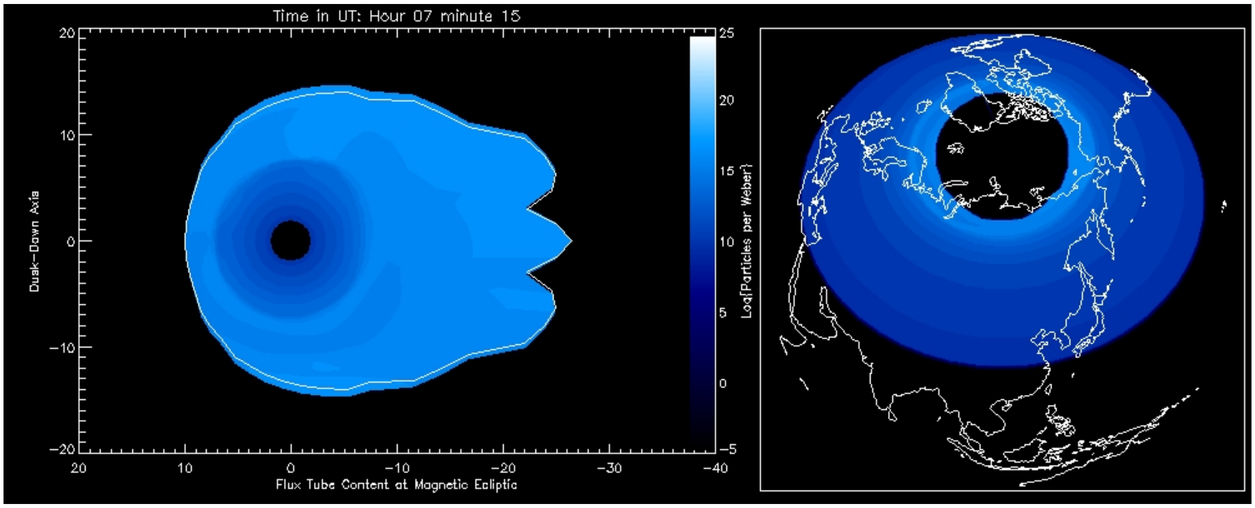
NGDC03: Space Weather

GOAL:
Assess the current state of the space environment from the surface of the sun to the upper atmosphere; use data-driven physical models to construct a realistic and authoritative gridded database of the space environment; and place that description into its long-term climatological perspective.

MILESTONE NGDC03.1:
Develop space weather climatological products using the Space Weather Analysis database.

ACCOMPLISHMENTS FOR NGDC03.1:
CIRES personnel working with scientists from within the NGDC space environment have completed and delivered a fifteen-year, near-Earth, space climatology to the Air and Space Natural Environment Program Office at the USAF Combat Climatology Center (AFCCC) in Ashville, NC. The objective of the Space Weather Analysis (SWA) was to generate a long-term space weather representation using physically consistent data-driven space weather models. The SWA project has created a consistent and integrated historical record of the near-Earth environment by coupling observational data from space environment monitoring systems archived at NGDC with data-driven, physically based numerical models. The resulting product is an enhanced look at the space environment on consistent grids, time resolution, coordinate systems and containing key fields allowing a user to incorporate quickly and easily the impact of near-Earth space climate in environmentally sensitive models.

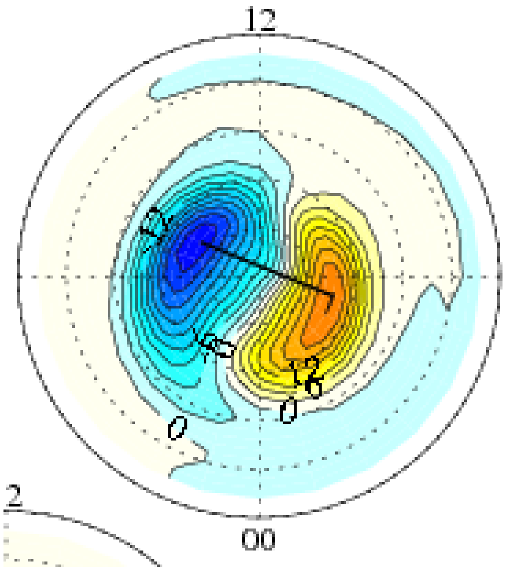
In order to generate this fifteen-year climatology, several well recognized models of the near-Earth space environment were computationally linked and run self-consistently. The Assimilative Model of Ionospheric Electrodynamics (AMIE) [Richmond et al., *J. Geophys. Res.*, 1988] was used to calculate ionospheric conductances, high-latitude electric fields and other ionospheric parameters of interest. Electric potential patterns created by AMIE were then used as drivers in a Simple Inner Magnetosphere Model (SIMM) [T. Garner, Thesis, Rice Univ, 2000] to describe the dynamic magnetosphere. Coupling and feedback between the ionosphere and the background thermosphere were provided by the Global Ionosphere-Thermosphere Model (GITM) [Ridley et al, *J. Geophys. Res.*, 2005]. These three models, each of which has a well-established legacy in space research, when self-consistently coupled provide realistic space weather climatology of interest to the operational and research communities. An example of the SWA output is provided in the figure below.



Prior to the SWA program, there were no long-term climate archives available for the space weather environment. Military planners use this SWA database to specify long-term climate changes that can potentially impact military operations. NOAA personnel, for their part, are using this multi-year space weather climatology database for scientific/research applications. SWA also provides the foundation for future space weather research by providing a means for scientists to assimilate model output in advanced modeling techniques.

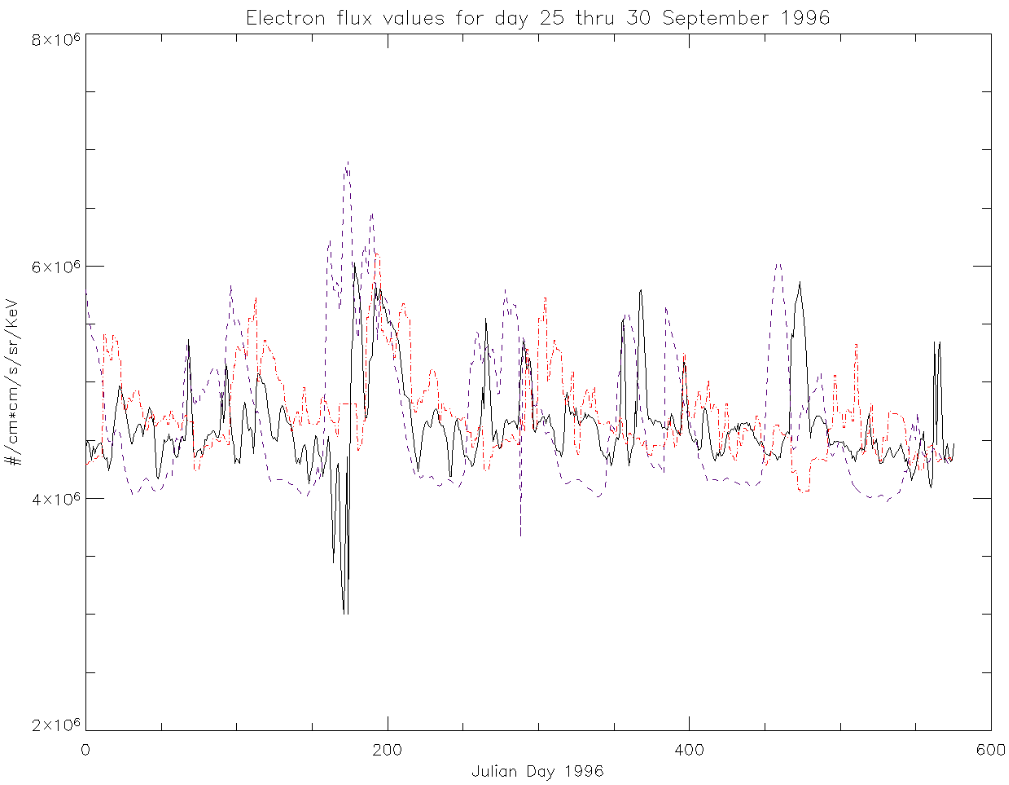
MILESTONE NGDC03.2:
Publish project results via web and integrate them with ongoing research projects.

ACCOMPLISHMENTS FOR NGDC03.2:
The SWA database has been made available through the web via the NOAA Space Physics Interactive Data Resource (SPIDR). The results of the SWA project have been presented at recent international meetings, including the Fall '06 AGU and the annual Space Weather Workshop. The model output is now available to the scientific community for use with ongoing research projects. A typical visual output of the database is a specification of the



high-latitude electric potential pattern, as shown in the figure at left. Comparisons to actual spacecraft measurements of electric fields and other parameters can be easily done for specific times within the data set history. A one-year comparison of the SIMM model to climatology and spacecraft measurement was recently completed, and the results of this comparison are now being prepared for publication.

The SWA products can be viewed through SPIDR at *http://www.spidr.ngdc.noaa.gov*.

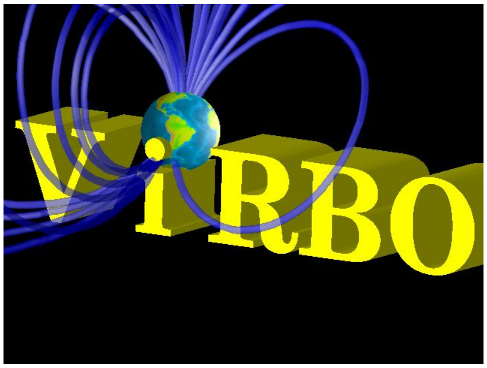


MILESTONE NGDC03.3:
Develop the Virtual Radiation Belt Observatory. Convert the real-time ionosonde network to a single architecture to better support operations.

ACCOMPLISHMENTS FOR NGDC03.3:
Several Virtual Observatories (VOs) have recently been formed to assemble and normalize disparate databases and to facilitate scientific research by providing standardized analysis tools. CIRES personnel within NGDC have contributed to the development of the Virtual Radiation Belt Observatory (ViRBO) as an interactive resource for researchers to access relevant data sets and model output. ViRBO also provides a mechanism for communication

and planning among researchers in the field of radiation belt modeling. Data made available through ViRBO is archived and managed by NGDC. Funding for ViRBO is provided by NASA and the tools under development within this VO are planned for implementation at other NASA virtual observatories.

We have converted the real-time ionosonde network to a single architecture known as MIRRION, the Mirrored Ionosonde database. MIRRION supports Space Weather Operations at the Space Environment Center (SEC) and at the Air Force Weather Agency (AFWA). MIRRION ingests data when it becomes available by the data provider and is quickly processed and made available to modeling operations. One example of an operational model supported by MIRRION is the Global Atmosphere Ionosphere Model (GAIM), which is run at the SEC in Boulder.



VIRBO can be viewed through the VIRBO website at *http://virbo.org/*

SEC01: Solar Disturbances in the Geospace Environment

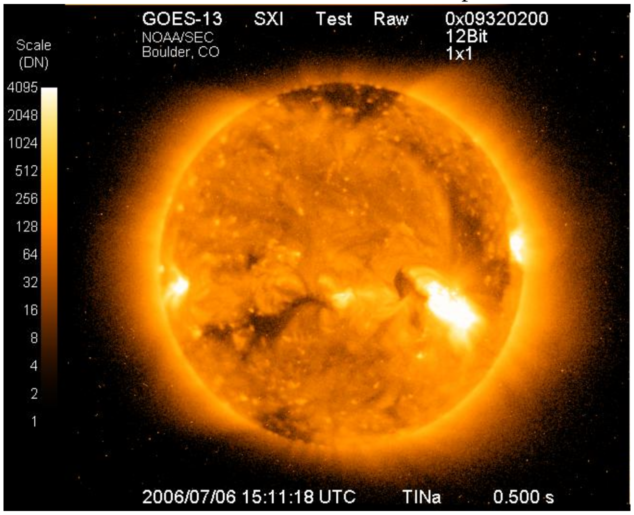
GOAL:

Improve the prediction of traveling solar disturbances that impact the geospace environment. Such disturbances, which are associated with both coronal holes and coronal mass ejections (CMEs) from the Sun, can cause substantial geomagnetic effects leading to the crippling of satellites, disruption of radio communications, and damage to electric power grids.

> ***MILESTONE SEC01.1:***
> Calibrate GOES X-ray Instrument: Use selected solar observations and 2005 rocket underflight data.

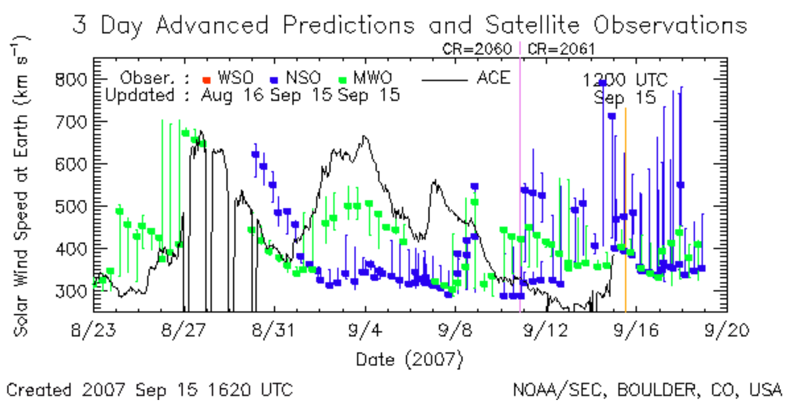
ACCOMPLISHMENTS FOR SEC01.1:

The Solar X-ray Imager (SXI) and disk-integrated X-ray Sensor (XRS) instruments currently flying are undergoing a sounding rocket “underflight” calibration with the Avalanche X-ray Spectrometer (AXS), which made solar observations simultaneously with the GOES instruments. An example SXI image is shown below. The AXS measurements provide the reference or “solar truth” that will be compared to the response functions of the GOES instruments. CIRES scientists have developed a forward model that takes the AXS spectrum and accounts for each element of the SXI instrument, including the pre-filter, mirror, and analysis filter. The results from this forward model have been compared to the observed SXI total intensity, and a similar forward model comparison has been done for the XRS instrument. The results match the XRS measurements well but show a discrepancy for SXI and they are currently working to resolve this discrepancy. Once that is complete, noise, contaminating signals, and secondary effects like vignetting will be investigated. Along with this effort, researchers will parameterize instrument models and adjust those parameters to obtain the best fit to the observations. Applying these models will improve knowledge of SXI and XRS instrument response and the improved measurements will be beneficial to space weather forecasting.



MILESTONE SEC01.2:
Global Solar Wind Predictions: Improve the SEC predictions system based on the Wang-Sheeley-Arge source-surface model, as coupled into a 3-D MHD propagation model, through advanced post-processing of input data.

ACCOMPLISHMENTS FOR SEC01.2:
The following accomplishments were achieved: (1) improved line-saturation correction for Mount Wilson Observatory magnetograms (2) a generic automated version of the Wang-Sheeley-Arge (WSA) model for distribution (3) a method to create synoptic maps from Mount Wilson Observatory magnetograms, and (4) automated verification program to check output of WSA code when distributed to other systems. The Mount Wilson and Wilcox Solar Observatories are now able to be run with the WSA model, which is now working at the Community Coordinated Modeling Center (CCMC) at NASA/GSFC. The improved WSA model was provided to the Center for Integrated Space Weather Modeling (CISM) at Boston University for validation studies. Finally, the daily running of coupled WSA-ENLIL model at NOAA/SEC was automated.



Predicted solar wind velocity at Earth.

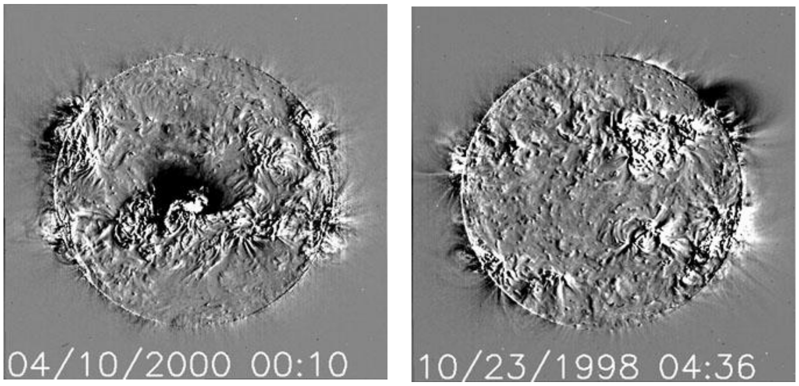
MILESTONE SEC01.3:
Coronal Mass Ejection (CME) Locator: Develop and implement a fully operational version of the CME Locator based on white-light corona observations from the NASA STEREO mission.

ACCOMPLISHMENTS FOR SEC01.3:
The aim of this project is to develop, test, and implement methods and forecast tools for the analysis of data from the NASA/STEREO spacecraft mission, which was launched on Oct 26, 2006. The primary tool is a geometric localization technique developed by Pizzo and Biesecker [2004] for determining in near-real-time the position, shape, and speed of coronal mass ejections (CMEs) using STEREO coronagraph observations. CIRES researchers have tested the ability of the geometric localization technique to estimate the speed, acceleration, and direction of propagation of simulated CMEs. Thus far, the results are very encouraging.

MILESTONE SEC01.4:
EIT (Extreme ultraviolet Imaging Telescope) waves and dimmings: Compare EUV dimming properties (intensity, solar location, and mass) with associated CME properties.

ACCOMPLISHMENTS FOR SEC01.4:
Coronal dimmings are a phenomenon frequently associated with CMEs (coronal mass ejections). Below are shown two examples of dimming events, the left one in the center of the solar disk and the right one on the solar limb. Dimmings can vary in size, shape and intensity, with observations suggesting a relationship between the mass loss from the dimming region and the mass contained within the CME. Researchers are conducting a statistical analysis of CME-associated dimming regions observed with the EIT (Extreme ultraviolet Imaging Telescope) on board the SOHO (Solar and Heliospheric Observatory) spacecraft. In this analysis, researchers first determine the relative dimming of each event compared to a pre-event image and then determine the area and intensity of each dimming. This has been done for more than 100 events and the statistics now exist to determine some general characteristics of

dimming events. For example, it was discovered that the average duration of a dimming event is 7.4 ± 4.0 hours. This duration can be divided into a depletion time of two to three hours and a recovery time of four to five hours. These results have been included in a paper that was submitted to the *Astrophysical Journal*. This analysis is now being extended to CME-related characteristics. The results from this study continue to provide insight into CME origins and may help improve predictions of CME-related parameters.



Two examples of dimming events, the left one in the center of the solar disk and the right one on the solar limb.

SEC02: Modeling the Upper Atmosphere

GOAL:

Understand responses of the upper atmosphere to solar, magnetospheric, and lower atmosphere forcing, and the coupling between the neighboring regions. Since many of the space weather effects occur in the ionosphere and neutral upper atmosphere, it is important to develop an understanding of the system to the point where accurate specification and forecasts can be achieved.

> ***MILESTONE SEC02.1:***
> Include the upper atmosphere physical processes into the Integrated Dynamics through Earth's Atmosphere (IDEA) model, and establish the structure to integrate the ionosphere-plasmasphere-electrodynamics (IPE) module.

ACCOMPLISHMENTS FOR SEC02.1:

The coupled general circulation model (GCM) of Integrated Dynamics through Earth's Atmosphere (IDEA) consists of two interacting models (Figure 1): the Whole Atmosphere Model (WAM) and the Global Ionosphere-Plasmasphere (GIP) model. The Whole Atmosphere Model is a GCM for the neutral atmosphere built on an existing operational Global Forecast System (GFS) model used by the U.S. National Weather Service (NWS) for medium-range weather prediction.

To create WAM, the spectral dynamical core of the GFS code has been extended to 150 layers with the top pressure level near a nominal altitude of about 600 km and the layer thickness approaching a quarter scale height in the stratosphere and above. The experimental version of the model is typically run at a relatively moderate spectral resolution T62 (roughly 1.8×1.8 degrees in latitude-longitude), but the horizontal resolution and vertical spacing may be easily changed if necessary.

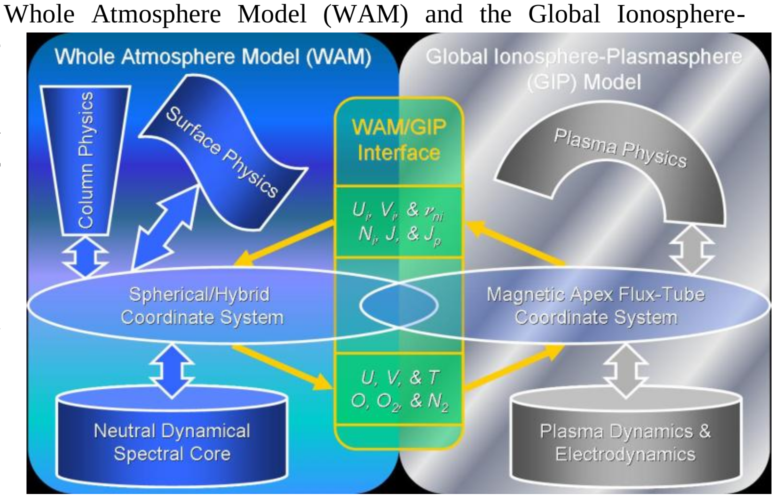


***Figure 1**. A schematic of the coupled general circulation model of Integrated Dynamics through Earth's Atmosphere.*

The vertical extension of the model domain has required the incorporation of additional physical processes and substantial changes in the dynamical core and in its interface with the model physics. As is well known in upper-atmospheric modeling, temporal and spatial variations of specific heat along air parcel trajectories have to be explicitly accounted for in the energy equation to represent correctly the effects of a highly variable thermospheric composition. These variations are commonly not accounted for in lower-atmospheric GCMs, and instead rely on the approximation of “virtual temperature” and assume that the composition deviations from the uniform “dry air,” primarily caused by the presence of water vapor, are small. A new spectral model formulation has been developed and implemented in the GFS, using specific enthalpy cpT, where cp is specific heat at constant pressure and T is temperature, as a prognostic variable instead of the traditional virtual temperature.

Molecular dissipative processes such as viscosity, heat conduction, and diffusion become so fast in the upper thermosphere that they can no longer be treated within the standard vertical-column interface. Horizontal molecular transport of momentum, heat, and constituents along pressure surfaces have been incorporated into the model as well. This physical dissipation eliminates the need for excessive numerical damping commonly used to stabilize numerical models in vertically extended domains. Additional physical processes incorporated in the extended model domain include UV and EUV radiative heating, infrared radiative cooling with the breakdown of local thermodynamic equilibrium, and non-orographic gravity waves. In the normal fully-coupled configuration ion drag, Joule and particle heating are calculated self-consistently within GIP. In a stand-alone WAM, these processes can be parameterized using an empirical ionosphere model.

Global Ionosphere Plasmasphere (GIP) model and electrodynamics. The plasma processes required in IDEA are provided by the Global Ionosphere Plasmasphere (GIP) module, which includes a self-consistent global electrodynamic solver. GIP was developed by extracting the plasma processes embedded in the Coupled Thermosphere Ionosphere Plasmasphere electrodynamics (CTIPe) model. In earlier versions of CTIPe, the Earth’s magnetic field was assumed to be a tilted dipole. In reality, however, the low-latitude geomagnetic field departs from the dipole equator by more than ten degrees over the Atlantic Ocean and Africa. Furthermore, ionospheric dynamo electric fields depend on the strength of the magnetic field, since the wind-driven currents depend on the field-line integration of the ionospheric conductivity and neutral wind.

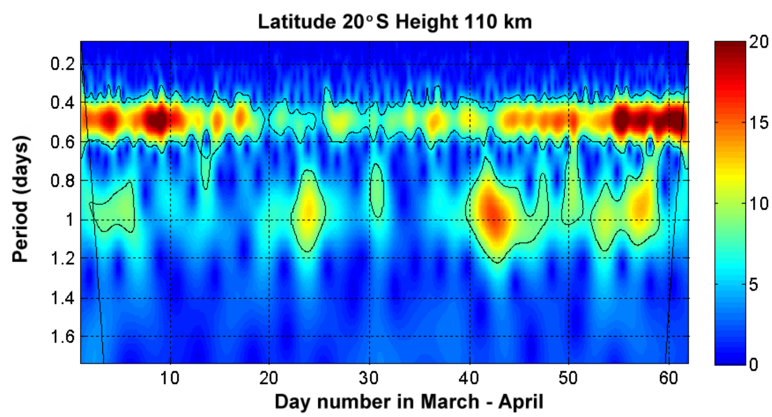


Figure 2. *Wavelet amplitude spectrum of zonal wavenumber 2 oscillation in the WAM zonal wind at 20°S and 110 km altitude as a function of period and day number in March and April.*

GIP now explicitly includes the International Geomagnetic Reference Field (IGRF), an accurate representation of the Earth’s magnetic field, in order to introduce true longitude dependence. The global ionospheric dynamics and energetics are solved in the magnetic APEX coordinate system. GIP receives the neutral atmosphere fields from WAM, computes the Joule heating, ion-drag, and auroral particle heating and passes these parameters back to WAM. The neutral and plasma domains are completely self-consistent and interactive.

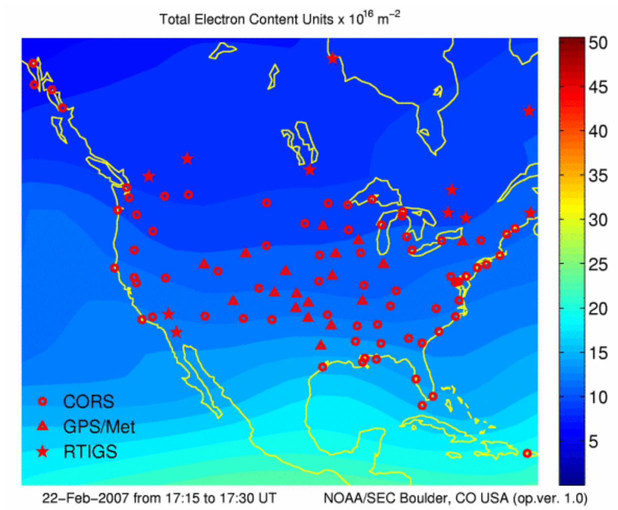
Self-consistent coupling between the WAM and GIP is completed by solving the global electrodynamics and by feeding the electric fields back into GIP. The electric fields are computed using a global potential solver in the same APEX coordinate system. The electrodynamics module receives the dynamics from WAM and the field-aligned conductivities from GIP, computes the electric fields, and provides the information back to both modules. The resultant ionospheric dynamo electric fields reflect the forcing from the lower atmosphere and realistic ionospheric structure through the use of the IGRF.

Early results from WAM provide the first confirmation that the model is capable of realistically reproducing the dynamics and variability in the upper atmosphere, and that terrestrial weather features can affect the thermosphere-ionosphere system. The characteristic periodicities of planetary normal modes of about two, five, eleven and sixteen days seen in the ionospheric observations are clearly present in the WAM middle and upper atmosphere.

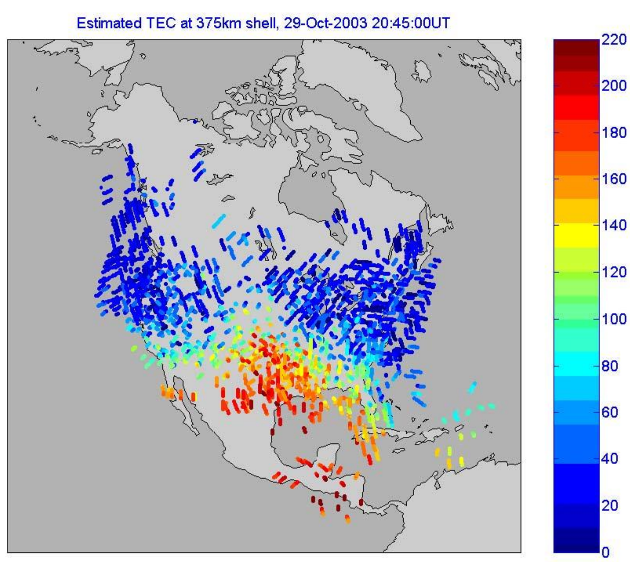
MILESTONE SEC02.2:
Expand the input data network for the US-TEC data assimilation scheme to include Canadian stations.

ACCOMPLISHMENTS FOR SEC02.2:

The Space Environment Center (SEC) and CIRES recently transitioned to a new regional data assimilation product designed to specify the vertical and slant total electron content (TEC) over the contiguous United States (CONUS) in real-time (see Figure 1, right). The model is based on a Kalman filter and ingests ground-based, dual frequency, GPS receiver measurements from various networks. The product was developed in collaboration between the National Geodetic Survey (NGS), the National Geophysical Data Center (NGDC), and the Global Systems Division (GSD) within ESRL.



Earlier versions of the product relied solely on the stations that were available in real-time from the network of ground-based, dual-frequency, GPS receivers operated by the U.S. Coast Guard for the National Differential GPS Service (NDGPS). The NDGPS system has twin GPS receivers currently operating at approximately 80 stations across the CONUS, which are streamed into SEC via NGDC. These data are also part of the Continuously Operating Reference Station (CORS) network, which comprise approximately 1000 stations that are used by NGS for geodetic application. To improve the accuracy of the U.S.-TEC product, two new real-time networks have been added to the data stream. The first is the GPS receiver network operated by GSD, for the GPS-MET project, which is designed to characterize water vapor over the CONUS in real-time. These same GPS stations can also be used for space weather applications and serve to fill areas of sparse data coverage in the NDGPS Coast Guard network. A third GPS network has also been added to the U.S.-TEC ingest data stream from the International GNSS Service (IGS). The IGS stations include stations in Canada, which improves the accuracy of the product towards the northern boarders of the CONUS.



An illustration of the data coverage available within a given 15-minute interval from the three networks is shown in Figure 2 (left). The points are color-coded, indicating the line-of-sight TEC value along each raypath, between every CORS, GPS-Met, or IGS station and all the GPS satellites in view at the time. The values are determined by the calibrated phase differences. The key to the color values is shown in the color bar in TEC units (1 TEC unit=1016 electrons m^{-2}). The plot displays the intersection points where the set of raypaths intersect a hypothetical shell located at an altitude of 375 km. All of the signal path intersection points within a 15-minute interval are shown. Signal paths for stations in coastal Alaska and Central America, as well as the continental United States, can be seen. This plot covers a time interval during the peak of the geomagnetic storm of October 29, 2003. The anomalously high TEC values due to the storm are visible over Central American, the southern regions of the U.S., and adjacent areas.

With the inclusion of the additional data sources, the estimates of accuracy of the vertical TEC over the CONUS is now estimated to be 1.7 TEC units. The product can be used to improve single-frequency GPS positioning, and provide information for more rapid integer ambiguity resolution for dual-frequency decimeter- and centimeter-accuracy positioning. Real-time maps can be found at *http://www.sec.noaa.gov/ustec*.

AMOS-04: Observing Facilities, Campaigns and Networks

GMD01: Central Ultraviolet Calibration Facility

GOAL:
Provide a central facility for the calibration and characterization of solar ultraviolet broadband and spectral measurement systems to improve the long-term stability and comparison of measurements across national and international networks.

> ***MILESTONE GMD01.1:***
> Analyze and publish a ten-year study of the stability of the CUCF's reference UVB broadband radiometers and 50+ network UVB radiometers. This includes analysis of multi-year spectral response and cosine response measurements.

ACCOMPLISHMENTS FOR GMD01.1:
A more extensive study of the erythema and instrumental calibration factors was performed this year. This study was part of a larger project with colleagues from Colorado State University (J. Hicke and J. Slusser) to analyze the long-term behavior of the broadband radiometers of the USDA UV monitoring network as a function of site and season. Last years' study of the "absolute" response revealed that, on average, the radiometers have changed by approximately 1.8% from 1997 to 2005. Note that "absolute" response is a misnomer and represents a signal using NIST traceable lamps where the spectral response of the radiometer is not taken into account. Erythema calibration factors for the CUCF YES reference triad at Table Mountain Test Facility (TMTF) were calculated from 1999-2005. There were approximately 100 full- or half-clear days per year. Because of down time or quality issues of either the U111 spectroradiometer or the broadband reference radiometers, there were approximately 35 calibration days per year. The erythema calibration factors at a solar zenith angle for 40 and 300 DU were plotted for 1999 to 2005, and a linear regression was applied. The linear regression showed no statistically significant slope. The erythema calibration factor at a solar zenith angle of 64 was plotted from 1999 to 2005 and showed no statistically significant slope. A solar zenith angle of 64 was chosen because the direct measurements could be used with no modeled ozone correction because the erythema calibration factor's dependence on total ozone is minimized at this angle. Uncertainties have not been defined for calibration of broadband radiometers. It was determined that a minimum uncertainty in solar irradiance from a precision spectroradiometer is approximately ±5% for two standard deviations (G. Bernhard et al. [2002]). This number for the U111 spectroradiometer is optimistic, e.g., dirty diffusers over the years have given 0-5% errors. Transferring the calibration from the U111 to the reference triad adds additional uncertainty. A minimum uncertainty for the calibration of the triad is estimated to be ±10%. An oral paper was presented at the SPIE Conference for Remote Sensing of Clouds in the Atmosphere, in Stockholm, Sweden.

> ***MILESTONE GMD01.2:***
> Publish a paper on a suite of filter radiometers involved in the June 2003 Spectroradiometer Intercomparison at Table Mountain, Colorado.

ACCOMPLISHMENTS FOR GMD01.2:
The CUCF conducts UV spectroradiometer intercomparison campaigns on an as-needed basis depending on UV instrumentation improvements and new instrumentation designs to validate the changes and compare between existing instrumentation. Ten UV spectroradometers participated in the Fifth UV Spectroradiometer Inter-comparison at the Table Mountain Test Facility (TMTF), 8 km north of Boulder. Five of the participating instruments were scanning spectroradimeters; one was a spectrograph measuring all wavelengths simultaneously, and four were filter radiometers. The scanning spectroradiometers and spectrograph had nominal bandpasses of 0.1 to 0.8 nm; therefore, to compare the data among these instruments, a routine from rivmSHIC was used to standardize the solar irradiance measurements. The rivmSHIC routine de-convolves the spectral solar irradiance using high-resolution extraterrestrial flux and re-convolves the spectral solar irradiance to a common 1-nm

triangular slit function. This method was compared to previous years that used a simple method of convolving with a common slit function. In addition, this year the reference spectrum was determined from a routine from Gardiner et al. [1997]. Although the routine is arduous, it has the advantage of providing an unbiased standard procedure for determining the reference spectrum. A draft of the spectroradiometer paper has been prepared. A comparison of the solar irradiance from the filter radiometers is presented in a second forthcoming paper.

> ***MILESTONE GMD01.3:***
> Update UV-MFRSR calibration data files from 1997 to 2005 for CUCF horizontal scale corrections, NIST vertical scale corrections, and out-of-band corrections.

ACCOMPLISHMENTS FOR GMD01.3:

Previously, the CUCF determined that the UV-MFRSR channels 3-6 were in poor agreement with the U111 spectroradiometer. These channels changed from Gallium Phosphide (GaP) photodetectors to Silicon (Si) to accommodate the failure of the GaP photodetectors in the field. Work indicated that the problem was primarily that the Si photodetectors were allowing out-of-band light from the NIST traceable halogen-tungsten lamps to contribute to the calibration signal, which resulted in an inaccurate calibration.

Studies showed that the contribution of out-of-band light to the signal depended on several factors. First, it depended on the channel, with the 317-nm channel typically being the most affected, i.e., average of 22.1%. Secondly, it depended on the instrument, where each instrument was different but grouped in about four different patterns, i.e., for the 317-nm channel the out-of-band light ranged from 37.7% to 6.6%. Lastly, the signal depended on the lamp that was used and likely due to the different color temperatures of the lamps, i.e., approximately 0-5% difference between lamps at 317-nm.

All 47 UV-MFRSR radiometers were characterized for out-of-band light. The last two radiometers came through the CUCF in December 2006. There were 193 UV-MFRSR calibration files corrected for out-of-band light since 2001. The UV-MFRSR calibration files were also corrected for the 1-2% NIST adjustment to the lamp irradiance scale and the 4-5% adjustment to the CUCF irradiance scale last year. In November 2006, 300+ corrected calibration files were sent to the USDA to replace the old files in their system. The USDA UV monitoring programs have updated the UV solar irradiance from their instruments, using the corrected calibration files. The corrected data are now available on their website including a web page to describe the corrections to the calibration files.

GMD02: Surface Radiation Network

GOAL:

Collect long-term research-quality up-welling and down-welling broadband solar and infrared radiation data at seven U.S. sites. Collect long-term, broadband ultraviolet radiation data to evaluate variations in the erythemal doses. Collect long-term, spectral filter data to measure column aerosol optical depth and cloud optical depth. Collect cloud cover data to assess the effect of clouds on the surface radiation budget.

> ***MILESTONE GMD02.1:***
> Analyze 10-year plus aerosol optical depth record of SURFRAD sites and publish the results.

ACCOMPLISHMENTS FOR GMD02.1:

Results from a recent decadal study of aerosol optical depth (AOD) over the U.S. reveal a general nationwide decrease, but also geographic differences. These new data from NOAA’s SURFRAD surface radiation budget network show high AOD in summer and low AOD in winter. The western stations have the lowest AOD and the eastern stations have the highest. Western stations also show a secondary springtime maximum caused by Asian dust. The abundance of aerosols in the east and their relatively small size is attributed to organic emissions, high humidity, and the predisposition for stagnant air in summer. These characteristics agree with previously published results, however, national and station decadal AOD tendencies show interesting features that may have climate change implications.

Nationally, 500nm AOD decreased from 1997 through 2006 by about 0.02, which is similar to recent results reported for the oceans. However, not all U.S. stations share this tendency. Results show that aerosols are decreasing in the eastern U.S. However, in the west a decrease is only observed at Desert Rock, NV and Fort Peck, MT. A very slight increase over the past decade occurred in Boulder, CO, which is likely caused by an upsurge in wildfires from 2000 through 2006. When the four years with the most abundant wildfires are removed, decadal tendencies at Boulder and Fort Peck are steady. If climate change is causing drier conditions in the western U.S., then higher than normal numbers of forest fires are likely to occur, and the observed AOD increase should be considered part of the background. In that case, the additional blockage of sunlight by direct and indirect effects of the fire-induced aerosols would act to offset the warming attributed to increasing greenhouse gases. If the increasing trend in western wildfires does not continue, then the recent AOD increase in the intermountain western U.S. can be considered temporary, and western AOD should be expected to remain steady, as suggested by the observed tendencies of the low-fire years. The only way to answer these and other questions related to aerosols and climate is to continue to build AOD times series into future decades so that tendencies can be determined with more certainty.

> ***MILESTONE GMD02.2:***
> Analyze the 10-year plus SURFRAD data record of irradiance for trends in the context of the current global dimming/brightening issue and publish results.

ACCOMPLISHMENTS FOR GMD02.2:

Preparatory to the analysis of the SURFRAD data for long-term changes in irradiance, an analysis of a SURFRAD-like data set from the Oklahoma/Kansas ARM site was performed. Looking at the trends in the annual-averaged data between 1993 and 2003, there were no statistically significant trends in the data. There were upward tendencies in total horizontal irradiance, direct beam irradiance, and even in the diffuse irradiance, however, the statistical uncertainty was much too large to claim a trend. The seven SURFRAD sites will be examined for the total record length to determine whether taken together theses sites corroborate what is now just a tendency at one site. Separation of the data into seasons indicated that summer showed the largest upward tendency with the other seasons flat. Again, this is not statistically significant.

Scientific Theme: CLIMATE SYSTEM VARIABILITY

CSV-01:	**Detection of Climate Modes, Trends and Variability**	
	GMD03:	Climate Trend Analysis
	PSD04:	Decadal Climate and Global Change Research
	NGDC04:	Paleoclimatology—Understanding Decadal- to Millennial-Scale Climate Variability
CSV-02:	**Mechanism and Forcings of Climate Variability**	
	CSD03:	Chemistry, Radiative Forcing, and Climate
	PSD01:	Modeling of Seasonal to Interannual Variability
	PSD02:	Understanding and Predicting Subseasonal Variations and their Implications for Longer-Term Climate Variability
	GMD04:	Climate Forcing
CSV-03:	**Stratospheric Ozone Depletion**	
	CSD04:	Tropospheric and Stratospheric Transport and Chemical Transformation
	GMD05:	Ozone Depletion
CSV-04:	**Climate Dynamics**	
	CSD06:	Turbulent Meteorological Motions
	PSD03:	Empirical and Process Studies
	PSD06:	Climate Dynamics
	PSD15:	Surface Processes
CSV-05:	**Climate Research Database Development**	
	NSIDC01:	Digitizing Analog Cryospheric Data under the Climate Database Modernization Program
	NSIDC02:	Observations for SEARCH–Data Integration for Arctic Reanalysis and Change Detection
	NSIDC03:	World Data Center for Glaciology, Boulder–Current Programs
CSV-06:	**Regional Climate Systems**	
	PSD10:	Cloud and Aerosol Processes
CSV-07:	**Climate Services**	
	PSD05:	Experimental Regional Climate Services
	PSD07:	Experimental Climate Data and Web Services

CSV-01: Detection of Climate Modes, Trends and Variability

GMD03: Climate Trend Analysis

GOAL:

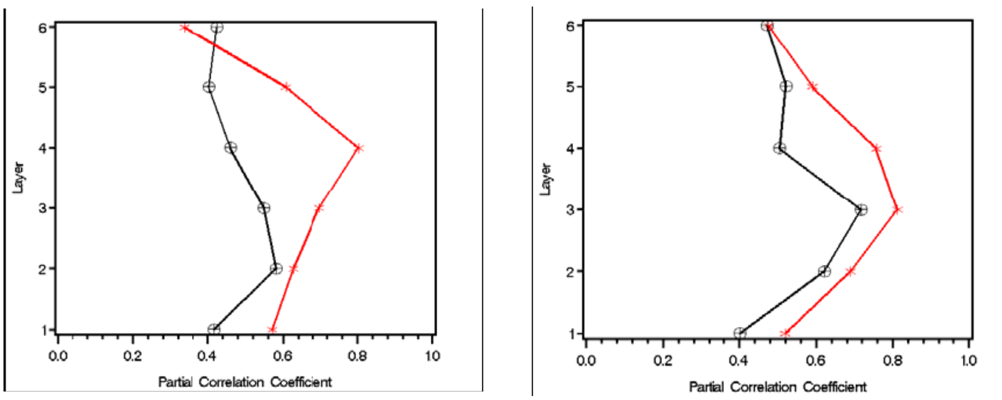
Interpret operational data (ozone column, ozone profile, aerosol extinction, broadband spectral radiation, and other environmental parameters) collected by NOAA ground-based and NCAR aircraft-based instruments. Assess data for long-term quality. Evaluate stability and inter-annual variability in the ground-based and aircraft-based data sets. Provide scientific community with information relevant to climate research and evaluate usefulness of data for validation of other independent measurements, including satellite observations.

MILESTONE GMD03.1:

Assess newly updated ozone-profile database for trends and changes in trends and validate it against ozone products derived from remote and *in situ* measuring systems such as satellites and ozone-sounding.

ACCOMPLISHMENTS FOR GMD03.1:

This work evaluated the quality of tropospheric ozone information derived from the ground-based Dobson and Brewer measurements. A newly developed Umkehr ozone-profile retrieval algorithm allowed separation of the tropospheric ozone measurement into two or three layers. The Umkehr-retrieved tropospheric ozone data were validated through comparisons with co-incident ozonesonde measurements of high vertical resolution. The analysis concentrated on the short-term and long-term tropospheric ozone variability detected by co-incident and co-located Dobson and Brewer data, along with ozone profiles from ozonesondes available from Boulder, CO, and Hilo, HI. Analyses suggest that the Dobson Umkehr technique is capable of monitoring short-term variability in tropospheric ozone. It can explain about 50% of the variability measured by ozonesondes. It was found that the one-day co-incident data have higher correlation coefficients than the two-day window for Boulder, but not for Mauna Loa. In addition, correlation coefficients calculated for co-incident Umkehr and ozonesonde data were found to be relatively large (40-60%) and statistically significant in the troposphere, although the highest correlation (70%) was found in the lower stratosphere. Ozonesonde data smoothed with the corresponding Umkehr Averaging Kernel function showed larger correlation coefficients (up to 80%) as compared to comparisons using layer-integrated ozonesonde data. Based on correlation analysis, Dobson Umkehr data can capture tropospheric ozone variability. The Umkehr method is capable of measuring long-term changes in tropospheric ozone [Petropvalovskikh et al., AGU, 2006].



Correlation between co-incidental sonde and Dobson ozone measurements (in excess of a priori) as function of Umkehr layer (~5 km wide) for (right) MLO station record during 1985-2005, and (left) Boulder station records during 1985-2005 time period. Black lines represent results for layer-integrated ozonesonde data, red lines show results for Umkehr smoothed ozonesonde data.

MILESTONE GMD03.2:

Optimize and validate algorithm for ozone column retrievals from photo-actinic flux hyper-spectral measurements on board an aircraft under a variety of atmospheric conditions. Provide data to OMI/AURA satellite validation campaigns.

ACCOMPLISHMENTS FOR GMD03.2:

This research is in support of Aura satellite validation activities. The solar radiation measurement instrumentation was developed by the National Center for Atmospheric Research group (R. Shetter) and deployed on the NASA WB-57 and DC-8 aircraft platforms in several Aura Validation Experiment (AVE) campaigns. These instruments are CCD-based Actinic Flux Spectroradiometers (CAFS) to determine the down- and up-welling UV and visible actinic flux as a function of wavelength. The Ozone Monitoring Instrument (OMI) total ozone columns and Microwave Limb Sounder (MLS) integrated ozone profiles were validated in the tropical region. The CR-AVE campaign base in Costa Rica took place in January and February of 2006. The CAFS observations were taken aboard the NASA WB-57 flights co-incident with the OMI ozone observation (~10,900 data points). The average difference between OMI DOAS (Differential Optical Absorption Spectroscopy) and CAFS total ozone column estimates was -5.4 DU with a standard deviation of 5.2 DU. The average difference between OMI TOMS (Total Ozone Mapping Spectrometer) and CAFS total ozone column estimates was -4.2 DU with a standard deviation of 4.1. Comparisons of the OMI and the CAFS total ozone residuals suggest dependence on the total ozone column in both versions of the OMI retrieved data. These differences are well within the validation requirements of ±2% for the OMI total ozone column data product. Analysis of CR-AVE comparisons found no significant differences between the MLS and CAFS integrated ozone columns at flight altitudes between 17 and 20 km (or above the 100-mb pressure level). The standard deviation for the matched data was 1.5%. At flight altitudes between 15 and 17 km (or 146- and 100-mb atmospheric pressure, respectively) the average bias was less than 1% with less than 1% standard deviation. The analysis of the matched data at altitudes below 15 km (or below 146-mb pressure level) indicated less than 1% bias between the MLS and CAFS ozone columns. The analysis of the data over the entire range of altitude between 13 and 19 km shows that the agreement between the two systems is within 3% (two standard deviation level). The above results help to assure the quality of the tropospheric ozone column derived as a difference between the OMI total ozone column and the MLS integrated stratospheric ozone column.

PSD04 Decadal Climate and Global Change Research

GOAL:

(i) Improve understanding of long-term climate variations through analysis of observations and hierarchies of GCM experiments. (ii) Seek dynamical explanations of oceanic variability and changes through observational analyses and GCM experiments. (iii) Provide attribution for long-term regional climate changes.

> ***MILESTONE PSD04.1:***
> Diagnose impacts of ENSO-related and non-ENSO related tropical SST changes over the last 50 years.

ACCOMPLISHMENTS FOR PSD04.1:

CIRES researchers have applied a pattern-based filtering technique developed by Penland and Matrosova [*J. Clim.*, 2006] to partition the ENSO-related and ENSO-unrelated portions of tropical SST anomaly fields on a month-by-month basis throughout the 135-yr (1871-2005) historical climate record. They have also assessed the global impacts of the ENSO-related and ENSO-unrelated tropical SST trends over the last 50 years using the NCAR/CAM3 and the NCEP/GFS atmospheric general circulation models, with particular emphasis on the impacts on precipitation trends over the Americas, western Africa, and Europe. Both GCMs indicate substantial precipitation trend responses in these regions to the tropical SST trends that are generally in excellent mutual agreement and with the observed precipitation trends.

Both the ENSO-related and the ENSO-unrelated portions of the tropical SST trends are found to be important in this regard. Specifically, the ENSO-unrelated SST trends account for most of the precipitation trends in areas bordering the Atlantic Ocean, whereas the ENSO-related SST trends account for most of the North American precipitation trends. It is interesting that the observed moistening trend over the eastern U.S. has generally not been captured by coupled climate model simulations of the 20th century. If its attribution to the ENSO-related SST trends suggested by this study is correct, then the failure of the coupled models may be partly due to their general tendency to misrepresent ENSO variability, and therefore likely also the ENSO-related tropical SST trends and their global impacts.

> ***MILESTONE PSD04.2:***
> Assess possibility of abrupt climate change over North America in the next several decades triggered by continued warming of the Indian Ocean.

ACCOMPLISHMENTS FOR PSD04.2:

The tropical oceans have warmed significantly over the last half-century, especially in the already warm Indian and western Pacific basins. An extensive set of atmospheric GCM integrations were performed with a prescribed continuation of this warming trend. These runs suggest that the continued tropical ocean warming will gradually modify the atmospheric jet streams to the point where the ability of the jet streams to channel atmospheric disturbances along the upper tropospheric waveguide will undergo a relatively sudden shift sometime in the next century. This will cause relatively rapid shifts in the climates of North America and Europe.

> ***MILESTONE PSD04.3:***
> Assess impacts of coupled air-sea interactions, decadal ocean dynamics, land-surface feedbacks, and land-use changes on decadal atmospheric variability.

ACCOMPLISHMENTS FOR PSD04.3:

The coupled ocean-atmosphere response to Indian Ocean warmth was studied. It was shown with atmospheric models that Indian Ocean warmth forces a positive polarity phase of the North Atlantic Oscillation (NAO), confirming results of previous studies. Coupled model experiments showed that this NAO response forces a local air-sea feedback over the North Atlantic Ocean, which intensifies the NAO response. This enhancement is realized through a positive feedback between the NAO atmospheric circulation anomaly and a tripolar North Atlantic SST pattern, consistent with other studies on North Atlantic air-sea interactions. It was concluded that the North Atlantic and European climate response to Indian Ocean warming may be considerably greater than hitherto judged from analyses of atmospheric model experiments alone.

NGDC04: Paleoclimatology—Understanding Decadal- to Millennial-Scale Climate Variability

GOAL:

Improve our understanding of observed long-term climate variations through compilation and analysis of data from the pre-instrumental record and provide access to both data and information from the paleoclimatic record.

> ***MILESTONE NGDC04.1:***
> Create a fire-history portal on the FRAMES (Fire Research and Management System) website.

ACCOMPLISHMENTS FOR NGDC04.1:

The goal of the Fire Research and Management System (FRAMES) program, which is supported by the U.S. Forest Service and the U.S. Geological Survey's National Biological Information Infrastructure Program, in cooperation with the College of Natural Resources at the University of Idaho, is to facilitate the exchange of information and transfer of technology among wild-land fire researchers, land managers, and other stakeholders. To this end, they are hosting a web portal that is organized into several functional Subject Areas, and CIRES-NOAA personnel have taken over the role of content managers for the Fire-History Subject Area. Fire-history data are increasingly seen as critical information for contemporary management of public lands by providing opportunities for understanding the range of variability in fire frequency, severity, extent, and spatial complexity, as well as the role of fire in ecosystems and the feedbacks that link fire, climate, vegetation, and management decisions. Fire-history data provide managers with models of long-term ecosystem behavior with which to assess degree and nature of departure in current conditions, and direction and justification for ecological restoration efforts, fuels treatments, and other resource management projects. CIRES-NOAA personnel have created and maintained the portlets and web pages for the FRAMES Fire History Subject Area, and in particular have made data from the International Multiproxy Paleofire Database, which is an archive of fire history data derived from natural proxies that is housed at NOAA's Paleoclimatology Branch and maintained by CIRES-NOAA personnel, available via text- and geographical-based searches through the portal.

> ***MILESTONE NGDC04.2:***
> Implement protocols that provide paleoclimate metadata to remote crawlers and harvesters, including the PAGES and FRAMES portals.

ACCOMPLISHMENTS FOR NGDC04.2:

In an effort to improve data accessibility and ease of data browsing, the Paleoclimatology branch put the metadata from data sets into a database. Collections of metadata XML were then produced from the database and those XML files were then transformed into HTML web pages using XSLT code. An XSLT conversion was run on the XML metadata records to produce data index pages for each proxy type with Title, Principal Investigators and Location listed for each data set. The page has column headers that may be sorted for easier browsing. The XSLT also produced an HTML page for every study in the collection, which are linked from the index listing page. One major benefit of having individual web pages for each data set is that a web browser search engine text search on a data set title, PI or core name will now turn up those individual studies from the data collection that previously required visitors to be on the NOAA Paleoclimatology website to search for those sites. It opens up this data to the whole world of Google-style searching without users having to know the web address first. The data set description HTML pages also serve as the data description pages when users and partners such as FRAMES (Fire Research And Management Exchange System) and PAGES (Past Global Changes) use the OAI-PMH metadata search tool to find data sets.

MILESTONE NGDC04.3:
Implement harvesting and indexing of paleoclimate data to make data sets from remote servers and remote databases available from the NOAA Paleoclimatogy website.

ACCOMPLISHMENTS FOR NGDC04.3:
CIRES scientists implemented the Open Archive Initiative Protocol for Metadata Harvesting (OAI-PMH) in order to harvest paleoclimate metadata from other sources. They then harvested more than 54,000 metadata files from Pangaea/World Data Center for Marine Environmental Sciences, a major repository for marine sediment data. These metadata files are now indexed at the NOAA Paleoclimatology website as a special set, which allows visitors to the NOAA Paleoclimatology website to search for any combination of Pangaea and WDC-Paleoclimatology data by using the searching capabilities described in Milestone NGDC04.2. This implementation gives users a one-stop shop for paleoclimate data; rather than visiting multiple websites to search for paleoclimate data, users can visit the NOAA Paleoclimatology website and make one search for all data. Since only metadata are harvested, users are linked to the original provider's website to obtain the current updated copy of the data itself.

CIRES researchers have also contributed to the National Integrated Drought Information System (NIDIS), the U.S. portal for drought information. By integrating information from many websites and agencies, this portal will provide the public with another one-stop shop for accurate, timely and integrated information on drought conditions at the relevant spatial scale to facilitate proactive decisions aimed at minimizing the economic, social and ecosystem losses associated with drought. CIRES scientists led the selection process for the portal software for this project and evaluated different portal software, interviewed user groups and conducted surveys, and wrote a report to the NIDIS Program Manager. The recommended software, BEA AquaLogic, has been purchased and the portal will be live in late 2007.

CSV-02: Mechanism and Forcings of Climate Variability

CSD03: Chemistry, Radiative Forcing, and Climate

GOAL:
(i) Observe and model the radiative forcing due to stratospheric ozone changes and tropospheric radiatively active gases. (ii) Carry out upper-troposphere airborne experiments and diagnostic analyses that characterize the dynamical and chemical processes that influence the radiative balance in the global atmosphere. (iii) Quantify the chemical and optical properties that determine the lifetimes, abundances, and trends of greenhouse gases. (iv) Use passive cloud observations to develop techniques that can be used to estimate cloud properties.

MILESTONE CSD03.1:
Plan and execute the Gulf of Mexico Air Quality and Climate Change Study (GoMACCS) field study.

ACCOMPLISHMENTS FOR CSD03.1:
In 2006, NOAA/ESRL and CIRES led a major multi-institutional intensive field program that focused on investigating important scientific questions that are common to both climate and air quality. The NOAA/ESRL and CIRES components of the program are the Texas Air Quality Study (TexAQS) and the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). This intensive field study provided significant new information that is required to afford a better understanding of the sources, and atmospheric processes responsible for the formation and distribution, of ozone and aerosols in the atmosphere and the influence that these species have on the radiative forcing of climate regionally and globally, as well as their impact on human health and regional haze. The study was carried out between July 1 and October 15, 2006, throughout Texas and the northwestern Gulf of Mexico. Three NOAA platforms were deployed: a NOAA WP-3 aircraft, a NOAA Twin Otter, and the NOAA R/V *Ronald H. Brown*. All objectives of this portion of the study were met.

GoMACCS was the NOAA/ESRL and CIRES climate change component of this field program, and characterized marine/continental chemical and meteorological processes over Texas and the Gulf of Mexico in order to improve the simulation of the radiative forcing of climate change by lower-atmosphere ozone and aerosols. In addition to clear-sky radiative effects, GoMACCS investigated the influence of aerosols on cloud properties and the role of clouds in chemical transformation. The measurements addressed the following specific areas of research:

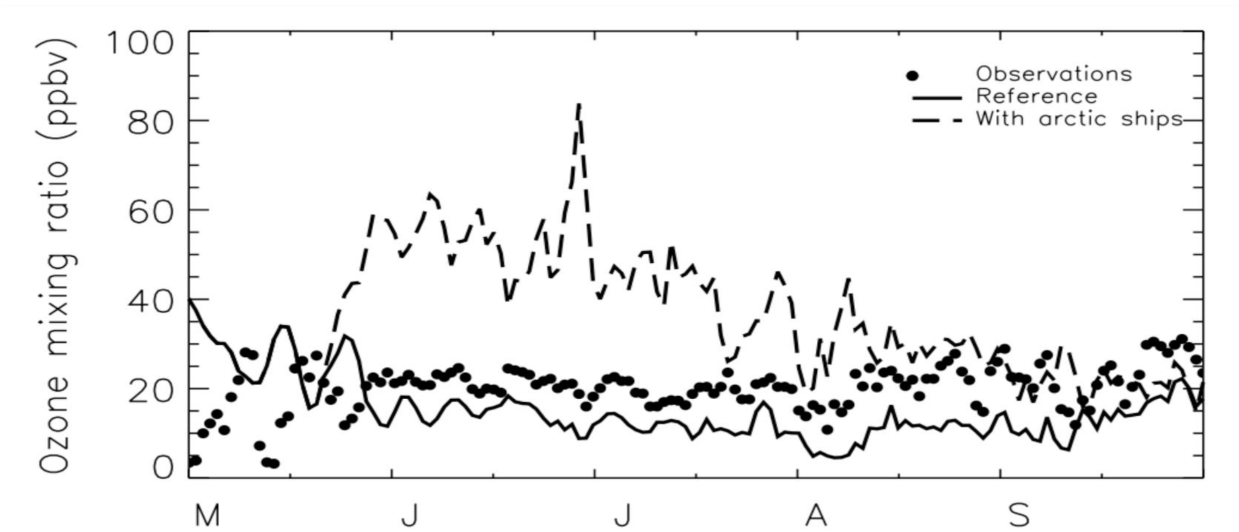
1) Emission of aerosols and greenhouse gases from large point sources (electric power generating units – EGUs);
2) Composition of the aerosol and gaseous (aerosol precursor) components in exhaust of commercial marine vessels;
3) Chemical processing of aerosols after emission from sources;
4) Variation of water uptake by aerosols (f(RH) effect) with chemical processing time;
5) Determination of mass-based emission factors of black carbon and sulfur dioxide from commercial shipping;
6) Influence of African dust transport on the aerosol environment of Texas and the Gulf of Mexico.

MILESTONE CSD03.2:
Use global chemistry/dynamics models to examine the effect of future ship traffic in the Arctic northern passages on Arctic pollution, particularly in regard to the role of black carbon.

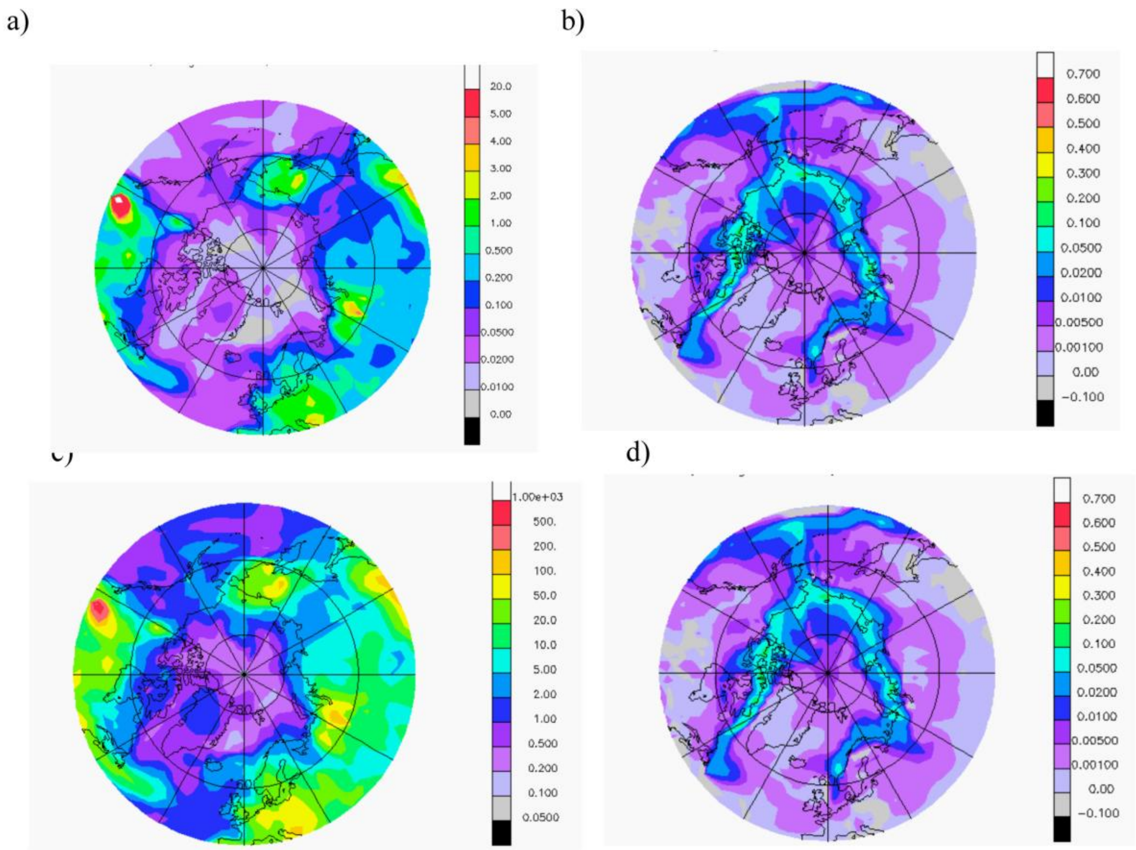
ACCOMPLISHMENTS FOR CSD03.2:
Sea ice is expected to recede substantially in the Arctic during the 21st century as a result of projected climate change. This could lead to considerable changes in global shipping patterns in the decades ahead. The opening of viable shipping routes through the northern passages will generate new environmental problems in the Arctic. The emissions of chemical compounds by ship engines are expected to enhance the atmospheric concentration of photo-oxidants in this region.

CIRES scientists have used a coupled ocean-atmosphere model and a global chemical-transport model of the atmosphere to quantify the potential changes in the surface ozone level in response to future ship traffic in the Arctic. They have calculated that, during the summer months, surface ozone concentrations in the Arctic could be enhanced by a factor two to three in the decades ahead as a consequence of ship operations. Projected ozone concentrations of 40-60 ppbv from July to September in some areas in the Arctic are comparable to summer time values currently observed at many locations of the industrialized regions in the Northern Hemisphere.

Particles such as black carbon are also emitted by ship engines. Simulations have been performed that show that these new emissions of black carbon could lead to significant increases in the amount of black carbon in the Arctic atmosphere, and in the deposition of black carbon on ice, as shown in the figures below. Over the next months, scientists will continue this study in order to evaluate the possible impact of the increase in the deposition of black carbon on ice and snow on the albedo in the Arctic areas.



Surface ozone observed at the station of Barrow (71.2 N; 156.4 W) in Alaska (dots) from May to September 1997. The background ozone mixing ratios calculated for current chemical emissions and for ECMWF meteorological fields during the same period are shown by the full line. Ozone mixing ratios derived when Arctic ships emissions are taken into account, are shown by the dashed line.

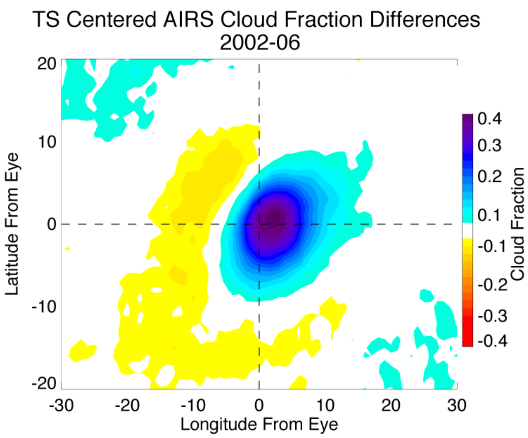


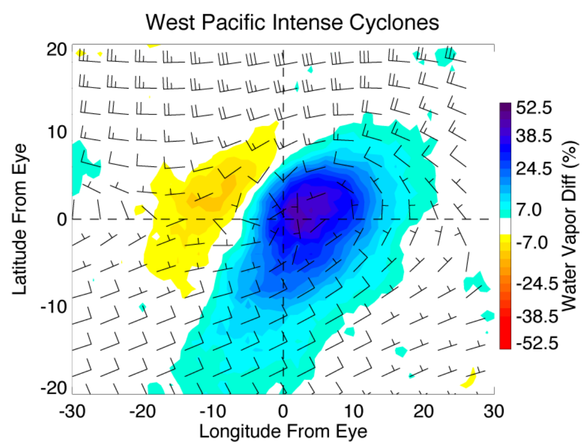
Distribution of surface black carbon in the Arctic (a) in ppbv when no ships are present in the Arctic, and increase (in ppbv) in black carbon concentration resulting from ships. Surface deposition of black carbon (in μg/m2/day) when no ships are considered, and increase in the surface deposition resulting from ships.

MILESTONE CSD03.3:
Understand the processes that maintain the observed fall-off in tropical methane profiles between 12 km and the tropopause. Understand how these processes affect the corresponding profiles of ozone and water.

ACCOMPLISHMENTS FOR CSD03.3:
The tropical upper troposphere and lower stratosphere is an important region for climate and global change. Deep convection and transport associated with intense tropical storms have a significant impact on the chemical composition of this region. Related to this topic researchers have done an analysis on AIRS and MLS satellite water vapor and cloud property data from 2002-06 in all the ocean regions around the world where tropical cyclones occur [Ray and Rosenlof, 2007]. They gathered tropical cyclone positions and intensities from the Joint Typhoon Warning Center and the Hurricane Research Center best-track data sets for the different ocean basins. For each year and ocean basin region, they compiled average water vapor and cloud properties in the upper troposphere during both intense (category 3 or larger) and "weak" (category 2 or lower) tropical cyclones.

The primary results from this analysis are that (1) tropical cyclones of all intensities are effective at hydrating and increasing the cloudiness of the upper troposphere and (2) tropical cyclones may be an important contributor to the global tropical water vapor budget of the upper troposphere. AIRS water vapor mixing ratios and NCEP wind fields at the 173 hPa pressure level averaged over all the intense tropical storms in the western Pacific are shown below (left figure). Some interesting features include the location of the peak region of elevated water vapor to the east of the eye of the storms and the region of elevated water vapor advected to the southwest by the upper level anticyclonic flow around the storms. Average differences from the monthly mean of AIRS cloud fraction for the western Pacific region during intense tropical cylones are shown below (right figure). Cloudiness increases near the cyclone and there is a compensating region of lower cloudiness on average to the west of the cyclones. Overall, the net cloudiness in the entire region around the cyclones increases by a few percent.





PSD01: Modeling of Seasonal to Interannual Variability

GOAL:
Understand how much predictability, especially outside the tropics, exists on seasonal-to-interannual timescales beyond that associated with linear ENSO signals, and what additional useful predictive information can be extracted by making large ensembles of nonlinear General Circulation Model (GCM) integrations.

MILESTONE PSD01.1:
Determine sensitivity to past and future SST changes in different parts of the tropical oceans.

ACCOMPLISHMENTS FOR PSD01.1:
A study highlighting the sensitivity of global warming to the pattern of tropical ocean warming was published. The current generations of climate models are in substantial disagreement as to the projected patterns of sea surface

temperatures (SSTs) in the tropics over the next several decades. CIRES scientists showed that the spatial patterns of tropical ocean temperature trends have a strong influence on global mean temperature and precipitation trends and on global mean radiative forcing. They identified the SST patterns with the greatest influence on the global mean climate and found very different, and often opposing, sensitivities to SST changes in the tropical Indian and West Pacific Oceans. This work stresses the need to reduce climate-model biases in these sensitive regions, as they not only affect the regional climates of the nearby densely populated continents, but also have a disproportionately large effect on the global climate.

MILESTONE PSD01.2:
Document and diagnose the causes of skewed seasonal precipitation distributions in observations and models.

ACCOMPLISHMENTS FOR PSD01.2:
CIRES scientists have continued to investigate precipitation around the globe in satellite, reanalysis, and GCM data sets. They have found that the 500-mb mean vertical velocity at a given location can be used to explain many of the features of the shape of the seasonal-mean precipitation distribution at that location. Accounting for vertical-velocity variability and moisture provides a complete theory for the shape and movements of precipitation distributions.

MILESTONE PSD01.3:
Continue 20th century re-analysis efforts in collaboration with NCEP, NCAR, NCDC, ECMWF, U. of East Anglia, Environment Canada, ETH-Zurich, and the UK Hadley Centre.

ACCOMPLISHMENTS FOR PSD01.3:
Climate variability and global change studies are increasingly focused on understanding and predicting regional changes of daily weather statistics. Assessing the evidence for such variations over the last hundred years and evaluating the quality of models making predictions for the next hundred requires a subdaily (as opposed to monthly or longer-term average) tropospheric circulation data set. The only data set available for the early 20th century consists of error-ridden, hand-drawn analyses of the mean sea-level pressure field over the Northern Hemisphere. Modern data assimilation systems have the potential to improve upon these maps, but prior to 1948, few digitized upper-air sounding observations are available for such a “reanalysis.” CIRES scientists have investigated the possibility that the quantity of newly recovered surface-pressure observations is sufficient to generate useful re-analyses of at least the lower-tropospheric circulation back to 1900. Surprisingly, they have found that with an Ensemble Kalman Filter that blends an ensemble of six-hour numerical weather prediction model forecasts with the available observations, one can produce high-quality reanalyses of even the upper troposphere using only surface pressure observations. For the beginning of the 20th century, the errors of such upper-air circulation maps over the Northern Hemisphere in winter would be comparable to the two- to three-day errors of modern weather forecasts. Under this project, the Ensemble Filter and newly gathered surface-pressure observations are being used to produce the first-ever reanalysis data set for the period 1892-2007. This will nearly double the record of six-hourly tropospheric gridded fields from 60 years to 116, spanning a period for which no gridded upper-air analyses are currently available. These tropospheric circulation fields will also be the first to have objective uncertainty estimates for every variable. Initial results from the reanalysis fields spanning the period 1918-1949 are very encouraging.

PSD02: Understanding and Predicting Sub-seasonal Variations and their Implications for Longer-Term Climate Variability

GOAL:
Investigate the variability and predictability of weekly averages of the atmospheric circulation through modeling and diagnosis of the observed statistics, and also through detailed analysis of numerical weather forecast ensembles for Week Two.

MILESTONE PSD02.1:
Investigate the variability and predictability of extra-tropical sub-seasonal variations in all seasons of the year using a linear empirical-dynamical model that includes both tropical and stratospheric influences. Assess the predictability from deterministic as well as probabilistic perspectives, particularly in regard to the case-by-case and regime-dependent variations of predictability.

ACCOMPLISHMENTS FOR PSD02.1:
The relative impacts of tropical diabatic heating and stratospheric circulation anomalies on wintertime extra-tropical tropospheric variability have been investigated in a linear inverse model (LIM) derived from the observed zero-lag and five-day lag covariances of seven-day running-mean departures from the annual cycle. Analysis of interactions among the LIM's variables shows that tropical diabatic heating greatly enhances persistent variability over most of the Northern Hemisphere, whereas stratospheric effects are largely confined to the polar region. Over the North Atlantic, both effects are important, although some of the stratospheric influence is ultimately traceable to tropical forcing. In general, the tropically forced anomalies extend through the depth of the troposphere and into the stratosphere, whereas stratospherically generated anomalies tend to be largest at the surface and relatively weak at mid-tropospheric levels. Overall, tropical influences are generally found to be larger than stratospheric influences on extra-tropical tropospheric variability, and to have a pronounced impact on the persistent, and therefore the potentially predictable, portion of that variability

> ***MILESTONE PSD02.2:***
> Develop an empirical-dynamical coupled atmosphere-ocean model of tropical subseasonal variations.

ACCOMPLISHMENTS FOR PSD02.2:
The impacts of air-sea coupling on the predictability of weekly variations of tropical SST and atmospheric circulation and diabatic heating have been investigated in a coupled linear inverse model (C-LIM). The C-LIM accurately reproduces the observed power spectra of both SST and the atmospheric variables. It is found that coupling SST to the atmosphere has a pronounced impact on interannual variability but only a minor effect on intraseasonal variability, acting to slightly lengthen propagation and persistence timescales.

> ***MILESTONE PSD02.3:***
> Investigate tropical intra-seasonal variability using ocean OGCMs, with emphasis on the impact of multiple MJO events on the ocean.

ACCOMPLISHMENTS FOR PSD02.3:
Effects of atmospheric intra-seasonal oscillations (ISOs) on the Indian Ocean zonal dipole mode (IOZDM) were investigated by analyzing available observations and a suite of solutions to an ocean general circulation model, namely, the Hybrid Coordinate Ocean Model (HYCOM). Data and model solutions for the period 1991-2000 were analyzed, a period that includes two strong IOZDM events, during 1994 and 1997, and a weak one, in 1991. Both the data analysis and model results suggest that atmospheric ISOs played a significant role in causing irregularity of the two strong IOZDM events and the premature termination of the weak one.

GMD04: Climate Forcing

GOAL:
(i) Greenhouse gases: Conduct research to understand better the interactions of the atmosphere with the land and ocean. (ii) Aerosols: Characterize the means, variabilities, and trends of climate-forcing properties for different types of aerosols, and understand the factors that control these properties. (iii) Radiation: Research into broadband irradiance to improve benchmarks for climatic processes.

> ***MILESTONE GMD04.1:***
> Merge mesoscale model B-RAMS with global transport model TM5.

ACCOMPLISHMENTS FOR GMD04.1:
Work has begun on merging these two models. Custom boundary conditions have been created with TM5 for use with B-RAMS. The B-RAMS team is currently implementing these parameters within their model.

> ***MILESTONE GMD04.2:***
> Begin measurements of Radon-222 at two tower sites in the continental U.S.

ACCOMPLISHMENTS FOR GMD04.2:
Two Radon-222 sensors, collecting data at half-hourly resolution, have been installed at the NOAA/GMD tall-tower at Moody, TX, (site-code, WKT) and at the DOE ARM Southern Great Plains site (site-code, SGP).

MILESTONE GMD04.3:
Implement following carbon flux emissions models for use within GMD Ensemble Kalman Filter Carbon Data Assimilation System: Fire, fossil fuel and ocean carbon.

ACCOMPLISHMENTS FOR GMD04.3:
Fire, fossil fuel and ocean carbon modules were implemented with the ensemble Kalman filter system (commonly referred to as CarbonTracker. *http://www.esrl.noaa.gov/gmd/ccgg/carbontracker*). This website contains detailed output of national and global carbon fluxes, and the atmospheric CO_2 concentrations consistent with those fluxes, as produced by the model. There are also general and detailed explanations of the modeling system. This documentation and all the model outputs are available for public download.

MILESTONE GMD04.4:
Implement full description of $^{14}CO_2$ (radio-carbon) within TM5 global transport model, for simulation of North American and global $^{14}CO_2$ measurements.

ACCOMPLISHMENTS FOR GMD04.4:
A full description of $^{14}CO_2$ (radiocarbon) has been implemented with the global model TM5. The model has been tested against $^{14}CO_2$ observations in both North America and Siberia, and has performed very well.

MILESTONE GMD04.5:
Establish two new tall-tower sites in the NOAA/GMD North American Carbon Observing System (Carbon America).

ACCOMPLISHMENTS FOR GMD04.5:
Two new tall-tower sites were established during FY07, one near Boulder, CO, using a 300-m tall NOAA research tower and the other near West Branch, IA using a privately owned >400-m television transmission tower. Continuous *in-situ* Carbon Dioxide/Carbon Monoxide mixing ratios and regular air samples (analyzed in Boulder for up to 40 atmospheric trace gas species) are publicly available and are being used as part of the CarbonTracker system mentioned above.

MILESTONE GMD04.6:
Complete development of automated quality control algorithms.

ACCOMPLISHMENTS FOR GMD04.6:
Work is ongoing, but continued funding restrictions are delaying completion of these automated algorithms.

MILESTONE GMD04.7:
Develop and field test a temperature/humidity/GPS system to augment current trace gas vertical profile measurements in the NOAA/GMD Carbon America aircraft network (allowing for automated measurements of the ambient temperature and humidity and the position and altitude of each sample in a vertical profile); and install systems at five sites.

ACCOMPLISHMENTS FOR GMD04.7:
The current system has been installed and is operating at five sites in the NOAA/ESRL/GMD Carbon America aircraft network. GPS position/height data and ambient temperature, pressure, humidity data are part of the auxiliary data stream for these aircraft-based trace-gas measurements.

MILESTONE GMD04.8:
Field test new automated carbon dioxide analyzer systems aboard the small-aircraft platforms used in the NOAA/GMD Carbon America aircraft network.

ACCOMPLISHMENTS FOR GMD04.8:

This system has been field tested aboard the locally based aircraft used for sampling near Carr, CO, and was successfully operated aboard a Purdue University research aircraft around and over Iowa as part of a NOAA/CIRES/Purdue collaboration during the Mid-Continent Intensive (MCI) project (part of the North American Carbon Program) during the early summer 2007. Data and results from the MCI experiment will be used in a significant portion of a graduate thesis project at Purdue University and is available to the MCI collaboration in conjunction with all data collected as part of this field campaign.

> ***MILESTONE GMD04.9:***
> Establish two new overseas sampling sites in the long-term NOAA/GMD Cooperative Global Atmospheric Sampling Network.

ACCOMPLISHMENTS FOR GMD04.9:

Two new overseas sampling sites were established in Mexico during FY07. The air samples from these sites will be analyzed and the data made available as part of the long-term NOAA/ESRL/GMD Cooperative Global Atmospheric Sampling Network.

> ***MILESTONE GMD04.10:***
> Modify an existing spectro-radiometer as well as develop algorithms for the instrument to measure wavelength-dependent aerosol optical properties throughout the shortwave spectrum.

ACCOMPLISHMENTS FOR GMD04.10:

Modification of an existing spectro-radiometer, as well as development of algorithms for the instrument to measure wavelength-dependent aerosol optical properties throughout the shortwave spectrum, will be continued.

Algorithm development for the retrieval of high spectral resolution aerosol properties has progressed through modeling of the sensitivity of the wavelength-dependence of aerosol properties for different aerosol types. Correlations with commonly observed wavelengths provide the information contained in portions of the spectrum that are not typically available from routine measurements. This information provides guidance for the deployment and processing of data from spectral instruments in the future. Data obtained from spectro-radiometer shows features that are not evident in routine measurements at limited wavelengths. A sensitivity analysis using a radiative transfer model is used to show the variability in aerosol properties that may produce these features. This analysis shows the utility of spectral measurements in the field on a routine basis. These results will be presented at the CIRES' Innovative Research Program Poster Session and, if accepted, at the Fall 2007 AGU Meeting. A manuscript is in progress.

> ***MILESTONE GMD04.11:***
> Deploy a counter-flow virtual impactor (CVI) to two locations. The first location is in the United Kingdom downstream of an urban environment. The second deployment is onboard an aircraft.

ACCOMPLISHMENTS FOR GMD04.11:

A CVI was successfully employed at Holme Moss in the United Kingdom in November 2006. The site was very polluted as indicated by the amount of absorbing aerosol. Data analysis is on-going, but preliminary results show a distinct difference in the fractional soot content of interstitial and cloud drop residuals, with the interstitial fractional soot content being about a factor of ten higher than that of cloud drop residuals. Initial results from this project will be presented at the AAAR conference in Reno, NV, at the end of September 2007.

A CVI was also deployed on the Battelle G-1 in June 2007 to investigate differences in aerosol properties within and outside of clouds. Again, data analysis is on-going. Preliminary findings show that the chemistry of the cloud drop residuals (as indicated by the sulfate-to-organic-aerosol-mass ratio) was quite different from that of the ambient aerosol. Ambient aerosol particles tended to contain more organics than sulfates, while cloud drop residuals showed the opposite tendency and were dominated by sulfate material. Preliminary results from this project will be presented at the AGU conference in San Francisco, CA in early December 2007.

CSV-03: Stratospheric Ozone Depletion

CSD04: Tropospheric and Stratospheric Transport and Chemical Transformation

GOAL:
(i) Improve theoretical capabilities to predict the natural and human influences on the stratospheric ozone layer. (ii) Characterize the photochemical reactions relating to the human-induced loss of ozone in the stratosphere. (iii) Carry out in-situ *studies of the photochemical and dynamical processes that influence the stratospheric ozone layer.*

> ***MILESTONE CSD04.1:***
> Understand transport processes associated with the sub-tropical jet stream, both by analysis of airborne and dropsonde data and by high-resolution modeling.

ACCOMPLISHMENTS FOR CSD04.1:
The transport of air between regions of the atmosphere (troposphere and stratosphere) and across latitude regions affects atmospheric composition and is thereby important to many processes involved in climate and stratospheric ozone depletion. CIRES research has shown that there is clear evidence from high-altitude aircraft observations (WB57F) in the tropical upper troposphere and lower stratosphere that air exchanges across the subtropical jet stream, between this region and the mid-latitude lower stratosphere, situated poleward [Tuck et al., 2003, 2004; Richard et al., 2006]. The research confirms that atmospheric abundances are affected significantly by the exchange processes. For example, observations of methane (a key short-lived climate gas) show depletion from tropospheric values between 12- and 16-km altitude in the tropical upper troposphere. These conclusions have been reinforced by work directly on the subtropical jet stream, using the NOAA Gulfstream 4 aircraft. The turbulent structure in the winds and tracers shows that the exchange is scale invariant, anisotropic and substantial [Ray et al., 2006; Lovejoy et al., 2007].

GMD05: Ozone Depletion

GOAL:
(i) Stratospheric Ozone Measurements: Measure ozone declines during the past two decades at northern hemispheric midlatitudes and the tropics and to characterize dramatic ozone depletions over Antarctica. (ii) Ozone-Depleting Gases: Conduct research in the troposphere, stratosphere, oceans, polar snowpack, and terrestrial ecosystems in an effort to understand and predict the atmospheric behavior of these gases. (iii) Stratospheric Aerosols: Conduct experiments and measurements on aerosols to determine their impacts on solar insolation. (iv) Stratospheric Water Vapor: Conduct measurements to determine the change in water vapor and its coupling with aerosols.

> ***MILESTONE GMD05.1:***
> Measure ozone-depleting nitrous oxide (N_2O) in the planetary boundary layer (PBL) of the Amazon basin during a month-long aircraft-based campaign scheduled for October 2006. Estimate the large-scale natural emissions of N_2O from this region of very high primary productivity.

ACCOMPLISHMENTS FOR GMD05.1:
This milestone became a future objective when the Amazon project was delayed one year due to the extra time needed to obtain approval from the Brazilian government. The project is now tentatively scheduled to begin in October 2007.

> ***MILESTONE GMD05.2:***
> A new index for assessing the changes in the atmospheric burden of ozone-depleting gases will be introduced. This Ozone Depleting Gas Index will be derived from the atmospheric measurements of ozone-depleting gases that are regularly conducted at NOAA in collaboration with CIRES personnel.

ACCOMPLISHMENTS FOR GMD05.2:
Measurements of atmospheric concentrations of ozone-depleting gases continued during the July 2006-June 2007 period. Several accomplishments and products derived from these measurements:

In late 2006, the Ozone Depleting Gas Index was first introduced and posted on the NOAA website. This index allows a summary of progress being made in the global effort to reduce the atmospheric burden of ozone-depleting gases. Subsequently, measurement data were updated in early 2007 that extended the index through the end of 2006.

> ***MILESTONE GMD05.3:***
> Utilize aircraft and stratospheric balloon platforms to measure several ODSs (N_2O, CFC-11, CFC-12) in the troposphere and stratosphere. These data will be used to validate measurements by space-borne instrumentation aboard the Aura satellite.

ACCOMPLISHMENTS FOR GMD05.3:
Nitrous oxide (N_2O) was measured *in situ* aboard the Unmanned Aircraft System (UAS) Altair by an automated gas chromatograph during the October 2006 NASA-USDA Forest Service Fire Mission. Vertical profiles of N_2O were obtained between the middle troposphere and lower stratosphere during numerous spiral ascent/descent maneuvers of the aircraft. These (and other) vertical profile data obtained during the mission have been compared to the vertical profiles retrieved from near-coincident soundings of the Microwave Limb Sounder (MLS) and Tropospheric Emission Spectrometer (TES) aboard the NASA Aura satellite. A stratospheric balloon platform was not available for CIRES/NOAA instruments during this report period.

CSV-04: Climate Dynamics

CSD06 : Turbulent Meteorological Motions

GOAL:
Understand the mechanisms and effects by which turbulence influences atmospheric chemistry, composition, radiation, and transport on all scales, from that of molecular diffusion to that of the globe, some nine orders of magnitude.

> ***MILESTONE CSD06.1:***
> Continue efforts to link, via high-resolution observations, the macroscopic theory of scale invariance with molecular-scale non-equilibrium statistical mechanics; examine the implications for the definition of atmospheric temperature in the horizontal with aircraft data and in the vertical with dropsonde data.

ACCOMPLISHMENTS FOR CSD06.1:
The work has reached the stage of presentable syntheses, which either have been published this year, are in press or have been submitted. The case has been established that the molecular dynamics of the population of air molecules in an anisotropic environment leads to the emergence of vorticity on very short time and space scales, picoseconds and nanometers. In turn, this generation of vorticity on very small scales has implications for radiative transfer and for atmospheric chemistry; turbulent dynamics, radiation and chemistry are coupled at the molecular level, in a way that is not compatible with the widely used assumption of local thermodynamic equilibrium. Atmospheric temperature is not proportional to the width of a Maxwell-Boltzmann distribution of molecular speeds – there is an overpopulation of translationally hot air molecules, largely but not wholly maintained by photo-fragments from ozone photo-dissociation.

PSD03: Empirical and Process Studies

GOAL:
Improve understanding of basic physical processes that contribute to climate variability across a broad spectrum of scales, with emphasis on (i) moist atmospheric convection, (ii) radiative transfer in cloudy areas, and (iii) air-sea interaction.

MILESTONE PSD03.1:
Continue improving the representation of physical processes and the Madden-Julian Oscillation (MJO) in the NCEP Global Forecasting System (GFS).

ACCOMPLISHMENTS FOR PSD03.1:
To put the MJO errors of the NCEP/GFS in context, a comprehensive study of the fidelity of the MJO in fourteen coupled general circulation models (GCMs) participating in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) was conducted. Eight years of daily precipitation from each model's 20th-century climate simulation were analyzed and compared with daily satellite-retrieved precipitation. Space-time spectral analysis was used to obtain the variance and phase speed of the dominant convectively coupled equatorial waves. The results show that all current state-of-the-art GCMs have significant problems in simulating tropical intra-seasonal variability. The total intra-seasonal (2-128 day) variance of precipitation is too weak in most of the models. About half of the models have signals of convectively coupled equatorial waves. However, their variances are generally too weak. The MJO variance approaches the observed value in only two of the fourteen models, and is less than half of the observed value in the other twelve models. Moreover, the MJO variance in thirteen of the fourteen models does not come from a pronounced spectral peak, but rather from part of an over-reddened spectrum, which in turn is associated with too strong persistence of equatorial precipitation. The two models that arguably do best at simulating the MJO are the only ones having convective closures/triggers linked to moisture convergence.

MILESTONE PSD03.2:
Diagnose the physical mechanisms behind the tropical biases in current GCMs, such as double-ITCZ, ENSO, and MJO.

ACCOMPLISHMENTS FOR PSD03.2:
A study examining the double-ITCZ problem in the coupled general circulation models (CGCMs) participating in the IPCC's Fourth Assessment Report (AR4) was completed. Twentieth century climate simulations of 22 IPCC AR4 CGCMs were analyzed, together with the available "AMIP" (i.e., prescribed SST) runs from 12 of them. To understand the physical mechanisms contributing to the double-ITCZ problem, the main ocean-atmosphere feedbacks, including the zonal sea surface temperature (SST) gradient−trade wind feedback (or Bjerknes feedback), the SST−surface latent heat flux (LHF) feedback, and the SST−surface shortwave flux (SWF) feedback, were studied in detail. The results show that most of these CGCMs have a double-ITCZ problem, which is characterized by excessive off-equatorial and insufficient equatorial precipitation over much of the tropics. The excessive off-equatorial precipitation causes overly strong trade winds, excessive LHF and insufficient SWF, leading to significant cold SST bias in much of the tropical oceans. Most of the models also simulate insufficient latitudinal asymmetry in precipitation and SST over the eastern Pacific and Atlantic Oceans. The "AMIP" runs also produce excessive precipitation over much of the tropics, which also lead to overly strong trade winds, excessive LHF and insufficient SWF. This suggests that the excessive tropical precipitation is an intrinsic error of the atmospheric component of the coupled models, and that the insufficient equatorial Pacific precipitation in the coupled models is due to errors in ocean-atmosphere feedbacks. These feedback errors are of three types: (1) excessive Bjerknes feedback, which is caused by excessive sensitivity of precipitation to SST and overly strong time-mean surface winds; (2) overly positive SST-LHF feedback, which is caused by excessive sensitivity of surface air humidity to SST; and (3) insufficient SST-SWF feedback, which is caused by insufficient sensitivity of cloud amount to precipitation. Off the equator over the eastern Pacific stratus region, most of the models produce insufficient stratus-SST feedback associated with insufficient sensitivity of stratus cloud amount to SST, which may contribute to the insufficient latitudinal asymmetry of SST in their coupled runs. These results suggest that the double-ITCZ problem in CGCMs may be alleviated by reducing the excessive tropical precipitation and the above-feedback-relevant errors in the atmospheric models.

MILESTONE PSD03.3:
Investigate improved methods of representing subgrid-scale variability in clouds and radiative transfer in weather and climate models, conceptually as a series of sub-columns within a GCM's large-scale column. Explore connections with more traditional single-column parameterizations as well as "super-parameterizations" being developed by other researchers.

ACCOMPLISHMENTS FOR PSD03.3:

A new method for representing subgrid-scale cloud structure in which each model column is decomposed into a set of sub-columns has been introduced into the Geophysical Fluid Dynamics Laboratory's global atmospheric model AM2. Each sub-column in the decomposition is homogeneous, but the ensemble reproduces the initial profiles of cloud properties, including cloud fraction, internal variability (if any) in cloud condensate, and arbitrary overlap assumptions that describe vertical correlations. These sub-columns are used in radiation and diagnostic calculations and have allowed the introduction of more realistic overlap assumptions.

> ***MILESTONE PSD03.4:***
>
> Assess stochastic influences on climate variability and predictability, through (a) linear and nonlinear inverse modeling, and (b) development and implementation of stochastic parameterizations in weather and climate models.

ACCOMPLISHMENTS FOR PSD03.4:

A study of the impacts of state-dependent stochastic heat fluxes on daily-to-decadal-scale extra-tropical SST variability was completed. The classic view of extra-tropical air-sea interaction assumes that the surface heat flux can be simply parameterized as noise associated with atmospheric variability plus a linear temperature relaxation rate. This study suggests, however, that rapid fluctuations in the relaxation rate, expected for example from the gustiness of the surface winds, cannot be ignored. Such fluctuations are in general not independent of the SST anomalies themselves. Accounting for the SST-dependence can affect both the persistence and the likelihood of high-amplitude SST anomalies. To test this hypothesis, daily observations at several Ocean Weather Stations (OWSs) were examined. Significant skewness and kurtosis of the SST probability distributions were found, consistent with the SST-dependence of the amplitude of the noisy fluxes. The analysis shows that the SST-dependent noise increases the persistence, predictability, and variance of extra-tropical SST anomalies. The effect is strongest on annual and longer time scales and may, therefore, be important for understanding and modeling inter-annual and inter-decadal SST and related climate variations.

PSD06: Climate Dynamics

GOAL:

Conduct research to improve understanding of (i) tropical Pacific Ocean dynamical processes related to the sub-seasonal atmospheric variability, (ii) the dynamics and the microphysics of precipitating cloud systems, and (iii) atmospheric circulation, convection, and moisture and heat budgets associated with the El Niño phenomenon.

> ***MILESTONE PSD06.1:***
>
> Retrieve the vertical profile of raindrop size distributions from 50-MHz, 920-MHz, and 2835-MHz profiling radar observations collected during the Tropical Western Pacific–International Cloud Experiment (TWP-ICE) conducted in Darwin, Australia, in January-February 2006. The profiler-retrieved raindrop size distributions and their estimated uncertainties will be used to quantify the error characteristics of differential reflectivity measurements from simultaneous C-band polarimetric scanning radar observations made over the profiler site.

ACCOMPLISHMENTS FOR PSD06.1:

Wind profiler data collected during the Tropical Western Pacific–International Cloud Experiment (TWP-ICE) conducted in Darwin, Australia, were used to estimate the vertical air motion and the raindrop-size distribution (DSD) from near the surface to just under the freezing level. The retrieved DSDs were compared with a rainshaft microphysics model, and the inter-comparison verified that the dynamical evolution of the DSD with altitude during stratiform rain can be quantified by a stochastic advection-coalescence-breakup equation. Also, the profiler-retrieved DSDs were compared with simultaneous polarimetric C-band scanning-radar observations made over the profiler site and the analysis indicated that the measurement errors from both radars were less than the statistical errors of estimating the median drop diameter and rainrate using polarimetric power-law regressions.

> ***MILESTONE PSD06.2:***
>
> Analyze multi-frequency profiler observations and multi-frequency polarimetric scanning radar observations collected during the Front Range Pilot Study in Colorado to determine the error

characteristics of Quantitative Precipitation Estimates (QPEs). The use of normalized raindrop size distributions will be investigated as a means of describing the profiling and scanning radar retrieved raindrop size distributions.

ACCOMPLISHMENTS FOR PSD06.2:
Surface disdrometer, multi-frequency profiler, and multi-frequency polarimetric scanning radar observations from the Front Range Pilot Study were analyzed to quantify the temporal and spatial variability of the normalized raindrop size distribution parameters retrieved by the three types of instruments. These parameters are used in Quantitative Precipitation Estimates (QPEs) and are inputs into numerical weather forecast models. Dr. Anthony Illingworth from Reading University, United Kingdom, spent three months of his sabbatical at CIRES/ESRL working on this problem. Two conference presentations were made on this topic and a peer-reviewed manuscript will be submitted in September 2007. Also, analysis of the multi-frequency profiler observations during the North American Monsoon Experiment (NAME) revealed differences in the vertical structure of reflectivity during stratiform rain between the ground-based profiler and the satellite-based NASA Tropical Rainfall Measuring Mission (TRMM) precipitation radar indicating a possible bias in the satellite retrieval algorithm.

MILESTONE PSD06.3:
Investigate the effect of coupled vs. decoupled lower-tropospheric flow over the East Pacific Cold Tongue on equatorially trapped waves over the East Pacific.

ACCOMPLISHMENTS FOR PSD06.3:
Previous work [Hartten and Datulayta, 2004] had shown that decoupled lower-tropospheric flow over the Galapagos occurred with SST<23°C, while coupled flow occurred when SST>24°C. In an attempt to identify periods when SSTs were inside that 23-24°C range, CIRES scientists examined 1994 to 2003 SST data from six near-equatorial TAO buoys along 95°W and 110°W. Our results showed that SSTs between 23ºC and 24ºC were less frequent at the 2°N buoys, during strong El Niño periods, and in the middle of cold (July to October) and warm (February to May) seasons.

PSD15: Surface Processes

GOAL:
Develop and/or improve physical representations of atmosphere-surface interactions.

MILESTONE PSD15.1:
Examine the role of artificial correlation in data analysis of turbulent Prandtl number.

ACCOMPLISHMENTS FOR PSD15.1:
Measurements of atmospheric turbulence made during the Surface Heat Budget of the Arctic Ocean Experiment (SHEBA) have been used to examine the behavior of the turbulent Prandtl number, Prt, in the stable atmospheric boundary layer (SBL) over the Arctic pack ice. It is found that Prt increases with increasing stability if Prt is plotted versus gradient Richardson number, Ri; but at the same time, Prt decreases with increasing stability if Prt is plotted versus flux Richardson number, Rf, or versus z/L. This paradoxical behavior derives from the fact that plots of Prt versus Ri (as well as versus Rf and z/L) have built-in correlation (or self-correlation) because of the shared variables. For independent estimates of how Prt behaves in the SBL, Prt is plotted against the bulk Richardson number; such plots have no built-in correlation. These plots show that, on the average, Prt decreases with increasing stability and Prt <1 in the very stable case. For specific heights and stabilities, though, the turbulent Prandtl number has more complicated behavior in the SBL. It is conceivable that the turbulent Prandtl number does not have a universal behavior.

MILESTONE PSD15.2:
Complete the study and submit a paper on the role of shallow boundary layer processes on nitric oxide concentrations over the Antarctic Plateau.

ACCOMPLISHMENTS FOR PSD15.2:
This study focused on the use of an acoustic sounder, or sodar, during the 2003 Antarctic Tropospheric Chemistry Investigation (ANTCI), to document the behavior of very shallow (<50 m) stable boundary layers thought to be one

of the critical factors for explaining the very high levels of nitric oxide [NO] found in past field experiments at the South Pole. The use of a tethered balloon profiling wind, temperature, NO, and ozone provided for a detailed interpretation of sodar data for the period December 12-30, 2003. For the same period, sonic anemometer 2-m turbulence measurements, averaged to 0.5 h, linked surface processes to the evolution of the boundary layer in response to changing radiative balance and synoptic weather changes. A mixing-layer detection method was developed and applied to half-hour average sodar amplitude profiles for the period November 23 – December 30, 2003. These data also allowed for testing of simple diagnostic equations for the mixing-layer depth as well as estimates of vertical diffusion rates under stable conditions, the latter being important for the effective depth of the mixing layer vis-à-vis the nonlinear NO chemistry postulated from earlier analyses. With the extended sampling period, two sub-seasonal regimes were examined: (1) a late-December period, with the full suite of supporting measurements, where the earlier results that shallow mixing layers associated with light winds and strong surface stability can be among the dominant factors leading to high NO levels, were repeated and (2) a late-November period that revealed additional complexities with very high NO concentrations appearing at times in concert with higher winds, weaker surface stability, and deeper mixing layers. The latter results are only consistent with a more complicated picture of how NO can build to very high levels that involves invoking the previously expressed dependence of elevated NO levels on nonlinear NOx (NOx = $NO+NO_2$) chemistry, greater fluxes of NOx from the snowpack than previously observed at the South Pole, and the potential for enhanced NOx accumulation effects involving air parcels draining off the high plateau. The results of ANTCI from 2003 thus argue for more complete future observations of boundary layer conditions over the high Antarctic Plateau and determination of the spatial and temporal variability of snow nitrate concentrations over the high plateau and their relation to NO recycling and the snow accumulation/ablation/erosion cycle.

> ***MILESTONE PSD15.3:***
> Install an "HMT Mesonet" to enhance surface observations in the American River Basin to try to trace the radar and free-air meteorology to what actually happens on the ground surface and gets into the streams. This will include more snow measurements and surface precipitation measurements and some soil and radiation measurements.

ACCOMPLISHMENTS FOR PSD15.3:

The maritime mountain ranges of western North America span a wide range of elevations and are extremely sensitive to flooding from warm, winter storms, primarily because rain falls at higher elevations and over a much greater fraction of a basin's contributing area than during a typical storm. Accurate predictions of this rain-snow line are crucial to hydrologic forecasting. This study examines how remotely sensed atmospheric snow levels measured upstream of a mountain range (specifically, the brightband measured above radar wind profilers) can be used to portray accurately the altitude of the surface transition from snow to rain along the mountain's windward slopes, focusing on measurements in the Sierra Nevada, California, from 2001-2005. Snow accumulation varies with respect to surface temperature, diurnal cycles in solar radiation, and fluctuations in the free-tropospheric melting level. At 1.5°C, 50% of precipitation events fall as rain and 50% as snow, and on average, 50% of measured precipitation contributes to increases in SWE. Between 2.5 and 3°C, snow is equally likely to melt or accumulate, with most cases resulting in no change to SWE. Qualitatively, brightband heights (BBHs) detected by 915-MHz profiling radars up to 300 km away from the American River study basin agree well with surface-melting patterns. Quantitatively, this agreement can be improved by adjusting the melting elevation based on the spatial location of the profiler relative to the basin: BBHs decrease with increasing latitude and decreasing distance to the windward slope of the Sierra Nevada. Because of diurnal heating and cooling by radiation at the mountain surface, BBHs should also be adjusted to higher surface elevations near midday and lower elevations near midnight.

> ***MILESTONE PSD15.4:***
> Compare soil moisture measurements with river gage height and precipitation events in the Russian River Basin of Northern California. Investigate how the correlation between precipitation and river flow changes after the soil has reached field capacity.

ACCOMPLISHMENTS FOR PSD15.4:

An analysis of soil moisture and river gauge data taken in the Russian River Basin of Northern California has been completed. One notable case analyzed occurred during December 2005 in the basin. All of the soil moisture stations located in the basin at Healdsburg, Rio Nido, and Cazadero showed that the soil was extremely dry in early December. Stream flows were at or below seasonal norms. Large-scale synoptic weather systems began bringing significant amounts of precipitation into the region shortly after December 15. These storms began the process of slowly saturating the soil, and flows in the Russian River and the Austin Creek tributary began rising slowly. Each subsequent precipitation event brought the soils up to field capacity, which occurred just before Christmas Day. At that time, the soil could no longer absorb water, and all the precipitation falling into the basin quickly made its way into the basin's streams and rivers. A major synoptic-scale cyclone began making its way into the Coastal Mountains around December 29. On December 31, the Russian River crested near 25 ft at Healdsburg, nearly six ft above flood stage. Later that day, the River crested at 43 feet at Guerneville, twelve ft over flood stage. Major portions of the town of Guerneville were flooded and California Highway 116 was closed by the event.

CSV-05: Climate Research Database Development

NSIDC01: Digitizing Analog Cryospheric Data under the Climate Database Modernization Program

GOAL:
Scan and make available on-line data from NSIDC's analogue collections so that it is more easily located, browsed, and obtained by users.

MILESTONE NSIDC01.1:
Complete metadata entry for the several thousand scanned images now at NSIDC, and post the images on-line.

ACCOMPLISHMENTS FOR NSIDC01.1:
A total of 401 glacier photographs were added to the Online Glacier Photograph Database. In addition, a new Climate Database Modernization Project task, Discovery and Access of Historical Literature of the IPYs (DAHLI), digitized 52 books and approximately 1300 IGY glacier photographs.

NSIDC02: Observations for SEARCH–Data Integration for Arctic Reanalysis and Change Detection

GOAL:
"Unaami," the changes in the Arctic that are the subject of the Study of Environmental Arctic Change (SEARCH) program, became apparent to researchers in the context of long-term and pan-Arctic observations. This work aims to assess what data are relevant to SEARCH reanalysis and change-detection activities, collect these data from a wide variety of sources, and facilitate the SEARCH research community's access to the data. Another key element of the effort is to assess the Arctic performance of existing atmospheric reanalyses, with the aim of identifying shortcomings that will need to be addressed in developing a dedicated Arctic System Reanalysis (ASR). Note that this work is funded through Task III, rather than Task II.

MILESTONE NSIDC02.1:
Report on the Indicator work in appropriate venues, and to provide data management support to the NOAA SEARCH program. *(Due to funding cuts, data development efforts under this project will be in maintenance-mode in July 2006 - July 2007. It is hoped that funding will resume in FY2008.)*

ACCOMPLISHMENTS FOR NSIDC02.1:
A presentation on the Cryospheric Climate Indicators Website and time series was given at the International Glaciological Society meeting: A joint NSIDC/NCAR data-management proposal for the Arctic Observing Network was funded by NSF. This will provide data management for some NOAA SEARCH activities.

MILESTONE NSIDC02.2:
Finalize ongoing assessments of the Arctic performance of the ERA-40 reanalysis. As assessments of precipitation and surface temperature are nearly complete, efforts will thus focus on other important aspects of the Arctic climate system, including its large-scale heat budget. In

addition, output from the new JRA-25 reanalysis (from the Japan Meteorological Agency) will be examined.

ACCOMPLISHMENTS FOR NSIDC02.2:

A major paper was published in the *Journal of Geophysical Research* synthesizing a variety of atmospheric and oceanic data to examine the large-scale energy budget of the Arctic. Assessment of the atmospheric budget relies primarily on the ERA-40 reanalysis. The seasonal cycles of vertically integrated atmospheric energy storage and the convergence of energy transport from ERA-40, as evaluated for the polar cap (defined by the 70°N latitude circle), in general, compare well with realizations from the NCEP/NCAR reanalysis over the period 1979-2001. However, inaccuracies in the radiation budget at the top of the atmosphere, as compared with satellite data, and the net surface flux contribute to large energy-budget residuals in ERA-40. The seasonal cycle of atmospheric energy storage is strongly modulated by the net surface flux, which is also the primary driver of seasonal changes in heat storage within the Arctic Ocean. Averaged for an Arctic Ocean domain, the July net surface flux from ERA-40 of -100 Wm^{-2} (i.e., into the ocean), associated with sea-ice melt and oceanic sensible heat gain, exceeds the atmospheric energy transport convergence of 91 Wm^{-2}. During winter, oceanic sensible heat loss and sea ice growth yield an upward surface flux of 50-60 Wm^{-2}, complemented with an atmospheric energy convergence of 80-90 Wm^{-2} to provide a net radiation loss to space of 175-180 Wm^{-2}.

MILESTONE NSIDC02.3:

Complete inter-comparisons among the Arctic performance of different land surface packages, and identify shortcomings that will need to be addressed for the ASR.

ACCOMPLISHMENTS FOR NSIDC02.3:

A paper was published in the *Journal of Geophysical Research* comparing the performance of five land-surface models (CHASM, Noah, CLM, VIC, ECMWF) in the simulation of hydrological processes across the terrestrial Arctic drainage system for the period 1980-2001. The models represent a wide range of model physics, particularly with respect to high-latitude processes, and are forced with surface meteorology derived from the ERA-40 reanalysis. Models offer great potential for enlightenment regarding large-scale hydrology in this poorly observed region; thus, the objective is to assess the ability of the models to capture various aspects of Pan-Arctic hydrology as well as identify those features that contain the largest uncertainty. Results reveal up to a 30% difference in annual partitioning of precipitation between evaporation and runoff with major Arctic watersheds such as the Lena. Capturing the correct base-flow of the large rivers is a consistent problem. The model hydrographs are often out of phase, peaking too early in comparison to observations. However, allowing for a large uptake in soil moisture as well as moisture movement during frozen periods alleviates this discrepancy. A negative correlation exists between models and observations for annual runoff time series over the Yenesi basin, apparently due mostly to inconsistencies in the input data. Compared to station data, all models produce similar errors in snow-water equivalent; yet they differ widely in their snow regimes in terms of snowfall quantity, estimated snow depths, and most importantly, sublimation rates. Additionally, model albedo is consistently higher than observations in the presence of snow. No single model is the best or worst performing when compared to a range of observations.

NSIDC03: World Data Center for Glaciology, Boulder–Current Programs

GOAL:

Improve understanding of recent and unexpected changes in polar regions, including lower sea-level atmospheric pressure, increased air temperature over most of the Arctic, lower temperatures over eastern North America and Greenland, reduced sea ice cover, thawing permafrost, and changes in precipitation patterns.

MILESTONE NSIDC03.1:

Maintain and update and existing research data sets (e.g., the Online Glacier Photo Collection). Publish new data sets such as the NIC Ice Chart collection. Improve access to existing data sets, provide data via new access methods (e.g. Geospatial One Stop) and formats (e.g., more data sets in GeoTIFF and GIS formats).

ACCOMPLISHMENTS FOR NSIDC03.1:

In 2006, CIRES scientists built momentum toward the goal of making data sets available in geospatial formats and exposing these data to new user communities. Accomplishments in this area included making the Online Glacier

Photograph Database, permafrost maps, global ice and snow extent, and the Sea Ice Index available in Google Earth KML files, and daily snow extent from a NOAA operational product available in GeoTIFF format. Hundreds of glacier photographs were added to the Online Glacier Photograph Database. The most significant data release was release of the National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format data set.

> ***MILESTONE NSIDC03.2:***
> Make research information available through the NSIDC Information Center, acquire and catalog cryospheric materials in the NSIDC library, and maintain NSIDC's analog data sets.

ACCOMPLISHMENTS FOR NSIDC03.2:
The NSIDC Information Center provided research assistance and document delivery to more than 120 users during FY07. During the same time frame, 361 books, reprints, and other media were added to the Center's collection as purchases and from donated materials. Users borrowed 218 items from the collection and accessed another 268 items in-house. The Climate Database Modernization Project (CDMP) digitization project continued to scan the historic glacier photograph collection adding hundreds of photographs to the online database. Thirty seven field expedition notebooks were also digitized and will be made available online next fiscal year. One historic film was preserved, digitized, and shown to a local audience in collaboration with the University of Colorado's International Film Series. This film included footage of Boulder area glaciers from 1938 – 1942 and drew the IFS's largest audience of the season.

> ***MILESTONE NSIDC03.3:***
> As resources allow, play a lead role in data management for the SEARCH program (NOAA and NSF) and for NOAA's IPY activities, and accelerate production of climate data records from NPP and NPOESS missions, with a focus on sea ice.

ACCOMPLISHMENTS FOR NSIDC03.3:
As reported above for NSIDC03.1, CIRES scientists worked to make data sets available in geospatial formats and exposing data to new user communities. Some Sea Ice Index images are now used in the Arctic Research Mapping Application (*http://www.armap.org/home.aspx*) as well.

The NOAA liaison and other NSIDC staff served on a Study of Environmental Arctic Change (SEARCH) data management advisory panel, and responded to action items from NOAA headquarters regarding NOAA's IPY data legacy. Work began on a sea ice CDR joint with the Danish Meteorological Institution.

A newly released data set from 216 Russian stations fills gaps in the historical precipitation record needed for applications including reanalysis validation and climate change studies. Documentation includes a section describing the relationship between this data set and other commonly used precipitation data sets. This is an important addition because the number and variety of sometimes overlapping precipitation data sets often make it difficult to use them for climate studies. The NOAA Arctic Research Program funded this effort as a contribution to the interagency SEARCH program.

CSV-06: Regional Climate Systems

PSD10: Cloud and Aerosol Processes

GOAL:
Make observations of clouds, aerosols, and water vapor over a variety of ice, land, and sea surfaces using a multi-sensor, multi-platform approach to improve retrieval techniques useful for satellite-validation studies.

> ***MILESTONE PSD10.1:***
> Participate in VOCALS research cruises in October 2006; deploy cloud radar, radiometer, and flux systems to measure key surface marine boundary layer parameters, low cloud macrophysical, microphysical, and radiative properties.

ACCOMPLISHMENTS FOR PSD10.1:
The systems were deployed on the NOAA R/V *Ronald H. Brown* for three weeks in October 2006. All systems obtained data on the cruise. Data products are available at the PSD ftp site for this project (*ftp://ftp.etl.noaa.gov/et6/archive/STRATUS_2006/RHB)*.

> ***MILESTONE PSD10.2:***
> Complete deployment of ground-based cloud, aerosol, radiative, and surface meteorological instruments in Canada for SEARCH Arctic observations with an emphasis on regions with strong connections to the Arctic oscillation.

ACCOMPLISHMENTS FOR PSD10.2:
A suite of atmospheric observation equipment has been deployed at the SEARCH research site in Eureka, Canada, which is located in the high Arctic at 80°N. These systems include a cloud radar, a high spectral-resolution lidar, a spectral infrared interferometer, and a microwave radiometer. A high data-recovery rate (>85%) has been accomplished for each instrument and data are available at the PSD ftp site: *ftp://ftp.etl.noaa.gov/et6/search*. In addition, preliminary work has started towards an additional deployment of a flux tower system to Eureka in the year 2007.

> ***MILESTONE PSD10.3:***
> Participate in AMMA research cruises in June-July 2006; deploy cloud radar, radiometer, and flux systems to measure key surface marine boundary layer parameters, low cloud macrophysical, microphysical, and radiative properties.

ACCOMPLISHMENTS FOR PSD10.3:
The systems were deployed on the NOAA R/V *Ronald H. Brown* for four weeks in May 2007. All systems obtained data on the cruise. Data products are available at the ETL ftp site for this project (*ftp://ftp.etl.noaa.gov/et6/archive/AMMA_2007/RHB)*.

CSV-07: Climate Services

PSD05: Experimental Regional Climate Services

GOAL:
Couple enhanced observations and research in regions of strong climate variability and societal impact with analysis of past data and improved modeling. Determine factors influencing the occurrence of extreme events. Improve the diagnosis, modeling, and prediction of the regional consequences of climate change and variability on timescales of days to decades on hydrological variables of relevance to society.

> ***MILESTONE PSD05.1:***
> Monitor daily, seasonal, and longer-term precipitation variability over the western U.S. Complete alternate classification of U.S. climate divisions based on coherent regional precipitation variability. Downscale NCEP Week Two ensemble forecasts for Colorado water resource managers.

ACCOMPLISHMENTS FOR PSD05.1:
- The first version of alternate climate division analysis has been released.
- A regional web page of Week Two forecasts produced for Colorado River management has been developed. Training documents/Users Guide for Water Managers are in preparation. Work-in-progress reports were presented at AMS and CPASW meetings.

> ***MILESTONE PSD05.2:***
> Continue developing seasonal forecast guidance tools for the U.S. based on the predictability of tropical SSTs several seasons in advance, training these tools on the atmospheric responses to different types of anomalous tropical SSTs in large new sets of seasonal integrations made with the NCAR, GFDL, and NCEP GCMs.

ACCOMPLISHMENTS FOR PSD05.2:

An upgraded seasonal forecast tool using the ensemble of AMIP-type simulations of four new AGCMs is being developed. Preliminary hindcast experiments indicated that, compared to the forecast tool currently being used in real-time experimental seasonal forecasts, the new forecast tool has the potential of making improved forecasts of U.S. seasonal precipitation and surface temperature.

> ***MILESTONE PSD05.3:***
> Conduct studies of recent climate change in the hydroclimatology of the western U.S., partly resulting from changes in tropical teleconnections, with emphasis on changes in stream flow and watershed health.

ACCOMPLISHMENTS FOR PSD05.3:

CIRES scientists collaborated with U.S. Bureau of Reclamation and U.S. Geological Survey researchers in studying the potential for use of existing seasonal forecast products and/or remote teleconnections for stream-flow temperature/ecosystem and reservoir management in California.

> ***MILESTONE PSD05.4:***
> Continue programmatic development and impact assessments of climate, weather, and water services, especially in conjunction with the newly established National Integrated Drought Information Service (NIDIS).

ACCOMPLISHMENTS FOR PSD05.4:

There was coordination with, and major contributions to, the NIDIS Implementation Plan.

PSD07: Experimental Climate Data and Web Services

GOAL:

Improve public access to climate information and forecast products to facilitate research, to inform public planning and policy decisions, and to assist any interested parties impacted by climate.

> ***MILESTONE PSD07.1:***
> Continue updating the extensive, publicly accessible climate data holdings on the CDC/PSD website. Develop and install on local platforms netCDF versions of the ECMWF ERA-40 and other reanalysis data sets of the global and North American atmospheric circulation. Acquire new precipitation and soil moisture data sets.

ACCOMPLISHMENTS FOR PSD07.1:

New data sets:

- NOAA Merged Air Land and SST Anomalies

Updated data sets:

- Climatic Research Unit at the University of East Anglia
- Temperature anomalies (CRUTEM3, HADCRUT3 and HADCRUT3V)
- Goddard Institute for Space Studies (GISS) surface temperature analysis
- Kaplan SST
- NASA Global Precipitation Climatology Project (GPCP)
- NCEP Global Ocean Data Assimilation System
- NCEP Marine
- NCEP-NCAR Reanalysis 1
- NCEP-DOE AMIP-II Reanalysis (AKA Reanalysis 2)
- NCEP Pacific Ocean Experiment
- NOAA Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP)
- NOAA CPC Soil Moisture
- NOAA Extended Reconstructed SST
- NOAA Interpolated OLR

- NOAA Operation Model
- NOAA Optimally Interpolated SST

MILESTONE PSD07.2:
Finish ingesting a new data set, NCEP's North American Regional Reanalysis (NARR), which is much higher in resolution (vertically as well as horizontally) than any of CDC's previous data sets, in a CF-compliant NetCDF format.

ACCOMPLISHMENTS FOR PSD07.2:
The NARR data set was extended through the end of 2006. It is an ongoing data set for NCEP, so “finishing” it is not good terminology. Further updates are planned on a space-available basis. The Lambert Conformal Conic projection has proven to be an additional complication, but the CF metadata standard has provisions for handling it.

MILESTONE PSD07.3:
Continue developing and maintaining the CIRES/NOAA website dedicated to real-time predictions of tropical convection variations associated with the MJO and their remote impacts. Display various experimental and operational ensemble predictions in a uniform format to enable inter-comparisons and skill evaluation.

ACCOMPLISHMENTS FOR PSD07.3:
The goal of the MJO experimental prediction project is to access and compare MJO forecasts, and to analyze the effects of MJO events on tropical and mid-latitude weather forecasts. An article describing the project’s accomplishments was published in the *Bulletin of the American Meteorological Society* in April 2006. The project website *(http://www.www.cdc.noaa.gov/MJO/)* continues to be maintained and developed.

Scientific Theme: GEODYNAMICS

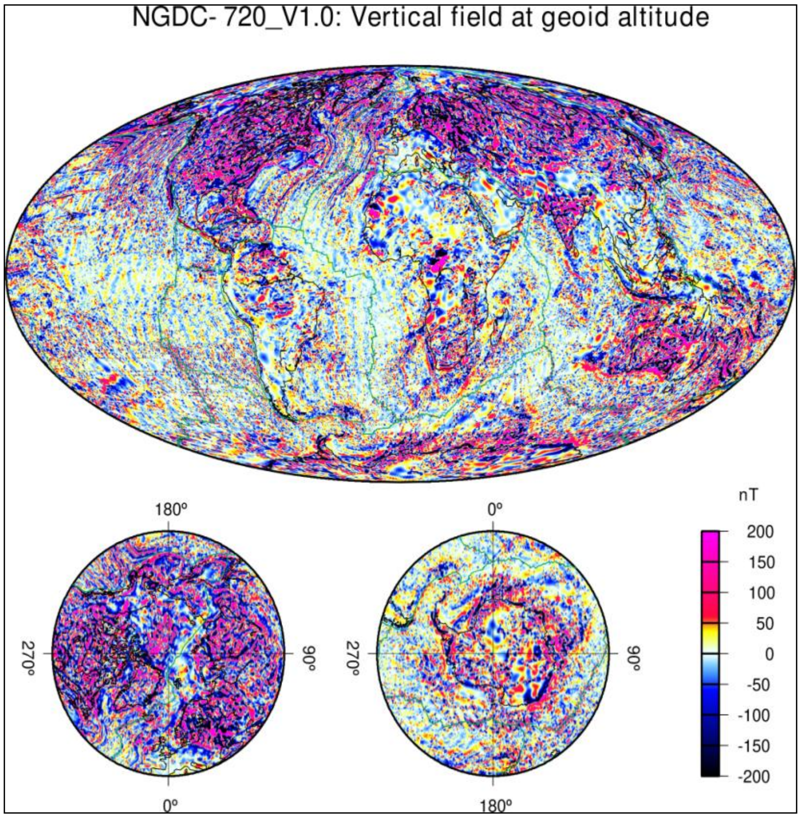
GEO-01: Geophysical Data Systems

NGDC05: Instrumentation Design, Prototyping and Analysis

GOAL:
Improve integration and modeling of geophysical data, further research into core-mantle processes, improve representation of magnetic fields at or near the Earth's surface, improve models of tsunami-threatened coastal regions, and improve understanding of past hazardous events and potential future impacts.

MILESTONE NGDC05.1:
Produce a global spherical-harmonic degree-720 model of the Earth's crustal magnetic field from a joint inversion of all available marine magnetic, aeromagnetic, and CHAMP satellite magnetic measurements.

ACCOMPLISHMENTS FOR NGDC05.1:
The study of geomagnetism is one of the oldest of the geophysical sciences, tracing back to before the publication of William Gilbert's *De Magnete* in the year 1600. A convenient way for modern scientists to represent the geomagnetic field is to expand the scalar magnetic potential into spherical harmonic functions that can then be evaluated at any desired location to provide the magnetic field vector direction and strength. The magnetic field as measured at or near the surface of the Earth is a composite of the main (internal) magnetic field, the crustal magnetic field, and the magnetic field from external sources. Of these, the main field comprises approximately 90% of the signal and is represented through global magnetic field models such as the International Geomagnetic Reference Field (IGRF) and World Magnetic Model (WMM). The time-varying external and spatially varying crustal magnetic fields are the primary sources of uncertainty in navigation applications of the geomagnetic field.



Degree-720 spherical harmonic model of the Earth's magnetic field, vertical field (Z) component at geoid height.

The NGDC-720 model is a new high-resolution crustal field model that extends previous main field models from a spherical harmonic degree 16 to 720 corresponding to a waveband improvement of 2500 km to 56 km. The degree-720 cut-off corresponds to an angular wavelength of 30 arc-minutes, providing a 15-arc-minute model resolution. The degree-720 magnetic model is the first step in the development of an Enhanced Magnetic Model needed for improved navigation by ships, aircraft, and near-Earth orbiting spacecraft. These higher-resolution models are also important for natural-resource exploration of natural gas, petroleum, and minerals. Finally, the improved model has application in scientific investigations focused on understanding the physics of changes in the terrestrial magnetic field.

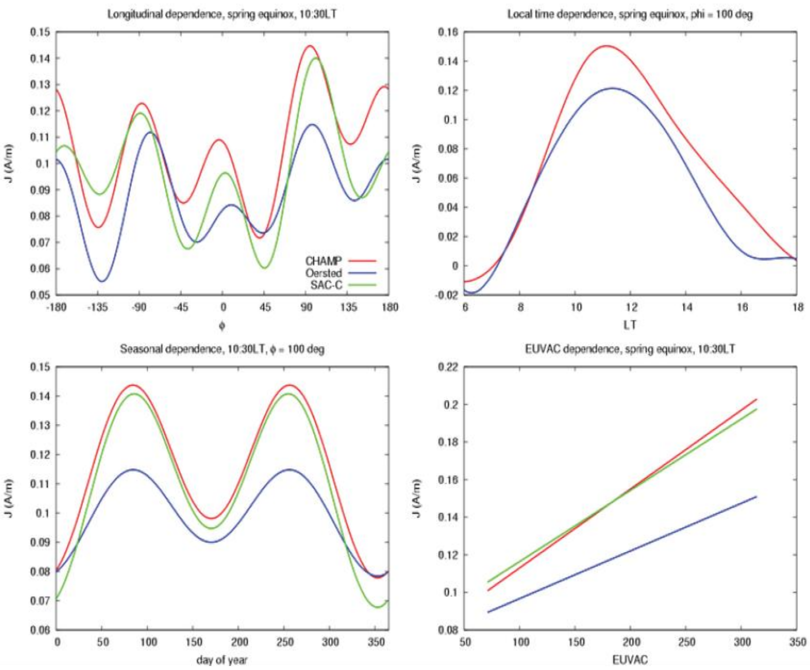
This research also directly supported the International Association of Geomagnetism and Aeronomy World Digital Magnetic Anomaly Map Project (IAGA/WDMAM) and studies of crustal magnetism contributing to geodynamic models of the lithosphere, geologic mapping, and natural resource exploration. Inferences from crustal magnetic field maps, such as the WDMAM, interpreted in conjunction with other information, can help delineate geologic provinces, locate impact structures, dikes, faults, and other geologic entities that have a magnetic contrast with their surroundings. The Magnetic Anomaly Map of the World, based on the NGDC-720 model, will be published in July 2007 by UNESCO and the Commission for the Geological Map of the World.

Products include:

- The Extended Magnetic Field Model (EMM-06), including software and the main field, secular variation, NGDC-720-V1 crustal field, magnetospheric field, and induced field is now available via on-line access (*http://www.ngdc.noaa.gov/seg/EMM/*).
- Candidate model for the World Digital Magnetic Anomaly Map Project (*http://geomag.org/models/wdmam.html*).

MILESTONE NGDC05.2:
Produce a climatological model of the equatorial electrojet by analyzing CHAMP, Ørsted, and SAC-C satellite magnetic data.

ACCOMPLISHMENTS FOR NGDC05.2:



One dimensional slices of the 4D EEJM1 model for each model parameter, holding the other 3 parameters fixed.

The Earth's equatorial ionosphere is a region of complex electrodynamics resulting from solar-driven ponder-motive forces and ionospheric conductivity gradients. Understanding the physics of these interactions is important for specifying the morphology of currents flowing in the upper atmosphere and for predicting the occurrence of ionospheric scintillation that can have a deleterious effect on communications. Recent satellite missions have provided measurements of the geomagnetic field with unprecedented accuracy and resolution, which are now used to infer the electrodynamics of the equatorial ionosphere. Deviations from the main geomagnetic results are used to model height-integrated current densities within the ionosphere from which local electric fields and plasma motions can be inferred.

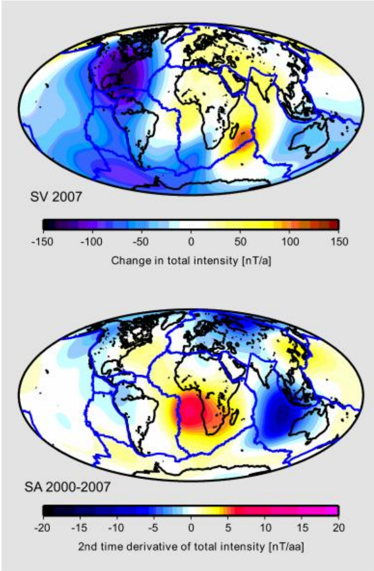
CIRES scientists working at NGDC developed the Equatorial ElectroJet Model (EEJM1) climatological model using high-quality magnetic measurements from recent satellite missions. The EEJM1 is composed of three models of the equatorial electrojet that were constructed based on six years of satellite magnetic measurements from each of the CHAMP, Ørsted, and SAC-C satellites. The models are based on data that comprise half of a solar cycle (from solar maximum to solar minimum). The Equatorial Electrojet Model—coefficients and driver program—is available online at *http://www.earthref.org and at http://models.geomag.us/EEJ.html*.

MILESTONE NGDC05.3:
Produce the 2006/2007 CIRES/NGDC scientific geomagnetic field model, accounting for recent changes of the Earth's magnetic field.

ACCOMPLISHMENTS FOR NGDC05.3:

The two primary reference models for magnetic navigation and pointing are the World Magnetic Model and the International Geomagnetic Reference Field. The CIRES geomagnetism team is strongly involved in producing and supporting both of these models. This requires a detailed monitoring of the time variations of the geomagnetic field. These time variations are captured in scientific main field models, which are updated every year.

CIRES scientists working at NGDC produce and support a main magnetic field model called POtsdam Magnetic Model of the Earth (POMME), in collaboration with the CHAMP satellite team at GeoForschungsZentrum Potsdam. The time variations of the geomagnetic field, as measured by the CHAMP satellite from 2000.5 to 2007.5, are represented as a second degree Taylor series expansion in time around the model epoch 2004.0. The first time derivative (secular variation) and the second time derivative (secular acceleration) are displayed in the figure to the right. With this Taylor series expansion, the geomagnetic field can be predicted forward in time for periods up to a few years. Further details and images can be found at *http://geomag.org/models/pomme4.html*.



Secular variation (top) and secular acceleration (bottom) of the geomagnetic field as given by POMME-4 model

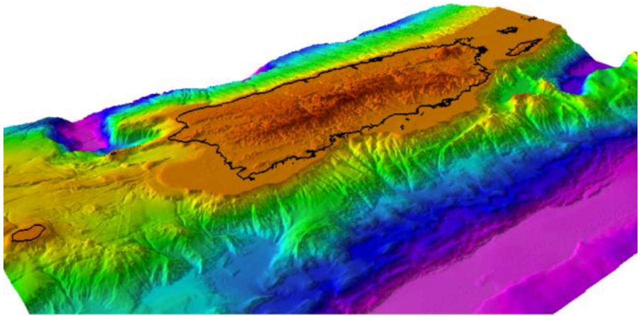
MILESTONE NGDC05.4:

Produce bathymetric-topographic digital elevation models sufficient for tsunami propagation, run up and inundation prediction for 19 priority regions, defined by the U.S. tsunami community.

ACCOMPLISHMENTS FOR NGDC05.4:

CIRES researchers developed 21 high-resolution digital elevation models (DEMs) for select tsunami-threatened U.S. coastal regions. These combined bathymetric–topographic DEMs are used to support tsunami forecasting and modeling efforts at the NOAA Center for Tsunami Research, Pacific Marine Environmental Laboratory (PMEL). The DEMs are part of the tsunami forecast system SIFT (Short-term Inundation Forecasting for Tsunamis) currently being developed by PMEL for the NOAA Tsunami Warning Centers, and are used in the MOST (Method of Splitting Tsunami) model developed by PMEL to simulate tsunami generation, propagation, and inundation.

Bathymetric, topographic, and shoreline data used in DEM compilation are obtained from various sources, including NGDC, NOAA's National Ocean Service (NOS), the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), and other federal, state, and local government agencies, academic institutions, and private companies. DEMs are referenced to the vertical tidal datum of Mean High Water (MHW) and horizontal datum of World Geodetic System 1984 (WGS84). Geographic cell sizes for the DEMs range from 1/3 arc-second (~10 meters) to 3 arc-seconds (~90 meters). This project is a priority for NOAA; it has been presented to Congressional staffers, and featured on the NOAA website.



Perspective view of the 1 arc-second Puerto Rico DEM. Elevations range from -6612 meters (purple) to 1330 meters (dark red).

MILESTONE NGDC05.5:
Provide community with web access to bathymetric-topographic grids developed for tsunami prediction as standard products, with documentation of procedures, analysis, quality control and quality assessment of data.

ACCOMPLISHMENTS FOR NGDC05.5:
CIRES scientists at NGDC developed the "NGDC Tsunami Inundation Gridding Project" website (*http://www.ngdc.noaa.gov/mgg/inundation/*) for public access of tsunami inundation DEMs. On this site, visitors may download completed DEMs, with corresponding metadata and documentation. The site also identifies coastal communities for which bathymetric–topographic DEMs are planned to be built in the future.

CIRES scientists at NGDC also developed an ArcIMS "DEM Discovery Portal" map service (*http://map.ngdc.noaa.gov/website/mgg/dem/viewer.htm*) for spatially locating DEMs from NGDC and other sources. The portal provides information on the DEMs (source, cell size, datums, units, etc.), shaded-relief images, and links to websites where they may be downloaded. Currently indexed DEMs, from NOAA and USGS, range from 5 arc-minutes (ETOPO5 Global Relief) to 2 meters (Crater Lake Bathymetry).

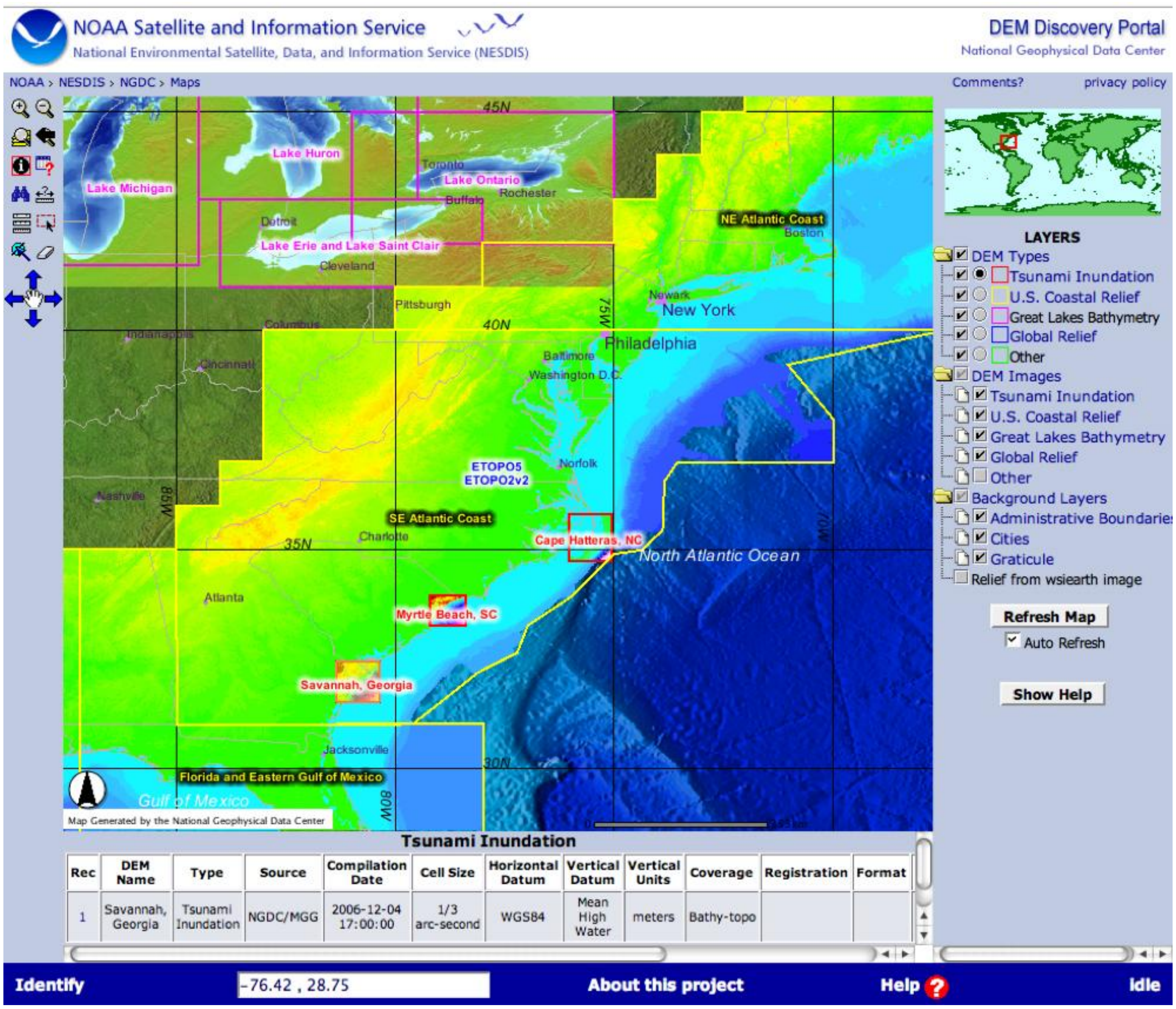
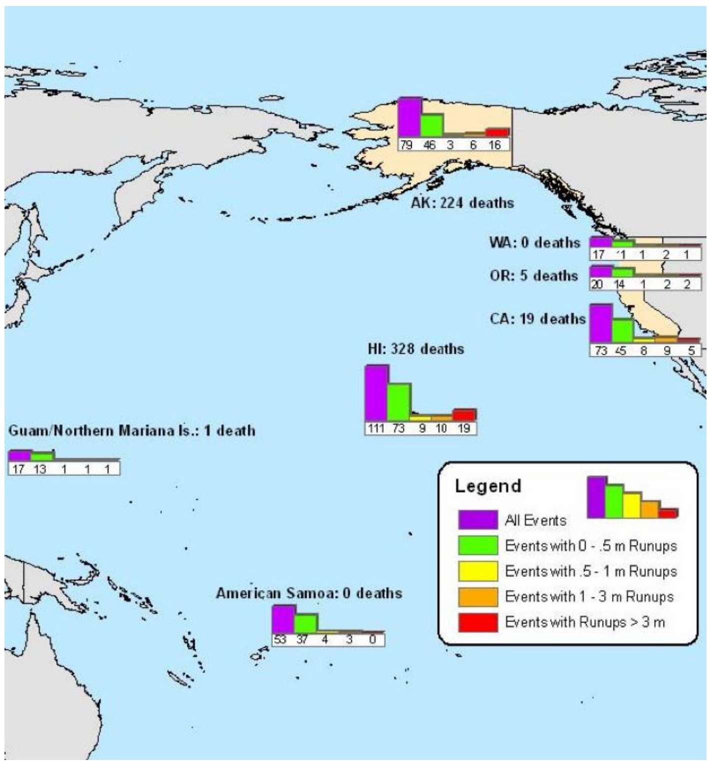


Image of the ArcIMS "DEM Discovery Portal" map service for spatially locating DEMs from NGDC and other sources.

MILESTONE NGDC05.6:
Produce a U.S. Tsunami Hazard Assessment which will describe tsunami sources and estimate tsunami frequency based on historical and geological tsunami data.

ACCOMPLISHMENTS FOR NGDC05.6:
CIRES researchers at NGDC conducted a tsunami hazard assessment for U.S. states and territories, which has been documented in a draft NOAA report "U.S. States and Territories National Tsunami Hazard Assessment, 2006: Historical Record and Sources for Waves." This document awaits NOAA approval for publication. Tsunamis are infrequent high impact events that can cause a considerable number of fatalities, inflict major damage, and cause significant economic loss to large sections of the U.S. coastlines. Since the beginning of the 20th century, tsunami events have caused more than 800 deaths and over $200 million in damage to the U.S. coastal states and territories. Approximately 53% of the U.S. population now live in coastal communities and are at risk for impacts from a destructive tsunami. As this trend continues, the risk of more deaths and damage will continue to climb.



Map showing total number of tsunami events and total number of events causing runup heights from 0.01 meter to greater than 3.0 meters for U.S. states and territories in the Pacific Ocean.

Region	Hazard based on runups	Hazard based on frequency	Hazard based on deaths
Atlantic Coast	Very low to low	Very low	None
Gulf Coast	None to very low	Non to very low	None
Caribbean	High	High	Very high or severe
West Coast	High	High	High
Alaska	Very high or severe	Very high	Very high or severe
Hawaii	Very high or severe	Very high	Very high or severs
Western Pacific	Moderate	High	Low to moderate

Qualitative Tsunami Hazard Assessment based on NGDC databases.

Scientific Theme: INTEGRATING ACTIVITIES

IA-01: Science and Society
CSD10: Scientific Assessments for Decision Makers
Policy01: Science Policy Lecture Series

IA-02: Western Water Assessment
WWA01: Scientific Assessments
WWA02: Climate Products
WWA03: Climate and Water Affairs
WWA04: Management

IA-03: Resource Development for Educators and Decision Makers
Policy02: Outreach to Decision Makers through the Internet
Policy03: Outreach to Decision Makers through Newsletters

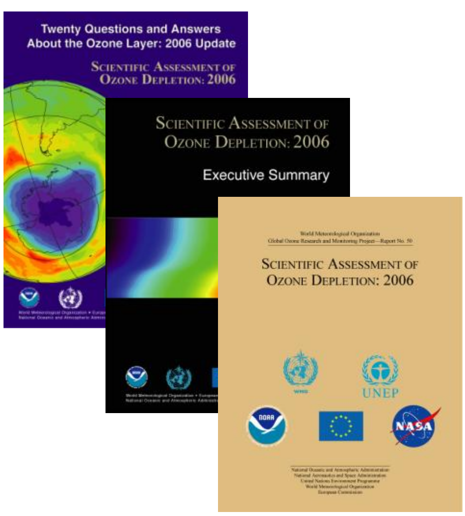
IA-01: Science and Society

CSD10: Scientific Assessments for Decision Makers

GOAL:
Plan, lead, prepare, and disseminate assessments for the decision making communities associated with ozone-layer depletion, greenhouse warming, and regional air quality.

MILESTONE CSD10.1
Serve as authors, reviewers, and coordinating editor to accomplish the final preparation and printing of the World Meteorological Organization/United Nations Environment Programme 2006 scientific state-of-understanding assessment of the ozone layer for the U.N. Montreal Protocol.

ACCOMPLISHMENTS FOR CSD10.1



The 2006 international state-of-understanding report on the science of the ozone layer was completed in December 2006 and printed in April 2007, a major milestone in the work of the Scientific Assessment Panel of the U.N. Montreal Protocol on Substances that Deplete the Ozone Layer. The report ("Scientific Assessment of Ozone Depletion: 2006") is the sixth in a series of periodic assessments that are prepared for the United Nations Montreal Protocol. The report will be distributed to the more than 190 nations (including the United States) that are parties to the Montreal Protocol, who use it as the scientific basis for their discussions regarding protection of the ozone layer.

The 2006 report, approximately 500 pages in length, describes past and expected future levels of ozone-depleting substances, past and expected future behavior of the ozone layer in polar regions and throughout the globe, implications for ultraviolet radiation at the Earth's surface, short-lived ozone-depleting substances, and interrelationships between climate and ozone depletion.

The 2006 report updates findings of the previous report in 2002 and builds upon the foundation of knowledge forged in earlier reports in 1988, 1991, 1994, and 1998. This regular series is the output product of updated knowledge on this topic. Each of the reports is prepared by hundreds of scientists worldwide who participate as authors, contributors, and reviewers.

The ozone assessment is an important component of NOAA's Climate Goal. Scientists in CIRES, the Chemical Sciences Division, the Global Monitoring Division, and elsewhere in NOAA have played prominent roles in leading, authoring, and reviewing the 2006 ozone assessment. Roles of CIRES scientists in the 2006 report included participation as coauthors, contributors, reviewers, and coordinating editor for the report.

POLICY01: Science Policy Lecture CIRES

GOAL:
Provide useful information that will help improve the relationship between societal needs and science and technology policies.

> ***MILESTONE POLICY01.1***
> Edit a book that will include chapters based on each science advisor's talk in the series supplemented by chapters written by other science policy experts. Continue the planning process for the second science policy lecture series, which likely will focus on a series of debates on science policy and energy-related topics.

ACCOMPLISHMENTS FOR POLICY01.1
Researchers at the Center for Science and Technology Policy Research have completed 10 chapters of the book based on their Presidential Science Advisor lecture series. The book includes chapters written by all seven of the participating science advisors – Donald Hornig, Edward David, Frank Press, George Keyworth, John Gibbons, Neal Lane, and John Marburger – as well as four chapters by other science and policy scholars. The completed manuscript is expected to be sent to the prospective publisher by the end of summer 2007 with an anticipated publication date sometime in 2008. Planning for the second lecture series has been put on hold but it is hoped that the process will resume in the coming year.

IA-02: Western Water Assessment

WWA01: Scientific Assessments

GOAL:
Identify and characterize regional vulnerabilities to climate variability and change for use by Intermountain water-resource decision makers.

> ***MILESTONE WWA01.1:***
> Front Range water needs to 2040. Colorado's Front Range is one of the most rapidly growing areas in the West. This on-going model-based study (SPRAT – South Platte Regional Assessment Tool) will investigate the region's ability to meet new water needs through proposed projects, conservation, and groundwater. How a varying climate might affect these future needs and projects will also be studied.
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ACCOMPLISHMENTS FOR WWA01.1:
The SPRAT workgroup continued efforts to incorporate climate change into the SPRAT modeling framework. These efforts included meeting with user groups such as Denver Water to discuss the use of SPRAT to develop a better understanding of the potential effects of climate change on their water rights portfolio. In addition to this work, a team member will be presenting the SPRAT model and output at the 2007 South Platte Forum.

> ***MILESTONE WWA01.2:***
> Front Range large water providers' vulnerabilities and climate products needs. This on-going task will inform future assessment and climate products of the Western Water Assessment through studying six large water providers in the Front Range of Colorado.

ACCOMPLISHMENTS FOR WWA01.2:

In the last year, interviews with Denver, Northern Colorado Water Conservancy District (NCWCD), and Westminster were held. Interviews with the other three cities are currently being scheduled. Information gathered during these interviews is being added to a report describing the annual and long-term decision processes and uses and needs for climate information by these cities. This information will be useful for other WWA researchers who need background information about these cities. Three articles have been outlined that will be submitted for publication with conclusions from all six cities. These articles are intended for three audiences: water managers, climate information providers, and the *Water Resources Research* journal. These articles will examine ways that Front Range water managers use climate information, ways that they could use information that they do not currently use, the reasons that some information is more useful than other information, and how climate information can be presented to make it more useful.

> ***MILESTONE WWA01.3:***
> Current and Future Water Demand at a Major Front Range City. This task will investigate the many forces that impact water demand at a major Denver suburb, Aurora, with infrastructure requirements over the next ten years in excess of $1B. A literature review on water demand will be created. How the recent drought, climate variables, demographics, pricing, irrigation technology, in-home water meters and other variables affect demand will also be studied.
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ACCOMPLISHMENTS FOR WWA01.3:

A website, as well as several papers and presentations about water demand in Aurora, CO, were produced.

Web Related: Created new Water Demand and Conservation site:

- *http://wwa.colorado.edu/resources/water_demand_and_conservation/.*

Publications/White Papers:

- Residential Water Demand Management in Aurora: Lessons from the Drought Crisis, Colorado Water.
- Factors Influencing Residential Water Demand: A Review of the Literature. White Paper.

Presentations

- Managing Residential Water Demand: Lessons from Aurora. Presented as part of the Center for Science and Technology Policy Research (CSTPR) seminar series., March 13, 2007,
- Behavioral and Econometric Lessons from Urban Water Demand under Extreme Drought: Focus on Aurora, Colorado. Department of Agricultural and Resource Economics & Department of Economics U.S. Forest Service Rocky Mountain Research Station Spring 2007 Seminar Series. February 16, 2007.

> ***MILESTONE WWA01.4:***
> Colorado Meteorological Station Data long-term trends. In conjunction with the Colorado State Climatologist's office, evaluate all suitable stations in Colorado for long-term precipitation and temperature trends.

ACCOMPLISHMENTS FOR WWA01.4:

A preliminary assessment of long-term precipitation and temperature trends has been completed. These results have been presented at several venues, including the Water Availability Task Force and the WWA Climate Change Conference held in Golden, in December of 2006.

> ***MILESTONE WWA01.5:***
> IPCC AR4 Model Suitability for Colorado. Investigate value of recent AR4 model run data for use by Denver Water and others.

ACCOMPLISHMENTS FOR WWA01.5:

This project was put on hold during FY07, but work is now in progress.

> ***MILESTONE WWA01.6:***
> Streamflow Variability. In parallel with ongoing NSF effort, we will investigate apparent tendencies for Western rivers to show increasing variability and synchroneity.

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ACCOMPLISHMENTS FOR WWA01.6:
This project is on temporarily on hold until the faculty research position is filled.

MILESTONE WWA01.7:
Colorado River Flow Yield Study. Synthesize lessons from paleo streamflow reconstructions, future streamflow projections from models and other sources, and native streamflow reconstructions.

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ACCOMPLISHMENTS FOR WWA01.7:
Note: Milestones 7, 8, and 9 were combined into a single project done for the U.S. Bureau of Reclamation.

WWA hosted a kick-off meeting with the Bureau personnel in November of 2006 in Boulder to form a Climate Technical Work Group to assist bureau members with assessing the state of the climate change science in its Colorado River planning studies. This meeting was attended by approximately 25 people from Reclamation's Lower Colorado River office (Boulder City, NV), Upper Colorado River Office (Salt Lake City), National Center for Atmospheric Research, and consultants.

A six-member "climate technical work group" was created after the kickoff meeting. During the spring of 2007, the group drafted "Review of Science and Methods for Incorporating Climate Change Information into Reclamation's Colorado River Basin Planning Studies." The report was peer-reviewed during the summer. It is slated for release by Reclamation this fall; it may become an appendix in Reclamation's ongoing Environmental Impact Statement for the "shortage sharing" and combined operation of Lake Powell and Lake Mead. This is the first report of its kind by Reclamation anywhere in the U.S.

MILESTONE WWA01.8:
Colorado River Drought Analysis. Build upon the 1995 Severe and Sustained Drought Study by updating analysis including lessons learned from the 1999 – 2004 drought.

ACCOMPLISHMENTS FOR WWA01.8:
See text above; milestones WWA01.7, WWA01.8, and WWA01.9 were combined into a single project done for Reclamation.

MILESTONE WWA01.9:
Colorado River Climate Change Analysis. Utilize USBR CRSS Model to investigate vulnerability of basin to changes in inflows based on IPCC AR4 model runs.

ACCOMPLISHMENTS FOR WWA01.9:
See text above; milestones WWA01.7, WWA01.8, and WWA01.9 were combined into a single project done for Reclamation.

MILESTONE WWA01.10:
Estimating the impacts of complex climatic events: The economic costs of drought in Colorado, Nebraska and New Mexico. In addition to developing impact assessment methodologies, this study will develop guidelines for impacts reporting at the state and local levels. This effort supplements a SARP funded proposal and will be a joint effort with the National Drought Mitigation Center.

ACCOMPLISHMENTS FOR WWA01.10:
The project PIs have produced an assessment of the following methods.

(1) PIs identified the sectors/subsectors within each state that have been affected by drought within the past 10 years in Nebraska. This forms a prototype for similar reports from Colorado and New Mexico, the other states involved in the project.

(2) The PIs have begun to develop a protocol for reporting drought impacts.
(3) Project PIs are also working on organizing a drought workshop (with a specific component aimed at economic impacts assessments of drought) in partnership with the State of Colorado Office of Water Conservation & Drought Planning.

WWA02: Climate Products

GOAL:
Develop information, products and processes to assist water resource decision makers throughout the Intermountain West.

MILESTONE WWA02.1
Nonparametric streamflow reconstructions. This task will investigate an entirely new way of reconstructing streamflows using a statistical technique not previously used by dendrochronologists. Jointly funded by US Bureau of Reclamation, Boulder City, NV Office.

ACCOMPLISHMENTS FOR WWA02.1:
Due to problems with reprogramming funding for this activity, this effort was delayed. Background work by the consultant, Hydrosphere, was performed. This work will be completed this year.

MILESTONE WWA02.2:
Streamflow Reconstructions for Water Managers in Gunnison Basin for EIS. Using a novel combination of historic gage data, and tree-ring data, create new streamflow reconstructions.

ACCOMPLISHMENTS FOR WWA02.2:
Due to a lawsuit involving the ongoing Environmental Impact Statement, work was temporarily halted. However, work has now been completed on comparing the current method of using stream flows (ISM) with our proposed method based on a nonparametric nearest neighbor ("knn") algorithm.

A report documenting the advantages of the knn method has been prepared for the U.S. Bureau of Reclamation and the water managers in the Gunnison Basin and is online here: *http://animas.colorado.edu/~nowakkc/EIS.html*. Work will now proceed on the paleoclimatology portion of the project.

MILESTONE WWA02.3:
Monthly Intermountain Climate Summary. Climate information is widely scattered on the web and other locations. Water managers and other climate sensitive sectors have requested a single monthly summary of climate information including precipitation, temperature, snow water equivalent, long-lead temperature and precipitation outlooks, reservoir levels and streamflow forecasts.

ACCOMPLISHMENTS FOR WWA02.3:
Released about eight times per year, *Intermountain West Climate Summary* provides updated climate and water supply information catered to municipal water providers. See:
http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/.

MILESTONE WWA02.4:
Web-based seasonal guidance for Water Managers, Climate Prediction Center. Improve ability of federal, state, and local water managers to plan water operations during drought. Provide input to CPC seasonal outlooks.

ACCOMPLISHMENTS FOR WWA02.4:
Assistance in the creation of CPC's seasonal forecasts has been provided. A key element of this assistance is the regular creation of "experimental seasonal guidance," a statistically created forecast specific to the Four-Corners

region of the U.S. Forecasts are at *http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/index.html*. Note: This information is also presented to the Drought Task Force, and that activity is covered under another milestone.

> ***MILESTONE WWA02.5:***
> National Integrated Drought Information System. As necessary, WWA will provide support activities for NIDIS implementation efforts.

ACCOMPLISHMENTS FOR WWA02.5:
WWA researchers were instrumental in the shaping of the National Integrated Drought Information System (NIDIS), including playing a major role in writing the NIDIS overview document organized by the Western Governors' Association. (*http://www.westgov.org/wga/publicat/nidis.pdf*). This effort with WGA also led to WWA involvement in the most recent WGA water report on sustainability (*http://www.westgov.org/wga/publicat/Water06.pdf*). In 2006-2007, WWA researchers assisted with the creation of the NOAA NIDIS implementation plan and with discussions about NIDIS pilot projects. A presentation was delivered at the NIDIS Implementation Plan workshop held in September of 2006.

> ***MILESTONE WWA02.6:***
> Grand Canyon Adaptive Management. Develop forecasts of late-summer storms and associated sediment input into the Grand Canyon to support multi-stakeholder adaptive management experiments aimed at sustaining ecological, cultural and recreational activities. This work is in collaboration with the Grand Canyon Monitoring and Research Center.

ACCOMPLISHMENTS FOR WWA02.6:
This project is continuing to produce experimental climate information on late-summer inputs of sediment into the Colorado River at Grand Canyon. This input is now the most important source of sediment into the Grand Canyon for adaptive management of cultural resources and endangered species in the Canyon. PIs have also been involved in meetings and presentations with the Adaptive Management Working Group (representatives from states, tribes, recreation, and energy NGOs within the basin) to inform the reassessment of the Environmental Impacts Statement and management plans over the next five years.

> ***MILESTONE WWA02.7:***
> Dendrohydrological Website. Expand and redesign existing website on tree-ring streamflow reconstructions for Colorado, to encompass reconstructions across the western U.S. Allow water managers to utilize streamflow sequences vastly in excess of the historical gage record to better plan for climate variability and change. Jointly funded by the NCDC Paleoclimatology Branch.

ACCOMPLISHMENTS FOR WWA02.7:
WWA currently maintains two websites devoted to paleo-reconstructions of stream flow:

- *http://www.ncdc.noaa.gov/paleo/streamflow/*
- *http://wwa.colorado.edu/resources/paleo/*

During the last year, both were updated, but the WWA site received the most work. A key addition to the WWA site was a series of pages on the Colorado River:

- *http://wwa.colorado.edu/resources/paleo/lees/*

The substantial web material on the dendrohydrological workshops is discussed elsewhere in this report.

> ***MILESTONE WWA02.8:***
> Lee Ferry Reconstructions website. This site will provide information on the new Woodhouse, Gray, Meko tree-ring reconstruction of Colorado River streamflow, and a comparison with other reconstructions of the same gage.

ACCOMPLISHMENTS FOR WWA02.8:
See previous milestone.

MILESTONE WWA02.9:
Colorado River Climate, Management, Law and Policy website. Enhance and update existing site on matters of interest to Colorado River water managers. Add discussion of useful existing climate products and new climate product needs by water managers.

ACCOMPLISHMENTS FOR WWA02.9:
This website was updated and is located here: *http://wwa.colorado.edu/resources/colorado_river*/.

MILESTONE WWA02.10:
Colorado River Climate Primer. Summarize climate of the basin in one document.

ACCOMPLISHMENTS FOR WWA02.10:
This document, "Colorado River Climate Primer," is under production. It was held up because it is a joint effort with another NOAA project, and that study was not funded due to the federal budget problems in FY 07.

WWA03: Climate and Water Affairs

GOAL:
Increase decision makers' level of knowledge about climate science so they can become better consumers and demanders of climate products and assessments, and help WWA set its research agenda.

MILESTONE WWA03.1:
Dendrohydrological Workshops. Increasing interest by water managers in tree-ring reconstructions of streamflow has led to demand for a hands-on workshop on how the reconstructions are generated and assessed. Goal is to provide managers with the tools to better interpret and apply the reconstructions to planning.

ACCOMPLISHMENTS FOR WWA03.1:
Workshops in Tucson (November 1, 2006) and Durango (May 31, 2007) were organized and conducted by WWA. Full information on these workshops can be obtained at *http://wwa.colorado.edu/resources/paleo/workshops.html*. This site includes the PowerPoint files from the presentations.

MILESTONE WWA03.2:
Dendrohydrological Capacity Building. Researchers in Wyoming have expressed interest in learning technical details about streamflow reconstructions. This workshop will provide these researchers with capacity to begin streamflow reconstructions

ACCOMPLISHMENTS FOR WWA03.2:
A one-day workshop was conducted to provide background and training on dendrochronological techniques to representatives of the civil engineering department at the University of Wyoming and of the Wyoming Water Development Commission. The training session was an important step toward the establishment of a tree-ring laboratory and active research program in reconstructing stream flows at the University of Wyoming.

MILESTONE WWA03.3:
Climate Change for Water Resource Managers Workshop. In conjunction with local consulting firm which is working on a NOAA CPO grant to study climate change with a local water provider (Stratus), sponsor a workshop on climate change for water managers. Invitees will include Colorado and Wyoming managers.

ACCOMPLISHMENTS FOR WWA03.3:
This workshop was delayed because Stratus and its subcontractor, Hydrosphere, encountered difficulties in completing their work products. These work products are a key element of the planned workshop. It will be held in

fall 2007 in Boulder, likely in October. WWA held a workshop on November 17, 2006 in Golden, Colorado, with water managers from approximately 20 agencies to discuss climate change impacts on water resources.

MILESTONE WWA03.4:
Forecast Verification Workshop. In order to gauge forecast quality, users must know the accuracy and skill of seasonal forecasts. This workshop will introduce water managers to the basics of forecast verification statistics. Invitees will include Colorado and Wyoming managers.

ACCOMPLISHMENTS FOR WWA03.4:
This workshop has been delayed until the fall or winter of 2007/2008.

MILESTONE WWA03.5:
Climate and Tourism Workshop. Tourism and recreation in the West are a large part of the economy and are strongly linked to climate. This workshop will result in an applied research and services agenda.

ACCOMPLISHMENTS FOR WWA03.5:
This workshop was held January 23-24, 2007 at NCAR in Boulder. Approximately 25 people attended. A workshop summary has been accepted for publication in *BAMS*. Information on the workshop is here: *http://wwa.colorado.edu/outreach/climatetourworkshop.html.*

MILESTONE WWA03.6:
Water Availability Task Force. Provide technical support for Governor's drought task force as needed.

ACCOMPLISHMENTS FOR WWA03.6:
The WWA team regularly attends the Water Availability Task Force meetings, which occur about ten times per year. The team supplies the task force with "experimental guidance" (located at *http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts*/ and responds to climate-related information requests from the task force.

MILESTONE WWA03.7:
Law School Climate Change Workshop. Co-sponsor a large event at the CU Law School on climate change for attorneys and other decision makers.

ACCOMPLISHMENTS FOR WWA03.7:
27th Annual NRLC Summer Conference: Climate Change and the Future of the American West: Exploring the Legal and Policy Dimensions. WWA assisted as a co-sponsor for the CU Law School Workshop on climate change for attorneys and other decision makers.
http://www.colorado.edu/law/centers/nrlc/summerconference/2006/index.htm.

MILESTONE WWA03.8:
Speakers for Interested Organizations and Public Events. From time to time, WWA is invited to speak on the interaction of climate and water at public events or to various organizations.

ACCOMPLISHMENTS FOR WWA03.8:
Many workshops, meetings and presentations were conducted to facilitate information sharing and interaction between scientists and local stakeholders about water demands and climate change.
Selected Workshops, Meetings & Presentations

- National Association of Clean Water Agencies. Future Water Quality Challenges and the Role of Reuse. Seattle, WA. July 20, 2006.
- "WWA Activities" poster. NIDIS Planning Meeting. Longmont, CO. September 21-22, 2006.

- Future Water Policy in the Western U.S.: The Colorado River. American Meteorological Society Policy Briefing. Washington, DC. September 25, 2006.
- High Country Citizens' Alliance. The Changing Climate of Climate Change. Crested Butte, CO. September 28, 2006.
- Aspen "Canary Project" Workshop: WWA team members attended workshop and served as a climate information source for Workshop organizers and affiliates. Aspen, CO. October 5, 2006.
- Water, Drought and Wyoming's Climate: WWA co-sponsored an all day workshop hosted by the University of Wyoming and others dedicated to understanding how climate variability and change impacts Wyoming's water resources. URL: *http://www.uwyo.edu/enr/WyomingWater.asp*. University of Wyoming, Laramie, WY. October 5, 2006. Workshop Report: *http://www.uwyo.edu/enr/WaterClimateConfFall2006/WaterDroughtWyomingClimateWorkshopFinalReportNov2006.pdf*
- Climate Change and Variability in the San Juan Mountains. WWA co-sponsored a workshop to facilitate information sharing and interaction between scientists and local stakeholders regarding the implications and potential impacts of climate variability and change in the San Juan Mountain region. Durango, CO. October 11-13, 2006. *http://www.mountainstudies.org/*
- South Platte Forum. Presented forecast for the upcoming winter season. Longmont, CO. October 26, 2006.
- Climate Diagnostics and Prediction Workshop (CDPW). Boulder, CO. October 26, 2006.
- Climate Support Collaboration with Bureau of Reclamation: In response to the five-year 1999-2004 drought, Reclamation began an Environmental Impact Statement (EIS) in 2005 to determine how to operate Lakes Mead and Powell in a coordinated fashion, and to establish objective criteria for declaring and implementing shortages on the Colorado River. WWA sponsored a large kick-off meeting with approximately 30 individuals. Boulder, CO. November 7, 2006.
- Workshop for Resource Managers: Congreso Internacional de los Servicios Ecosistemicos en los Neotropics. "Paleohydrologic records of streamflow: Research to applications." Universidad Austral de Chile, Valdivia, Chile, November 13-17, 2006.
- Western States Water Council: "What's a RISA anyway? Irvine, CA. November 15, 2006.
- Climate Change for Water Resource Managers Workshop. WWA held a meeting to discuss climate change impacts on water resources. Invitees included Colorado and Wyoming managers, Golden, CO. November 17, 2006.
- National Wildlife Federation Tribal Lands Conference. Climate Threats to the Colorado River. Yuma, AZ. December 5, 2006.
- Upper Colorado River Commission. Climate Change Predictions and Impacts on Colorado River Water Supplies. Las Vegas, NV. December 13, 2006.
- Climate and Tourism Workshop: Identifying links between climate variability and change and tourism industries on the Colorado Plateau. Boulder, CO, January 23-24, 2007.
- National Seasonal Assessment Workshop (NSAW) for Wildfire Potential in the Western States and Alaska. Boulder, CO. April 24, 2007.
- Integration of WWA Activities with the "Climate and Management of the Colorado River" project, funded separately by NOAA under the Human Dimensions (SARP or "Sectors") initiative. This project entails a variety of interactions between WWA personnel and Colorado River stakeholder at relevant meetings (e.g., the annual meeting of the Colorado River Water Users Association). Collaboration resulted in five presentations throughout the year.
- Front Range Residential Water Demand: Collaboration resulted in three presentations throughout the year.

WWA04: Management

GOAL:
Provide overall guidance to project as well as day-to-day management.

MILESTONE WWA04.1:
General Management Activities. Hold biweekly team meetings. Prepare Annual budget. Interact with RISA Program managers. Interact with CIRES and NOAA administrative staff. Establish strategic activities.

ACCOMPLISHMENTS FOR WWA04.1:
General management activities were preformed. The WWA budget and statement of work are the products of this activity, and were submitted to NOAA in June 2007.

MILESTONE WWA04.2:
Western Water Assessment Website. Provide a portal into all Western Water activities for researchers, water providers and the public.

ACCOMPLISHMENTS FOR WWA04.2:
The Western Water Assessment website is located at *http://wwa.colorado.edu*. During the year, a new interface that features our current activities was added. The interface includes “Water and Climate in the News,” “Upcoming Events,” and “Recent WWA Activities.” Significant content during the year was added to the following sections:

- *http://wwa.colorado.edu/about/homepages/udall/*
- *http://wwa.colorado.edu/resources/colorado_river/*
- *http://wwa.colorado.edu/resources/western_water_law/*
- *http://wwa.colorado.edu/resources/paleo/*

A major redesign in 2007-2008 with a more user-centric focus is planned.

MILESTONE WWA04.3:
Inform NOAA about Climate Services Needs. An important part of the WWA mission is to keep NOAA NWS and OAR informed of new and evolving user needs, existing product limitations, and general lessons from the water management community.

ACCOMPLISHMENTS FOR WWA04.3:
WWA provides input to the NWS on a variety of fronts:

1) Participation in regular teleconferences with CPC to assist with seasonal forecasting;
2) Contribution to the creation of Drought Monitor;
3) Regular interaction with NWS Regional Climate Focal Points and attendance at events sponsored by NWS;
4) Collaboration with NWS Colorado River Basin Forecast Center to improve volumetric forecasts and communication thereof;
5) Attendance at the NWS Climate Services Division-sponsored annual event, “Climate Prediction Applications Science Workshop.”

IA-03: Resource Development for Educators and Decision Makers

Policy02: Outreach to Decision Makers through the Internet

GOAL:
Provide useful information that will help improve the relationship between societal needs and science and technology policies.

MILESTONE Policy02.1:
Completely revamp the widely read science policy weblog, Prometheus, to make it more user-friendly, as well as continue to maintain and upgrade the Center's website as a whole.

ACCOMPLISHMENTS FOR Policy02.1:
Researchers at the Center for Science and Technology Policy continue to add content to their website to keep it timely and informative but have had to delay substantial expansion and upgrading for the time being, because they currently do not have a webmaster. One significant addition this year was a new page describing books authored by Center personnel.

Policy03: Outreach to Decision Makers through Newsletters

GOAL:

Provide useful information that will help improve the relationship between societal needs and science and technology policies.

MILESTONE Policy03.1:

Continue to improve content of newsletter to make it of greater interest to the science and technology policy community and decision makers. Increase the number of subscribers and distribute the newsletter more widely. Add a bimonthly science-policy briefing email that is sent to hundreds of science policy decision makers in Washington, D.C. and elsewhere, highlighting Center activities. Continue to expand and upgrade this effort in the 2006-2007 time period.

ACCOMPLISHMENTS FOR Policy03.1:

Policy Center personnel continue to strive to make the quarterly newsletter of interest to the science and technology policy community by soliciting contributions from experts in the field on highly topical subjects. They have increased the subscription rate by 8% since last year. The science-policy briefing mailing list has grown from more than 2,000 to almost 3,500 science-policy decision makers around the world, and the center continues to receive positive feedback about the briefing.

Scientific Theme: PLANETARY METABOLISM

PM-01: **Biosphere-Atmosphere Interactions**
CSD07: Biosphere-Atmosphere Exchange

PM-02: **Response of Natural Systems to Perturbations**
NGDC07: Anthropogenic Remote Sensing

PM-01: Biosphere-Atmosphere Interactions

CSD07: Biosphere-Atmosphere Exchange

GOAL:
Gain an improved understanding of the role that the exchange of gases between the surface and the atmosphere plays in shaping regional climate and air quality.

MILESTONE CSD07.1:
Determine the impact of the 2004 forest fires in Alaska and western Canada on the atmosphere over North America.

ACCOMPLISHMENTS FOR CSD07.1:
During aircraft measurements in 2004 over the northeastern United States, large forest fires were burning in Alaska and western Canada, and the emissions were regularly observed over eastern Canada and the northeastern U.S. Using measurements of acetonitrile (CH_3CN), a unique tracer for forest-fire emissions, CIRES scientists were able to detect the emissions and compare the observations to the output from the Lagrangian transport model Flexpart. In general, Flexpart reproduced the observations very well, in particular when the emissions were released in the model not at the surface but at an altitude of several kilometers, indicating the importance of pyro-convection.

The measurement results were used to estimate the contribution of forest-fire emissions to the carbon monoxide (CO) observed over the northeastern U.S. Using acetonitrile as a tracer for forest-fire emissions and chloroform as a tracer for urban emissions, scientists were able to separate the contribution of these sources to CO. Averaged over the study period, forest-fire CO contributed 30% and urban CO 70% of the enhancements over the continental CO background: Urban CO dominated in the boundary layer, whereas in the free troposphere the contributions from urban and forest fire CO were about equal. The observations in the boundary layer were consistent with those made from the R/V *Ronald H. Brown* in the Gulf of Maine. The source attribution was compared with the output from the Flexpart model. In general, there was a good qualitative agreement between urban CO in the measurements and the model. However, the model over-predicted the observed urban CO, indicating that emissions inventories for this trace gas may be too high as observed by others. The agreement between measured and modeled forest-fire CO was also quite good; in this case, the model reproduced the measurements quantitatively, indicating that emissions from forest fires are accurately represented in the inventories. This study allows us to estimate the total emissions of CO due to forest fires in Alaska and western Canada as 22 Tg during the measurement period in 2004, in quite good agreement with a previous study that used satellite data for CO and an inverse-model estimate of the emission sources.

PM-02: Response of Natural Systems to Perturbations

NGDC07: Anthropogenic Remote Sensing

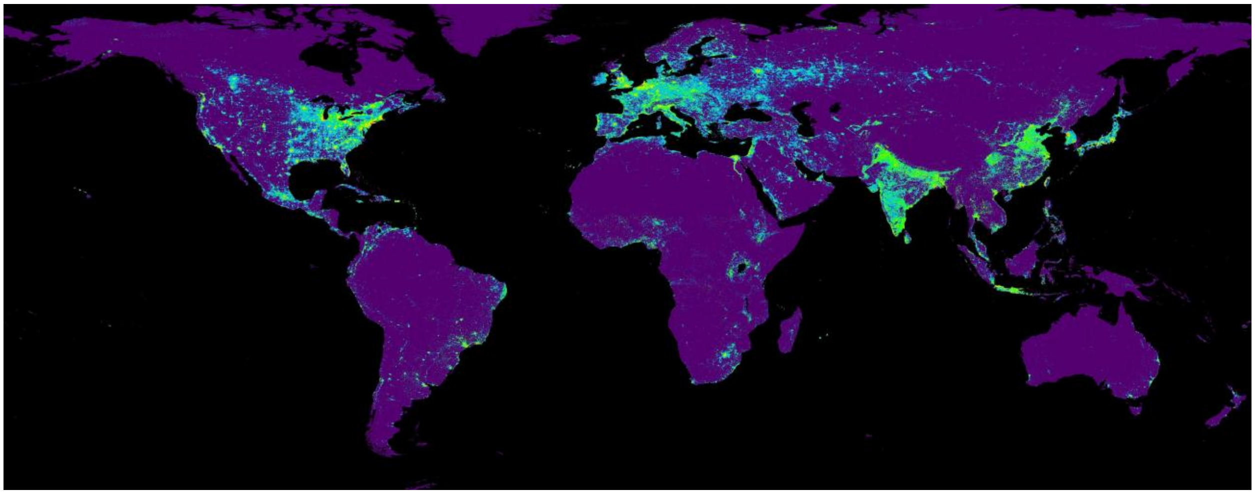
GOAL:
Provide spatial and temporal depictions of human activities based on satellite detection and mapping of population centers, fires, gas flares, and heavily lit fishing boats.

MILESTONE NGDC07.1:
Produce the first global ~1 kilometer map of the density of constructed impervious surface areas.

ACCOMPLISHMENTS NGDC07.1:
Although exact numbers are elusive, there is a general consensus that in the past 30 years the world's population has had the highest absolute increase in human history. Additionally, it is agreed that more and more of the world population will live in urbanized areas, leading to increases in impervious surfaces world wide. Increases in impervious surface area (ISA) have a widespread impact on the environment. The effects range from altering hydrology and temperature to impact on the carbon cycle. To understand these changes, ISA around the globe must first be mapped. To this end, a global map of ISA has been created and made available to the public. Three data sets were used in the process: Nighttime Lights from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS); population counts from Landscan (2004); and aerial photographs collected along urban to rural development transects for 13 major cities in the United States. All the data were converted to 1 km-equal area grids. Gridded point counts were performed on a 1-km aerial photo tile (matching a 1-km grid cell in the other two data sets) to estimate the percentage of ISA in each tile. Linear regression was then used to develop a model for estimating percentage of ISA based on the Nighttime Lights and population. The global map of ISA can be used for studies in a variety of fields including hydrological modeling, analyzing terrestrial carbon dynamics, and urban growth modeling.

MILESTONE NGDC07.2:
Develop near-real-time global nighttime lights mosaic processing and access system

ACCOMPLISHMENTS NGDC07.2:
CIRES personnel in collaboration with NOAA scientists have implemented a prototype, near real-time visible and thermal global mosaic generation and online access system using nighttime data from the Operational Linescan System (OLS) sensor on the Defense Meteorological Satellite Program (DMSP) spacecraft. The real-time mosaic products are now available to authorized users of the DMSP nighttime lights product for assessment and comment via web mapping service (WMS) and Web Coverage Service (WCS). Further testing and product refinement are expected as users become familiar with the product and develop Earth-imagery analysis capabilities based on the availability of these mosaics. Real-time imagery using the DMSP Nighttime Lights has immediate application in natural-disaster mitigation, homeland security applications, and military operations.

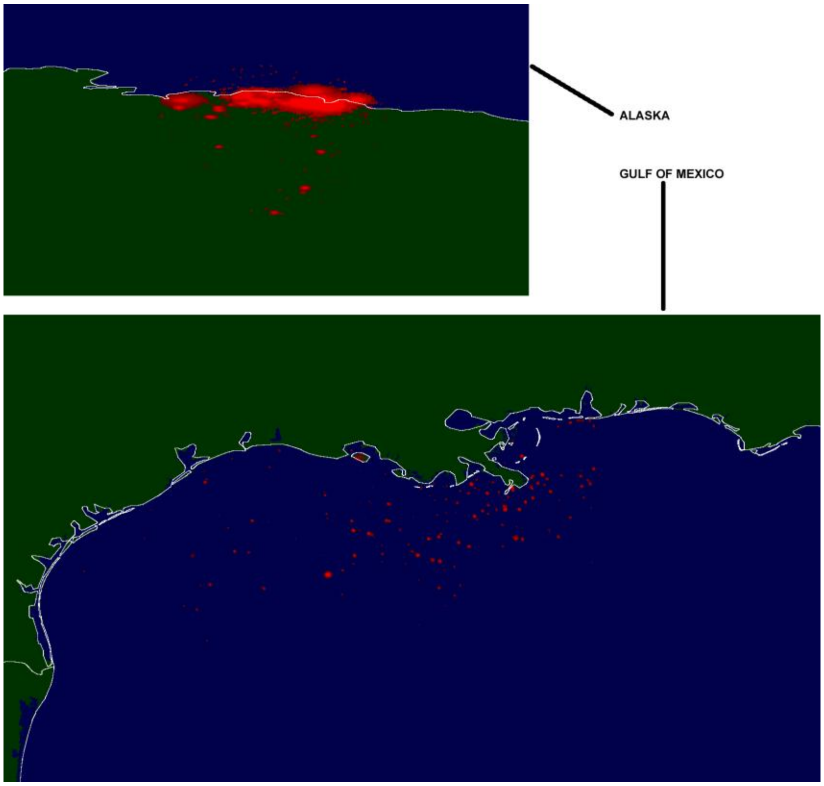


Near-real time global nighttime lights mosaic.

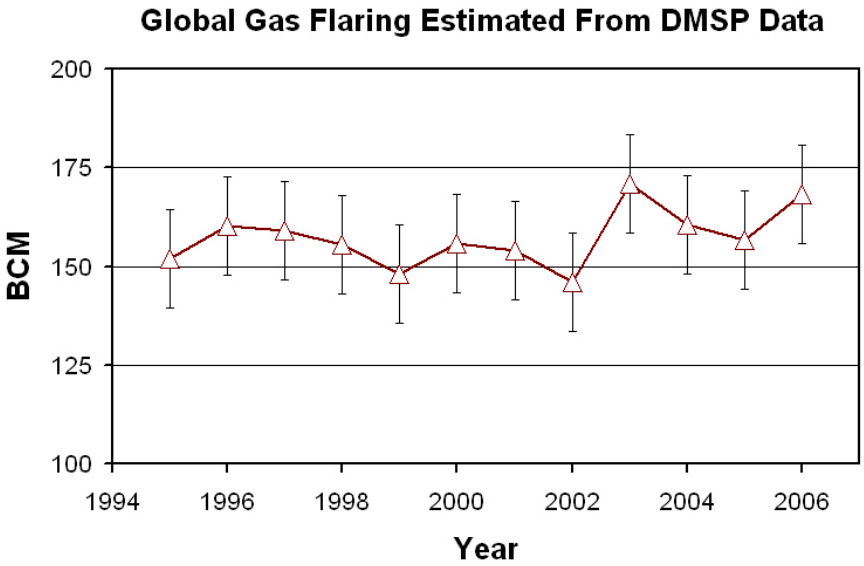
MILESTONE NGDC07.3:
Develop time series of national gas flaring volume estimates extending from 1992 through 2005.

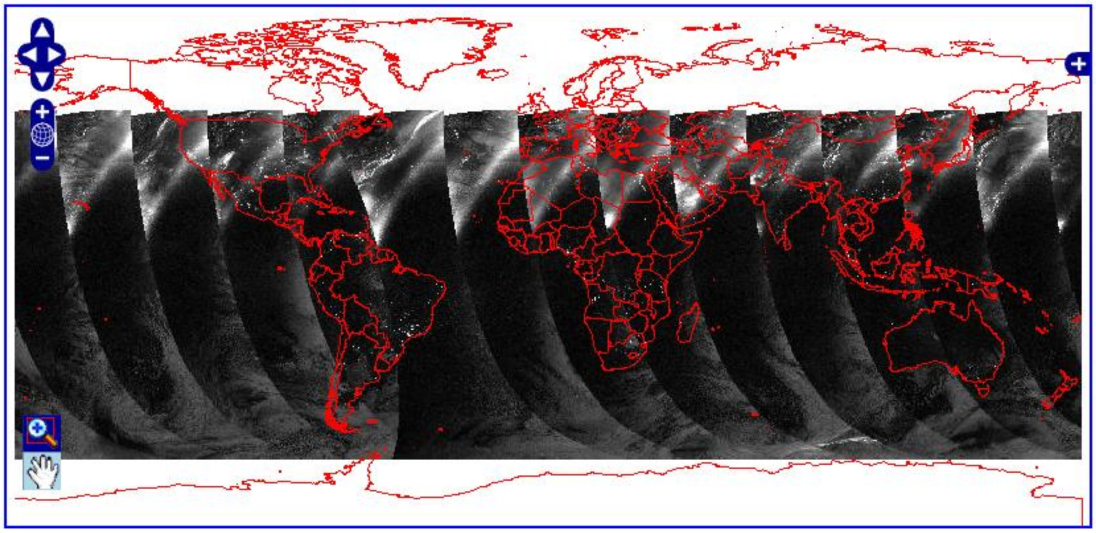
ACCOMPLISHMENTS NGDC07.3:
CIRES scientists have assisted NOAA in the development of annual estimates of national and global gas flaring for the years 1995 through 2006 using low-light imaging data acquired by the Defense Meteorological Satellite Program (DMSP) spacecraft. These gas flaring estimates are based on a calibration procedure developed using known national gas flaring volumes and data from individual gas flares. Using the Earth-imagery data from DMSP, NOAA

has shown that the global gas flaring volume has remained largely stable over the past twelve years and in the range of 150 to 170 billion cubic meters (BCM) per year. In 2006, the gas flaring estimate of 168 BCM represented 27% of the natural gas consumption by the United States with a potential market value of $69 billion. Another factor to consider is that the global gas flaring adds more than 84 million metric tons of carbon to the atmosphere each year. Capture and effective use of the flared gas is an obvious candidate in efforts to reduce global carbon emissions. Global gas-flare imagery and estimates of flaring by country:



http://www.ngdc.noaa.gov/dmsp/interest/gas_flares.html.



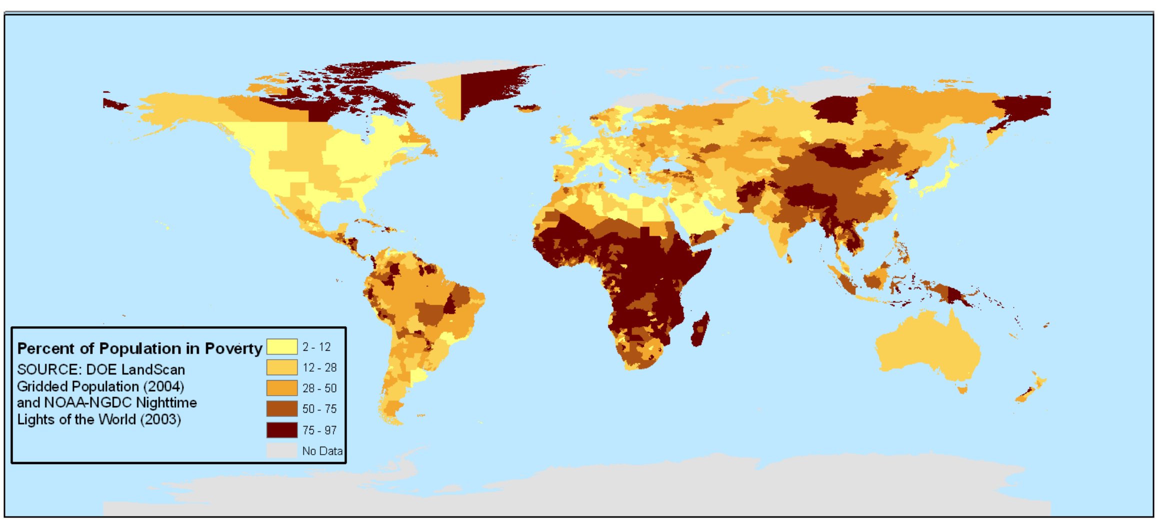


Time series of national gas flaring volume estimates extending from 1992 through 2005.

MILESTONE NGDC07.4:
Develop the first global map of poverty rates derived from satellite data.

ACCOMPLISHMENTS NGDC07.4:

CIRES has assisted NOAA in developing a global poverty map that has been produced at 30-arc second resolution using a derived poverty index calculated by dividing population count (LandScan 2004) by the brightness of satellite-observed nighttime lighting for the Defense Meteorological Satellite Program (DMSP) spacecraft. Inputs to the LandScan product include satellite-derived land cover and topography, plus human settlement outlines derived from high-resolution imagery. The poverty estimates have been calibrated using national-level poverty data from the World Development Indicators (WDI) 2006 edition. The total estimate of the numbers of individuals living in poverty is 2.3 billion, slightly under the WDI estimate of 2.6 billion. This significant work demonstrates a new technique for determining global poverty rates. It is expected that this technique will become increasingly more accurate as new reference data for calibration of poverty estimates become available and as improvements are made in the satellite observation of human activities related to economic activity and technology access. *http://www.ngdc.noaa.gov/dmsp/download_poverty.html*.



Develop the first global map of poverty rates derived from satellite data.

Scientific Theme: REGIONAL PROCESSES

RP-01: **Regional Hydrologic Cycles in Weather and Climate**
PSD11: Water Cycle

RP-02: **Surface/Atmosphere Exchange**
PSD12: Air-Sea Interaction

RP-03: **Regional Air Quality**
CSD08: Regional Air Quality
GMD06: Baseline Air Quality
GSD02: Regional Air Quality Prediction
PSD13: Air Quality

RP-04: **Intercontinental Transport and Chemical Transformation**
CSD05: Tropospheric and Stratospheric Transport and Chemical Transformation

RP-05 **Aerosol Chemistry and Climate Implications**
CSD09: Aerosol Formation, Chemical Composition, and Radiative Properties

RP-01: Regional Hydrologic Cycles in Weather and Climate

PSD11: Water Cycle

GOAL:
Improve weather and climate predictions through an increased knowledge of regional and global water cycle processes.

> ***MILESTONE PSD11.1:***
> Plan and execute the 2007 HMT-West (Hydrometeorology Testbed) field campaign in the northern California American River basin, located in the Sierra Nevada Mountains west of Lake Tahoe and east of Sacramento. This effort will involve deployment of several instrument systems utilized in HMT-West 2006 deployment in the American River Basin that will yield critical new understanding of orographic influences on airflow and precipitation growth over the Sierra Nevada mountains as well as streamflow response. CIRES investigators will be key participants and contributors to this activity.

ACCOMPLISHMENTS FOR PSD11.1:
The second year of full-scale field operations for HMT in the American River Basin (HMT-West 2007) was conducted from November 30, 2006 to March 22, 2007. The winter was drier than normal in the area, and only seven intensive operating periods (IOPs) were conducted, compared to fourteen in the previous wetter-than-normal winter. Not surprisingly, streamflow was also much reduced during HMT-West 2007 compared to HMT-West 2006. However, two of the seven IOPs were very large storms; one dropped nine inches of rainfall (IOP 5) and the other dropped three feet of snow at Blue Canyon (IOP 7). Concentrated arrays of unattended instruments, including wind profilers, S-band precipitation profilers, various disdrometers, conventional and experimental precipitation and snow gauges, soil moisture sensors, stream level gauges, and surface meteorological stations monitored atmospheric and hydrologic conditions continuously for the entire four months. These observations were augmented during IOPs by manned operations of the NSSL SMART-R gap-filling Doppler radar and serial radiosonde launches by local students managed by ESRL PSD. Supplemental rawinsondes were released from Reno on three of the seven IOP's. Unfortunately, staffing limitations at Oakland allowed supplemental rawinsonde releases during part of only one IOP. Experimental, high-resolution (3 km) numerical weather-prediction models were run daily by ESRL GSD and produced probabilistic forecasts of various precipitation amounts in the Basin. Forecasts, crew deployments, and storm debriefings were discussed on daily conference calls among the NWS, ESRL, and NSSL participants of HMT-West 2007.

MILESTONE PSD11.2:
Develop and test an attenuation-based method to retrieve vertical profiles of rainfall rate from vertically pointing Ka-band radars.

ACCOMPLISHMENTS FOR PSD11.2:
A method to retrieve vertical profiles of rain rates was developed for application with the ARM vertically pointing Ka-band radars. Unlike traditional radar approaches, this method is based on reflectivity vertical gradient measurements and utilizes a linear relation between rain rate and the attenuation coefficient. Applications of the method to a number of rain events observed at the ARM instrumented sites indicated its robustness for rain rates greater than about 4 mm/h.

RP-02: Surface/Atmosphere Exchange

PSD12: Air-Sea Interaction

GOAL:
Perform cutting-edge micrometeorological and climatological research over the open ocean aboard research vessels, sea-based towers, and buoys.

MILESTONE PSD12.1:
Process Eastern Pacific Investigations of Climate (EPIC) and the North American Monsoon Experiment (NAME) data sets, provide a detailed analysis of these air-sea interaction data products, and make the final data set publicly available. Deployment on new excursions within the EPIC STRATUS region is imminent, as is a cruise in African Monsoon Multidisciplinary Analyses (AMMA) region.

ACCOMPLISHMENTS FOR PSD12.1:
CIRES scientists participated in STRATUS 2006 and AMMA 2007 cruises. Data from 25 cruises are now on the ESRL/PSD archive (*ftp://ftp.etl.noaa.gov/et6/archive*).

MILESTONE PSD12.2:
Parameterization of sea spray will continue as part of the NOAA hurricane studies.

ACCOMPLISHMENTS FOR PSD12.2:
The sea-spray parameterization work was re-invigorated with a grant from the Joint Hurricane Testbed (JHT). A new version was developed that uses inputs for kinetic energy lost to wave breaking, friction velocity, wave height, and wave period. This version was tuned to the University of Miami MM5 coupled ocean-atmosphere-wave model and UM has done some preliminary hurricane simulations. CIRES scientists are now collaborating with the University of Rhode Island on a similar approach using the GFDL wave model planned for the HWRF. A new version of the sea-spray parameterization was developed. This model uses inputs for kinetic energy lost to wave breaking, friction velocity, wave height, and wave period.

MILESTONE PSD12.3:
Further quantify the air-sea transfer of gases and use a detailed physical analysis of data obtained from the Post-GasEx surface processes experiments to evaluate and improve gas-transfer parameterizations. Participate in the 2006 TexAQS Air Quality Study in Houston and deploy a ship-based system for ozone flux measurements.

ACCOMPLISHMENTS FOR PSD12.3:
Work continued with parameterizations for CO_2, ozone and DMS. Ozone data from the TexAQS and STRATUS 2006 cruises will be used to evaluate the ozone parameterization.

MILESTONE PSD12.4:
Develop a robust ship-based system for routine ship-based CO_2 flux measurements that will be integrated into the existing ESRL-PSD ship-based turbulent flux measurement system.

ACCOMPLISHMENTS FOR PSD12.4:

This project involves the repackaging of fast CO_2 sensors to permit continuous, unattended deployment on the NOAA R/V *Ronald H. Brown*. The goal is to obtain an extensive database of CO_2 flux and transfer velocity for a variety of verification and parameterization development objectives. The project has been underway for about a year. A system has been designed, sensors acquired, and tested at the pier at Duck, NC. The system was field tested on a Norwegian ship in the summer of 2006. The data are presently being evaluated. An improved version of the sensor will be deployed on the GOMECC cruise in July 2007.

> ***MILESTONE PSD12.5:***
> Create a multi-year global oceanic data set of near-surface temperature and humidity using a multi-sensor satellite retrieval method recently developed at the ESRL Physical Sciences Division.

ACCOMPLISHMENTS FOR PSD12.5:

A 12-year (1993-2004) global oceanic data set of near-surface humidity has been developed using SSM/I and SSM/T-2 satellite sensors, and a 7-year (1999-2005) data set of both near-surface humidity and temperature has been developed combining AMSU-A and SSM/I satellite sensors. Updated regression coefficients using an enhanced training data set generally provide less bias than the previous version and particularly improve the Qa retrievals exceeding 16 g/kg. A stability correction was introduced to the humidity retrieval to repair wet biases in the summertime North Pacific observations that often exceeded 3 g/kg. Multi-year comparison with I-COADS indicates a smaller bias and rms difference when compared with existing single-sensor SSM/I retrieval methods. Ultimately, improvements in these Ta and Qa products will help improve retrievals of latent and sensible heat fluxes derived from air-sea bulk turbulent flux models. Heat fluxes derived using these products and the COARE version 3 bulk model are currently being conducted. Products include:

- A 12-year near-surface humidity data set of daily mean 1-degree data derived from SSM/I and SSM/T-2 observations
- A 7-year near-surface humidity and temperature data set of daily mean 1-degree data from AMSU-A and SSM/I observations.
- 0.5 degree/3-hourly grid data are currently available for 1999 but will be extended to the same time periods as the 1 degree/daily averaged data given above.

> ***MILESTONE PSD12.6:***
> Study and parameterization of stable boundary-layers as part of the NOAA/NSF Polar Programs.

ACCOMPLISHMENTS FOR PSD12.6:

Structure of the stable boundary layer (SBL) in the Arctic has been examined based on measurements made during the Surface Heat Budget of the Arctic Ocean experiment (SHEBA). Turbulent and mean meteorological data collected at five levels on a 20-m tower over the Arctic pack ice during eleven months of measurements cover a wide range of stability conditions, from the weakly unstable regime to very stable stratification. According to SHEBA data, stratification and the Earth's rotation control the SBL over a flat rough surface. Traditional Monin-Obukhov similarity theory works well in the weakly stable regime. As stability increases, the near-surface turbulence is affected by the turning effects of the Coriolis force (the turbulent Ekman layer). In this regime, the surface layer, where the turbulence is continuous, may be very shallow (less than 5 m). Turbulent transfer near the "critical Richardson number" is characterized by small but still significant heat flux and negligible stress. The supercritical stable regime where the bulk Richardson number exceeds a critical value 0.2 is associated with collapsed turbulence and the strong influence of the Earth's rotation, even near the surface. The comprehensive data set collected during SHEBA allows study of the profile stability functions of momentum (nondimensional gradient of wind-speed), sensible heat (non-dimensional gradient of temperature), and derivative quantities such as the turbulent Prandtl number and the gradient Richardson number in detail, including the very stable case.

New parameterizations for the profile stability functions in stable conditions are proposed to describe the SHEBA data; these cover the entire range of the stability parameter z/L from neutral to very stable conditions, where L is the Obukhov length and z is the measurement height. In the limit of very strong stability, stability functions of momentum follows the "1/3" dependence in the very stable regime (in log-log coordinates), whereas stability functions of sensible heat flux initially increases with increasing z/L, reaches a maximum at about z/L=10, and then tends to level off with increasing z/L

RP-03: Regional Air Quality

CSD08: Regional Air Quality

GOAL:
Carry out laboratory measurements, atmospheric observations, and diagnostic analyses that characterize the chemical and meteorological processes involved in the formation of pollutant ozone and fine particles. Undertake research that contributes to the enhancement of air quality prediction and forecasting capabilities.

> ***MILESTONE CSD08.1:***
> Plan and execute the 2006 Texas Air Quality Study (TexAQS) field study.

ACCOMPLISHMENTS FOR CSD08.1:
In 2006, NOAA/ESRL and CIRES led a major multi-institutional intensive field program that focused on investigating important scientific questions that are common to both climate and air quality. The NOAA/ESRL and CIRES components of the program are the Texas Air Quality Study (TexAQS) and the Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS). This intensive field study provided significant new information that is required to afford a better understanding of the sources and atmospheric processes responsible for the formation and distribution of ozone and aerosols in the atmosphere and the influence that these species have on the radiative forcing of climate regionally and globally, as well as their impact on human health and regional haze. The study was carried out between July 1 and October 15, 2006, throughout Texas and the northwestern Gulf of Mexico. Three NOAA/ESRL and CIRES' platforms were deployed: a NOAA WP-3 aircraft, a NOAA Twin Otter, and the NOAA/ESRL R/V *Ronald H. Brown*. All objectives of this portion of the study were met.

TexAQS 2006 was the NOAA/ESRL and CIRES air quality component of this field experiment. This field campaign investigated the sources and processes that are responsible for photochemical pollution and regional haze during the summertime in Texas. The focus of the study was the transport of ozone and ozone precursors within the state and the impact of the long-range transport of ozone or its precursors into the state. In this regard, special attention was paid to nighttime chemistry and transport. The study also investigated how the various urban, industrial and natural sources of aerosols and aerosol precursors within the state, and the transport of aerosols from outside the state, contribute to the regional haze that is observed in the state.

The research carried out during the TexAQS/GoMACCS 2006 field campaign was organized around the following five research areas, each with an associated overarching science question.

- Emissions verification and assessment – How well do current inventories represent actual emissions for cities, point sources, ships, and vegetation?
- Transport and mixing – What are the relative amounts of pollution imported to Texas and exported from the continental boundary layer to the marine boundary layer and the free troposphere?
- Chemical transformation – How do gaseous and aerosol emissions evolve chemically and physically as they are transported away from the source regions to the remote atmosphere?
- Aerosol properties and radiative effects – What are the chemical, physical, and optical properties of the aerosol in this region, and how do these properties affect regional haze and aerosol direct and indirect radiative forcing of climate?
- Forecast models – What is the current skill of air-quality forecast models on local, regional and global scales, and what improvements can be made to enhance the accuracy and extend the periods of these forecasts?

Initial policy-relevant findings from this study that were obtained by NOAA/ESRL and CIRES scientists have been incorporated into a Rapid Science Synthesis Report that is posted on the web. Initial scientific findings from the study were presented at a workshop that was held in Austin from May 29 to June 1, 2007. NOAA/ESRL and CIRES scientists at this workshop presented seventy posters and oral presentations. The results of this portion of the study will also be reported at the Fall Meeting of the AGU in December 2007.

MILESTONE CSD08.2:
Evaluate sulfur dioxide emissions from power plants sampled during the New England Air Quality Study campaign using new ultraviolet spectroscopy methods.

ACCOMPLISHMENTS FOR CSD08.2:
Sulfur dioxide (SO_2) emissions are regulated under the National Ambient Air Quality Standards (NAAQS) as criteria pollutants due to their role in the formation of acid rain. However, SO_2 also contributes to other atmospheric chemistry processes such as the formation of sulfur-containing particles that play a critical role in climate change. The main emitter of SO_2 in the United States is power plants, which account for 67% of the SO_2 released into the atmosphere. Accurate measurements of SO_2 from power points are therefore critical in order to understand their impacts on regional air quality.

Therefore, a near-ultraviolet (UV) spectrometer was deployed during the New England Air Quality Study 2004 (NEAQS2K4) aboard the NOAA WP-3D aircraft to measure SO_2 emissions from point sources. Using the differential optical absorption spectroscopy (DOAS) method, SO_2 and oxygen dimer (O_4) differential slant-column densities are retrieved from the UV spectra. The SO_2 differential slant-column densities are used to identify point source plumes. In a novel approach, the O_4 differential slant-column densities are used to calculate an air mass factor (AMF) or path-length enhancement of photons through the atmosphere. The AMF is used to convert the SO_2 differential slant-column densities into SO_2 differential vertical-column densities. From the SO_2 differential vertical-column densities, SO_2 emission fluxes from point sources sampled during NEAQS2K4 are calculated. The measured SO_2 emission fluxes are compared to the reported SO_2 emission fluxes from the point sources. The results show good agreement between the measured and the reported point sources of SO_2 emission fluxes.

MILESTONE CSD08.3:
Gather data during the 2006 Texas Air Quality study to investigate the role of meteorological processes in transport and mixing of pollutant species in the nighttime stable boundary layer (SBL).

ACCOMPLISHMENTS FOR CSD08.3:
The NOAA ship-based Doppler lidar was used to investigate the structure of the nighttime boundary layer over the Gulf of Mexico, corresponding to a marine boundary layer, and close to shore near Houston and Galveston, where the environment was more indicative of a terrestrial boundary layer. In the Gulf, CIRES researchers found that Doppler lidar-derived mixing heights and flux-tower surface heat flux measurements showed little to no indication of a diurnal cycle. Closer to shore, in places like Barbour’s Cut and the Houston Ship Channel, they observed frequent nocturnal low-level jets that were always followed by low-ozone days (as measured in those locations). Depending on background levels and other atmospheric conditions, nights with low-wind speeds (i.e., without nocturnal low-level jets) were more likely to be followed by high ozone days. At the Galveston Bay and ship channel locations, strong diurnal cycle characteristics in lidar-derived mixing layer heights were also observed, with nighttime mixing heights as low as 150 meters during low-level jets, and up to 500 meters during nights with low-wind speed profiles.

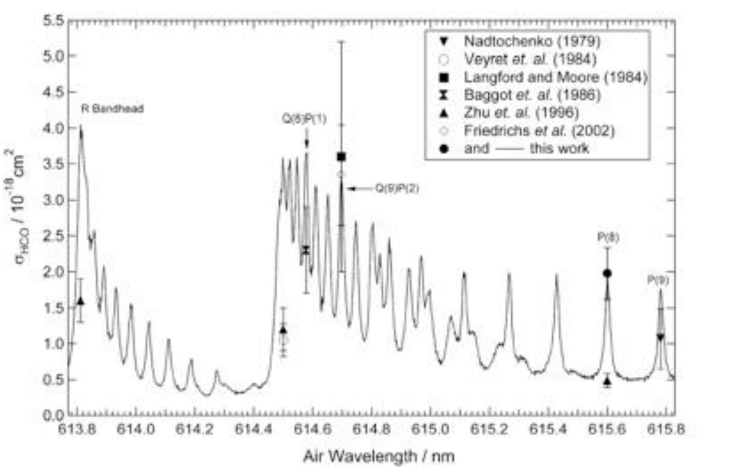
MILESTONE CSD08.4:
Contribute to the 2006 TexAQS/GoMACCS Air Quality Study in the Houston, TX, vicinity by deploying several lidars on an aircraft and a research ship.

ACCOMPLISHMENTS FOR CSD08.4:
An airborne ozone lidar and two shipborne lidars (a Doppler wind lidar and another ozone and aerosol profiling lidar) were successfully deployed during the 2006 Texas Air Quality Study (TexAQS II). These three remote-sensing systems produced extensive, multi-dimensional data sets of wind speed, wind direction, atmospheric turbulence, ozone concentration, aerosol backscatter and extinction, and mixed-layer height. Results obtained from the analysis of these data sets will be key in addressing several important science questions regarding local buildup and regional transport of pollutants in eastern Texas. The analysis of the lidar data sets is ongoing, but several important findings have already emerged and these results have been presented at the TexAQS II Principal Findings Data Analysis Workshop in Austin, TX, at the end of May 2007.

The airborne lidar measurements were used to provide mesoscale estimates of background ozone under different synoptic flow regimes. Background ozone levels were significantly higher when air advected into eastern Texas was continental rather than marine in origin. The highest observed ozone background value was 86 ppb (which is above the 8-hour NAAQS ozone standard) and occurred after several days of continuous easterly flow conditions. In order to quantify the export of pollutants from strong localized sources to surrounding rural areas, airborne ozone lidar data from flight transects downwind of Houston and Dallas were used to compute the horizontal flux of ozone produced by these two metropolitan areas. The ozone flux produced by the Houston metro area over an 8-hour period is equivalent to a 10-ppb increase in ozone over an approximately 10,000 square-mile area, assuming a 2-km-deep boundary layer. The ozone flux for the Dallas metro area was about a factor of 2-3 smaller than that observed for Houston. Other applications of the airborne lidar data include the investigation of the correlation between boundary layer depth and ozone concentration downwind of source regions, the relationship between wind speed and above-background ozone concentrations, and the enhancement of mixing height associated with the urban heat island effect. Data from the ship-borne Doppler lidar were utilized to characterize the land sea breeze circulation, low-level jets, and vertical mixing, all important meteorological processes that contribute to pollution buildup or depletion in the Houston area. In particular, vertical wind velocity data from the Doppler lidar provided information on the temporal evolution and spatial distribution of mixed-layer height over the Gulf of Mexico and Galveston Bay. It was found that near the shore, mixing heights can vary greatly, from ~150 meters in the presence of a nocturnal low-level jet, to 2 km when offshore flow advects a deep well-mixed boundary layer over the water.

MILESTONE CSD08.5:
Measure the absorption cross sections for formyl (HCO) radicals to high accuracy for use in future laboratory studies of aldehyde (RCHO) photochemistry.

ACCOMPLISHMENTS FOR CSD08.5:
Absorption cross sections for HCO were determined at 295 K using pulsed laser photolysis combined with cavity ring-down spectroscopy. Formyl radicals (HCO) were produced from the reaction of atomic chlorine, generated by photolysis of Cl_2 at 335 nm, with formaldehyde. The concentration of HCO was calibrated using two independent photochemical methods. The peak cross section of the P(8) line was determined to be $(1.98 \pm 0.36) \times 10^{-18} cm^2$, and the intensity of the entire band was normalized to this line. The results from this work will be used in future studies of the aldehyde UV photolysis.



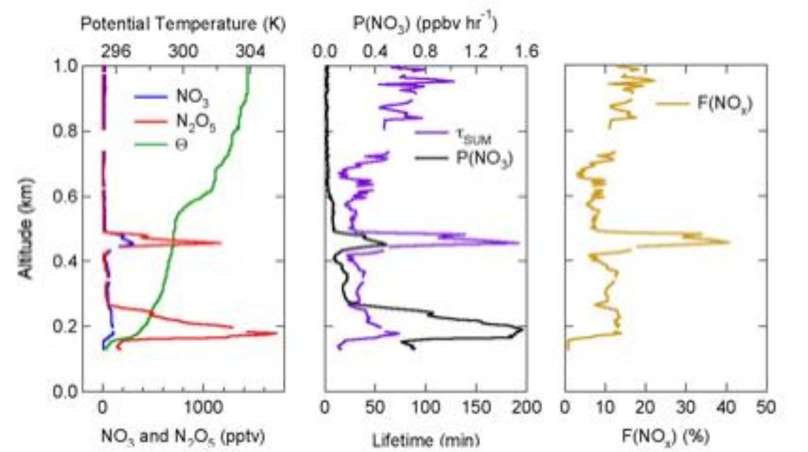
Comparison of reported HCO absorption cross-section data available in the literature to that measured in this work. The solid line is the spectrum of HCO measured in this work normalized to the average P(8) cross section of $(1.98 \pm 0.36) \times 10^{-18} cm^2$.

MILESTONE CSD08.6:
Measurement of vertical profiles in NO_3, N_2O_5, and related compounds within and above the shallow, nocturnal boundary layer.

ACCOMPLISHMENTS FOR CSD08.6:
Vertical profiles of the nocturnal nitrogen oxides, NO_3 and N_2O_5, and related trace gases, aerosols and meteorology, have been measured within and above the shallow nocturnal boundary layer in four recent field campaigns. These include the 2004 New England Air Quality Study (NEAQS 04) and the 2006 Texas Air Quality Study (TexAQS 2006), during which these profiles were measured from the NOAA P-3 aircraft, and two studies at Erie, CO (30 km west of Boulder and 50 km north of Denver) in 2004 and 2007, during which profiles were measured from a movable carriage on a 300-m tower. There are currently two publications from this work. Results from the Erie 2004

study appeared in *Atmospheric Chemistry and Physics* in January 2007, and results from NEAQS 2004 are currently in press in the *Journal of Geophysical Research*. Results from TexAQS 2006 and Erie 2007 are anticipated in the coming year.

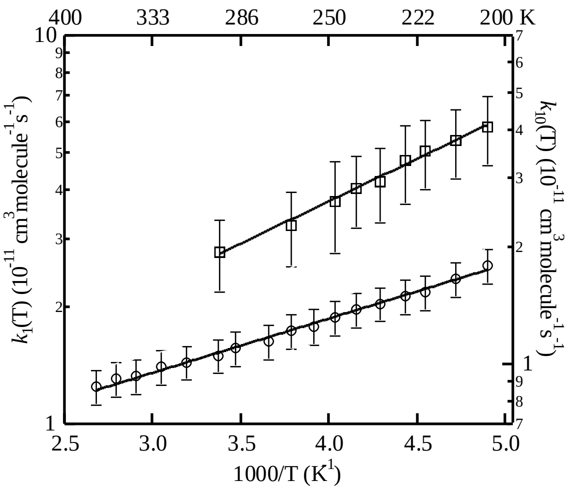
The figure below shows an example of a vertical profile from the TexAQS 2006 study. The left graph is NO_3 and N_2O_5 along the bottom axis and potential temperature along the top axis against altitude on the vertical axis. The structure in the potential temperature profiles shows the low-level stratification of the nighttime atmosphere, with distinct regions of stability near 200 and 600 m. Associated with each feature is a nitrogen oxide plume. The two right graphs show the formation rate of NO_3, $P(NO_3)$, the lifetime of NO_3 and N_2O_5, or their concentrations divided by their formation rate, and the partitioning among nitrogen oxides, F(NOx), a measure of the amount of NOx present as NO_3 and N_2O_5. The two nitrogen oxide plumes are less than 100 m in depth, and have distinctly different chemistry, as measured by their lifetimes and partitioning. Because this chemistry is an important factor in determining the atmospheric residence time of emitted NOx pollution and the nocturnal loss rates for O_3 pollution, and because it varies on small spatial scales at night, detailed studies of the vertical distributions of these compounds are critical to understanding their role in chemical transformations of pollutants and regional air quality.



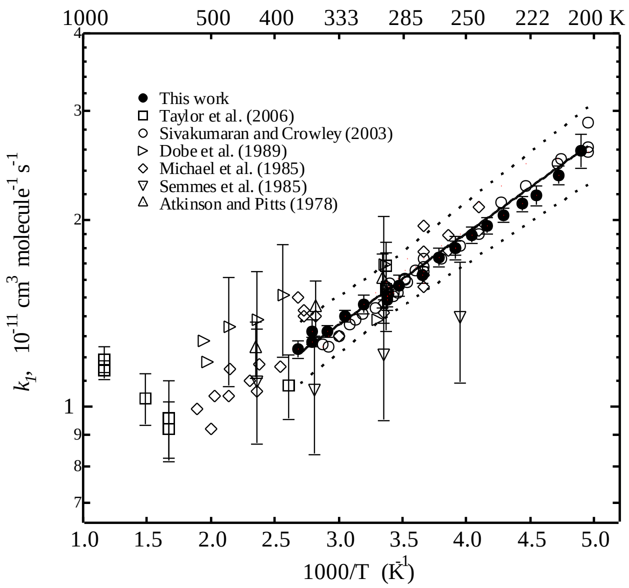
MILESTONE CSD08.7:
Measure the rate coefficient for the reaction of hydroxyl radical with acetaldehyde, $CH_3C(O)H$, over the range of temperatures common to the troposphere and lower stratosphere to better elucidate the role of oxygenated hydrocarbons in radical (HOx) and ozone production.

ACCOMPLISHMENTS FOR CSD08.7:
CIRES researchers measured the rate coefficient for the reaction of hydroxyl radical with acetaldehyde, $CH_3C(O)H$, over the range of temperatures common to the troposphere and lower stratosphere (between 204 and 373 K) to better elucidate the role of oxygenated hydrocarbons in radical (HOx) and ozone production. This research provided rate coefficient data for the accurate determination of the atmospheric loss of acetaldehyde by reaction with the OH radical. Knowledge of atmospheric lifetimes and chemical destruction pathways for acetaldehyde (an oxygenated hydrocarbon) is important for characterizing climate-chemistry coupling.

The temperature dependence of the rate coefficients for the reaction of OH with CH_3CHO was measured using pulsed laser photolytic production of OH coupled with its detection via laser-induced fluorescence. Acetaldehyde was purified and its concentrations were measured using three methods: FTIR spectroscopy, UV absorption at 184.9 nm and gas flow rates. The rate coefficients for the title reaction between 204 and 373 K are reported in the Arrhenius format: $(5.32\pm0.74)\times10^{-12}\exp[(314\pm37)/T]$, which gives $k1(298\ K) = (1.52\pm0.15)\times10^{-11}$, in units of $cm^3\ molecule^{-1}\ s^{-1}$. The rate coefficients for the reaction of OH(v = 1) with CH_3CHO between 204 and 296 K were determined and is expressed in the Arrhenius format: $(3.5\pm1.4)\times10^{-12}\ \exp[(500 \pm 90)/T]$, which gives a value of $(1.9\pm0.6)\times10^{-11}\ cm^3\ molecule^{-1}\ s^{-1}$ at 298 K. The obtained results are compared with previous data. Atmospheric implications of the data are discussed.



Left. Arrhenius plots for k1(T) (circles) and k10(T) (squares) from the present study. The individual k1(T) and k10(T) were obtained from linear least squares analysis of all and D-D0, respectively, vs. [CH_3CHO] at each temperature. Error bars include precision and estimated systematic errors at the 95% confidence level.



Right. Comparison of k1(T) from various previous studies. The solid line is the unweighted fit of the data of Sivakumaran and Crowley and of the present measurements to an Arrhenius expression. The dashed lines represent the upper and lower bounds of k1(T) at the 95% confidence level.

GMD06: Baseline Air Quality

GOAL:

Study intercontinental transport events to improve our understanding of their importance in affecting overall air quality and its impacts on public health.

MILESTONE GMD06.1:

Carry out daily ozone profile measurements at Trinidad Head, CA and Boulder, CO during the intensive Measurements of Ozone over North America (MONA) study in August 2006.

ACCOMPLISHMENTS FOR GMD06.1:

During August 2006, near daily ozonesondes were launched from fourteen sites in North America stretching from Barbados and Mexico City in the south to southern Canada in the north and from the Pacific to the Atlantic coasts. The purpose was to determine the role of various sources to the tropospheric ozone budget over North America. Over 400 ozone and meteorological vertical profiles were obtained during the month, including the daily soundings from Trinidad Head, CA and Boulder, CO. A key finding of this intensive campaign was the important contribution to the upper tropospheric (6-11 km) ozone budget from lightning-produced nitrogen oxides [Cooper et al., 2007]. This enhancement is collocated with the summertime upper tropospheric anticyclone centered over the southeastern U.S. Convection associated with the North American summer monsoon located at the westernmost edge of the anticyclone is the primary source of the lightning-produced nitrogen oxides. Ozone in the upper troposphere over the Southeast U.S. was nearly twice the amount seen in air entering the west coast of the U.S.

MILESTONE GMD06.2:
As part of the Department of Energy Atmospheric Radiation Measurement Program, deploy a mobile measurement facility to the Murg Valley in Heselbach, Germany. The instrument package measures aerosol radiative, hygroscopic and cloud-forming properties.

ACCOMPLISHMENTS FOR GMD06.2:
The Aerosol Observing System was deployed to the Murg Valley in Germany in March of 2007. All instruments have operated well, and data have been archived in both the NOAA ESRL archive and the Department of Energy Atmospheric Radiation Program archive (*http://www.arm.gov*). Despite being a rural region, the aerosol of the Black Forest region in Germany is relatively polluted with a high concentration of absorbing aerosol. In August 2007, a comparison of the NOAA aerosol scattering coefficient as a function of relative humidity will take place with the instruments from the Paul Scherrer Institute of Switzerland. The next deployment of this system will be to the Tai Lake Region south of Shanghai, China.

GSD02: Regional Air Quality Prediction

GOAL:
Design and evaluate new approaches for improving air-quality prediction.

MILESTONE GSD02.1:
In collaboration with national and international scientists, implement generalized tools such as the Kinetic PreProcessor (KPP) into the next version of the fully coupled Weather Research and Forecasting Chemistry (WRF/Chem) model.

ACCOMPLISHMENTS FOR GSD02.1:
In collaboration with the Max Planck Institute in Mainz, Germany, KPP was included in WRF/Chem in July 2006. It was improved further in May and June of 2007. KPP is now a part of WRFV2.2/Chem, which was officially released in March of 2007. Tutorial notes where prepared for WRF/Chem. These can be found on the web at *http://ruc.fsl.noaa.gov/wrf/WG11/2007_wrf_wksp.htm*.

MILESTONE GSD02.2:
Perform real-time weather/air-quality forecasts with WRF/Chem during the Houston 2006 field experiment.

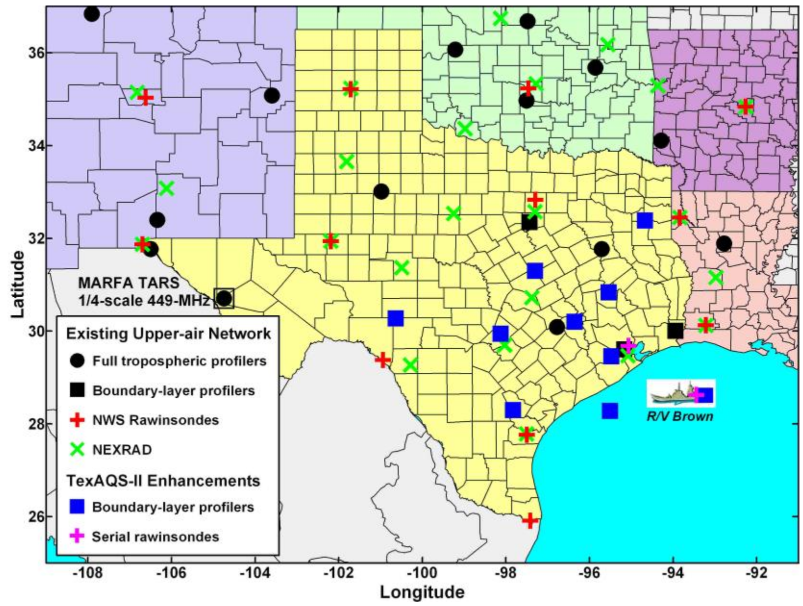
ACCOMPLISHMENTS FOR GSD02.2:
WRF/Chem was run in real-time to support the Texas 2006 Air Quality Field experiment. Results were presented in real-time at the Houston field operations center during August and September. Model results will be used to prepare publications and evaluate the model in comparison to other models as well as observations.

PSD13: Air Quality

GOAL:
Gather and analyze atmospheric observations to characterize meteorological processes that contribute to high-pollution episodes. Compare these measurements with air-quality forecasting model predictions to assess and improve research model performance.

MILESTONE PSD13.1:
CIRES investigators will participate in the second Texas Air Quality Experiment (TexAQS-II) by leading the deployment of six integrated wind profiling observing systems and two flux towers. The field study will occur in Aug and Sep of 2006.

ACCOMPLISHMENTS FOR PSD13.1:



CIRES investigator Allen White led the design of the enhanced wind profiler network for the 2006 Texas Air Quality Study (TexAQS-II). NOAA contributed eight wind profilers and Sonoma Technology contributed two. The network was designed specifically to address air pollution transport in East Texas as well as interstate pollution transport. The data from the wind profilers were incorporated into the NOAA wind profiler trajectory tool, which was available in near-real time for the Texas Air Quality Study (collaboration with CIRES investigators Christoph Senff, Irina Djalalova, and Dave White). The trajectory tool was used in mission planning of the various aircraft during the study. In post-experiment analysis, the tool will be used to better understand transport pathways during high pollution episodes. Products include TexAQS-II wind profiler data archive web browser at *http://www.etl.noaa.gov/et7/data/archive/UneditedNonActive/* and TexAQS-II interactive wind profiler trajectory tool at *http://www.etl.noaa.gov/programs/2006/texaqs/traj/*

MILESTONE PSD13.2:
CIRES investigators will help collect wind profiler, air/sea fluxes, ozone fluxes, and rawinsonde data onboard the NOAA R/V *Ronald H. Brown* during the TexAQS-II field study.

ACCOMPLISHMENTS FOR PSD13.2:

The systems were deployed on the NOAA R/V *Ronald H. Brown* for five weeks in July and August 2006 as part of the TexAQS project. All systems obtained data on the cruise. Data products are available at the PSD ftp site for this project *ftp://ftp.etl.noaa.gov/et6/archive/TexAQS_2006/RHB*.

MILESTONE PSD13.3:
Use data sets collected during TexAQS-II to develop specific results for the Rapid Science Synthesis Team. These findings will assist the state of Texas in development of their state implementation plans.

ACCOMPLISHMENTS FOR PSD13.3:

Several CIRES scientists in PSD and CSD contributed to the Rapid Science Synthesis Team Report, which was delivered to the Texas Commission on Environmental Quality soon after the 2006 Texas Air Quality Study field campaign ended. The preliminary report is available at *http://www.tceq.state.tx.us/assets/public/implementation /air/am/workshop/2006101213/RSST_Preliminary_Findings_Report_20061031.pdf*.

MILESTONE PSD13.4:
Publish analysis of measurements of air-sea fluxes and gas transfer in the New England experiment on the R/V *Ronald H. Brown* in August 2004.

ACCOMPLISHMENTS FOR PSD13.4:

Research conducted by CIRES staff on data sets collected onboard the NOAA R/V *Ronald H. Brown* during the 2004 New England Air Quality Study has culminated in several successful research publications in peer-reviewed journals.

RP-04: Intercontinental Transport and Chemical Transformation

CSD05: Tropospheric and Stratospheric Transport and Chemical Transformation

GOAL:
Carry out modeling studies and airborne and surface measurements of chemical species in order to elucidate the processes involved in the intercontinental transport of photochemical pollution.

> ***MILESTONE CSD05.1:***
> Use measurements from a fully instrumented NOAA P-3 aircraft to accurately and precisely characterize the chemistry of plumes of pollutants from urban areas as they are transported over the North Atlantic Ocean. Use recently developed fast-response instruments that measure both emitted trace gases (NO, CO, and others) and secondary products (HNO_3, O_3, and others) formed from chemical reactions that occurred in that atmosphere.

ACCOMPLISHMENTS FOR CSD05.1:
Measurements obtained from the NOAA P-3 aircraft in the summer of 2004 during the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) study have been used to examine the transport of pollutants from the United States over the Atlantic Ocean. A large number of studies have been performed, examples are highlighted below. The measurements have been used to test the ability of global chemical transport models to represent the sources, chemistry, and export of pollutants from North America to the free troposphere. The research shows a large U.S. anthropogenic contribution to global tropospheric ozone, which is an important greenhouse gas. The measurements have also been compared with those obtained by international collaborators across the Atlantic Ocean with the goal of improving the understanding of the mechanisms of pollutant transport from North America to Europe. Transport of air masses below 3-km altitude in the lower free troposphere was found to enhance ozone and is responsible for most pollution events observed at a remote site located in the Azores. Additionally, aircraft measurements obtained from Europe have been compared with those obtained from the P-3 to demonstrate a successful Lagrangian experiment by sampling air masses multiple times during transit across the North Atlantic Ocean. Lastly, the chemistry and transport of pollution plumes that occur during the first couple of days of transport were studied extensively by sampling plumes multiple times up to 1000 km downwind from east coast urban areas. These studies showed that stable stratification over the ocean often confines pollution to layers between 160 m and 1.5 km altitude, where the air did not interact with the surface. Consequently, the nitric acid abundance was considerably higher than previously observed over the continent, since the plumes were decoupled from the surface where nitric acid is rapidly removed. This is important because high levels of nitric acid that survive in the atmosphere for days will slowly photolyze to produce NOx, which allows for continuing ozone production.

RP-05: Aerosol Chemistry and Climate Implications

CSD09: Aerosol Formation, Chemical Composition, and Radiative Properties

GOAL:
Carry out airborne and ground-based experiments that characterize the chemical composition of radiatively important aerosols in the upper troposphere and at the Earth's surface.

> ***MILESTONE CSD09.1:***
> Use field data from the NOAA R/V *Ronald H. Brown* in combination with laboratory experiments to assess the effect of the molecular speciation of organic aerosols in their effectiveness as cloud condensation nuclei.

ACCOMPLISHMENTS FOR CSD09.1:
Data on the composition of the organic fraction of atmospheric aerosol were acquired aboard NOAA R/V *Ronald H. Brown* during the TexAQS/GoMACCS field campaign in August and September 2006. The mass spectra showed significant variations in the composition of the organic fraction of atmospheric aerosol on hourly to daily timescales. Data reduction was performed during fall 2006 to winter 2007, and instrument characterization experiments are

ongoing. Laboratory experiments are planned to examine the composition of secondary organic aerosol and its relation to aerosol hygroscopicity.

MILESTONE CSD09.2:
Plan for and participate in the Gulf of Mexico Atmospheric Composition and Climate Study in August/September 2006, specifically investigating the role of urban aerosol in cloud microphysics and cloud evolution in Houston.

ACCOMPLISHMENTS FOR CSD09.2:
During the summer of 2006, an airborne study of aerosol-cloud interactions was undertaken through a partnership between NOAA, the California Institute of Technology, the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS), and various university collaborators. The primary objectives of this study were to:

1. Study the regional-scale aerosol chemical, optical, and radiative properties in Texas/Gulf of Mexico;
2. Acquire an extensive data set on aerosol, cloud and radiation interactions to evaluate models that predict cloud drop number concentration, cloud evolution, and cloud radiative properties;
3. Provide sub-orbital support and validation for satellite remote sensing of aerosol and aerosol-cloud interactions.

The CIRPAS Twin Otter, the primary platform for this study, was instrumented with a suite of aerosol samplers, cloud probes, and radiation measurements. It performed 22 flights between August 21 and September 15. Fourteen of these focused on aerosol-cloud-radiation interactions. All 22 flights yielded valuable measurements of aerosol composition and optical properties from a range of Houston-area sources (urban aerosol, petrochemical plants, power plants, etc.) as well as aerosol transported to the region (Saharan dust and forest fires).

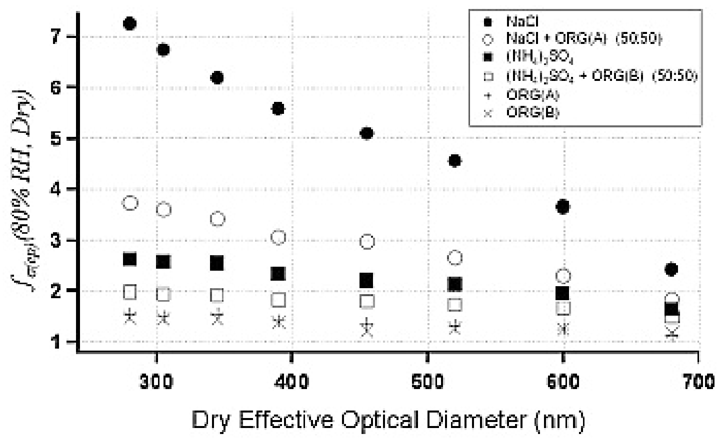
To date (with much of the analysis still in progress) a number of interesting results are emerging:

1. CIRES/CSD boundary layer model appears to capture successfully the main statistical properties of the cloud macroscale (cloud fraction and cloud size) and microphysical fields (liquid water and drop concentration).
2. Observed aerosol effects on cloud microphysics show that in the polluted air in Houston, a relatively small fraction of the aerosol accumulation mode is activated. This is in contrast to cleaner air where activated fractions are higher. The model simulations capture this low activated fraction reasonably well.
3. Clouds are significant sources of organic aerosol (oxalate).

MILESTONE CSD09.3:
Study the relative humidity dependence of aerosol light extinction for surrogate atmospheric aerosol using cavity ring-down aerosol extinction spectroscopy.

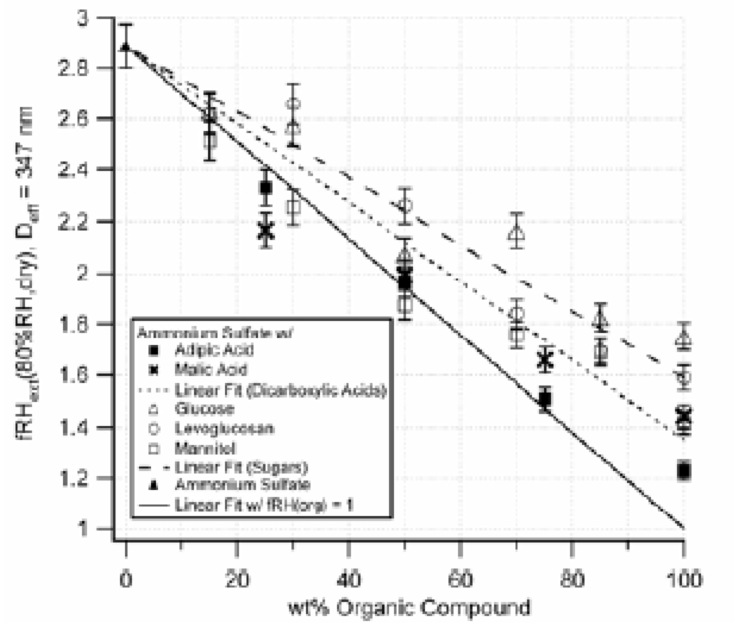
ACCOMPLISHMENTS FOR CSD09.3:
This laboratory research helps determine improved parameterization for the relative humidity dependence of aerosol light extinction for atmospheric aerosol and accuracy of radiative forcing calculations. The relative humidity dependence of aerosol light extinction ($f_{\sigma(ep)}$(80%RH, Dry)) at 532 nm for non-absorbing surrogate atmospheric aerosols was measured to determine the influence of particle size, composition (inorganic vs. organic), and mixing state (internal vs. external) on aerosol light scattering. Results for mixtures of NaCl and $(NH_4)_2SO_4$ with a few dicarboxylic acids are included. For atmospheric conditions, the variability in the RH dependence of aerosol light scattering ($f_{\sigma(sp)}$(RH, Dry)) is most sensitive to aerosol composition and size. The influence of the mixing state on $f_{\sigma(sp)}$(RH, Dry) is small. These laboratory results imply that $f_{\sigma(sp)}$(RH, Dry) can be reasonably estimated from the aerosol size distribution and composition (inorganic/organic) using the mass-weighted average of $f_{\sigma(sp)}$(RH, Dry) for the individual components.

This study also used laboratory-generated particles to examine the connection between aerosol light extinction, chemical composition, and hygroscopicity for particles composed of internal mixtures of ammonium sulfate and water-soluble organic compounds. The extinction coefficient (σep) at 532 nm was measured for size-selected particles at <10% RH and 80% RH. The ratio of the extinction coefficients at 80% RH to <10% RH is reported as fRHext(80% RH, dry). The fRHext(80% RH, dry) values were similar for particles composed of various water-soluble organic compounds and different functional groups. In addition, fRHext(80% RH, dry) values were relatively insensitive to the composition of the organic fraction for internal mixtures of ammonium sulfate with sugars, dicarboxylic acids and complex mixtures of water-soluble organic compounds. Finally, fRHext(80% RH, dry) was found to vary linearly with the organic/inorganic content, allowing for simple incorporation of organic properties into atmospheric models. Investigators derived a generalization of fRHext(80% RH, dry) = 2.90 – 0.015(wt% organic species) for a particle size distribution with a dry mean optical diameter of 0.35 μm. This parameterization for ammonium sulfate/water-soluble organic aerosol is applicable to the fine particle mode fraction of atmospheric aerosol. Information necessary to incorporate the variation in the size distribution is also included. This suggests that neglecting the water uptake by the organic fraction of atmospheric particles could lead to significant underestimation of the cooling at the Earth's surface due to light scattering by aerosol.



Left. Variation of $f_{\sigma(ep)}$(80% RH, Dry) with dry effective optical diameter for λ = 532 nm. Shown are 100% NaCl (solid circle), 50 wt% NaCl and 50 wt% organic mixture A (open circle), 100% $(NH_4)_2SO_4$ (solid square), 50 wt% $(NH_4)_2SO_4$ and 50 wt% organic mixture B (open square), 100% organic mixture A (+), and 100% organic mixture B (×).

Right. Measured fRHext(80% RH, dry) for ammonium sulfate mixed with adipic acid (solid squares), DL-malic acid (crosses), glucose (open triangles), levoglucosan (open circles) and mannitol (open square). The top dashed line is the best fit to the sugar data (all open symbols) and the middle dashed line is the best fit to the dicarboxylic acid data. The solid black line models the case where water uptake is dictated only by ammonium sulfate (labeled "Linear Fit w/ fRH(org) = 1").



MILESTONE CSD09.4:
Measure particle nucleation and particle growth rates in laboratory experiments following the gas-phase oxidation of biogenic monoterpene compounds by O_3 and the OH radical.

ACCOMPLISHMENTS FOR CSD09.4:
Measurements of particle nucleation following the gas-phase oxidation of α pinene and β pinene were measured. Particle nucleation following the ozonolysis and O_3 plus OH initiated monoterpene oxidation was measured in a 70 L Teflon bag reactor over the temperature range 278 K to 320 K. Particle concentration temporal profiles were measured for a range of initial monoterpene and ozone concentrations using ultra-fine condensation particle

counters. Profiles were interpreted using a coupled gas-phase chemistry and kinetic multi-component nucleation model to determine the molar yield of the nucleating species in the ozonolysis experiments to be 1×10^{-5} and 0.009, for α pinene and β pinene, respectively. OH initiated oxidation was found to increase the nucleator yield for α pinene, by approximately a factor of three, but not for β pinene. The molar yield of condensable reaction products (vapor pressure < 20 ppt at 296 K) was determined to be 0.06 for both α pinene and β pinene and was independent of the oxidation source. Particle growth, which is determined by the condensable reaction products, was nearly temperature independent. Atmospheric box model calculations of nucleation and particle growth for α and β pinene oxidation under typical tropospheric conditions are presented and show (1) nucleation can be significant under favorable conditions, (2) nucleation is dominated by OH-initiated oxidation, and (3) the partitioning of the condensable monoterpene oxidation products makes a significant contribution to the growth of atmospheric aerosol and is capable of explaining the observed particle growth rates commonly observed in remote forests.

Complementary Research

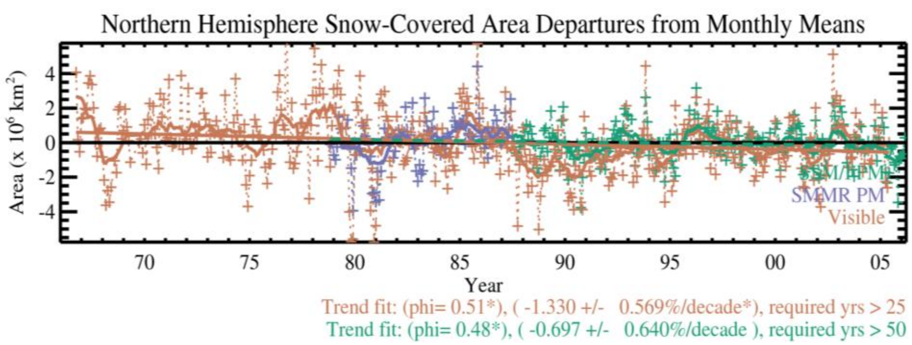
Faculty Fellows Research

Global Snow Cover Mapping

Richard Armstrong
Funding: NASA Earth Science

Objective and Background
Generate a climate data record for Northern Hemisphere snow cover and analyze statistical significance of long-term trends. Optimize the combination of passive microwave and visible satellite remote sensing data.

The extent and variability of seasonal snow cover are important parameters in climate and hydrologic systems due to effects on energy and moisture budgets. Northern Hemisphere snow cover extent, comprising about 98% of global seasonal snow cover, is the largest single spatial component of the cryosphere, with a mean maximum extent of 47 million square kilometers (nearly 50% of the land surface area). Since 1966, much important information on Northern Hemisphere snow extent has been provided by the NOAA weekly snow charts, derived from visible-band polar orbiting and geo-stationary satellite imagery. Since 1978, satellite passive microwave sensors (SMMR and SSM/I) have provided an independent source for snow monitoring. Trend analysis on the passive microwave record is complicated by the change in sensors from SMMR to the SSM/I in 1987 and by the short overlap period.



Northern Hemisphere snow-covered area departures from monthly means derived from visible and passive microwave satellite data for the period 1966-2006. The visible data show a statistically significant decrease in snow cover of -1.3% per decade while the microwave indicate a decrease of -0.7% per decade although not significant at the 90% level.

Accomplishment
To derive a temporally consistent map of snow cover from the two microwave sensors, we evaluate brightness temperatures at fixed Earth targets with a range of physical characteristics. Individual targets were chosen for temporal and spatial stability and together include a range of brightness temperatures representing the cold through warm end of the emission range. Cold targets include oceans and ice sheets, while warm targets include tropical forests and mid-latitude deserts. The SMMR and SSM/I brightness temperatures are adjusted using the regression coefficients derived from the comparison of the two data sets. The adjusted data are then applied to the microwave snow retrieval algorithms, and a time series of monthly standardized anomalies for the Northern Hemisphere for the period 1978 to 2006 is generated. Respective trend lines are calculated along with autocorrelation, trend estimates and the number of years of data required to detect a real trend of a calculated magnitude. Both positive and negative statistically significant trends are detected, depending on region and time of year. Regional trend analysis of both visible and microwave snow cover data have been compared with gridded temperature anomalies from the NASA GISS Surface Temperature Analysis data. The western United States is one of the largest regions of the Northern Hemisphere showing a statistically significant decrease in snow cover during the past three decades. In addition, we have developed an optimal approach to snow cover mapping, which involves the synergy of both microwave and visible sensor data. CIRES collaborators on this project include Mary Jo Brodzik, Matthew Savoie and Betsy Weatherhead.

The Dynamics of the Residual Layer Determined from High-Resolution In Situ Observations during CASES-99

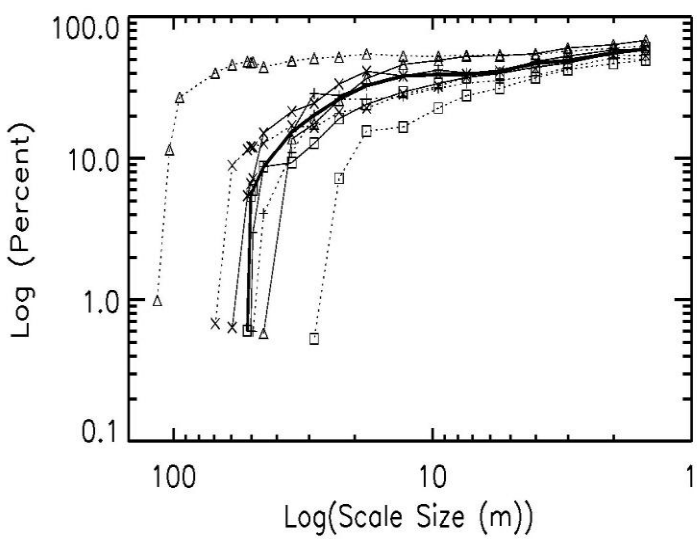
Ben Balsley

We are currently examining a number of new results derived from high-resolution *in situ* studies of the residual layer (RL) obtained during the CASES lower atmospheric campaign in eastern Kansas in October, 1999. These studies typically used data gathered by the CIRES-developed Tethered Lifting System, which consists of a state-of-the-art kite or an aerodynamic balloon that has high-resolution instruments suspended well below from the tether.

The RL lies between the stable boundary layer (the lowest region of the nighttime atmosphere that is tightly coupled to the Earth's surface) and the steep temperature gradient that defines the bottom of the free atmosphere. Although the RL is a poorly studied region owing to its inaccessibility, it is important for studying the turbulent transport into the free atmosphere of pollutants generated at ground levels.

Our results show that the RL is not—as has been generally portrayed in the literature—a passive, quiescent remnant of the previous afternoon's convective boundary layer. Rather it is a complex, rapidly changing, and dynamic arena harboring regions of intense turbulent variations with extremely sharp gradients. Our current studies show that RL turbulence: (1) is always present, (2) can exceed stable boundary turbulence levels by an order of magnitude, (3) can range in intensity over more than three orders of magnitude, (4) is generated locally on scales of a few tens of meters or less by velocity shears, and (5) can be entrained into the underlying stable boundary layer, particularly when the RL turbulence is intense and the stratification between the RL and stable boundary layer is relatively weak.

The figure at right shows a set of eight ascents and descents, plus a curve of the median value of all eight flights, which portrays the percentage of RL heights having critical Richardson number values ($Ri \leq 0.25$) as a function of the analyzed vertical-scale size. Both axes are plotted using logarithmic scales in order to show details over a wide range of scale sizes and percentages. The fundamental conclusion that can be drawn from this result is that, while there are reasonable variations in the flight-to-flight results as shown by the various curves, the RL is clearly dynamically unstable only on scales smaller than a few tens of meters. The significance of this result is that the current computer models employed to examine turbulence generation and the concomitant dynamics in the stable boundary layer do not have sufficient resolution to examine such small-scale instabilities.



The causal mechanisms for the generation of these small-scale instabilities is currently under study. A list of likely mechanisms could reasonably include turbulence generation by atmospheric gravity waves, frontal passages, and a variety of local orographic features.

Twentieth Century Sea Ice in the Eurasian Arctic from Russian Data Sources

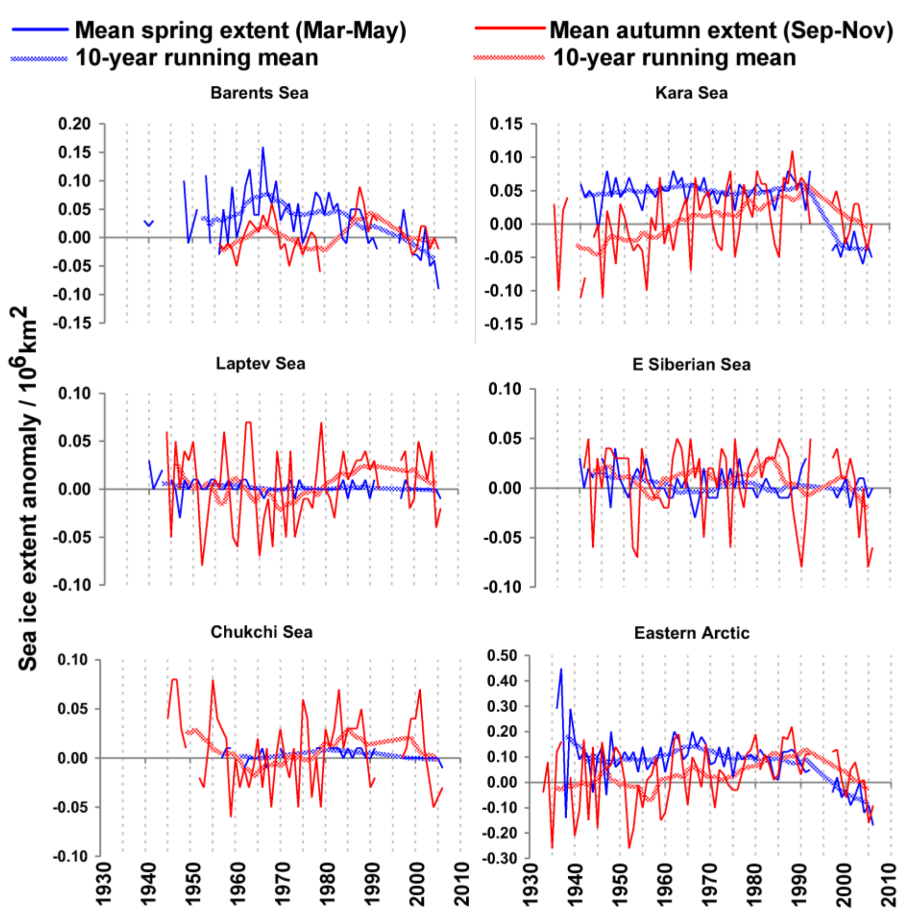
Roger G. Barry
Funding: NASA: Cryospheric Sciences

The primary objective of this work is to fill gaps in the Arctic sea ice data record by extending the record back and forward in time. A secondary objective is to provide summary statistics, and to assess the evidence for climate change in the Russian Arctic over the period 1930s-2005. The 1930-40s saw significant high latitude warming and therefore it is important to document accompanying changes in ice conditions for comparison with those of summers since 1990.

Two significant sources of historical sea ice charting data in digital form are the WMO Global Digital Sea Ice Data Bank and the Environmental Working Group Sea Ice Atlas. The sea ice atlas includes Arctic-wide U.S. National Ice Center seven-day sea ice charts, 1972-1994, and Russian Arctic ten-day sea ice charts, 1950-1992.

Sea ice charts for 1933–49 based on aerial reconnaissance, and recent data for 1993-2005, have been digitized at the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia, and can be viewed using an interactive browser at *http://www.aari.nw.ru/gdsidb/sea_ice/real_sigrid/view.html*

We have acquired digitized historical ice charts of the Eurasian Arctic from the AARI for the periods 1933-1992 and 1997-2006. We also have ice index data for the periods 1924-1933 and 1993-1996, creating an observational ice record that spans over 80 years. From ice chart data, we have located the ice edge where possible in every chart and calculated seasonal ice extent anomalies for the marginal seas of the eastern Arctic. These results (Figure, left) indicate that although there was also a retreat in autumn (annual minimum) sea ice extent in the early part of the 20th century, there was no apparent retreat in springtime (annual maximum). In recent years however, there has been a year-round retreat of eastern Arctic sea ice extent.



We are currently examining historical meteorological station data and atmospheric indices (such as the AO) to seek correlations between Arctic climate and the observed variability in sea ice. We are also comparing the AARI ice chart dataset with other digital sea ice data with the aim of producing an optimized dataset of Arctic sea ice.

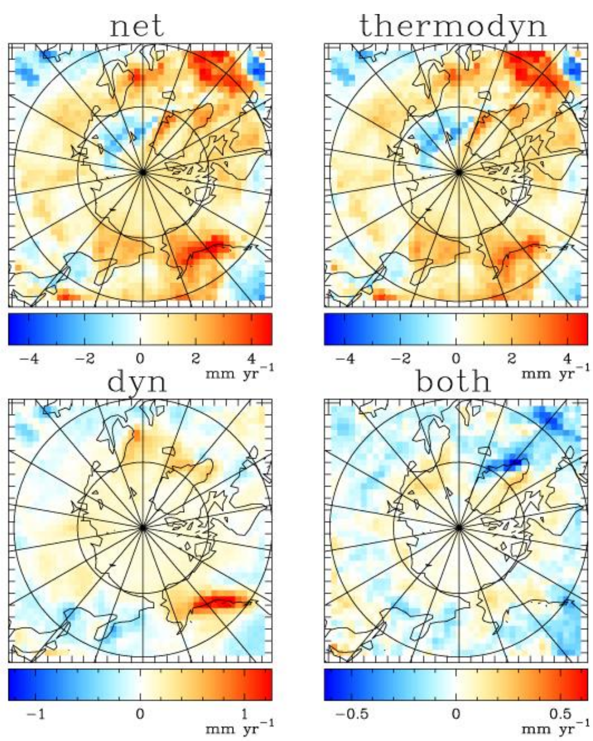
Predicted Changes in Forcing of Net Precipitation in the Polar Regions during the 21st Century

John Cassano

Funding: National Science Foundation Office of Polar Programs

One avenue of current research in the Cassano Polar Climate and Meteorology group at the University of Colorado is the attribution of the forcing for projected changes in polar net precipitation over the next century. Net precipitation is a key climate parameter as it determines atmospheric mass input to ice sheets and glaciers, which then affects global sea level. In the Arctic, net precipitation over the large Arctic watersheds alters the input of freshwater to the Arctic Ocean via discharge from these rivers. Changes in freshwater input to the Arctic Ocean can then change sea ice processes and alter regional to global oceanic circulations.

This research has utilized output from 15 global climate system models (GCSMs) that were run in support of the Intergovernmental Panel on Climate Change Fourth Assessment Report. The ability of each model to accurately simulate the synoptic climatology of the Arctic and Antarctic was evaluated using a method based on self-organizing maps. Based on this analysis we found that only four (Arctic) or five (Antarctic) of the 15 GCSMs were able to accurately simulate the synoptic climatology of the polar regions at the end of the 20th century.



Arctic annual net precipitation change components [total change (net), thermodynamic change (thermodyn), dynamic change (dyn), and dynamic change acting on thermodynamic change (both)] (mm/yr) from the 4-model ensemble for 2046-2055 vs 1991-2000. Note that the color scale differs in each panel.

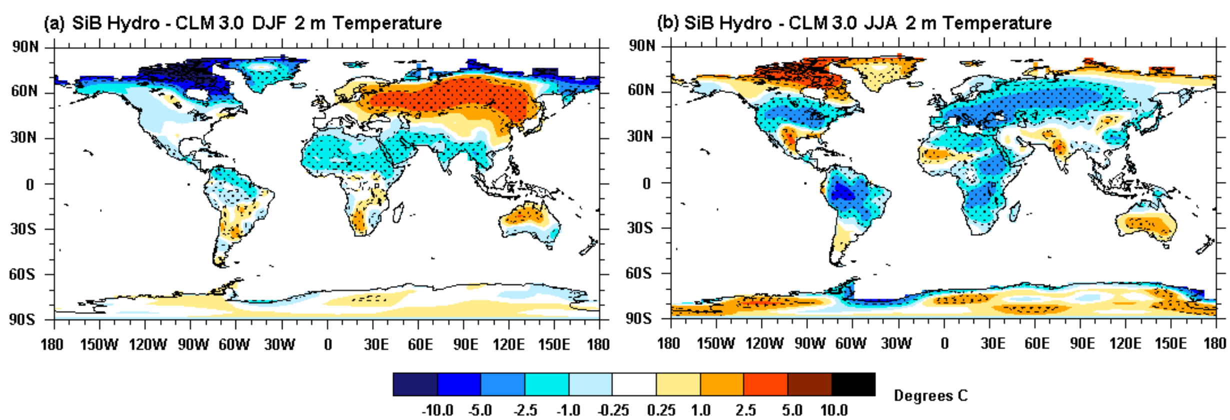
This reduced set of GCSMs was further analyzed to evaluate changes in net precipitation from the end of the 20th century to the end of the 21st century. In both polar regions, the subset of GCSMs indicates an increase of approximately 20% in net precipitation over the next century. The largest rate of change of net precipitation is predicted to occur during the first half of the 21st century, with smaller increases occurring during the second half of the century. The changes in net precipitation are not uniform across the polar regions, and show significant spatial variability (see figure, left).

The final portion of this project estimated the relative contribution of changes in circulation (via changes in the synoptic climatology) and thermodynamics to the projected changes in net precipitation. While the synoptic climatology of both regions is projected to become increasingly dominated by cyclonic weather patterns, the largest contribution to the projected changes in net precipitation was through thermodynamic processes. Over the Antarctic ice sheet over 90% of the projected change in net precipitation during the 21st century was found to be due to thermodynamic processes, while in the Arctic nearly 80% of the change in net precipitation was associated with changes in thermodynamics (Figure, left).

Land Surface Hydrology and Global Climate

Tom Chase

In recent climate sensitivity experiments with the Community Climate System Model (CCSM 3.0) we found that the Community Land Model (CLM 3.0) simulates mean global evapo-transpiration with low contributions from transpiration (15%), and high contributions from soil and canopy evaporation (47% and 38%). This evapo-transpiration partitioning is inconsistent with the average of other land-surface models used in GCMs. To understand the high soil and canopy evaporation, and the low transpiration observed in the CLM 3.0, we compared select individual components of the land-surface parameterizations of the Simple Biosphere Model (SiB 2.0) against the equivalent parameterizations used in CLM 3.0. We also compared alternative parameterizations from literature that simulated the same processes that control transpiration, canopy and soil evaporation, and soil hydrology in both models. The behavior of the CLM 3.0, SiB 2.0 and alternative parameterizations were assessed with each other through idealized off-line simulations performed over a range of soil moisture, radiation and atmospheric conditions. We used the findings of these investigations to develop new parameterizations for CLM 3.0 that would reproduce the functional dynamics of land-surface processes found in SiB 2.0 and other alternative land surface parameterizations. We performed global climate sensitivity experiments with the new land-surface parameterizations to assess how the new SiB 2.0-consistent CLM land surface parameterizations impact the surface energy balance, hydrology and atmospheric fluxes in CLM 3.0, and the larger scale climate modeled in CCSM 3.0. The new parameterizations enable CLM to simulate evapo-transpiration partitioning consistently with the multi-model average of other land surface models used in GCMs as evaluated by Dirmeyer et al. [2005]. The changes in surface fluxes also resulted in a number of improvements in the simulation of precipitation and near surface air temperature in CCSM 3.0, although substantial biases remain. The improvements in evapo-transpiration partition however, do provide a substantially more robust framework for performing land cover change experiments in CLM and CCSM than the existing CLM 3.0 parameterizations. Temperature maps of climate anomalies associated with the changed land surface hydrology are shown below. A major result is that correcting the land surface hydrology resulted in an annually, globally averaged change in near-surface temperature of 0.55 degrees, or approximately the observed change in surface temperature over the last century. This is an indication that climate change cannot be adequately simulated without a reasonable hydrologic cycle — something which remains elusive.

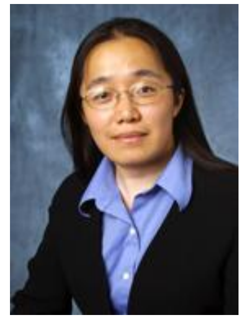


Changes in near surface temperature due to changes in land-surface hydrology.
Left panel: Dec., Jan., Feb. average. Right panel: Jun., Jul., Aug. average.
Note that errors in land surface hydrology were responsible for
larger climate changes than observed in recent years.

Lidar Remote Sensing and Laser Spectroscopy for Atmospheric Sciences

Xinzhao Chu

Funding: NSF Aeronomy, MRI, and CEDAR Programs



To advance our understanding and knowledge of global atmosphere composition, temperature, and dynamics, as well as climate change issues, it is essential to develop new generation lidar remote sensing instruments so that we can acquire crucial atmosphere data globally to improve atmospheric models and theories. The major efforts of the Chu Research Group in the last 12 months were spent on the revolution of lidar technology, and two milestones were reached.

First, a Major Research Instrumentation (MRI) proposal led by Dr. Xinzhao Chu for developing a mobile Fe-resonance/Rayleigh/Mie Doppler lidar received all excellent reviews and was funded by the National Science Foundation MRI program in August 2007. This MRI lidar integrates the state-of-the-art technologies of lasers, novel laser spectroscopy, advanced electro-optics, and sensors into a single system to produce a powerful and robust tool with unmatched measurement capability throughout the middle and upper atmosphere. The chirp-free and dither-free frequency locking and saturation-free Fe layer resonance result in a bias-free estimate of winds and temperatures, which is revolutionary for resonance Doppler lidar.

Second, a Consortium of Resonance and Rayleigh Lidars (CRRL) was funded by the National Science Foundation in August 2006, and Dr. Xinzhao Chu began to establish a national lidar Consortium Technology Center at CIRES, aiming to consolidate lidar expertise and advance the middle- and upper-atmosphere lidar technology to meet new science challenges. During the 2006-2007 winter break, Dr. Chu and her team conducted research on novel Doppler-free spectroscopy and created new ideas of achieving accurate pulsed-laser frequency calibration for lidar, which significantly contributed to the MRI proposal. The MRI lidar will be developed for the science community and become part of the CRRL.

In addition, Dr. Xinzhao Chu received the Faculty Early Career Development (CAREER) award from the National Science Foundation in April 2007 and is leading her team to study global middle-atmosphere thermal and dynamic structures using lidar, satellite data, and atmospheric models.

The Chu Research Group recruited one research scientist (Dr. Wentao Huang), three Ph.D. students, one master's student, and one undergraduate student in the last 16 months. Though the team is still very young, they continue to make good progress. They established a lidar and laser laboratory at CIRES, and established a lidar observatory (T-2) at NOAA's Table Mountain facility in collaboration with Dr. Mike Hardesty (CIRES-NOAA/ESRL) and his team. Dr. Chu brought a lidar container from Rothera, Antarctica to CU, and it is now residing beside T-2 and will host the MRI lidar transmitter for future mobile deployment.

The LabView-software-based servo loop and real-time signal inquiry/processing that the team is developing, if successful, will significantly improve CRRL lidar frequency accuracy and stability. Traditionally, lidar system parameters were not recorded routinely, which put the measurement accuracy into question. The new computer-based system will enable automatic control, measurement, and recording of lidar parameters to improve accuracy and stability.

CU mobile lidar container (front) and lidar observatory (back) at NOAA Table Mountain. The container will host the MRI lidar transmitter.

With the lidar data collected from Antarctic and equatorial regions, the Chu Research Group did scientific investigations on stratospheric gravity waves, polar stratospheric clouds, polar mesospheric clouds, and middle atmosphere temperatures. The interesting results obtained from these studies further motivated the team to develop the best lidar instruments, make global observations to collect more data, and conduct further investigations on global atmosphere composition, thermal structure, and dynamics.

Analysis of the Poor Catalytic Performance of Pentachlorophenol Hydroxylase

Shelley D. Copley
Funding: DOD Army Research Office

Pentachlorophenol (PCP) is a highly toxic pesticide that was first introduced into the environment in 1936. Biodegradation of PCP is challenging because it uncouples oxidative phosphorylation and alters membrane fluidity. Despite its toxicity and recent introduction into the environment, PCP can be completely degraded by *Sphingobium chlorophenolicum*, several strains of which have been isolated from PCP-contaminated soil. Although the ability of *S. chlorophenolicum* to mineralize PCP is remarkable, the inefficiency of the metabolic pathway has limited the potential for its use in bioremediation.

S. chlorophenolicum appears to have assembled a new pathway for degradation of PCP by recruiting previously existing enzymes from at least two other metabolic pathways (Figure 1, right). None of these enzymes functions very well. TCHQ dehalogenase (PcpC), the enzyme that removes two chlorines from the aromatic ring, is particularly critical, as dioxygenases that cleave hydroquinones are unable to cleave substrates with multiple electron-withdrawing chlorine substituents.

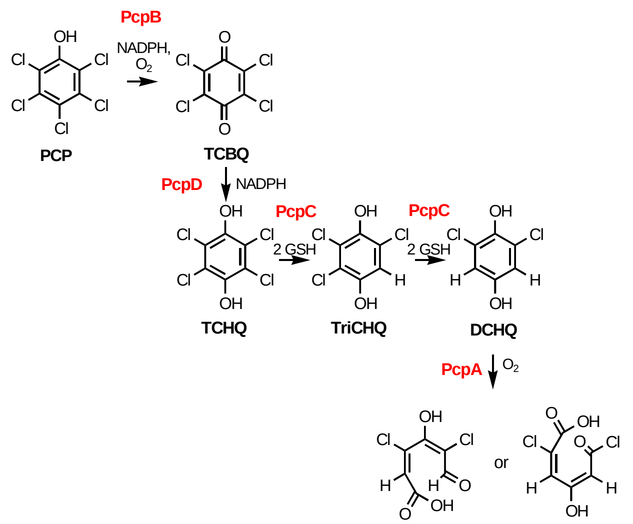


***Figure 1**. Pathway for degradation of PCP in S. chlorophenolicum ATCC 39723. PcpB, PCP hydroxylase; PcpD, TCBQ reductase; PcpC, TCHQ dehalogenase; PcpA, DCHQ dioxygenase (PcpA); GSH, glutathione.*

TCHQ dehalogenase is subject to severe inhibition by its aromatic substrates (TCHQ and TriCHQ) (Figure 2, below). This is very unusual; typically, the rate of an enzymatic reaction increases with substrate concentration until the enzyme is saturated. We investigated the mechanism of this substrate inhibition. The enzyme actually dehalogenates the substrate at a respectable rate–about 25 s^{-1}. However, the dehalogenation reaction leaves the enzyme in an altered form, with a glutathione covalently attached to a cysteine at the active site. This glutathione must be removed by reaction with a second molecule of glutathione to regenerate the free enzyme. When the aromatic substrate binds prematurely to the active site, this reaction cannot take place and the enzyme is trapped in a non-reactive state. Higher concentrations of substrate lead to more and more sequestration of the enzyme in the inactive state. These results help us to understand both why the current enzyme is a poor catalyst, and the aspects of enzyme performance that need to be manipulated to evolve a better enzyme.

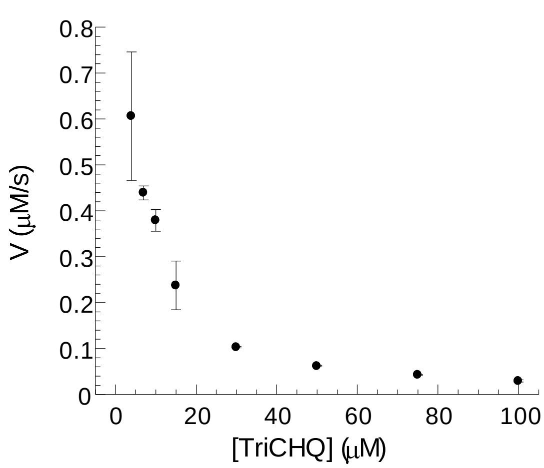


***Figure 2**. Inhibition of TCHQ dehalogenase by its substrate.*

Temporal Variability in Airborne Microbial Populations

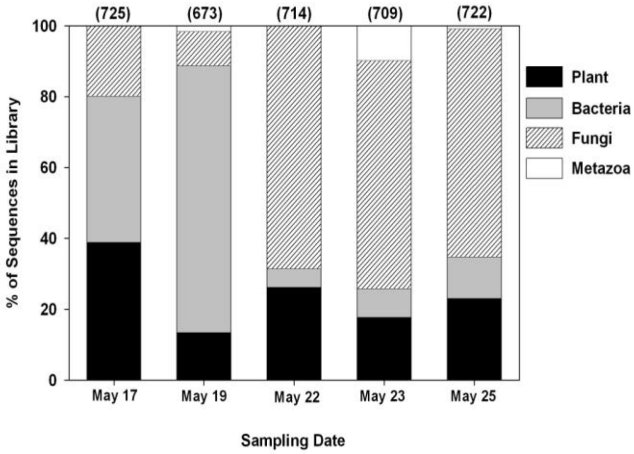
Noah Fierer
Funding: A.W. Mellon Foundation, NSF

Bacteria and fungi are ubiquitous in the atmosphere and represent a large proportion of total airborne particulates. Atmospheric transport is a key mode of microbial dispersal and the transmission of airborne plant and animal pathogens can have significant impacts on ecosystems, human health, and agricultural productivity. Despite their importance, there have been very few studies describing the full extent of bacterial and fungal diversity in the atmosphere. We used a cultivation-independent molecular approach to identify the bacteria and fungi present in air samples collected from a single site in Boulder, Colorado. We documented shifts in the types of bacteria and fungi found in air from the site over an eight-day period to assess the temporal variability associated with the diversity of airborne microbes and the climatic factors driving this variability.

We found that the air samples were dominated by potentially allergenic fungi and a diverse array of bacteria, including specific types of bacteria that are commonly found in air samples collected from across the globe. Bacterial:fungal ratios varied by two orders of magnitude over the sampling period, and we observed large shifts in the diversity of bacteria present in the air samples collected on different dates. We observed more phylogenetic similarity between bacteria collected from geographically distant sites than between bacteria collected from the same site on different days. These results suggest that outdoor air may harbor similar types of bacteria regardless of location, and that the short-term temporal variability in airborne bacterial assemblages can be very large. We are currently expanding on this work to further understand how airborne microorganisms vary across space and time so we can better predict disease outbreaks (including allergenic asthma) triggered by airborne bacteria and fungi.

Figure 1. *Air sampling equipment on site in north-eastern Colorado.*

Figure 2. *The taxonomic composition of the biological aerosols sampled from Boulder, CO on five dates.*



Tectonics of Foundering Lithosphere, Sierra Nevada, California

Craig H. Jones
Funding: EarthScope Program and Continental Dynamics Program

In contrast with ocean tectonics, continental tectonics are diffuse and occur in places and with styles not easily anticipated from plate kinematics. One potential cause is the antibuoyant mantle lithosphere under continents and the potential that it could detach and sink into the mantle. The Sierra Nevada of California might overlie lithosphere that foundered in the past 10 million years; Dr. Jones and colleagues at two other universities are conducting a new seismological experiment to understand the dynamics of this process.

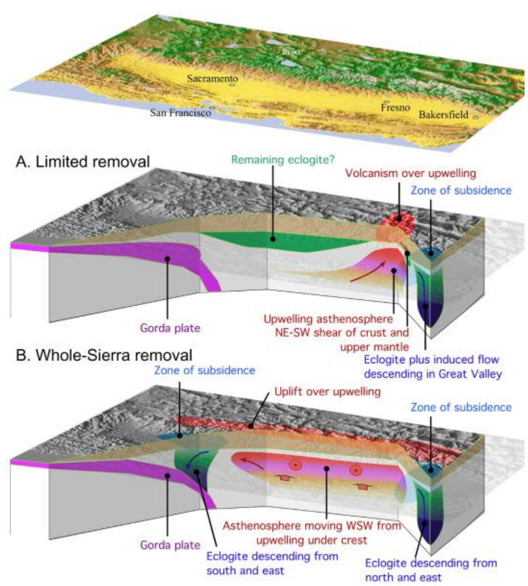
CIRES student Heidi Reeg and CIRES alum Hersh Gilbert complete installing the last SNEP seismometer, January 2007

Accomplishments

The present Earthscope grant represents the very first deployment of the FlexArray facility being constructed by IRIS PASSCAL as part of the U.S. Array component of the NSF ~$200M MRE (Major Research Equipment) EarthScope program. In our second year, we moved most of our network of over fifty field stations to cover the northern Sierra Nevada. Four CU students, as well as hosted IRIS interns from Georgia Tech and Princeton, have gained considerable field experience. Some early results were summarized in a May 2007 issue of *Eos*. The associated and newly awarded Continental Dynamics grant supports four CU faculty (including three CIRES Fellows) and financed a workshop of both projects' PIs and some outside scientists in the Sierra in the fall of 2006.

Significance

The removal of mantle lithosphere has long been proposed as a means of driving enigmatic deformation in continents, but hypotheses for the impacts of such an event were largely based on theory. Recognizing that the Sierra overlies freshly removed lithosphere provides the chance to understand this process from observations. Previously, Dr. Jones and his colleagues (including CIRES Fellow G. Lang Farmer) had proposed that the foundering of sub-Sierran lithosphere had led to widespread uplift of the Sierra and western Great Basin, extensional faulting in the western Great Basin, contraction across the California Coast Ranges, and a shift in Pacific-North America plate motion from the western towards the eastern side of the Sierra (figure at right, bottom panel). Work by Jones and CIRES Fellow Peter Molnar had shown that the descent of this lithosphere was consistent with Rayleigh-Taylor instabilities and laboratory experiments on rock rheology provided that high-stress limits on power law rheologies were honored, indicating that such high-stress limits on rock strength are probably real. The constraint of the new experiment on the base of the descending body is critical in providing bounds on descent of this kind of material. Furthermore, the unusual geometry of the descending body, not predicted by experiments to date, poses new challenges for understanding this process and suggests unforeseen factors at play.



Competing explanations in the Sierra: localized lithospheric foundering with minimal implications (center) and widespread foundering with widespread consequences (bottom).

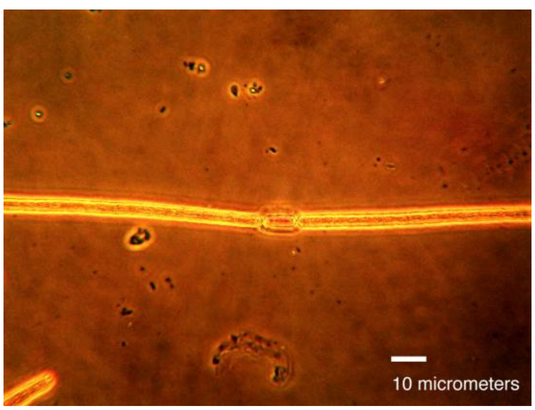
Nitrogen Fixation in Lakes

William M. Lewis, Jr.

All lakes contain phytoplankton, a diverse community of unicellular algae that are able to live suspended in the water column because of their very low sinking rates. Phytoplankton are not visible individually because they grow as unicells or small colonies with a median size of approximately 100 µm. In lakes that receive small amounts of plant nutrients – phosphorous (P) and nitrogen (N) – phytoplankton are collectively invisible. Where plant nutrients are abundant, phytoplankton pigments bring visible color to the water. At high concentrations of P and N, phytoplankton become so abundant that they cause a very strong green color and reduce transparency in a lake. Strong growth (“blooms”) of algae are responsible for many undesirable changes in lakes, including anoxia in deep water, formation of scums, production of toxic substances or taste and odor, and interference with filtration processes used by water-treatment plants.

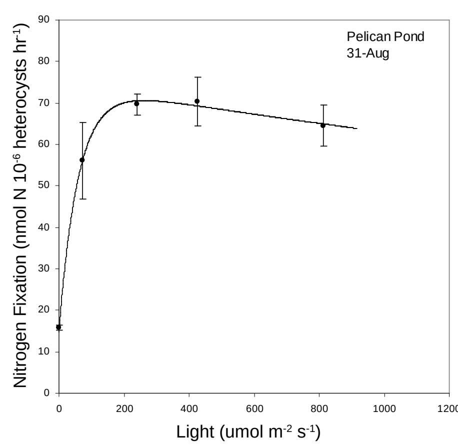
Lakes containing high concentrations of anthropogenic P often show depletion of inorganic N because the human sources have a much higher ratio of P:N than natural sources. Under these conditions, N-fixing algae often become dominant. While other algae are held back by a lack of inorganic N, the N fixers convert N_2 (which is biologically inert) to NH^{4+}, which allows their continued growth. N-fixing algae are potent scum formers and sources of toxins.

Blue-green algae are in fact cyanobacteria, which separates them from the other algae in phytoplankton, which are eukaryotic (non-microbial). The N fixers have growing filaments containing one or more specialized cells (heterocysts) that are specialized for N fixation. Within the heterocyst, photosystem II does not function, and no oxygen is released. Therefore, the anoxic conditions necessary for N fixation are available inside the heterocyst.



Aphanizomenon, showing the N-fixation cell (heterocyst, center).

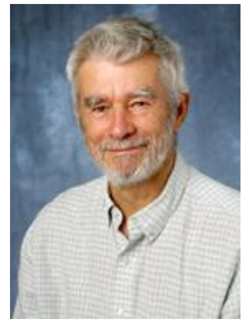
One particularly potent N fixer in Colorado and throughout the west is *Aphanizomenon*, which forms blooms in many local lakes, such as Cherry Creek Reservoir, and national lakes, such as Upper Klamath Lake, Oregon. It has not been clear why *Aphanizomenon* is more successful than some other genera of N fixers. Research led by Mark Bradburn, CIRES graduate student, has provided recent insight into the success of *Aphanizomenon*. Using an acetylene reduction method to measure N fixation rates, Bradburn conducted experiments leading to the construction of light-response curves for *Aphanizomenon* and, uniquely to his work, experiments with neon dark fixation. Mark showed that *Aphanizomenon* is extraordinarily efficient at using weak sources of light in fixing N, and that it has a remarkable capability to conduct fixation in the absence of light. The secret to *Aphanizomenon’s* success is its ability to fix N in water that is thickly crowded with algal cells, thus providing only weak light for most of the cells in the water column, and its ability to store reductant during brief exposure to light near the surface for later N fixation at night or when the cell is located beyond the reach of downwelling irradiance. Bradburn’s research suggests that forced mixing might be quite effective in controlling *Aphanizomenon*. The effect of forced mixing would be to cause *Aphanizomenon* to exhaust its stored reductant at a pace faster than the reductant could be restored by exposure to strong light.



Mark has a position with NOAA’s Cooperative Institute for Limnology and Ecosystem Research program (CILER) that we hope will be the first step toward his participation in NOAA’s very active and important program on nuisance algal species, which plague not only freshwater lakes but also estuaries throughout the world.

Emergence of the Maritime Continent and the Demise of Permanent El Niño?

Peter Molnar



Description

Peter Molnar devoted a part of his research effort in 2006 to understanding how the development of Indonesia might have transformed the climate from a permanent El Niño state before 3-4 Ma to its present state dominated by ENSO (El Niño-Southern Oscillation). Katherine Dayem, a graduate student at the University of Colorado; David Noone, CIRES Fellow; and Molnar examined the distribution of rainfall over Indonesia and over the Warm Pool of the western Pacific using the TRMM satellite. The motivation was that islands in the Indonesian region emerged during the past 3-4 million years.

Accomplishments

Dayem et al. [2007] found that rain falls heavily on the islands (Figure 1). The strength of the Walker circulation correlates with rainfall over the islands of Indonesia, but not with rainfall over the western Warm Pool, and negatively with rainfall over the whole Warm Pool (Figure 2)

Significance

This suggests that the permanent Pre-Ice-Age El Niño state may owe its existence to the emergence of the islands in the Maritime Continent.

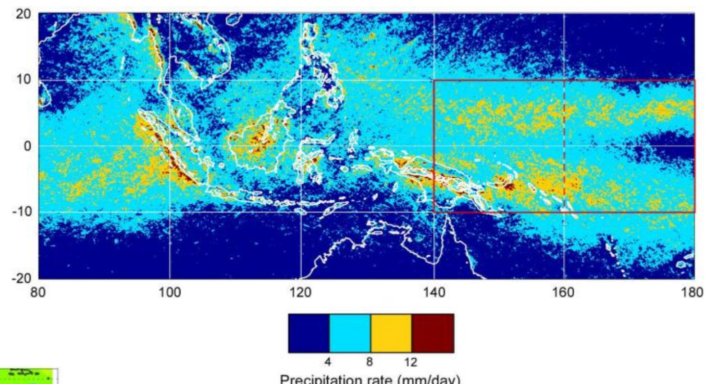


Figure 1 *(right). Average TRMM precipitation rate (mm/day) for December 1997 to November 2005. Contours of elevation at 0, 1000, and 2000 m are shown in thick white lines. The area of the warm pool is shown by the solid red box, and the area of the western warm pool is west of the dashed red line.*

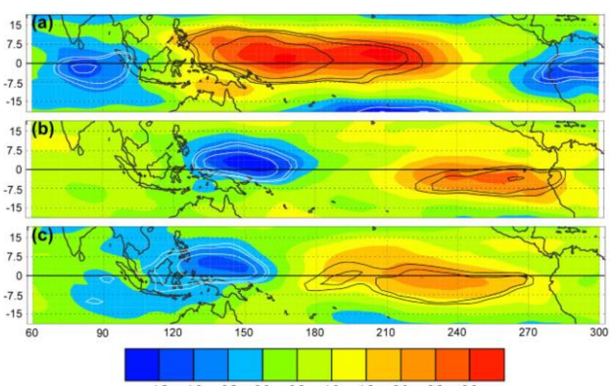


Figure 2 *(left). Linear regression coefficients between precipitation of over Maritime Continent and zonal wind shear (m/s)/(mm/day) (a measure of strength of the Walker Circulation). Regression coefficients are shown with colors. Contours of t (from outer contour to inner contour) represent 90%, 95%, and 99% confidence. Black (white) contours indicate positive (negative) correlations.*

Carbon Sequestration in a Front Range Forest

Russell K. Monson
Funding: DOE, NSF

For the past nine years, we have been monitoring the exchange of carbon dioxide from the top of a 27-meter tower at the Niwot Ridge AmeriFlux site near the C-1 NOAA site. Our aims are to understand the principal controls over, and magnitude of, the exchange of CO_2 from the trees and soils of the ecosystem, and their response to interannual climate variation. Our site is one of over 200 worldwide that functions in an integrated network known as Fluxnet. The purpose of Fluxnet is to provide fundamental insight and data to modelers using regional and global carbon budgets, particularly in response to future climate change. We have particularly focused on the question of how this mountain forest ecosystem responds to an acceleration of the onset of spring. In this forest, the transition from winter to spring has occurred 2-3 weeks earlier, on average, over the past five decades, compared to earlier decades. This acceleration is a systematic component of climate change in the Colorado Front Range, and is expected to continue in the face of future warming trends.

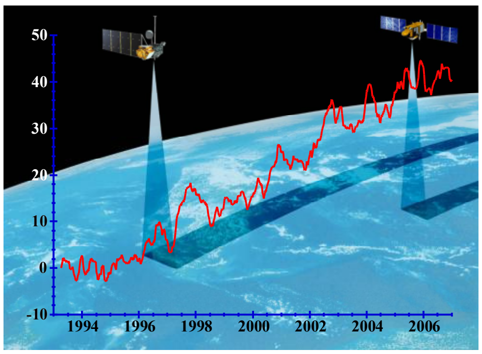
Niwot Ridge AmeriFlux Site. Rocky Mountains, Colorado, USA, Subalpine forest. Lodgepole pine, subalpine fir, Engelmann spruce. 3050 m elevation.

We have used a combination of direct observations using our tower flux systems and data assimilation into an ecosystem process model known as the Simple Photosynthesis and Evapotranspiration (SIPNET) model to evaluate component processes of the observed CO_2 fluxes. The results reveal a striking sensitivity of the local carbon cycle to snow depth and the timing of spring snowmelt. Unlike many temperate- and northern-latitude forests that appear to respond to earlier spring warming through increased annual CO_2 uptake, the Niwot Ridge forest responds to earlier spring warming through decreased annual CO_2 uptake. This is due to a high sensitivity of the photosynthesis processes of this forest to reduced soil water supply in the face of earlier snowmelt and lower spring snow depth, and to the acceleration of high rates of soil respiration as the snow pack recedes earlier in the summer. Thus, in the face of earlier spring warming, the forest takes less CO_2 out of the atmosphere through photosynthesis, and adds more CO_2 to the atmosphere through respiration. These results have led to a better understanding of an important feedback between climate warming and the forest carbon cycle in mountain forests of the western U.S.

Satellite Observations of Present-Day Sea-Level Change

R. Steven Nerem

Observations of long-term sea-level change can provide important corroboration of climate variations predicted by models and can help us prepare for the socioeconomic impacts of sea-level change. The TOPEX/Poseidon and Jason satellites have observed a mean rate of sea-level rise of 3.5 mm/year since 1993 (figure below, left). Current efforts focus on determining the causes of this change and relating the satellite record of sea-level change to the longer-term record from tide gauges.



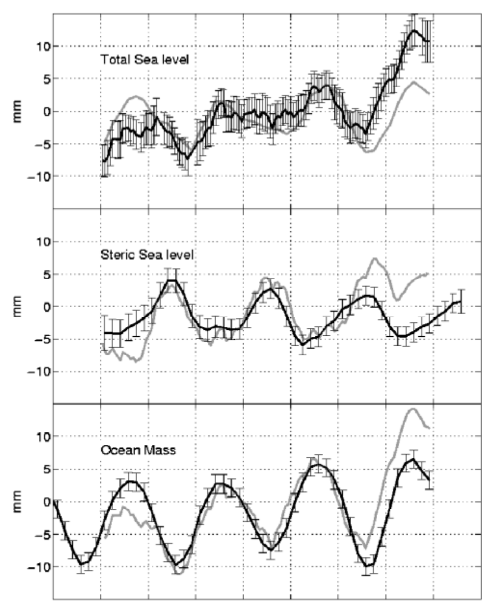
Accomplishments

Much has been learned over the past year regarding the contributions to the observed record of sea-level change from satellites. Of the observed 3.5 mm/year global averaged sea-level rise, approximately a third is now thought to be due to the warming of the oceans (thermal expansion), a third due to the melting of ice in mountain glaciers (~1 mm/year), and the rest due to other exchanges of freshwater with the continents including ice melt from Greenland and Antarctica. The total rise is significantly greater than has been observed over the last 75 years from tide gauges (~1.8 mm/year).

Recently, a new technique has been developed that allows the direct measurement of the continental water contributions from space. The GRACE satellite mission has precisely measured temporal variations in the Earth's gravitational field since 2002. As the melting of ice in mountain glaciers and ice sheets, in addition to other runoff, adds water mass to the oceans, GRACE has demonstrated the ability to directly measure this change in mass. GRACE can also determine the relative contributions of different areas on the continents. At seasonal frequencies, GRACE ocean mass estimates have been shown to compare quite well with estimates from satellite altimetry corrected for thermal expansion using shipboard measurements (figure below, right). The seasonal variations in ocean water mass are due to the seasonal exchange of water with the continents, and thus GRACE measurements are expected to make their greatest impact on studies of the global water cycle. However, eventually GRACE should help unravel the differences we have seen between the altimetry and the ocean temperature measurements, as in theory these are due to changes in global ocean mass.

Significance

Satellite altimeter and gravity measurements had a significant role in the formulation of the last IPCC climate assessment. Satellite altimetry has conclusively shown that sea-level rise has been higher over the last 15 years as compared to the last century, however this could still represent decadal variability in the Earth system, and any further conclusions will have to await a longer time-series of measurements. The record from the GRACE mission, while too short to detect climate signals, has demonstrated the ability to measure changes in the mass of the oceans and the mass of the polar ice sheets. Thus, as this time series becomes longer, it is expected that satellite gravity missions will play an equally important role to satellite altimetry in diagnosing the magnitude of sea-level change and its causes.



Global mean sea-level variability and its components. Total sea level (upper panel), the steric component of sea level (middle panel), and ocean mass variability (bottom panel). Black lines show the observed estimates from the satellite altimeter, Argo floats, and GRACE, respectively. Gray lines show the inferred estimates, computed by adding or subtracting the other two observation estimates as given by equation (1). Error bars represent random errors on the observed estimates. [Willis, Chambers, and Nerem, 2007].

Assessing Continental Hydrology with Water Isotope Measurements from Space

David Noone
In collaboration with the NASA Jet Propulsion Laboratory

Observations of the HDO to H_2O isotope ratio (expressed as δD) from the Tropospheric Emission Spectrometer on board NASA's Aura spacecraft is a valuable new resource for investigating the atmospheric hydrologic cycle. The isotopic composition of water vapor gives insight to the processes active in some regions because different processes have different isotopic signatures. For instance, lighter isotopes preferentially evaporate and heavier isotopes preferentially condense, which allows the observations to be used to determine the recycling efficiency (the relationship between evaporation and precipitation). Further, the isotopic composition of evaporation over the ocean reflects the thermal properties during evaporation, while that of evapotranspiration reflects the isotopic composition of previous precipitation. This contrast allows the observations to be used to partition the source of tropospheric water into that originating from the ocean and that from continents.

Accomplishments

We have established which processes control the atmospheric water vapor over three tropical continental regions: the Amazon, Southeast Asian monsoon region and northern Australia. Over the Amazon, the transport pathways for water with high and low isotope values are found with five-day back trajectories (figure below, top). During the wet season, there are two characteristically different regimes: 1) moisture originates over the Atlantic, and moves inland with continual condensation, and 2) moisture originates off the Venezuelan coast or over the continent itself and undergoes strong convective precipitation before arriving over the Amazon. Only the first of these is widely acknowledged in the literature. During the Amazon dry season it is again the second of these regimes, which dominates, and again shows the value of isotopes in allowing assessment of not only the conditions that control the precipitation but also those that control the evapotranspiration of the region (figure right, bottom). Although often considered climatologically similar, the wet season monsoon over Southeast Asia is found to have different combinations of moisture sources. Specifically, the isotopes suggest a stronger influence of advection from nearby oceanic regions, and that the high elevation Tibetan plateau supplies dry air via subsidence. The role of subsidence is also found to be a pronounced source of dry air over northern Australia during the dry season, while in that region this is balanced by strong local convection, which supplies water from the boundary layer. While many previous studies have focused on the importance of precipitation in hydrological analysis, an important outcome of this work is that it is also important to consider the fate of dry air and the local evaporation regime to establish a complete view of the hydrologic balance.

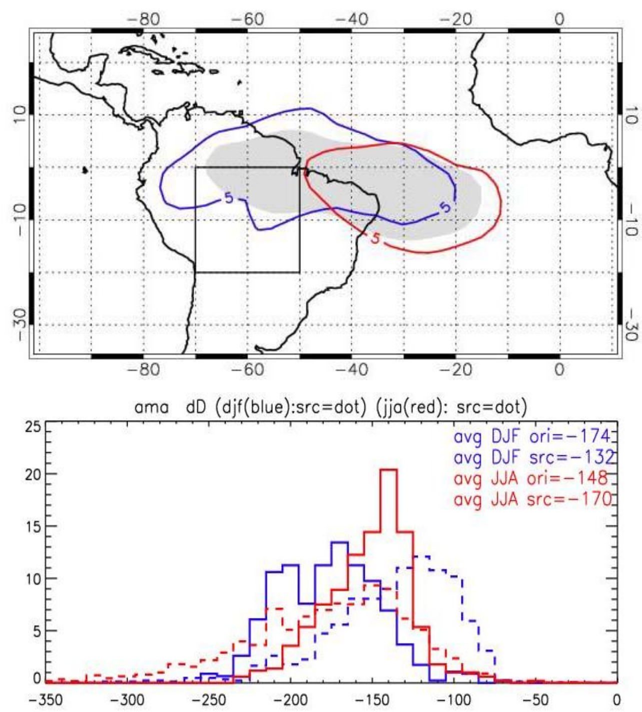


Figure shows the difference in conditions with most (blue) and least (red) depleted isotopic composition. (Top) Location of air parcels five days before they arrive in a box defining the Amazon region. The most depleted isotope observations (blue) are associated with strong local condensation, while least depleted vapor (red) has more direct history from the oceanic source. (Bottom) Frequency distribution of δD isotope values for the wet (blue) and dry (red) season over the Amazon. Solid lines show the values over the Amazon box, and dashed lines show the distribution in the source region. In the wet season condensation shifts the distribution toward more depleted values, while in the dry season local evapotranspiration injects new water vapor with a less depleted δD value of around -140 per mil.

Workshop on Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections, Summary Report

R. A. Pielke, Jr.
Funding: NSF

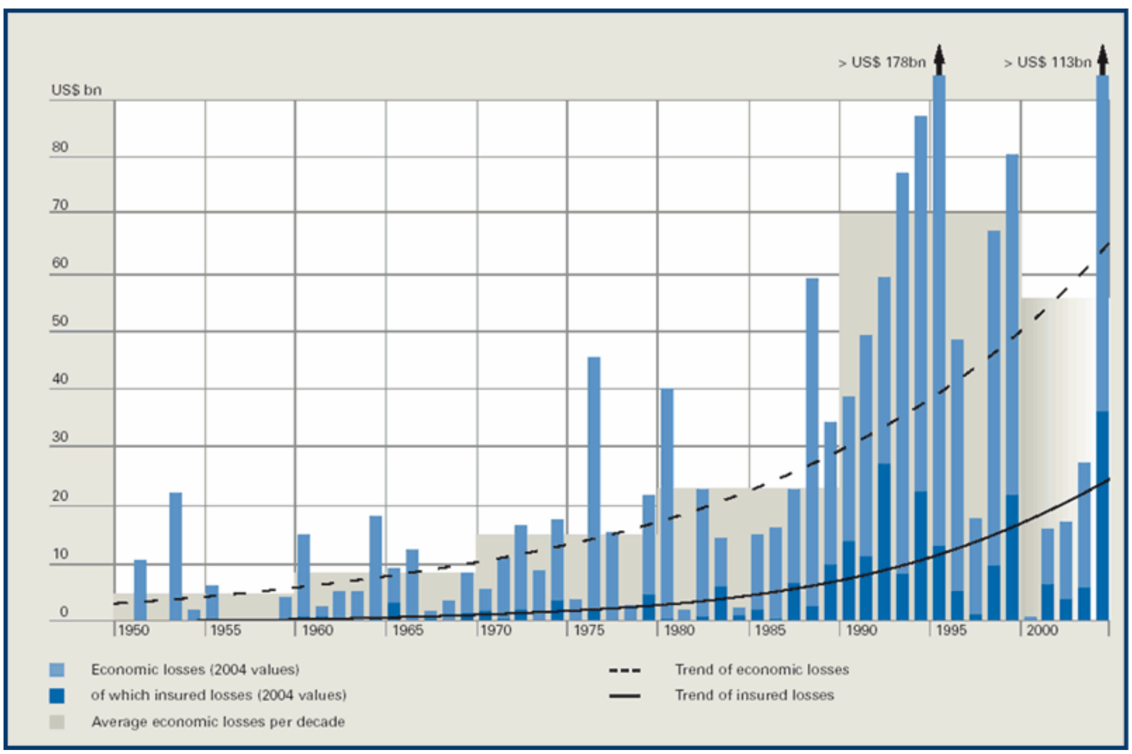
In May 2006, Roger Pielke, Jr. and Peter Höppe of the Geo Risks Research Department of Munich organized a workshop on the assessment of factors leading to increasing loss trends due to natural disasters. The workshop was timely, especially given the apparent lack of consensus on the role of climate change in disaster loss trends. The workshop brought together a diverse group of international experts in the fields of climatology and disaster research. The workshop was sponsored by Munich Re, U.S. National Science Foundation, Tyndall Center for Climate Change Research, and the GKSS Research Center.

The general questions answered at this workshop were:

- *What factors account for increasing costs of weather-related disasters in recent decades?*
- *What are the implications of these understandings, for both research and policy?*

A short brochure, which includes the 20 consensus and unanimous statements of the workshop participants, is available at
http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/ccdl_workshop_brochure.pdf

The full workshop report is available at:
http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/workshop_report.html.



The growing global toll of disasters, according to data collected by Munich Re Group.
Source: Munich Re Group (2005).

Understanding the Spatio-Temporal Variability of the North American Monsoon: Implications to Water Resources Management in the Southwestern U.S.

Balaji Rajagopalan
Funding: National Oceanic and Atmospheric Administration

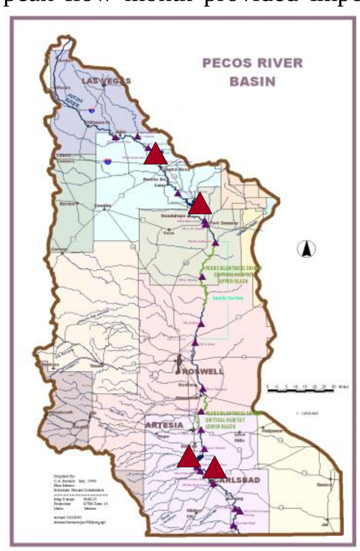
A significant part of the streamflow in the southwestern U.S. occurs during summer due to North American Summer Monsoon (NASM) precipitation (up to 50% of annual precipitation occurs during summer). Although the NASM is not a strong phenomenon, unlike its Indian and Asian counterpart, its impact on water resources management and planning activities is unquestionable. Therefore, understanding the spatio-temporal variability of summer precipitation and the associated hydrologic cycle is crucial for developing effective water management strategies. To this end, this interdisciplinary research effort will broadly involve: (a) Diagnosis: understanding the spatio-temporal and interannual variability of the summer precipitation, temperature and streamflows (b) Prediction: developing improved methods for ensemble hydrologic prediction that incorporates the climate variability information, and (c) Water Management: incorporate all of this in a Decision Support System (DSS) for water management with application to the Pecos River Basin.

Accomplishments

Streamflow Analysis - We investigated the spatial-temporal variability of the North American monsoon (NAM) rainfall in the previous years. These results were published in the special North American Monsoon issue of the *Journal of Climate* [Grantz et al., 2007] and received media coverage. This research was followed up with a similar analysis of streamflows in New Mexico and Arizona during winter, spring and summer. Streamflow stations were grouped into north (snowmelt dominated), central (early snowmelt and rain dominated), or south (summer rainfall dominated) regions based on streamflow climatology and peak flow month. The winter/spring streamflow exhibited a significant increasing trend, likely driven by enhanced ENSO activity in recent decades. Both the magnitude and timing of early summer streamflows showed a significant relationship with antecedent winter/spring precipitation in the NAM region, with increased precipitation favoring a weaker and later streamflow cycle, and vice-versa. Because summer streamflows in the northern region are significantly impacted by the antecedent spring runoff, a simple approach was applied to remove this influence. The hypothesis proposed in the precipitation chapter was tested and validated with streamflow variability. Results for the southern region monsoon streamflow supported the hypothesis more than the northern region streamflow. The results for the northern regions streamflow are mainly due to the effect of spring snowmelt extending into the summer months in the northern region. While NAM precipitation has been widely analyzed, only one known study has been conducted on the NAM streamflow. This research is unique in that it analyzed streamflow using observational data (rather than models) and it focused on the more variable region of New Mexico and Arizona (rather than Mexico). In addition, the technique of grouping stations based on peak flow month provided important insight to the relative importance of monsoon runoff in each region. This grouping technique could be useful in other streamflow studies (monsoon or otherwise) in the region. That the streamflow results corroborate those of the precipitation analysis strengthens the conclusions of both analyses.

Seasonal Streamflow Forecast: A modeling framework to provide ensemble forecasts of streamflows during the irrigation season on the Pecos River Basin, using large-scale land-ocean-atmosphere variables, was developed. Because water management in the region operates under the dry monsoon assumption, the framework's high forecast skill, particularly for wet years, has important implications for capitalizing on this "extra" water.

Water Management Application: Irrigation season streamflow forecasts on the Pecos River were coupled with the Pecos River Basin water operations model to demonstrate that using large-scale and local-scale climate information to predict the NAM can have significant positive impacts on water management.

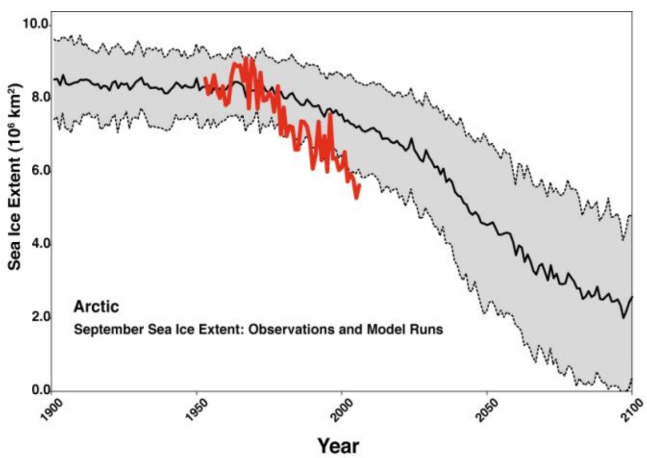


Pecos River Basin. Water is stored in the upper two reservoirs and released to meet the Irrigation demand in Carlsbad by the lower two reservoirs.

The Arctic's Shrinking Sea Ice Cover

Mark C. Serreze
with Julienne C. Stroeve, Walt Meier, Theodore Scambos, Andrew P. Barrett
Funding: NASA and NSF

Of the many environmental changes observed in the Arctic, the most visually striking is the rapid shrinking of its floating sea ice cover. Based on satellite data through 2006, September sea ice extent (the region of the Arctic Ocean with a fractional sea ice cover of at least 15%) has declined at a rate of over 9% per decade. As of the end of August 2007, sea ice extent had already set a new all-time low in the satellite record, with at least another two weeks of summer melt to go. Strong evidence for a role of increased atmospheric greenhouse gases (the greenhouse effect) comes from global climate models participating in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC-AR4). Essentially all of these models depict sea ice loss over the period of available records. The modeled trends, however, are smaller than those that are actually observed.



Time series of Arctic sea ice extent from the IPCC-AR4 models (1900-2100) and observations (1953-2006). The solid back line is the average from 13 different models. Shading encloses the ±1 standard deviation of the different simulations. The observed time series is represented by the thick red line.

Why is the sea ice cover shrinking more rapidly compared to model projections? When will we see an ice-free Arctic Ocean in summer? Answering these questions has been a central focus of our research group over the past year. There is little doubt that natural processes have served to "boost" the observed downward trend. Changes in the circulation of the atmosphere have helped to flush some of the Arctic's store of thicker sea ice into the North Atlantic. This has left the Arctic with thinner ice that can be more easily melted out in summer. There have been changes in the transport of ocean heat. For example, there is evidence that increasingly warm pulses of water have entered the Arctic Ocean from the Atlantic. Changes in cloud cover also appear to have played a role. However, after considering these issues, the emerging conclusion is that as a group, the IPCC-AR4 models are too conservative regarding their response to the greenhouse effect. Completely losing the summer ice cover by the year 2030 now seems like a realistic scenario.

What will be the impacts of sea ice loss? Some models suggest that we may see effects on atmospheric circulation and precipitation extending into middle latitudes. That the ice loss is already having impacts on the Arctic itself is clear. Climate models tell us that the rise in surface air temperature over the Arctic Ocean will be larger than in lower latitudes. This so-called Arctic amplification is directly tied to loss of the sea-ice cover, as with less ice, there will be strong transfers of heat from the ocean to the atmosphere during the cold season [Serreze et al., 2007a]. Observations show that Arctic amplification has arrived, most apparent in the autumn, and ahead of schedule. It seems that the Arctic is on the fast track of change.

Rio Grande Rift GPS Tectonics Project Underway

Anne Sheehan

Funding: NSF (project initiated with 2001 CIRES IRP seed grant)

Twenty-two high precision GPS monuments, with two more in progress, have been installed and instrumented throughout Colorado and New Mexico as part of an NSF-funded project to measure the crustal deformation of the Rio Grande Rift.

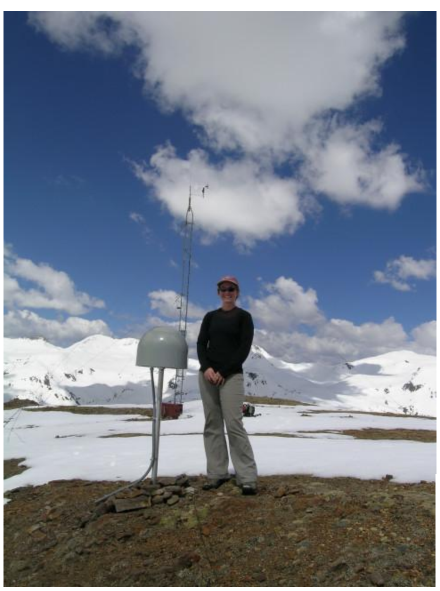
Accomplishments

The purpose of this NSF-sponsored study is to precisely measure the ground movement and earthquake potential of the Rio Grande Rift in Colorado and New Mexico. Using state-of-the-art Global Positioning System instruments at 24 sites in Colorado and New Mexico, we will track the rift's movement in millimeters during most of the next five years. This study will provide modern satellite geodetic estimates of the active tectonics of Colorado and New Mexico. The Rio Grande Rift formed between 35 and 29 million years ago when the crust began to spread apart, triggering volcanism in the region. The Rio Grande Rift extends hundreds of miles from Colorado's central Rocky Mountains to Mexico, and geologists have estimated it spreads apart up to five millimeters each year. However, the margin of error in these estimates can be nearly as much as the estimates themselves. A better understanding of the variable character of the rift could help us understand how and why tectonic plates undergo stretching, as well as the earthquake and volcanic hazards within rift zones. The project is part of NSF's EarthScope initiative, a NSF MRE project. Earthscope is funded by NSF and conducted in partnership with the U.S. Geological Survey and NASA to study North American geologic evolution, earthquakes and volcanic activity.

Education and Outreach

Anne Sheehan teamed with the CU Science Explorers program to develop a hazards curriculum. This curriculum was taught to nearly 1800 middle school aged children at 17 different locations throughout the state of Colorado. Over 350 Colorado middle school teachers were trained on the hazards curriculum, and they were given materials to take back to their classrooms to reach even more students.

Mark McCaffrey from the CIRES' Education and Outreach program developed a one-page FAQ handout on the Rio Grande Rift experiment. This FAQ was adopted by the Earthscope national office and is being widely distributed throughout the country. This FAQ has also been distributed at all of the CU Science Explorers workshops, to large geology classes at the University of Colorado, and to the public.



CU graduate student Monica Guerra at Putney GPS station near Silverton, Colorado, May 2007. Putney station is run with assistance from the Center for Snow and Avalanche Studies.

CIRES Aerosol Studies Have Led to Important Applications to Problems in World Health

Robert E. Sievers
(with Steve Cape, Chad Braun, Jessica Burger, David McAdams, Jessica Best, Akiko Komura and Nicolette Wolters)
Funding: Aktiv-Dry L.L.C.

Studies of atmospheric aerosols by the Sievers group led to new methods of synthesizing aerosol microparticles. This methodology for processing was patented in 1996 and has been applied subsequently by several pharmaceutical companies and vaccine scientists. The process consists of stabilizing microparticles of vaccines and pharmaceuticals then drying and micronizing them.

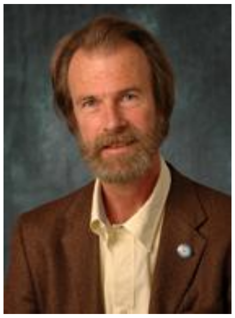
Accomplishments
Aerosol scientists, physicians, immunologists, formulation experts, engineers, device designers, and others are working together to make a stable, inhalable vaccine to reduce deaths from measles (now ca. 1,000 per day).

Because of its expertise in aerosol science, CIRES has been invited to play a leadership role in an international collaboration to develop an inhalable powder of live attenuated measles vaccine to be manufactured by the Serum Institute of India (SII). Development through Phase I human trials is being funded by a grant from Aktiv-Dry LLC as part of the Grand Challenges in Global Health initiative. The inhalable vaccine is being developed specifically for the developing world, with due consideration given to thermal stability, cost, ease of needle-free administration, and shipping volume and weight. Methods: Vaccine was supplied by SII (Pune, India). Candidate live and placebo formulations were dried from aqueous suspension to inhalable powder using the CIRES-patented process Carbon Dioxide Assisted Nebulization with a Bubble Dryer® (CAN-BD). Powder characterization included live-vaccine virus activity, moisture content, powder particle aerodynamic diameter after dispersal. An inexpensive active dry-powder inhaler is also under development; two patent applications have been filed by CIRES scientists, Bob Sievers, Steve Cape and Jessica Best. Results: Formulation with myo-inositol, gelatin, and L-arginine as the major constituents and CAN-BD drying yielded amorphous powders with 75%±16% retained activity (95% confidence interval), thermal stability that passed the WHO 7-day 37°C test, low moisture content of only 0.7 to 1.2%, and a mass-median aerodynamic diameter of 3 µm. Conclusions: The SII measles vaccine can be processed at 50°C into an inhalable dry powder with the CAN-BD process, with activity retention through processing similar to present commercial lyophilization, and short-term stability, meeting WHO requirements. If proven safe and effective, and introduced successfully into developing countries, WHO expects the demand for this inhaled aerosol vaccine to be 300,000,000 doses per year, and save many thousands of lives.

Photo of new Dry Powder Inhaler (DPI) to deliver aerosols of vaccines to 1 to 5-year-old children.

Greenland Ice Sheet Moulins – The Link to Increased Ice Velocity

Konrad Steffen
With Russell Huff, Alberto Behar[1], and graduate students
Funding: NASA Cryospheric Sciences
[1]Collaboration: NASA Jet Propulsion Laboratory, Pasadena, CA



Purpose and Objectives

Understanding the flow of water through the body of a glacier or ice sheet is important because the spatial distribution of water and the rate of infiltration to the glacier bottom is one control on water storage and pressure, glacier sliding and surging. According to the prevailing hypothesis, this water flow takes place in a network of tubular conduits.

The prevailing view of englacial water flow through tubular conduits is supported by observations of caves on the margins of glaciers and explorations into moulins (a vertical shaft in a glacier). Whether such features are unique to the margin and to moulins is unclear. We carried out two field expeditions along the margin of the Greenland ice sheet in summer 2006 and 2007 to measure the volume of moulins using a rotating laser scanner and video equipment. Further, we lowered an instrument package into the ice sheet along a 500-m long string measuring environmental parameters with HD video recording.

Moulin on the Greenland ice sheet along the western slope of the Greenland ice sheet. There are 45 moulin in an 10 km x 10 km are in the lower ablation region of the ice sheet, and they each drain approximately 4.5 10^6 m^3 water during one melt season.

Accomplishment

The surface velocity of the Greenland ice sheet varies significantly on both seasonal and shorter time-scales. Seasonal variations reflect the penetration of supraglacial water to the glacier bed through significant thicknesses of cold ice. There, velocity fluctuations were recorded with our GPS network (eight permanent Trimble stations) which has been operational in this region since 1995. Shorter-term events are associated with periods of rapidly increasing water inputs to the subglacial drainage system. Early-season short-term events immediately follow the establishment of a drainage connection between glacier surface and glacier bed, and coincide with the onset of subglacial outflow at the terminus. A mid-season short-term event occurred as surface melting resumed following cold weather, and may have been facilitated by partial closure of subglacial channels during this cold period. There is a close association between the timing and spatial distribution of horizontal and vertical velocity anomalies, the temporal pattern of surface water input to the glacier, and the formation, seasonal evolution, and distribution of subglacial drainage pathways. These factors presumably control the occurrence of high-water-pressure events and water storage at the glacier bed. The observed coupling between surface water inputs and glacier velocity may allow predominantly cold polythermal glaciers to respond rapidly to climate-induced changes in surface melting.

Laboratory Studies of Clouds and Aerosols

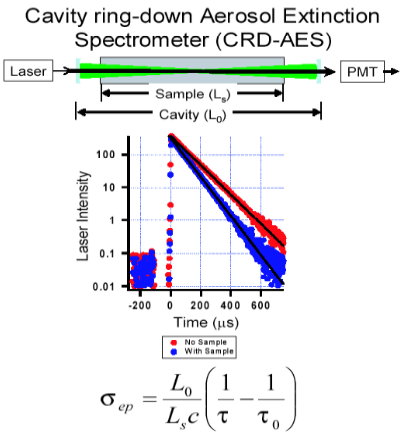
Margaret A Tolbert

Funding:

Cirrus clouds, composed of water ice, cover up to 30% of the Earth's surface at any time and subvisible cirrus are almost always present in parts of the tropics. Depending on meteorological conditions, the appearance of cirrus clouds ranges from wide sheets 100 to 1000 km in length from the outflow of cumulonimbus anvils, to wispy filaments from jet stream-induced wind shear, to a subvisible cloud layer near the tropical tropopause. A photograph of cirrus clouds is shown in Figure 1. Cirrus and subvisible cirrus clouds play an important role in the climate system as well as in controlling the amount of water getting into the stratosphere. The clouds are usually optically thin in the visible, allowing most, but not all, sunlight to reach the Earth's surface. In contrast, the outgoing infrared radiation is efficiently absorbed by cirrus ice particles. While the net effect of cirrus clouds on climate is usually a warming at the surface, the microphysical properties of the clouds dictate the overall climatic impact. The microphysical properties in turn depend on the nucleation mechanism of ice in the atmosphere. Laboratory studies in the Tolbert research group are examining heterogeneous ice nucleation on a wide range of possible atmospheric aerosols including organics, minerals, sulfates and combinations of these species.

***Figure 1**. Cirrus clouds over Boulder, photo by Mark Zondlo.*

In addition to clouds, research in the Tolbert group is focused on atmospheric aerosols. Atmospheric particles are a complex mixture of inorganic and organic compounds. Upon exposure to increasing relative humidity (RH), the particles can grow through water uptake. This hygroscopic growth affects the optical properties of the particles. This in turns influences how the aerosols contribute to visibility degradation and climate change. The Tolbert group, in collaboration with NOAA, is using cavity ring down (CRD) spectroscopy to determine the dependence of optical changes due to hygroscopic growth as a function of chemical composition of the particles. Figure 2 shows a schematic diagram of the CRD system that is currently in use. The system measures aerosol extinction, σ, of particles based on the decay times, τ, of laser light within the cavity in the presence and absence of particles. Experiments are probing the aerosol extinction for a wide range of chemical compositions, focusing on the effects of organics and mixed organic/inorganic particles.



$$\sigma_{ep} = \frac{L_0}{L_s c}\left(\frac{1}{\tau} - \frac{1}{\tau_0}\right)$$

***Figure 2**. Schematic of cavity ring down set up (top), with observed signals from an empty cell compared to a cell containing aerosols (middle), and the CRD equation to determine extinction (bottom).*

The Tolbert research group is also examining aerosols on Saturn's moon, Titan. One of Titan's most captivating features is the thick organic haze layer surrounding the moon, believed to be formed from photochemistry high in the CH_4/N_2 atmosphere. We are performing laboratory studies using a deuterium lamp to initiate particle production in simulated Titan atmospheres from UV photolysis. Using a novel analysis technique, the Aerosol Mass Spectrometer, we study the chemical composition, size, and shape of the particles produced as a function of initial trace gas composition. An example of the aerosol mass spectrometer data we obtain from photolysis of a 0.1% CH_4/N_2 mixture is shown in Figure 3. Here it can be seen that large organic molecules are produced in the particles that form via photolysis. In addition to relevance for Titan, it has been suggested that a similar haze layer may have formed on the early Earth. Ongoing research in the Tolbert group is probing the chemistry, properties and implications for such a haze on Earth at a time when life was just emerging.

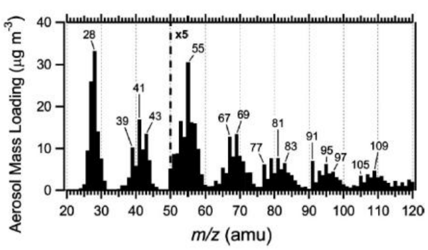


***Figure 3**. Aerosol mass spectrum for particles formed in 0.1% CH_4 in N_2.*

Modeling the Geomorphology and Archaeology of River Valleys

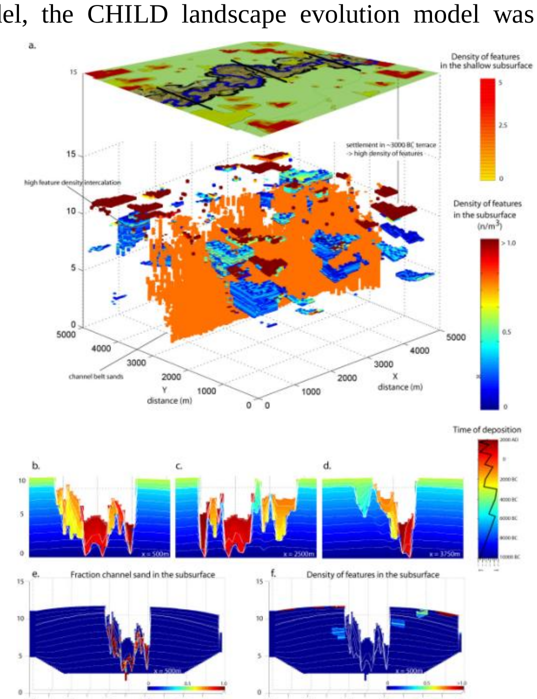
Greg Tucker

Funding: UK English Heritage, Netherlands NWO, ARO, NSF

Throughout human history, river valleys have provided access to water, transport, and fertile fields. As a result, river valleys often contain valuable archaeological records, as well as records of past environments. However, interpreting the alluvial “tape recorder” can be quite challenging. The dynamic nature of river systems and their sensitivity to climatic change often combine to produce complex, three-dimensional patterns in the stratigraphy beneath valley systems. To interpret these patterns correctly requires a quantitative understanding of the geomorphic processes that shape riverine environments. To address this challenge, our research team – led by postdoctoral associate Quintijn Clevis (now at Royal Dutch Shell) together with colleagues in the U.S. and Britain – set out to create a process-based, quasi-three-dimensional model that simulates the dynamic evolution of a river and its deposits. We have used this model to develop insight into how Holocene climate variations are scribed in alluvial river deposits, and how knowledge of geomorphic history can aid in mapping and recovering archaeological remains.

Accomplishments

A variety of processes contribute to shaping a meandering river valley and its deposits. Episodic floods can deposit fine sediment across a floodplain. Under the right conditions, these deposits can grow quite thick, burying the remains of campsites, settlements, and other archaeological materials. On the other hand, as the channel meanders back and forth across its valley, bank erosion can recycle substantial volumes of sediment, and in so doing destroy or disrupt buried archaeology. Meanwhile, the growth of point bars adds new sediment to the floodplain. In addition to the constant deposition and recycling of sediment as a river sweeps horizontally across a valley, the channel may also experience episodes of rapid aggradation or incision due to climatic, tectonic, or anthropogenic forcing. In order to capture the essence of these processes in a simulation model, the CHILD landscape evolution model was augmented with several novel capabilities: a dynamic re-meshing system that tracks the passage of a meandering channel as it winds its way across a floodplain, a stratigraphy module to compute and store deposits and their properties, and a very simple archaeological model that allows one to experiment with different hypotheses about human settlement behavior in a floodplain environment. Using this modeling system, one can explore alternative scenarios for floodplain evolution and archaeological site formation on 10,000-year time scales. For example, the figure below shows cross-sections and a cut-away view of floodplain deposits formed under a sequence of climate-driven cut-fill cycles, based on reconstructed Holocene elevation trends for Pomme de Terre River in Missouri. One of the findings to come out of this work is that both the visibility and degree of preservation of valley archaeology depend strongly and systematically on Holocene geomorphic history. Terraces generated during periods of alternating incision and stability provide good archaeological visibility but limited preservation, particularly in narrow valleys. Conversely, steady aggradation leads to excellent visibility but poor preservation. An intriguing application of this model lies in testing alternative sampling schemes for geochronology and archaeological recovery.



(Above) Cut-away view showing a simulated floodplain surface (channel in blue, floodplain in green) with buried archaeological sites (red-blue colors, with red indicating high artifact density) and channel deposits (orange). (Middle)Transverse valley cross sections colored according to sediment age (blue=oldest, red=youngest). (Bottom) Valley cross-sections colored according to the percentage of channel sand (left) and the density of archaeological remains (right).

Photoprocessing of Organic Acids in the Earth's Atmosphere

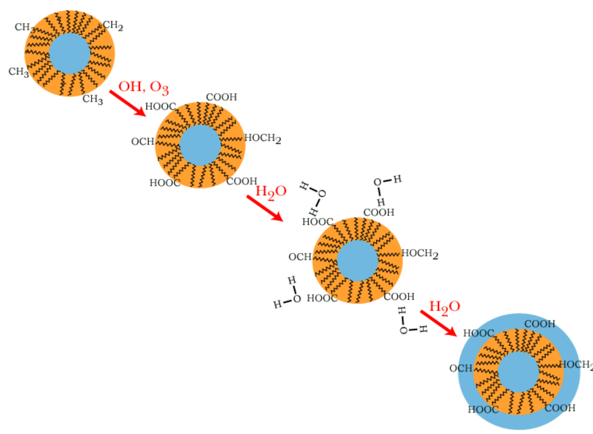
Veronica Vaida
Funding: NSF

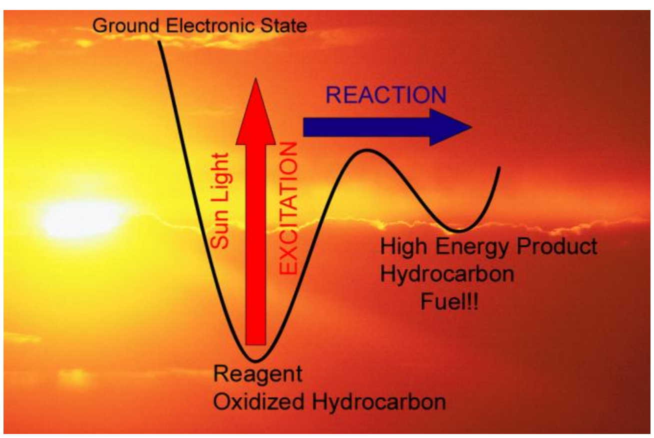
The Vaida group studies sunlight initiated chemistry of significance to climate. In the Earth's atmosphere, rapid oxidation of biogenic and anthropogenic emissions produces organic (acids, alcohols) and inorganic (HNO_3, H_2SO_4) hydrophilic compounds which are key ingredients in aerosol formation and subsequent cloud nucleation which significantly influence climate. Solar photons perform effective photo-reduction of atmospheric targets. The Vaida group studies sunlight-initiated chemical reactions proceeding in the ground electronic state by excitation of a vibrational overtone state by visible red light in aqueous environments. This chemistry affects aerosol processing and nucleation.

Aerosols are globally distributed suspensions of small particles in air and known to influence climate through reflection of solar radiation and nucleating clouds. Organics partition to the water-air interface and have a profound effect on climate and chemistry in the atmosphere. Organics emitted from sources such as biomass burning create a coating on the sea surface and on aerosols.

Accomplishments

The stability, partitioning, oxidative processing, and permeability of these organic films have been investigated in the Vaida lab. The results of these studies are used to explain recent field results, which show that the surfaces of collected aerosols are dominated by long-chain fatty acids.



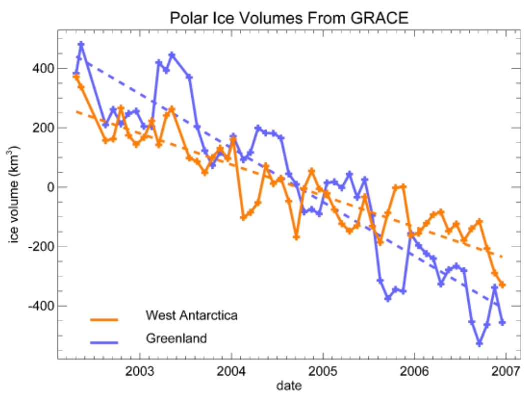


Time-Variable Gravity from GRACE

John Wahr, Isabella Velicogna, Sean Swenson, and Bryan Killett
Funding: NASA, JPL, NSF

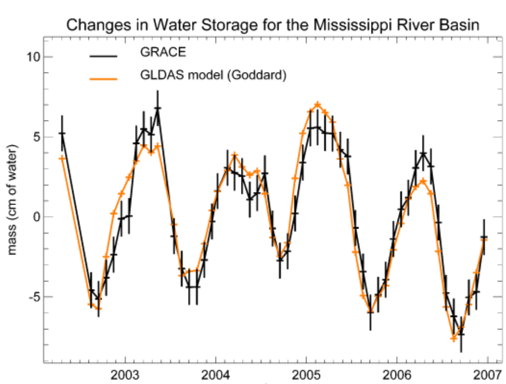
NASA, in partnership with the German Space Agency DLR, launched the twin GRACE (Gravity Recovery and Climate Experiment) satellites in March 2002. This ~10-year GRACE mission is mapping the Earth's gravity field to spectacular accuracy every month. Time-variations in gravity can be found by removing the temporal mean field from these monthly maps. Since it is mass that causes gravity, this time-variability can be used to estimate month-to-month changes in the Earth's mass distribution. GRACE can recover signals at scales of about 300 km and larger.

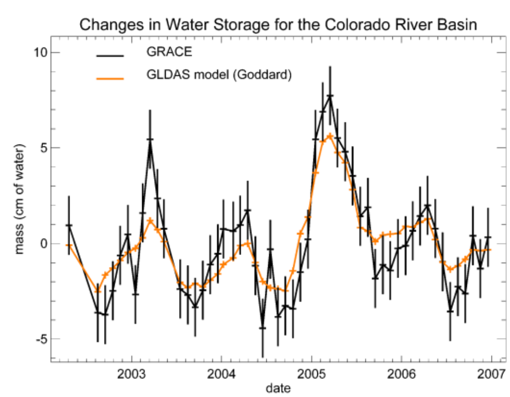
Accomplishments
We have been using these data to look at a number of geophysical signals, particularly those that involve the storage of water (including snow and ice) on continents and in the polar ice sheets.



For example, because of its large effective footprint and its sensitivity to mass, GRACE offers the best available method for measuring the total mass balance of the polar ice sheets. The figure at left shows monthly GRACE results for the mass variability of Greenland and the West Antarctic Ice Sheet, between April 2002 and December 2006. The best fitting trends, shown as the dashed lines, are -233±40 km^3/yr of ice for Greenland and -99±20 km^3/yr of ice for West Antarctica. The Greenland mass loss appears to have accelerated sharply starting in spring, 2004.

For other land areas, the GRACE mass results provide the sum of water on the surface, in the soil, and beneath the soil layers, and so can be used to assess land surface water storage models. Before GRACE, there was no practical way of measuring total water storage at regional- to global-scales. The figure below shows monthly water storage variations for the Mississippi and Colorado River basins, and compares the results with output from the GLDAS/Noah land surface model [Rodell et al., 2004]. The error bars on the GRACE results represent 68.3% confidence limits. Note that the errors are larger for the Colorado, reflecting the fact that the Colorado basin is smaller than the Mississippi basin. The agreement between GRACE and GLDAS/Noah is excellent for the Mississippi, showing that the GLDAS/Noah model does a superb job of predicting water storage variations there. For the Colorado, the seasonal phases are in good agreement, but the model tends to under-predict the amplitudes.





Ecological Resilience: Disturbance Interactions and Regeneration in a Subalpine Forest

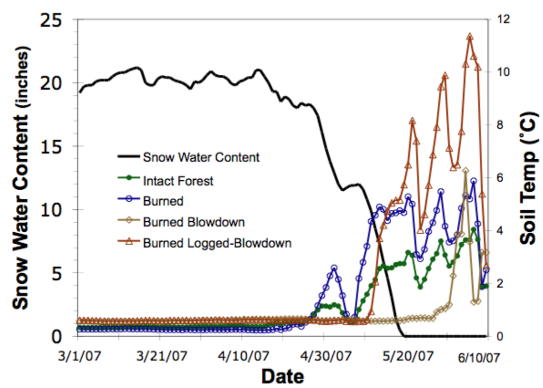
Carol Wessman with Kendra Morliengo-Bredlau
Funding: CU, EEB, CIRES, John Marr Memorial Ecology Fund

Non-equilibrium ecology suggests that the structure, composition, and dynamics of ecosystems are contingent on disturbance and management legacies. However, field observations do not yet provide compelling evidence for relationships described by some of the core concepts in non-equilibrium theory, such as the historical contingency of successional pathways.

This study focuses on mechanisms known to be important drivers of forest regeneration at landscape (e.g., recent disturbance history, fire severity, disturbance pattern) and local (e.g., biotic competition, microenvironment) scales. Our study site in Colorado's Routt National Forest recently experienced a series of catastrophic disturbances: a large blowdown in 1997, salvage-logging in 1999-2000, and a large fire in 2002 (figure below). We are examining subalpine forest regeneration, using a combination of field observations, remote sensing, and geospatial analysis to determine whether compound disturbances increase landscape heterogeneity by creating conditions that vary widely in their ability to support and maintain conifer regeneration.

Accomplishments

While the initial effects of the 2002 fire tended to "erase" the impact of previous disturbances on soil properties and nitrogen cycling, vegetation surveys four years after the fire suggest that pre-fire disturbances have a pronounced influence on understory establishment and conifer regeneration rates. Areas with multiple disturbances show significantly wider extremes between minimum and maximum diurnal surface soil temperatures throughout the growing season. Continued research will follow regeneration trends and soil biogeochemistry to further establish if post-fire ecosystem dynamics are qualitatively or quantitatively different because of pre-fire disturbance histories.



(Above) Surface soil temperature (4 cm depth) vs. Lost Dog Snotel data indicates that multiply disturbed areas may retain snow longer in the spring, but experience larger temperature swings once snow free.

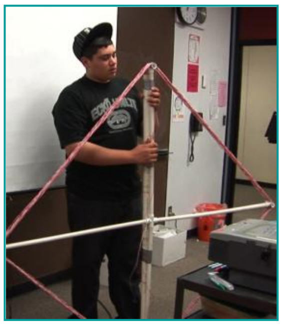
	Intact	Blowdown	Salvage Logged
Burned *(Mean ± SE)*			
Veg Cover (%) 2006	52.2 ± 3.3 ^{a}	20.5 ± 2.3 ^{c}	39.5 ± 2.8 ^{b}
Veg Cover (%) 2003	3.6 ± 0.75 ^{a}	0.0 ± 0.0 ^{b}	0.0 ± 0.0 ^{b}
Seedling density 2006 (trees / 10 m^2)	0.85 ± 0.46 ^{a}	0.03 ± 0.03 ^{b}	0.03 ± 0.01 ^{b}
Seedling density 2003 (trees / 10 m^2)	56.9 ± 37.65 ^{a}	0.0 ± 0.00 ^{b}	0.0 ± 0.00 ^{b}
Unburned *(Mean ± SE)*			
Vegetation Cover (%)	46 ± 3.6 ^{b}	70 ± 6.1 ^{a}	22 ± 4.3 ^{c}
Seedling density (trees/10 m^2)	7.9 ± 3.6 ^{c}	3.7 ± 1.5 ^{c}	2.9 ± 1.6 ^{c}

(Left) Four years following the Hinman fire, vegetation cover varied significantly among areas with different disturbance histories. Seedling establishment was significantly lower in multiply-disturbed areas. In comparison, prior to the burn (data from 2001), vegetation cover in blowdown areas was significantly higher than in salvage-logged areas, but was not significantly greater than the cover in control areas.

Education and Outreach Program

Description
The CIRES' Education and Outreach group extends the expertise of CIRES to serve the needs of our education partners. Our work emphasizes scientific inquiry, links with current research, and understanding of foundational concepts in geoscience.

Selected Accomplishments
The Extreme Ultraviolet Variability Experiment (EVE) and the Math, Engineering and Science Achievement (MESA) Program: "What do I need to do to be a scientist like you?" This question was asked of CIRES-NOAA scientist Dr. Eduardo Araujo-Pradere during an innovative new course for Spanish-speaking high school students developed for MESA by CIRES' EO. The MESA program prepares students to pursue undergraduate degrees in science and other math-based disciplines, with a focus on students from groups under-represented in those fields. Teacher Maria Murillo of Skyline H.S. introduced concepts in space weather, solar science, physics, mathematics, and computer technology. As part of their course-work, students built equipment to monitor disturbances in the ionosphere due to solar events, shared their data through the Stanford SOLAR project, participated in field trips and gave final presentations in English. The course will continue to be offered as an elective course at Skyline H.S. and is now being piloted in an after-school context. The course was funded through NASA as part of the LASP EVE satellite instrument project, scheduled to launch on the Solar Dynamics Observatory (SDO) mission in 2008.



An EVE-MESA student with the antenna used to monitor sudden ionospheric disturbances.

Earthworks: Earth System Science for Secondary Science Teachers: The tenth annual CIRES Earthworks workshop for secondary science teachers served twenty-six educators from fifteen states. Earthworks 2007 participants designed and conducted field-based studies in limnology, hydrology, ecology, soil science, geology and solar science. In 2007, Ms. Barney Peterson, a long-time participant of the Earthworks workshop, was named the Washington State winner of the Presidential Award for Excellence in Mathematics and Science Teaching. This award is the nation's highest honor given to educators in the fields of mathematics and science. Ms. Peterson writes, "Prior to my participation in Earthworks, my focus for student investigations was pretty much life science. Exposure to earth system science through Earthworks has encouraged and enabled me to develop a more rounded program. Students spend more time inquiring into the health of local wetlands from the bottom up and the top down (bedrock to topsoil and clouds to puddles)…By looking into the whole system, students (and parents, and teacher) get a better understanding of how it all works together." For more information about the Earthworks workshop series, see *http://cires.colorado.edu/education/k12/earthworks*

The Earthworks 2007 hydrology team demonstrates their study protocols.

Northeast Front Range Math and Science Partnership: Teachers from five local school districts attended an institute on Earth and space science led by outreach scientist Sandra Laursen. The 21 teachers engaged in inquiry-based activities, lab work, field trips, and discussions during the intensive two-week session. During four summer and fall follow-up sessions, teachers completed additional field and class work and conducted "lesson study" projects on their own classroom practice and student learning. The institute is offered by a Math/Science Partnership funded by the Colorado Department of Education. Project results have been disseminated at the Colorado Science Convention and included in a national study of 25 exemplary teacher professional development programs by the Council of Chief State School Science Officers.

Teacher Dave Title (Niwot HS) generates surface currents in a shoebox-sized ocean model.

National Ocean Sciences Bowl (NOSB): The 2007 NOSB "Mountain Mariner" regional competition was a great success. Team B from Poudre High School won the competition but the team was unable to attend the National finals. Therefore, runner-up Smoky Hill High School represented the Mountain Mariners in the National competition and placed fifth. The CIRES-based regional competition has historically been the most land-locked and one of the largest of the twenty-five regional competition sites. We draw students and families to the CU campus from all over Colorado and from the surrounding states. Scientists and staff from CIRES and NOAA volunteer to make the event enjoyable and challenging for some of the most accomplished students in the region. For more on the Mountain Mariner NOSB competition, see *http://cires.colorado.edu/education/k12/nosb/about.html*.

Resources for Scientists in Partnerships with Education (ReSciPE): ReSciPE is an NSF-funded project designed to assist scientists who are engaged with K-12 education. The project includes professional development workshops for scientists about how to work effectively within K-12 education, makes digital resources available, provides consultation help and includes a research study to identify how best to support scientists in these endeavors. While workshops continued to be offered, including a CIRES' workshop attended by CIRES, NOAA, and NSIDC scientists among others, this year's efforts focused on completing the evaluation and research study. First findings from this study were presented in two talks at AGU in December 2006 and are being prepared for publication in the *Journal of Geoscience Education*. To learn more see
http://cires.colorado.edu/education/k12/rescipe/

Ice Fest: Celebrating the Launch of the International Polar Year: In May 2007, CIRES hosted a series of events called *Ice Fest* to celebrate the launch of the International Polar Year. *Ice Fest* included a wide variety of activities on the themes of ice and snow, polar research and climate studies, including science and art talks, films, presentations and family activities. Highlights included presentations by National Geographic photographer James Balog and Antarctic photographer Rosemarie Keough of their spectacular images of polar regions, a keynote talk by Astronaut Don Pettit comparing and contrasting experiences on the International Space Station and in Antarctica, and a talk by Boulder filmmaker Michael Brown. Other events included a live video conference with the NOAA Barrow Station, numerous presentations by world renowned polar experts, a presentation on the climate crisis by 14-year-old climate activist Alex Budd, and a panel discussion by climate and energy experts. For a more complete description, see *http://cires.colorado.edu/events/icefest/*.

Welcome to IceFest by CU Chancellor Bud Peterson and David Skaggs.

Impact

The work we do extends the expertise of the institute into the community to meet real needs. We help scientists increase their professional contributions through the development of science-literate citizens and students. Through these contributions, scientists reap the benefits of increased skills, enjoyment, and satisfaction in their profession. For more information on these or other Outreach activities, see *http://cires.colorado.edu/~k12*.

CIRES' Scientific Centers

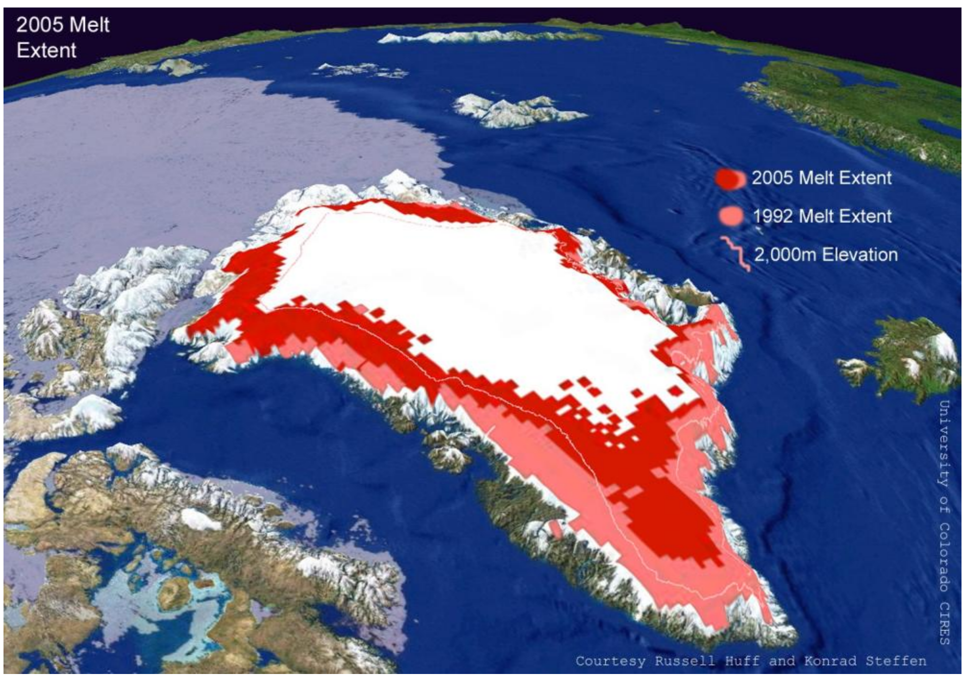
Center for the Study of Earth from Space

CSES was founded in 1985 to provide a focus for the development and application of modern remote sensing techniques used in the research of all aspects of earth sciences at the University of Colorado. Although measurements from space are emphasized, aircraft and field measurements are integral to any remote sensing project.

Within CSES, the aim is to work on all scales of problems extending from technique development in small test sites to understanding pattern and process on a regional and global scale. Data from the available electromagnetic spectrum, extending from the UV to the microwave region, are used. CSES facilities were developed with generous support from the W.M. Keck Foundation and matching funds from the University. The laboratories are dedicated to both research and teaching. CSES has four faculty associates and they support about 12 graduate students from Geography, Geology, Atmospheric and Ocean Sciences, Environmental Biology, and Engineering

Remote Sensing Research

The primary areas of study at CSES include Arctic climatology, ecology, geology, hyperspectral imaging, hydrology, paleoclimate, and remote sensing. A long-term goal of CSES research is to investigate problems in global geoscience, in particular questions of global change, through use of satellite observations. At present, the emphasis is on understanding the land and land-atmosphere interactions and the cryosphere. Some of the topics include biochemical cycles involving vegetation, soils, hydrology and water budgets, and human-induced change. Predictive models are being developed that incorporate inputs derived from satellite remote sensing data, and make it feasible to address global-scale questions.



Greenland melt extent derived from passive microwave satellite date for 2005, which was the largest melt year for the ice sheet during the 1979 – 2005 time period. The minimum melt extent is shown in pink color (1991).

Accomplishments

Ecology

Work during the past year on carbon sequestration in Southwestern rangelands demonstrates that dryland regions are changing mosaics of woody plant classes whose trends through time are logistically difficult to track with traditional ground-based techniques. Fieldwork linked to remote sensing imagery offers the capability to monitor and track changes in aboveground carbon pools over large dryland regions and at frequent intervals.

Polar Climate

Evidence of a temperature regulation mechanism at high latitudes related to sea-surface temperatures was found, which might explain the lower rate of observed Arctic warming than predicted by climate models. Researchers also found a strong feedback from biosphere albedo in a simple model of the Earth's climate system. Finally, observed trends in reanalysis products were compared with previous claims of tropospheric warming causing some of the rise in tropopause height in the same data and showed that no warming existed in the data.

Climate Modeling

Researchers published a simple, nonlinear climate model study called a Dynamical Area Fraction Model (DAFM), which laid the basic theoretical framework for developing simple nonlinear coupled-dynamic models. Two subsequent experiments with this revised model suggested the domination of negative feedback from the hydrologic cycle on the climate regulation: the active hydrological cycle greatly reduced the global climate temperature, despite powerful positive hydrological feedbacks like the ice-albedo and hydrological greenhouse feedbacks. These results contrast with anthropogenic explanations of climate change that rely heavily on assumptions of positive feedbacks from the hydrological cycle.

Education and Student Opportunities

Remote sensing is not a discipline in itself, but rather a major, evolving tool applicable to studies of the Earth involving the atmosphere, biosphere, hydrosphere, cryosphere, and the solid earth. CSES acts as a focus for research, campus-wide, in the use of remote sensing for global geosciences studies. So far, master's and Ph.D. candidates from the departments of Anthropology, Geography, Geological Sciences, Electrical Engineering, Ecology and Evolutionary Biology and the Interdepartmental Geophysics Program have carried out thesis research in CSES.

CSES Facilities

The CSES facilities include approximately 8000 square feet of lab and office space, which was completely refurbished in 1994 with support from the W. M. Keck Foundation of Los Angeles, CA. CSES occupies the second floor, South and West wings of the Ekeley Science building in the heart of the University campus. CSES also contains a 24-seat classroom for teaching, including 10 Windows workstations.

Future of CSES

Professor Alexander F.H. Goetz, director of CSES retired in 2006. CIRES completed a faculty search for a new director. Negotiations for the new director are almost complete, and it is envisioned that this faculty line and the director of CSES position will be filled in summer 2008.

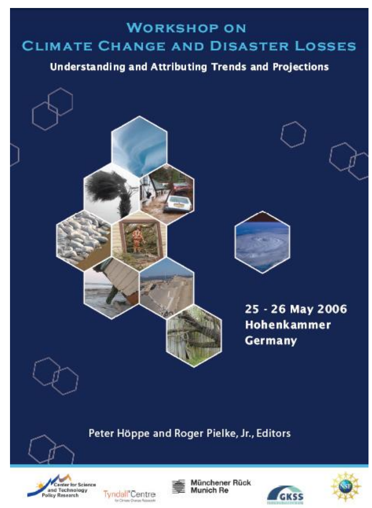
Center for Science and Technology Policy Research

Description

Since 2001, the Center for Science and Technology Policy Research has contributed to both the CIRES goal of "promoting science in service to society" and to the University's vision of establishing research and outreach across traditional academic boundaries. The vision of the Center is to serve as a resource for science and technology decision makers and those providing the education of future decision makers. Its mission is to improve how science and technology policies address societal needs, including research, education and service. The Center fulfills these objectives through activities within the following four "Strategic Intents":

- Help guide the University in educating the next generation of science and technology policy decision makers.
- Help make the nation's science portfolios more responsive to societal needs. Example areas include climate and global change, disasters, nanotechnology, biotechnology, and renewable/sustainable energy.
- Provide various means for people with differing perspectives to discuss research and practice related to science in its broader societal context.
- Build a sustainable, diverse and productive institution at the University.

Accomplishments FY 07

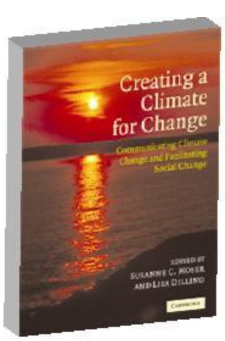


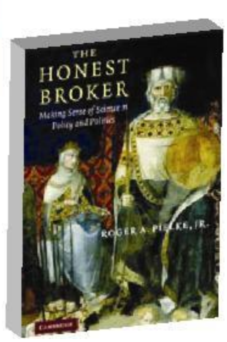
The **Graduate Certificate in Science and Technology Policy**, a rigorous educational program to prepare students pursuing graduate degrees for careers at the interface of science, technology, and decision making, is completing its third year. Fifteen students are currently enrolled in the certificate program. They come from a variety of University departments and institutes including Atmospheric and Oceanic Science, Computer Science, Geography, Journalism, Environmental Studies, CIRES, JILA (a joint institute of the University and the National Institute of Standards and Technology), and Engineering (Aerospace, Civil, Chemical, and Mechanical). Fourteen graduate students have already completed the program.

The Center's five-year NSF-sponsored project, **Science Policy Assessment and Research on Climate (SPARC)**, recently published reports from the following four SPARC workshops:

- 2006 Workshop on Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections
- 2006 Workshop on Multiple Stressors on Central Arizona Water Resources
- 2005 Workshop on Climate Science Policy: Lessons from the RISAs
- 2005 Decision Support and Carbon Cycle Science: Practical Strategies to Reconciling the Supply of and Demand for Carbon Cycle Science

The workshop reports are available online at *http://sciencepolicy.colorado.edu/admin/announcement_info.html?header=sparc&footer=sparc&event_id=1223*. This year, SPARC researchers made 33 presentations, published 14 articles, and submitted an additional 10 articles.





CIRES Visiting Fellow Lisa Dilling (with NCAR's Susi Moser) has a new edited volume from Cambridge University Press titled "*Creating a Climate For Change: Communicating Climate Change and Facilitating Social Change***.**"

Roger Pielke, Jr. has a new book out from Cambridge University Press titled "*The Honest Broker: Making Sense of Science in Policy and Politics***.**"

Roger Pielke, Jr. was awarded the **Eduard Brückner Prize** for outstanding achievement in interdisciplinary climate science. Center graduate student Shali Mohleji was one of seven students awarded the highly competitive **CIRES Graduate Research Fellowship** for the 2007-08 academic year.

Products
Center staff and students produced 22 peer-reviewed and non-peer-reviewed publications, and gave 41 presentations at academic conferences and other events. The Center also hosted 21 talks by affiliates and visitors. Other Center outreach efforts include a quarterly newsletter, a briefing that is sent to over 2,000 decision makers in Washington, DC and elsewhere, an extensive website, and a well-regarded science policy weblog that is ranked in the top .02% of all weblogs by Technorati, a well-recognized authority on weblogs.

Impacts
In January 2006, Center Director Roger Pielke, Jr., testified before the U.S. House of Representatives Government Reform Committee about "Political Interference in the Work of Government Climate Change Scientists." In May 2006, he testified before the U.S. House of Representatives Committee on Science and Technology about the findings of the fourth assessment report of the IPCC, Working Group III. Center staff were quoted or referred to numerous times by media including *Nature, Science,* Christian Science Monitor, Le Monde, Chronicle of Higher Education, National Review, Philadelphia Inquirer, Associated Press, New York Times, LA Times, San Francisco Chronicle, *Scientific American*, Boston Globe, and numerous local and regional publications.

During the summer of 2006, a Center graduate student interned for the second year with the Office of Management and Budget and another interned for the U.S. State Department in London. Center alumni are working as staff members for the U.S. House of Representatives Committee on Science in Washington, DC, for reinsurance companies, and as postdoctoral researchers.

National Snow and Ice Data Center

Description

The National Snow and Ice Data Center (NSIDC) supports research into our world's frozen realms: the snow, ice, glacier, frozen ground, and climate interactions that make up Earth's cryosphere. Scientific data, whether taken in the field or relayed from satellites orbiting Earth, form the foundation for the scientific research that informs the world about our planet and our climate systems.

NSIDC manages and distributes scientific data, creates tools for data access, supports data users, performs scientific research, and educates the public about the cryosphere. NSIDC has led the field of cryospheric data management since 1976.

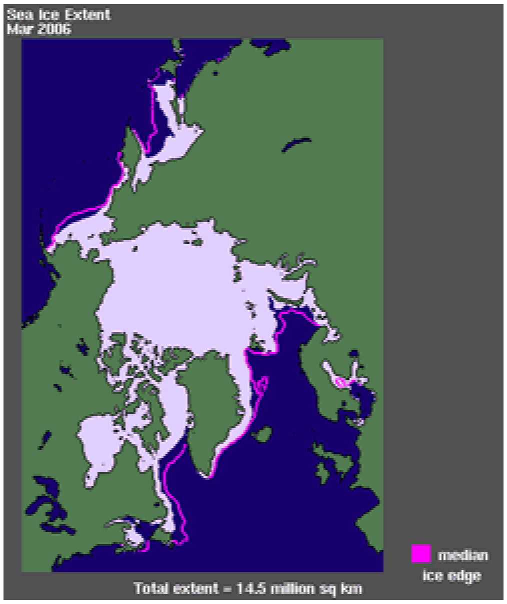
Accomplishments

In 2006, we added 35 new data sets to our online data offerings. We also continued to manage and disseminate the more than 500 data sets we offer through the NSIDC web pages, responding to requests from more than 46,000 users and providing them with 5 million data files containing 6.4 TB of data. In addition, we continued to develop our participation and interests in International Polar Year data management through the IPY Data and Information Service.

Our researchers and service personnel delivered dozens of presentations to audiences around the world, and our scientists spread word of our research through CNN, National Public Radio, the New York Times, British Broadcasting Corporation, and dozens of other major media outlets. Our scientists also helped inform decision makers through appearances at Congressional briefings in Washington, DC.

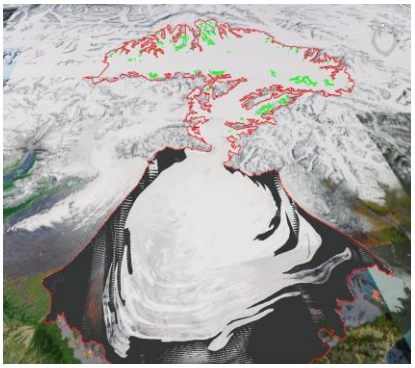
Research at NSIDC includes activities related to the cryosphere:

- ***Ice sheets and glaciers***: Glacier and ice sheet mass balance is an important and potentially variable contributor to sea-level rise. NSIDC scientists developed a new map of Antarctica and have been documenting the rates of movements of glaciers in critical parts of the Antarctic and Greenland ice sheets.
- ***Sea ice*****:** Sea ice is important both as an input to global climate models, and as an indicator of climate change. The Sea Ice Index, developed by NSIDC to meet a need for tracking changes in the ice as they occur, has indicated declines in Arctic sea ice extent and area during recent years.
- ***Permafrost and frozen ground*****:** Changes in the extent of permafrost and frozen ground are an indicator of climate change and have an impact on native communities, terrestrial ecology, and the infrastructure of northern lands. The carbon tied up in permafrost and frozen ground could affect the global carbon balance. Scientists at NSIDC are integrating *in situ* data with numerical models to refine predictions of frozen ground extent.
- ***Snow cover and snow hydrology*****:** Changes in the freshwater contribution to the northern seas are affecting the dynamics of ocean circulation. NSIDC's scientists are working with a variety of widely distributed data, in conjunction with synthesis and modeling approaches, to understand Arctic hydrology issues.
- ***Climate change in the cryosphere:*** Scientists working with near real-time monitoring of snow, sea ice, and vegetation under the Study of Environmental Arctic Change program are making progress toward documenting that change by using approaches such as the Sea Ice Index noted above.



The Arctic winter sea ice extent fell to a record low in March 2006, indicated by the solid off-white color. The pink line indicates the 1979-2000 mean sea ice extent in winter.

Impacts of changes on Arctic peoples: The impacts of changes on Arctic peoples are being recognized and incorporated into research projects. An NSIDC scientist has been living in a community in northeast Canada, documenting the observations of and impacts on the local people.



Alaska's Malaspina Glacier is so expansive it can only be seen in its entirety from space. The glacier outline from the GLIMS database is indicated in red and displayed in Google Earth.

The research activities and publications of NSIDC scientists are presented in the NSIDC Annual Report (*http://nsidc.org/pubs/annual*).

Impacts

Researchers using NSIDC data products are assessing and monitoring changes in the cryosphere that may have profound effects on society.

In particular, NSIDC scientists continue to help explain the importance of studying sea ice, snow, permafrost, glaciers, ice shelves, and other frozen aspects of our world, both through lectures, interviews with journalists, educational presentations, and helping provide online content.

Of note in 2006 was the impact of a new website, the Arctic Sea Ice News 2006 blog. NSIDC scientists and staff developed the blog to provide journalists and the public with up-to-the-moment updates on Arctic sea ice through the melt season. The site received between 18,000 and 20,000 hits *in a single day* after ABC News Online linked to the site from an article featuring NSIDC scientist Mark Serreze and his work on the sea ice minimum. By comparison, the most popular content on the NSIDC website typically receives approximately 700 hits per day.

Products

- ***NOAA at NSIDC and the World Data Center (WDC) for Glaciology, Boulder***
  The NOAA project at NSIDC operates in cooperation with the NOAA National Geophysical Data Center and Arctic Research Office to extend the NOAA National Data Center catalog of cryospheric data and information products, with an emphasis on *in situ* data, data rescue, and data sets from operational communities.
- ***The Distributed Active Archive Center (DAAC)***
  The NSIDC DAAC provides access to NASA's Earth Observing System satellite data, ancillary *in situ* measurements, baseline data, model results, and algorithms relating to cryospheric and polar processes. The DAAC is an integral part of the multiagency-funded efforts at NSIDC to provide snow and ice data, information management services, and user support.
- ***The Arctic System Science (ARCSS) Data Coordination Center (ADCC)***
  NSF has funded the ADCC at NSIDC to house data from Office of Polar Programs (OPP) Arctic System funded investigators, and to provide tools for investigators both submitting and looking for data.
- ***Antarctic Glaciological Data Center (AGDC)***
  The NSF OPP funds AGDC to archive and distribute glaciological and cryospheric-system data obtained by the U.S. Antarctic Program. AGDC facilitates data exchange and preservation of both new and historic data sets.
- ***U.S. Antarctic Data Coordination Center (USADCC)***
  NSF OPP funds USADCC to improve access to U.S. funded Antarctic scientific data by creating descriptions of these data and entering them into the Antarctic Master Directory, a node of the Global Change Master Directory. The Antarctic Master Directory is a web-based, searchable directory of thousands of data descriptions submitted by scientists from over twenty countries.
- ***The Frozen Ground Data Center (FGDC)***
  The FGDC is a collaborative effort between the World Data Center for Glaciology, Boulder and the International Arctic Research Center. FGDC works internationally to collect and distribute data gathered over many decades that are critical for environmental change detection and impact assessment.
- ***Global Land Ice Measurements from Space (GLIMS)***
  GLIMS, a cooperative project with the U.S. Geological Survey, is designed to monitor the world's glaciers primarily using data from the ASTER instrument aboard the Terra spacecraft launched in 1999. More than 56,000 glaciers are now entered in the GLIMS database.

Center for Limnology

Accomplishments

During 2006, the Center for Limnology continued its long-term commitment to the study of nitrogen biogeochemistry. Graduate student Mark Bradburn produced final results on an extensive study of nitrogen fixation in *Aphanizomenon*, a nuisance alga in the western U.S. His novel findings, which include a strong response to weak light for nitrogen fixation in *Aphanizomenon* as well as a striking ability to store reductant for use in the dark, show why *Aphanizomenon* is often dominant over other fixers and suggests how *Aphanizomenon* might be controlled.

Grand Lake, Colorado.

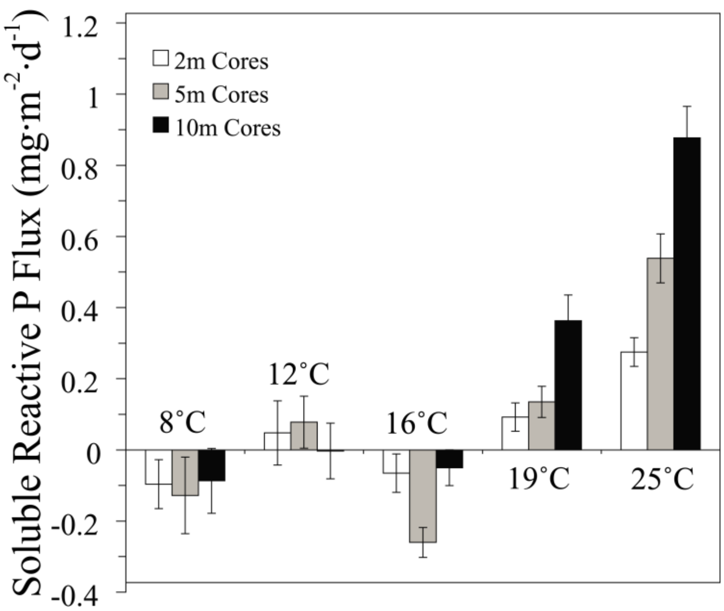
Research on nitrogen limitation in Colorado reservoirs led the Center to publish a new approach to a serious and persistent problem in the management of lake eutrophication (nutrient enrichment). Cherry Creek Reservoir was used as a case study. The Colorado legislature has allowed the Cherry Creek Basin Authority to charge entrance fees to the Cherry Creek Park to be used in controlling phosphorus for suppression of algal growth, which is sufficient at times to cause fish mortality and unpleasant scums. The Authority has invested millions of dollars in phosphorus control, but without any notable effect on algal populations. This sequence is common throughout the. It is based on a misunderstanding of the science related to ecological stoichiometry of algae. In lakes that are polluted with nutrients, algae grow to very high abundances, at which point inorganic nitrogen often is exhausted by algal demand, whereas inorganic phosphorus persists. Under these conditions, the nitrogen-fixing cyanobacteria take over the algal populations because of their ability to convert N_2 to ammonium; other kinds of algae cannot make this conversion. Lake managers are urged to control phosphorus in order to suppress algal growth, but do not realize that suppression of algal growth by control of phosphorus limitation cannot begin until sufficient phosphorus is removed from the system to induce phosphorus rather than nitrogen limitation. While the manager expects incremental progress, no progress is possible until photosynthesis limitation is induced. Managers and entities providing funding often are frustrated by this misunderstanding. The Limnology Center has presented a new methodology, based on ecological stoichiometry that will allow managers to project the amount of phosphorus that must be removed before any beneficial results are expected. Managers must then determine in advance, before spending very large amounts of money, whether this amount of phosphorus can be removed or not.

Also during 2006, graduate student James Anthony completed the data collection phases of his work on the release of phosphorus and nitrogen from lake sediments. Sediments contain large stores of nitrogen and phosphorus, but the availability of this nitrogen and phosphorus to algae during the growing season has not been quantified. Anthony created a turbulence generator ("turbulator") that is capable of controlling boundary-layer conditions for the sediment-water interface over experimental cores on a replicate basis. Extensive work with this system has given some new insight into the regulation of exchange at the boundary layer. The most surprising result is that boundary-layer turbulence has no great effect on exchange within the range that can be expected for lake sediments beyond the breakwater. Also surprising and unexpected was a drastic increase in phosphorus and nitrogen release from sediments beyond a critical temperature that is near the maximum annual temperature. This finding makes an unexpected but potentially significant connection to climate change, in that an increase in mean lake temperature of as little as 2°C could quadruple the nutrient efflux from lake sediments, thus producing a change in the nutrient regime.

Turbulator: A device for control of boundary-layer turbulence in cores.

The Limnology Center during 2006 also was heavily involved in preparing portions of a new *Encyclopedia of Inland Waters*, which is intended to be a landmark reference reflecting the combined expertise of international specialists on lakes, streams, and wetlands. The Encyclopedia is due for release in 2008. Also during 2006, the Center for Limnology served as the administrative center for International Society for Limnology.

During 2006, the Limnology Center continued its long-term biogeochemical investigations of the South Platte River, especially focusing on nitrogen and oxygen metabolism. A new twist for 2006 was the discovery of substantial amounts of nitrogen ebullition, not reported previously in rivers (probably because ebullition is generally assumed to be methane). Rates and mechanisms of ebullition were studied during 2006 and are being published during 2007. The discovery of ebullition will necessitate changes in the mass-balance analysis of nitrogen in rivers.



Evidence of a thermal response for nutrient release from lake sediments.

Climate Diagnostics Center

Description

The Climate Diagnostics Center (CDC) provides a research focus in CIRES for efforts to advance understanding and predictions of the climate system and its component processes. CDC activities involve a coordinated program of observational, diagnostic and modeling studies aimed at significantly advancing understanding and predictions of climate variability. Research disciplines include, but are not limited to, atmospheric sciences, oceanography, remote sensing, numerical computational methods, computer sciences, data management, and complex systems analysis. The development of more skillful and useful climate predictions requires an integration of these disciplines so that advances in the understanding of processes governing climate variability can be applied to improve models and methods used for climate predictions.

Accomplishments

In the 2006 calendar year, 36 peer-review publications were produced covering a broad range of climate-related topics. Scientific input was provided into numerous national and international programs including:

1) Provided leadership in the international Global Climate Observing System Surface Pressure Working Group to promote the development of long-term high-quality analyses of atmospheric surface pressure.
2) Started production of a 100-year global climate reanalysis based on ensemble data assimilation techniques that can produce high-quality products even with the sparse pre-radiosonde era observations. These efforts will extend our ability to quantify climate variability, provide uncertainty estimates for climate detection, and aid attribution efforts to inform policy decisions.
3) Supported NOAA and RISAs in experimental climate services through research to improve the delivery of the regional climate data, products and services needed to enhance public and private sector decision making and reduce climate-related risks.
4) Implemented a seasonal forecast guidance tool for surface temperature and precipitation over North America, which is a blend of dynamical and empirical methods, derived from the dynamical climate simulation data from an ensemble of four atmospheric general circulation models forced by known, monthly sea surface temperature fluctuations between 1950-1999.
5) Contributed to and serving on numerous WMO, national, AMS and AGU climate research panels and journal editorial boards, as well NASA, NSF, and DOE advisory and review panels.
6) Developed new and improved existing climate prediction capabilities through enhanced understanding of dynamical processes and predictability of the principal interacting components of the climate system on time scales of weeks to millennia, using a combination of observational and modeling approaches.
7) Led an international effort to improve monitoring of ENSO conditions through the development of a next-generation Multivariate ENSO Index.
8) Developed empirical projections of future Colorado River flows from IPCC AR4 climate models for use in risk management assessments

Impacts

Water managers in the seven Colorado River Basin states cannot adequately plan for a future of increased climate variability and change unless they can anticipate how future climate will affect streamflows in the Colorado River. Statistical techniques were used to transform IPCC AR4 climate model projections into Colorado River flows at Lees Ferry 9 (Figure 1). Results indicate a significant risk for dramatic reductions in flows in the coming decades.

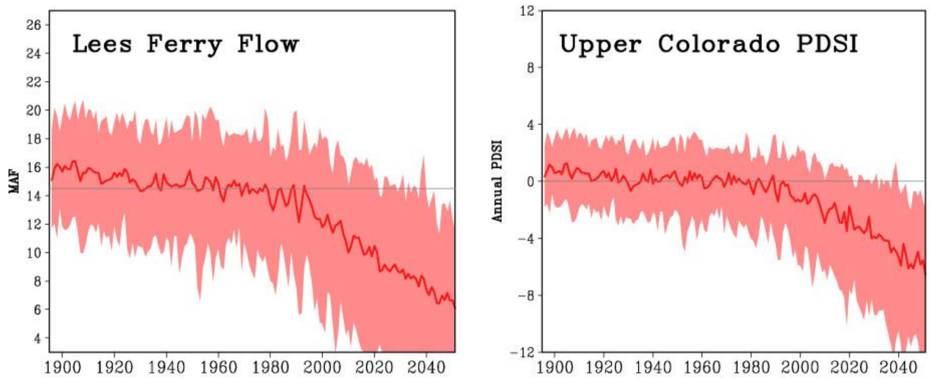


Figure 1. *The 1895-2050 Lees Ferry annual streamflow (left) derived from the AR4 simulations of PDSI (right) using a downscaling formula that relates observed Lees Ferry flow to observed PDSI during the 20th Century. The dark red curve denotes the 42-run average, and the cloud describes the 10%- 90% range of individual simulations.*

Products

A unique capability was developed to produce high-quality daily reanalyses for the troposphere from surface pressure observations alone using a data assimilation system based on the "Ensemble Filter" (Figure 2). The combination of recently improved surface observational records together with this data assimilation method provides an exciting new opportunity to extend the reanalyses back in time, perhaps providing for the first time a reanalysis data set of a century or longer.

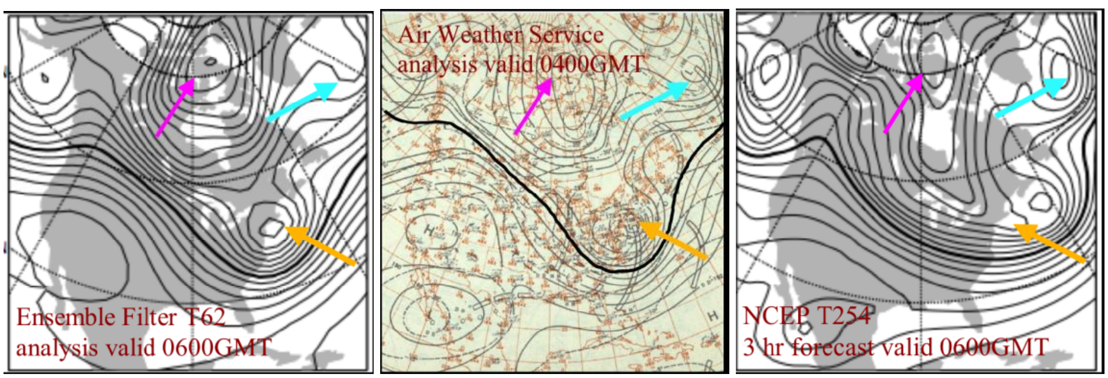


Figure 2. *The 500 hPa height analysis of 27 December 1947 06GMT from the Ensemble Filter data assimilation system using only surface pressure observations (left) and from the experimental NCEP T254 analysis using all available surface and upper air observations (right). An Air Weather Service map drawn in near-real time is also shown (middle). Colored arrows illustrate the same features in all three maps.*

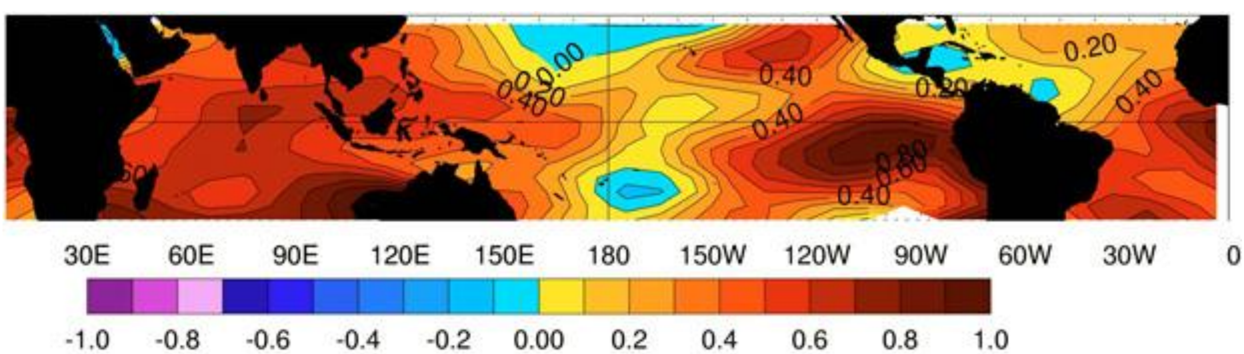
Innovative Research Program

Possibility of Abrupt Climate Change in the Next Few Decades

Investigator: Prashant D. Sardeshmukh (CIRES/NOAA ESRL)

Objective**.** We propose to perform several 100-year integrations of two global atmospheric general circulation models (GCMs) with prescribed ocean sea surface temperatures (SSTs) in the tropics and with coupling to a simple mixed-layer ocean model elsewhere. The prescribed tropical SST fields will incorporate a hypothesized continuation of the warming trend observed over the past 50 years, including the continued warming of the tropical Indian, western Pacific, and Atlantic oceans. For reasons explained below, we suspect that the global climate system is close to a "tipping point" with regard to the continued warming of especially the Indian Ocean. We believe that our GCM experiments, conducted with two different GCMs to generate confidence in the results, will provide a clear assessment of the likelihood of this tipping point being crossed in the next several decades, with potentially dramatic consequences for the climates of North America, Asia, and the Arctic.

Background**.** There is growing evidence that much of the global and regional climate changes over the next century associated with anthropogenic forcing will be mediated, or at least be strongly influenced, by tropical SST changes. The tropical oceans have already warmed substantially over the last 50 years (see figure below). Recently we demonstrated that this warming is outside the range of natural ENSO SST variability at almost all tropical locations. The warming of the Indian, western Pacific, and south Atlantic Oceans is especially significant in this regard. At present, it is not clear to what degree this warming is associated with anthropogenic forcing or with natural decadal and longer term variations of the climate system. The answer to this question has a large bearing on how this warming pattern will evolve over the next several decades and what its worldwide impacts will be. Most climate models involved in the IPCC Fourth Assessment of projected climate changes misrepresent important aspects of tropical climate dynamics, including ENSO, the long-term oceanic subsurface controls on ENSO, and the oceanic "dipole" dynamics of the Indian and Atlantic Oceans. These deficiencies greatly limit our confidence in their ability to predict the future evolution of the warming pattern. This is unfortunate because there is growing evidence that regional climate changes around the globe will be highly sensitive to the precise pattern of the tropical SST warming. This sensitivity arises mainly from the generally opposite global circulation responses to deep atmospheric convective heat sources over the west Pacific and Indian Oceans.



Observed warming of the Tropical Sea Surface Temperatures 1951-2000.

Importance**.** The opposite sensitivity of many aspects of the global climate to strong tropical Indian and west Pacific SST warming (strong enough that it leads to enhanced deep atmospheric convection in both basins) raises the possibility of a climatic "tipping point." The Indian Ocean warming has thus far not been strong enough to enhance the deep convection there, but if it continues, then at some point it will certainly trigger atmospheric deep convection and rapidly force an opposite global response to that already being forced by the west Pacific warming (which, among other effects, has been implicated in the extended four-year 1998-2002 drought over the Southwestern United States). This rapid change will be felt most dramatically in the Pacific-North American (PNA) sector, but also in the high Arctic latitudes. We believe this to be a serious possibility, and would like to assess it quantitatively in a realistic modeling environment.

Innovative. Given our current poor understanding of the precise causes of the warming trend shown in Figure 1, and also the inadequacies of current fully coupled atmosphere-ocean climate models in predicting its future evolution, we will take a completely different approach to assess the likelihood and impact of "awakening the sleeping Indian Ocean giant": We will force state-of-the-art global atmospheric GCMs with prescribed evolving sea surface temperatures, simply assuming that the pattern of the tropical SST warming observed over the past several decades will also continue for the next several decades. This assumption might seem unrealistic to some, but may in fact not be so, considering that the amplification of the warming in Figure 1 has been quite coherent over the past 50 years (not shown). There is also no better alternative at present.

Interdisciplinary. The possibility of a "tipping-point" being crossed by the triggering of enhanced atmospheric deep convection over the Indian Ocean has enormous implications not only for the climates of the nearby densely populated Asian continent but also through planetary Rossby wave dispersion, the climates of remote North America, the Arctic and even parts of Europe. Through its associated surface temperature and precipitation changes, it will influence drought and energy and water resources management in these areas, the future evolution of the Asian "brown cloud" through more efficient precipitation scavenging, and perhaps even the melting of the Greenland ice sheet.

Research Plan. We will run two different state-of-the-art atmospheric GCMs, the NCAR/CAM3 and the NCEP/GFS model, with prescribed SSTs in the tropics and with coupling to a simple slab mixed-layer ocean model elsewhere. The prescribed tropical SST fields will be climatology plus the trend pattern of Figure 1, whose amplitude will be increased linearly at its past 50-yr rate over the next 100 years. We will also make control 100-yr runs with the tropical SST fields fixed at climatology. Both of the GCMs to be run are already available to us in-house and we have extensive experience with their use. Computing needs will be met using the ESRL high performance computing and storage at the ESRL/GSD high performance computing facility.

Expected Outcome and Impact. Our focus in the warming trend runs will be on the point in time at which the Indian Ocean warming triggers significantly enhanced local deep atmospheric convection and affects the global climate. We will document the differences between the simulated global climates before and after this triggering, and assess their implications for climate change mitigation and adaptation strategies around the globe.

Highly Resolved Wavelength Dependencies of Aerosol Optical Properties in the Short-wave Spectrum

Investigators: Allison McComiskey (CIRES/NOAA ESRL), Thomas H. Painter (CIRES/NSIDC), Paul Ricchiazzi (ICESS/UCSB)

Objective. The objective is to measure the wavelength dependence of aerosol optical properties at high spectral resolution across the solar spectrum. Quantification of these properties is necessary for modeling the impact of aerosols on climate. However, direct, high-spectral resolution measurements of these properties have never been made. These measurements require instrumentation that can determine the angular distribution of sky radiance at high angular resolution (<0.1°) in certain angular domains with the capabilities of a field spectroradiometer. We propose to modify an existing field-portable, hyperspectral goniometer system and its angular sampling protocols to produce the first data set of this kind.

Background and Importance. Atmospheric aerosols directly scatter and absorb solar radiation and modify the development and characteristics of clouds, leading to a global average decrease in radiation and a cooling at the Earth's surface. This cooling may partially offset the warming caused by an increase in greenhouse gases, but the uncertainty in observations of aerosol optical properties makes this effect difficult to quantify. Aerosol distributions vary greatly in space and time, and continuous measurements are sparse. Moreover, the nature of these measurements has been sufficiently costly and complex that measurements have only been made in fewer than 10 wavelengths in the visible and near-infrared portions of the shortwave spectrum. In order to compute broadband shortwave radiation budgets for climate modeling, the wavelength dependence of these properties must be known continuously across the spectrum. Currently, model inputs are extrapolated from a few measurements using wavelength relationships that are unverified. The first-order uncertainty in modeling the recent observed changes in climate derives from the uncertainties associated with aerosol optical properties.

The following aerosol properties are required to calculate radiation budgets for climate modeling: aerosol amount (typically an optical depth), the single scattering albedo (ratio of scattering to extinction), and the asymmetry parameter (a metric of the directionality of scattering). The single scattering albedo is derived from knowledge of both aerosol scattering and absorption. The asymmetry parameter is the cosine weighted integral of the aerosol scattering phase function. A single value describes the angular scattering of aerosols that is computationally efficient for radiative transfer modeling. Routine methods for measuring these aerosol properties include *in situ* measurements from the surface or aircraft and ground radiometry, providing information for the entire atmospheric column. *In situ* measurements typically provide aerosol scattering and absorption at no more than three wavelengths in the visible spectrum. The asymmetry parameter can only be derived from an empirical relationship that requires large assumptions about the phase function of the aerosols. NASA's AERONET Program operationally retrieves aerosol properties from Cimel Sunphotometers (CSPHOT) that make angular radiance measurements but are limited to the almucantar plane and measurements at 8 wavelengths from 0.340 to 1.022 µm.

A method for retrieving the single scattering albedo and phase function from angular measurements of sky radiation has been developed by Wang and Gordon [1994]. This method was tested using CSPHOT data and extended by Ricchiazzi et al. [2006] to provide better accuracy by including a more detailed characterization of surface reflectance. We propose to apply this method to radiance data collected with the Automated Spectro-Goniometer (ASG), developed by Dr. Painter [Painter et al., 2003], a spherical robot that is coupled with a hyperspectral radiometer, an Analytical Spectral Devices (ASD) FieldSpec FR (Figure 1a). The ASD-FR has spectral resolution of 3 to 10 nm across the wavelength range 350 to 2500 nm. The ASG will measure sky radiance while moving though a comprehensive set of angles, similar to those accessed by the CSPHOT. Modification of the ASG to incorporate quadrant centering, reorientation to sky viewing, and introduction of sky-specific angular protocols with real-time solar tracking with updating at >1 Hz will facilitate a quantum step forward in the field of aerosol characterization.

Innovative and Interdisciplinary. The use of this instrument is novel for atmospheric characterization and the novel configuration proposed here, to scan the atmosphere, is an outgrowth of our published experience using the ASD-FR to analyze the sky radiance data at a high-latitude site. Most instruments developed for observation of downwelling atmospheric radiation are limited in either their spectral or angular resolution. This will be the first such instrument designed for combined, very high spectral and angular resolution, which provides the leverage to simultaneously retrieve the pertinent aerosol properties at high accuracy throughout the shortwave spectrum. This project also brings together researchers from different disciplines. The ASG was originally designed as a downlooking instrument for observations of surface reflectance properties. With the use of methods from the atmospheric sciences, the instrument can be applied to a very different and important problem in aerosol and climate science.

Research Plan. Radiometric retrievals of atmospheric aerosol properties require observations under cloudless conditions. In most cases, aerosol characteristics remain constant throughout a given day, though rapid changes are also possible when dictated by variations in meteorology and source strength. In order to incorporate as much of this variability as possible in our measurements, deployments will be made on clear sky days as often as possible throughout the year. Full sky-radiance scan will consist of measurements obtained at approximately 100 scattering angles, either in the principal plane, or at constant zenith viewing angle. This large number of sky-radiance samples will allow for the identification and removal of views contaminated by sub-visual cirrus clouds and to correct for angular pointing errors.

The robot will be programmed to produce up to 10 sky-radiance scans per hour, which is about an order of magnitude greater than the typical sample rate from AERONET. The availability of several scans per hour will help differentiate the effects of natural aerosol variation from noise introduced by scene conditions (e.g., sub-visual cirrus). Standard data products available from the AERONET Cimel sunphotometers are produced from measurements with less angular resolution (Figure 1b). These observations will provide detailed information on aerosol properties at spectral and temporal scales that are not available with current instruments.

The retrieval of aerosol properties is sensitive to situational variables, such as aerosol amount, the surface albedo, atmospheric pressure, and the presence of sub-visual cirrus cloud. In order to constrain these variables, we will make measurement near the Boulder Baseline Surface Radiation Network (BSRN) site. Continuous measurements at the site include solar downwelling global, direct, and diffuse radiation at the surface at the top of a 300-m tower as well as solar upwelling global radiation at the top of the tower at 1- to 3-minute resolution. Good estimates of aerosol optical depth will greatly reduce the need for precise absolute calibration of the ASD-FR. The BSRN direct and diffuse radiation observations will also be used to test closure by comparing modeled and observed radiation with the aerosol properties retrieved from the ASG.

Expected Outcome and Impact. These measurements will represent an unprecedented data set of spectrally resolved aerosol properties and a proven concept for dramatically more accurate and comprehensive measurements of these properties. This novel data set will include wavelength dependence of the asymmetry parameter and single scattering albedo across the entire shortwave spectrum for a variety of aerosol types. Modeling studies that attempt to calculate the radiative impacts of aerosol on climate have had to use a "best guess" at the dependence. This information in itself will have a significant impact on the uncertainties associated with modeling the impact of aerosols on climate. Finally, we will be able to assess the requirements for developing a robust and autonomous instrument using the ASD and goniometer configuration for continuous operation in the field.

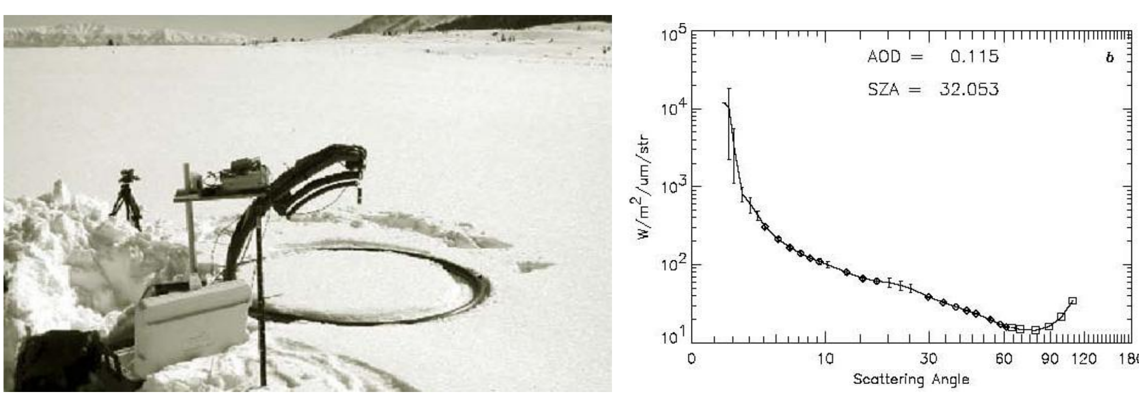


Figure 1 *(a, left) The Automated Spectro-Goniometer (ASG) deployed for measurements of directional reflectance of snow. (b, right) Cimel almucantar (diamonds) and principal plane (squares) observations of radiance at 676 nm obtained at the ARM program Southern Great Plain facility on 29 May 2003. These data were used as part of a study to test for closure between in-situ and remotely sensed aerosol retrievals [Ricchiazzi et al., 2006].*

Is the Ground Drying up in South Platte?

Investigators: Balaji Rajagopalan (CIRES, University of Colorado) and Harihar Rajaram (Department of Civil, Environmental and Architectural Engineering, University of Colorado)

Background and Objective. The South Platte Basin is home to a population of about 3 million. Despite substantial urban and suburban growth, there are more than a million acres of irrigated land in the basin. Water management in the South Platte Basin is complicated by the complex interactions between surface and groundwater, and the steep gradients in hydroclimatology between the mountainous regions, the Denver metropolitan area and Eastern Colorado. The sustained groundwater flow of about 515 acre ft/year (Figure 1) into the South Platte River helps to maintain in-stream flows for sustaining riparian ecosystems and water quality. However, continuous declines of groundwater levels in portions of the basin (Figure 2) have led to considerable difficulties in maintaining in-stream flows, requiring flow augmentation from reservoirs. During the severe drought that impacted the region in 2002, water managers faced substantial difficulties in providing water to agricultural users (from groundwater sources) while maintaining in-stream flows. This led to the recognition of a new objective in groundwater management – i.e. maintaining groundwater levels not just from a resource standpoint, but also in the context of sustaining the riparian ecosystem. While this region is no stranger to dry periods, the recent dry spell coupled with increasing population, economic growth and land-use change is placing significant stress on the groundwater resources. Despite the important role of groundwater in the basin, there are virtually no efforts to understand long-term behavior of the groundwater system within the context of climate variations.

Year-to-year variability of hydroclimate in the Western U.S. has been linked to large-scale climate features in the Pacific Ocean, in particular El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). Hoerling and Kumar [2003] use climate model simulations to present tantalizing evidence that the recent long dry spell could be a result of cooler than normal tropical Eastern Pacific and warmer than normal tropical Western Pacific (a La Niña pattern) and Indian Oceans. This long break from the El Niño-active period of 1980s and 1990s could be a strong factor for the dry spell. Which then raises the questions: Why now? Is climate change responsible in any way? Adding to these woes are recent indications [Regonda et al., 2005] that the annual cycle in precipitation is shifting early in the Western U.S., perhaps caused by global climate change. In particular, the spring warmth is tending to occur early with decreased winter snowpack. This implies reduced inflow into the rivers, as a majority of them is driven by snowmelt and groundwater recharge. Given the high stakes, the key questions are:

1. What does the future hold, especially under global change and interannual variability?
2. With climate fluctuations and change and land-use changes, will S. Platte groundwater dry up?
3. Even if declines in groundwater levels are not as drastic as implied by 2., will they decline to where the groundwater inflows that sustain in-stream flows are severely reduced?

Insights into these research questions will have significant impacts on current water resources management and on the future socio-economic development of the Western U.S.

Research Plan. Although there are several decision support systems such as the CDSS (Colorado Decision Support System) and SPMAP (South Platte Mapping and Analysis Program) that aid the State Engineer's office and Water Resources Agencies in managing the basin, few efforts have been made to incorporate long-term climate change scenarios into these systems. Our objective in this project is to evaluate the response of groundwater levels in the basin to long-term climate change. We plan to do the following:

1. Compile
    i. the space and time data of groundwater levels from the basin. This will be obtained from the State water resources office.
    ii. long records of precipitation (P) and temperature (T) from the basin from *http://www.ncdc.noaa.gov/*
    iii. climate change scenarios for the basin from the recent IPCC (Inter-governmental Panel on Climate Change) projections from several climate models runs by different modeling groups around the world and available at (*http://ipcc-ddc.cru.uea.ac.uk/asres/sres_climate/sres_home_climate.html*)
2. Develop and test a stochastic P and T generator for the basin.
3. Test and refine a well-established groundwater flow model for the basin (e.g. from the State Engineer's office) to ensure that the representation of surface-groundwater interaction and coupling of groundwater to recharge are adequate for capturing future scenarios (e.g. where hydraulic disconnection between the aquifer and stream may occur).

4. Couple the hydroclimate scenarios with the refined basin-scale groundwater flow model to generate long-term predictions of groundwater response and its impacts on sustainable water resource availability and in-stream flows in the South Platte.
5. Extend the overall modeling framework of 2, 3, and 4 to generate groundwater response scenarios to the combined influence of projected climate change and land use changes. This will lead to improved understanding of effective strategies for optimal land use planning under changing climate.

***Interdisciplinary*.** The proposed research, which focuses on groundwater and its interaction with surface water, will provide an excellent complement to surface water studies of the Western U.S. hydroclimatology under the Western Water Assessment (WWA) research program of CIRES/CDC/NOAA. We expect results from this effort to lead into a larger comprehensive proposal to funding agencies such as NSF, or DOE.

***Innovative*.** The proposal aims to understand the robustness of groundwater levels in the South Platte basin under climate change, climate variability and land use change scenarios. This will be achieved by coupling a hydroclimate generator to a basin-scale groundwater model. Furthermore, physical mechanisms governing the spatio-temporal variability of groundwater levels will be teased out from this framework. These two aspects of the proposal are unique and have never been attempted before. Another unique aspect of this work derives from the application of basin-scale three-dimensional groundwater flow models over decadal time scales – tremendous advances in computational technology over the last 2-3 years have made it feasible to run these models involving ~106-7 computational nodes, over long durations on high-end desktop workstations. We will use a state-of-the-art 64-bit AMD workstation equipped with 16GB of RAM for this purpose.

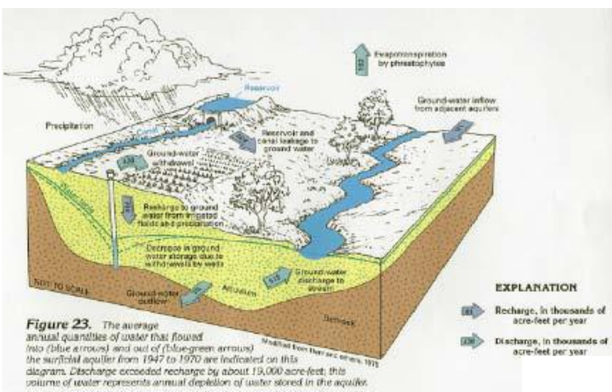


Figure 1 *(left). Water Balance of the South Platte Alluvial Aquifer showing the groundwater contribution to streamflow*

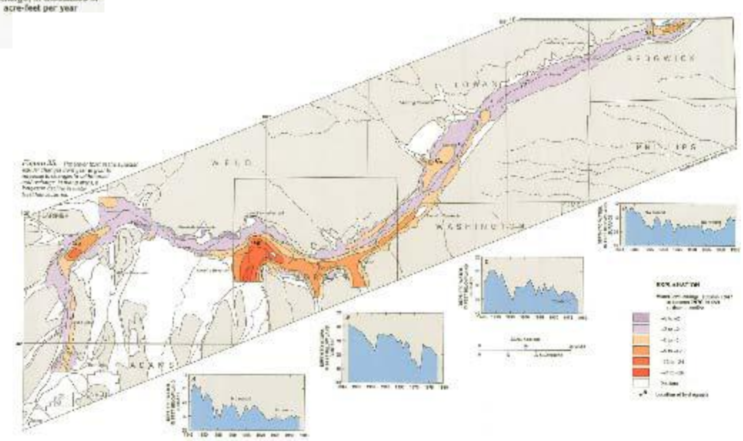


Figure 2 *(right). Water table declines in the South Platte Alluvial Aquifer during 1945-1985. Source for Figures 1 and 2: Groundwater Atlas of the United States.*

VOC Production by Soil Microorganisms: Linking Microbial Ecology and Atmospheric Chemistry

Investigators: Noah Fierer (CIRES, University of Colorado), Russ Monson (CIRES, University of Colorado)

***Objectives*.** The goal of this study is to characterize the types and quantities of volatile organic carbon compounds (VOCs) produced by soil microorganisms. We will determine if microbial VOC (mVOC) production is a potentially important source of atmospheric VOCs and if VOC analysis holds promise as a tool for the rapid assessment of soil microbial community composition.

***Background and Importance*.** The flux of VOCs from terrestrial sources to the atmosphere has an important impact on atmospheric chemistry at local, regional, and global scales [Monson and Holland, 2001]. For this reason, many studies have focused on the production of VOCs by plants, assuming that plants are the largest terrestrial source of biogenic VOCs. Surprisingly, only a handful of studies have looked at the production of VOCs by soil microbes, despite a number of lines of evidence suggesting that, like plants, microbes may also be an important terrestrial source. We know that bacterial and fungal isolates grown in the laboratory can produce large quantities of VOCs and a diverse array of individual compounds, including alcohols, aldehydes, amines, methylated halogens, terpenoids, and volatile fatty acids. We also know that soil microbes are the dominant decomposers in terrestrial systems, converting organic C substrates to volatile forms of carbon. While CO_2 is assumed to be the major product of microbial decomposition in aerobic soils, appreciable amounts of VOCs may also be released from soil during decomposition. Even if mVOC production is a small fraction of microbial CO_2 production, mVOC production may represent a major pathway by which carbon is moved from terrestrial to atmospheric pools. At this point, the paucity of relevant data means that we can only speculate on the magnitude of mVOC production from soil.

In addition to the likely biogeochemical importance of soil mVOC production, we expect that VOC analyses will provide a unique method for the assessment of microbial community structure. Although factors other than microbial community composition are likely to influence the VOC "fingerprint" of a given soil, we expect a strong correlation between microbial community composition and VOC production. We know that the production of certain VOCs is associated with specific microbial groups in soil and we know that mVOC production can mediate microbial interactions in soil with some mVOCs acting as "infochemicals" capable of stimulating or inhibiting the growth of specific microbial populations. Since the composition of soil microbial communities has an important influence on ecosystem dynamics, a rapid technique for assessing broad differences in microbial communities would be very valuable. Soil VOC analysis holds promise as an alternative to the expensive and time consuming methods currently used to assess microbial community structure.

VOC production by soil microbes is likely to have an important influence on terrestrial carbon dynamics, atmospheric chemistry, and soil ecology.

***Innovative*.** We are proposing that mVOC production may be more important than previously recognized. As the first study to comprehensively examine mVOC production in soil, this work may open up a new field of scientific inquiry. Furthermore, if we can show that VOC analysis provides insight into soil microbial community structure, this work may lead to the development of new methodological approaches to study complex microbial communities.

***Interdisciplinary*.** The proposed project is a collaboration between a microbial ecologist (Fierer) and an ecosystem ecologist (Monson), using analytical techniques developed by atmospheric chemists. We expect that our findings will be of interest to researchers in a wide range of disciplines, including atmospheric chemistry, ecosystem ecology, microbiology, and soil science.

***Research Plan*.** We will collect organic and mineral soils from a range of sites across the United States. We will focus on sites within the NSF-funded Long-Term Ecological Research network so that follow-up studies will be possible and NSF funds can accessed. The goal is to collect a diverse array of soil types (30-50 soils) so we can examine correlations between mVOC production and soil/site characteristics. After an equilibration period, root-free soils will be incubated in gas-tight containers for 24-48 h with headspace samples analyzed for VOCs using proton-transfer-reaction mass spectrometry (PTR-MS). Headspace samples will also be analyzed for CO_2 concentrations with an infrared gas analyzer so we can compare net CO_2 and net VOC production rates. We will collect relevant site information and measure basic soil physico-chemical characteristics for each soil. In addition, we will use the quantitative PCR approach described in Fierer et al. [2005] to quantify the abundances of bacterial and fungal groups in each soil sample. By analyzing a relatively large number of samples, we can determine if VOC "fingerprints" (the types and quantities of VOCs released) are unique to each soil type and we can assess relationships between specific soil characteristics and mVOC production. We will use multivariate statistical methods (non-metric multi-dimensional scaling and ANOSIM procedures, [Fierer and Jackson, 2006]) to look for correlations between VOC fingerprints and soil/site characteristics.

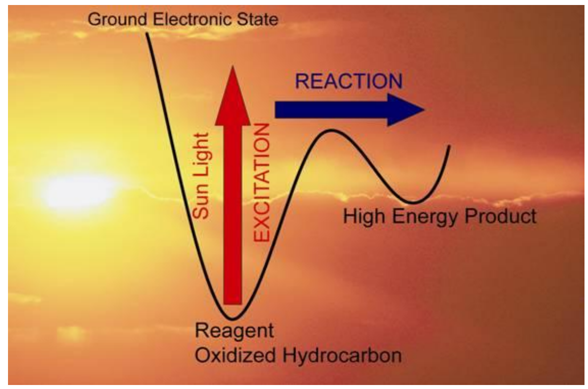
Once the cross-site study has established linkages between microbial VOC production and soil/site characteristics we will test our hypothesis that VOC production is strongly correlated with microbial community composition. By simply screening the collected soils, we cannot distinguish the effects of microbial community composition from other factors (soil organic carbon characteristics, texture, and nutrient status) that may also influence mVOC production. To determine the strength of the relationship between community composition and mVOC fingerprints, we will experimentally manipulate the microbial communities in five soils that have distinct VOC fingerprints by autoclaving each soil and re-introducing microbes with five different soil inocula, one from each of the five soil types. After an equilibration period, VOC production will be measured using the techniques described above. If VOC fingerprints correspond to microbial community composition, we should observe a strong effect of inoculum on VOC fingerprints from a given soil type. If VOC production is unrelated to microbial community composition, but is instead driven by intrinsic abiotic soil properties, we will see no apparent inoculum effect. The linkages between microbial community composition and VOC fingerprints will be further examined by adding known organic substrates (e.g. cellulose, proteins, sugars) to each of the five soils and measuring VOC production over time. If substrate characteristics are less important than community composition in controlling mVOC production, soils receiving the same substrate should yield distinct VOC fingerprints.

***Expected outcome and impact*.** This work is just the first step towards understanding microbial VOC production and its consequences. This work will allow us to parameterize the relative importance of soil VOC production and assess how VOC production varies across a wide range of soil types. We expect that the proposed work will yield valuable data sets than can be leveraged to obtain extramural funding in the future. If we find that microbial VOC production is an important source of VOCs, more detailed experiments and field studies will follow. If we find that VOC analysis can be used to infer microbial community composition, this work may to lead to the development of new methods for rapidly assessing soil biological characteristics.

Sunlight Initiated Chemistry by Low Energy Vibrational Overtone Excitation of Oxidized Organics in the Atmosphere

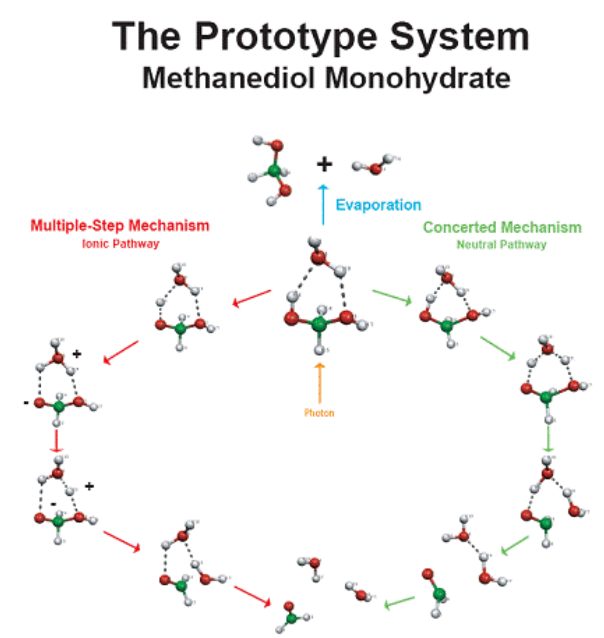
Investigators: V. Vaida (CIRES, University of Colorado), R. Skodje (Department of Chemistry and Biochemistry, University of Colorado)

Objectives. In a collaboration between experiment (Prof. V. Vaida) and theory (Prof. R. Skodje), we propose to investigate a new paradigm for sunlight-initiated chemical reactions occurring by low energy by excitation of vibrational overtones in the ground electronic state. The target for this study is oxidized atmospheric organics (acids, alcohols). An important objective of this work is to investigate the role of water in catalyzing environmental photoreactions. The contribution of such chemistry to photochemical processing of atmospheric aerosols, Arctic ice and other environmental media will be investigated with expertise available in CIRES.



Background and Importance. The incoming beam of photons from the Sun approximates the emission of a black body at about 5800K with a maximum flux in the red. The vast majority of photochemical reactions known in the atmosphere involve a molecule's excited electronic states at sufficiently high energy to rupture covalent bonds. This process requires UV wavelengths >400nm. Some of us have shown that photochemical reactions can occur in the ground electronic state by absorption of radiation by vibrational overtone transitions. The cross sections for such transitions near chemical thresholds are very low, yet in the Earth's atmosphere, excitation is effected near the solar wavelengths maxima. Visible light, obviously abundant in the solar spectrum, is sufficiently energetic to excite high overtone states of chromophores such as the hydroxyl-group (OH). If the overtone transition is sufficiently intense, and if the vibrational energy is effectively transferred to the reaction coordinate, vibrational overtone absorption may provide an important new mechanism for atmospheric chemistry. Previous studies by Vaida and coworkers suggest that vibrational overtone absorption likely plays a role in a number of atmospheric reactions.

This work is important in establishing the fundamental foundations for a new paradigm for processing organics in the atmosphere by sunlight. Environmental circumstances where such chemistry could be important are photochemical processing of atmospheric aerosols on ice, especially Arctic ice, where observations suggest additional mechanisms are needed to explain sunrise-promoted emissions from snowpacks.



Innovative.

- A new paradigm is proposed for photochemistry in the atmosphere by solar pumping of vibrational overtone transitions of the ground electronic state. For organic acids and alcohols under investigation, the excited-state photochemistry normally considered is irrelevant since the electronic states absorb in the UV at wavelengths filtered by stratospheric ozone.
- An interesting possibility is the lowering of the transition states for reaction by water. If this investigation determines the viability of such water-catalyzed reactions, water becomes an important environmental catalyst for processing of oxidized organics not previously considered.

Interdisciplinary. This study requires a synergistic approach based in chemical theory, laboratory experiments and atmospheric science. We described in the initial stage the collaboration between theory and experiment. Once the results are available, expertise with atmospheric aerosols, field observations regarding sunrise emissions from Arctic ice and atmospheric modeling are necessary and available in CIRES.

Research Plan. This study chooses for illustration the molecule methane-diol, $CH_2(OH)_2$ and its hydrated form $CH_2(OH)_2 \cdot H_2O$.

$$CH_2(OH)_2 + h\nu \rightarrow CH_2O + H_2O \qquad (A)$$

$$CH_2(OH)_2 \cdot H_2O + h\nu \rightarrow CH_2O + 2H_2O \qquad (B)$$

The dehydration reaction will be used as prototype reactions to study the vibrational overtone absorption mechanism. We already computed the reaction paths for A and B. A very interesting result was obtained. While the barrier to reaction was approximately 45 kcal/mol for reaction A, the reaction of the van der Waals complex (B) takes place with a barrier of only approximately 29 kcal/mol suggesting the possibility of catalysis of reaction (A) by water. The main focus of the theoretical research is the dynamics and kinetics of the vibrational overtone absorption-induced chemical reactions using the method of direct dynamics.

The experimental work will involve two related studies:

- A spectroscopic study of the vibrational spectrum of this molecule never before obtained. A Fourier-Transform spectrometer available in the Vaida group will be used to obtain the mid IR spectrum. A newly developed cavity-ring-down spectrometer will allow the investigation of high OH vibrational overtones, which are at the barrier for reaction.
- Light initiated reactions of the organic acids and alcohols will be investigated to obtain the fundamental data base needed as input to chemical atmospheric models.

Expected Outcome and Impact. The goal of this inquiry is to acquire a valid theoretical description confirmed by experiment of how water-catalyzed photochemical reactions occur. The outcome will be to introduce in atmospheric models new classes of photo-processing reactions relevant to atmospheric aerosols, ices and other water-air environmental interfaces.

Can Phytoplankton Change SST and Upper-Ocean Circulation?

Investigators: Toshiaki Shinoda (CIRES, University of Colorado), Weiqing Han (Department of Atmospheric and Oceanic Sciences, University of Colorado)

Background and Importance**.** It is well known that the turbidity of upper ocean water is primarily determined by phytoplankton distribution. Hence, the phytoplankton pigment concentration in the upper ocean significantly affects the mixed-layer absorption and penetration of solar radiation. Given that solar radiation is the largest component of surface heat fluxes that determine the sea surface and upper-ocean temperature in tropical oceans, variation of phytoplankton distribution can directly influence sea surface temperature (SST) and upper-ocean thermal structure. As a result, upper-ocean circulation can also be altered due to its sensitivity to the thermal structure. In most state-of-the-art ocean general circulation models (OGCM), however, turbidity of water is parameterized by a constant water type, and therefore spatial and temporal variations of phytoplankton are neglected.

The proposed research aims to understand the role played by phytoplankton in causing variabilities of SST and upper-ocean circulation in the tropical Pacific and Indian Oceans. The approach for this project is to perform OGCM experiments by including and excluding phytoplankton concentration, which can be inferred from chlorophyll-a (chl-a) concentration of satellite-derived ocean color data. The penetrative component of solar radiation (Qpenet) will be calculated from the ocean color data using a solar transmission parameterization based on chlorophyll concentration. To help test the sensitivity of penetrative radiation to vertical resolution, a 1-D mixed-layer model will also be used. Completion of the proposed research is expected to improve the simulation of SST and upper-ocean circulation by advancing the parameterization of penetrative radiation in OGCMs, and ultimately improve climate model simulations and predictions.

Innovative**.** While the satellite-derived ocean color data have been widely used to examine the upper-ocean biological processes, their effects on SST and upper ocean circulation are not emphasized. The proposed research is unique and innovative in that it will qualify and quantify the impact of spatial and temporal variations of phytoplankton pigment concentration on upper ocean physical processes, and thus will build a foundation for understanding the physical-biological interactions and their impact on climate variability.

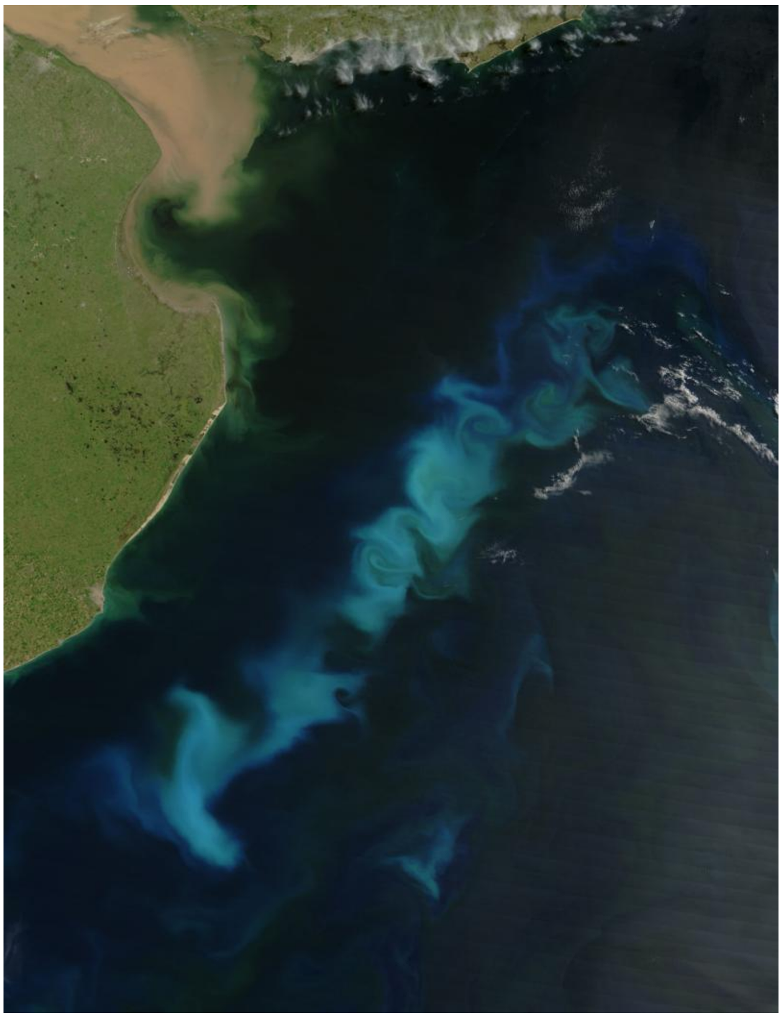
Objectives**.** Specific objectives of the proposed research are:

- To determine the extent to which variability of SSTs and currents in ocean models are improved by the new penetrative solar radiation calculation from the satellite-derived ocean color data.
- To quantify the impact of space and time variations of penetrative solar radiation on upper-ocean variabilities ranging from diurnal to seasonal time scales.

Research Plan**.** A parameterization of solar transmission based on the upper-ocean chl-a concentration along with remotely sensed ocean color data will be used to calculate Qpenet in ocean model experiments. Net irradiance profiles are expressed as a sum of two exponential terms. We will use Moderate-Resolution Spectroradiameter (MODIS) products that include the chl-a concentration data from recent satellite measurements (Aqua and Terra). Solar radiation at the surface will be obtained from the new satellite-based Earth's radiation budget (ERB) 3-hourly data.

The OGCM is the HYbrid-Coordinate Ocean Model (HYCOM). The fine-resolution global HYCOM will be operational for the Navy and the regional HYCOM (U.S. east and west coast) will be operational at NCEP with both scheduled for operational deployment around 2006-2007. The OGCM will be first integrated for the six-year period from February 2000 to 2005 after the high quality ocean color data are obtained. The model will be then forced with same-surface fluxes but with penetrative solar radiation calculated based on a constant water type in space and time. The difference between the two experiments estimates the impact of the use of satellite-derived ocean color data on upper-ocean variability. The model SST from these experiments will be compared with a variety of SST data (e.g., TRMM Microwave Imager SST) to determine to what extent the simulation of upper-ocean variability is improved by the use of satellite-derived ocean color data. We will further conduct a number of model experiments in order to isolate the effect of Qpenet variations on different time scales using low-pass filtered chl-a. 1-D mixed-layer model experiments will also be conducted in order to determine how the vertical resolution of the model affects the impact of Qpenet. 1-D model results with OGCM experiments also isolate the impact on only vertical processes. A particular emphasis in 1-D model experiments is given to the diurnal cycle of SST. The spatial variation of the amplitude of the diurnal cycle in each experiment will be described.

***Expected Outcome and Impact*.** Completion of the proposed research will lead to better solar transmission parameterization in ocean models and identify its impact on the upper-ocean variability. Thus, it will help climate model development and improvement. In addition, the proposed study is considered a “jump start” for further model diagnoses of climate variability. A variety of climate variability in the tropical Indian and Pacific Oceans can be diagnosed from the ocean model output. For instance, the Indian Ocean dipole variability in recent years can be investigated. In addition, a coupled ecosystem model, which can examine physical/biological feedback processes, could be developed in future projects as extension of the proposed research.



Phytoplankton bloom in the South Atlantic (February 15, 2006) seen from space. NASA image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA GSFC.

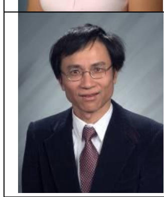
CIRES Visiting Fellows

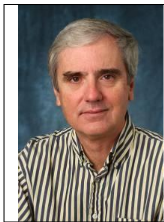
CIRES annually budgets approximately $500,000 to conduct a competitive visiting fellowship program that promotes collaborative research at the forefront of evolving scientific paradigms. One-year fellowships are made to Ph.D. scholars and university faculty planning sabbatical leave. Post-doctoral fellowships are supported for two years – the first year by CIRES and the second year by the sponsoring research group. Selections are based in part on the likelihood of stimulating academic interactions and the degree to which both parties will benefit from the exchange of new ideas. To further this goal, priority is given to candidates with research experience at institutions outside the Boulder scientific community. A Research and Education Fellowship is specifically funded for work in the area of education and outreach. The program is open to scientists from all countries, and appointments can begin at any time during the year. Visiting Fellows at CIRES last year are listed below. Further information can be found at *http://cires.colorado.edu/visfell/vf.html*. Approximately six fellowships are offered to scientists with research interests in the areas of:

- Physics, chemistry, and dynamics of the Earth system (atmosphere, biosphere, hydrosphere, lithosphere)
- Global and regional environmental change
- Climate system monitoring, diagnostics, and modeling
- Remote sensing and *in-situ* measurement techniques for the Earth system
- Interdisciplinary research themes

Following are the visiting fellows supported during the period covered by this report. Details of their research and the many resulting publications and presentations can be found in the appendices.

Post-Doctoral and Sabbatical Fellows

	NAME	AFFILIATION	MENTOR	PROJECT TITLE
	**Roya Bahreini**	CSD	F. Fehsenfeld	Chemical composition of aerosols
	**Thian Yew Gan**	Geography & Civil Engineering	R. Barry B. Rajagopalan	Seasonal teleconnection between North American monsoon and SMMR-SSM/I EASE-GRID Snow Water Equivalent Data, and possible detection of climate change impact on North America's snowpack
	**Shari Gearheard**	NSIDC	R. Barry	Bridging perspectives of change: Linking Inuit and scientific approaches to understanding Arctic environmental change
	**Neil Glasser**	NSIDC	R. Barry	The structure and stability of Antarctic Peninsula ice shelves

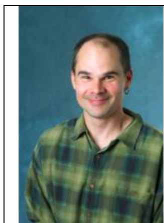
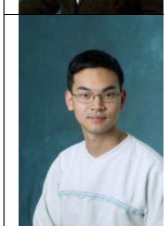
	**Steven Leavitt**	Geography	T. Chase	Tree rings and carbon isotope composition: Indicators of southwestern U.S. drought and changing water-use-efficiency
	**Sarah Tessendorf**	CSD	G. Feingold	Aerosol impacts on cloud microphysics in simulated deep convective clouds
	**Kevin Vranes**	Policy Center	R. Pielke	Examining decision making under uncertainty for climate change and severe storms, water resource management and earthquake mitigation
	**Cameron Wobus**	Geology	G. Tucker P. Molnar	A study of the links between climate and surface processes, focusing on erosion processes in river systems draining the eastern Colorado Front Range

Research and Education Fellow

	NAME	AFFILIATION	MENTOR	PROJECT TITLE
	**Ryan Vachon**	Outreach	S. Buhr	Documentary film making: celebrating polar science, environments, climates and societies in conjunction with the International Polar Year, and understanding processes controlling patterns of stable isotopes of precipitation

CIRES Graduate Research Fellows

CIRES has long supported a competitive Graduate Research Fellowship program to (1) attract outstanding students at the outset of their graduate careers, and (2) enable current students to place a greater emphasis on completing and publishing their research results. Support ranges from a summer stipend to tuition, stipend and partial health insurance for one year (12 months). Fellowships are restricted to Ph.D. students advised by a CIRES Fellow or any prospective or current graduate student who might be advised by a CIRES Fellow. Evaluations by a committee of CIRES Fellows are based on the candidate's University application, accomplishments, and the likelihood of their contribution to environmental science. Independence, passion for science, and the ability to communicate are also considered. This year, CIRES awarded fellowships to seven students, five of whom were new recruits, to explore topics ranging from climate change and the mass balance of the Greenland ice sheet to natural carbon storage in ecosystems and the role of organic haze in the early Earth's atmosphere.

	**Brandon Michael Connelly** From: Macalester College, B.A., Chemistry and History Department: Chemistry and Biochemistry Faculty Sponsor: Margaret Tolbert *Research Area: Uptake of organics by thin sulfuric acid/ammonium sulfate films: The kinetics of acid-catalyzed secondary organic formation*
	**Scott Gregory** From: Florida Atlantic University, B.S., Ocean Engineering; M.S., Ocean Engineering specializing in acoustics Department: Atmospheric and Oceanic Sciences (ATOC) Faculty Sponsor: David Noone *Research Area: Tropical/high-latitude climate linkages with El Niño Southern Oscillation (ENSO) signals in Antarctic ice cores*
	**Eileen McKim** From: University of Colorado at Boulder, B.A., Distributed Studies Earth Systems Science; M.A., Geography/Climatology Department: Geography Faculty Sponsor: Roger Barry *Research Area: Analyses of hydrological processes and interactions with the climate system-with goals of providing scientific assessment of global change in climate and the environment*
	**Lin Liu** Wuhan University, Hubei, P.R. China, B.S., Geophysics Department: Physics Faculty Sponsor: John Wahr *Research Areas: The use of Interferometric Synthetic Aperture Radar (InSAR) and its applications in geophysics and geology; Space Geodesy; and Physics of the Earth's core*
	**Mark Seefeldt** Florida State University/ University of Wisconsin at Madison, B.S., Meteorology/ M.S., Atmospheric Science Department: Atmospheric and Oceanic Sciences (ATOC) Faculty Sponsor: John Cassano *Research Area: An analysis of the Ross Ice Shelf air stream based on observational and numerical modeling studies*

Appendices

Governance and Management

CIRES' Leadership

Konrad Steffen: Director
William M. Lewis, Jr.: Associate Director
Jon Rush: Associate Director for Administration
Suzanne van Drunick: Assistant Director for Science

Divisions:

Cryospheric and Polar Processes: Roger Barry, Associate Director
Environmental Biology: Carol Wessman, Associate Director
Environmental Chemistry: Fred Fehsenfeld, Associate Director
Environmental Observations, Modeling and Forecasting: Michael Hardesty, Associate Director
Solid Earth Sciences: John Wahr, Acting Associate Director (Associate Director Roger Bilham is on sabbatical)
Weather and Climate Dynamics: Randall Dole, Associate Director

Fellows Committees

Council of Fellows

CIRES' Council of Fellows constitutes the "Board of Directors" and chief governing body of CIRES. It is comprised of individuals with an outstanding record of achievement and ability in diverse areas of environmental sciences. They are primarily university faculty, senior research scientists or government scientists who form the core leadership of the institute. Their responsibilities are to (1) provide leadership at all levels in environmental science, (2) maintain an active scientific research/education program, (3) support the CIRES infrastructure through indirect cost recovery and in-kind contributions, (4) participate in CIRES management, and (5) contribute interdisciplinary expertise and participate in collaborative work. As a group, they personify the concept of collaboration that is the founding principle of the NOAA Cooperative Institutes Program. Ex-officio individuals include representatives of the Members' Council and CIRES administration. Fellows meetings are held monthly during the academic year.

The Council of Fellows met eight times during FY06-07: August 31, 2006; September 14, 2006; October 19, 2006; November 16, 2006; January 25th, 2007; February 22, 2007; March 22, 2007; and April 19, 2007.

Richard Armstrong (Senior Research Scientists, National Snow and Ice Data Center)
Susan K. Avery (Vice Chancellor for Research and Dean of the Graduate School; Professor, Electrical and Computer Engineering)
Ben B. Balsley (Research Professor, Electrical and Computer Engineering)
Roger G. Barry* (Director, NSIDC; Professor of Geography)
Roger Bilham (Professor of Geological Sciences)
John Cassano* (Assistant Professor of Atmospheric and Oceanic Sciences)
Thomas N. Chase* (Assistant Professor of Geography)
Xinzhao Chu* (Assistant Professor of Aerospace Engineering)
Shelley D. Copley* (Professor of Molecular, Cellular and Developmental Biology)
Randall M. Dole (Director, Climate Diagnostics Center)
David Fahey (Research Physicist, Chemical Sciences Division)
Christopher W. Fairall (Supervisory Physicist, Physical Science Division)
G. Lang Farmer (Professor of Geological Sciences)
Fred C. Fehsenfeld (Senior Scientist, Chemical Sciences Division)
Graham Feingold (Scientist, Physical Science Division)
Noah Fierer* (Assistant Professor, Ecology and Evolutionary Biology Department)
Timothy J. Fuller-Rowell (Senior Research Scientist, CIRES/Space Environment Center)
Vijay K. Gupta* (Professor of Civil, Environmental and Architectural Engineering)
R. Michael Hardesty (Chief, Atmospheric Lidar Division, Chemical Science Division)

José-Luis Jiménez* (Assistant Professor of Chemistry and Biochemistry)
Craig Jones (Associate Professor of Geological Sciences)
William M. Lewis, Jr.* (Director, Center for Limnology; Professor of Ecology and Evolutionary Biology)
Peter H. Molnar* (Professor of Geological Sciences)
Russell K. Monson (Professor of Ecology and Evolutionary Biology)
William D. Neff (Director, NOAA/ESRL Physical Science Division)
Steven Nerem (Professor of Aerospace Engineering)
David Noone* (Assistant Professor of Atmospheric and Oceanic Sciences)
Roger Pielke, Jr.* (Director, Center for Science and Technology Policy Research; Professor of Environmental Studies Program)
Balaji Rajagopalan (Assistant Professor of Civil, Environmental and Architectural Engineering)
Prashant Sardeshmukh (Senior Research Scientist, Assistant Director of Climate Diagnostics Center)
Mark Serreze (Research Professor of Geography, Senior Research Scientist, National Snow and Ice Data Center)
Anne F. Sheehan* (Professor of Geological Sciences)
Robert E. Sievers* (Professor of Chemistry and Biochemistry)
Susan Solomon (Senior Scientist, Chemical Sciences Division)
Konrad Steffen* (Professor of Geography, Director of CIRES)
Margaret A. Tolbert* (Professor of Chemistry and Biochemistry)
Greg Tucker* (Assistant Professor of Geological Sciences)
Veronica Vaida (Professor of Chemistry and Biochemistry)
John M. Wahr (Professor of Physics)
Carol A. Wessman* (Professor of Ecology and Evolutionary Biology)

** = rostered in CIRES/Graduate School*

Emeritus Fellows
John Birks – Professor of Chemistry and Biochemistry
Alex Goetz – Professor of Geological Sciences
Carl Kisslinger – Professor of Geological Sciences
George Reid – Senior Scientist, NOAA CRD
Hartmut Spetzler – Professor of Geological Sciences
Doug Robertson – NOAA/NOS/NGS

CIRES Affiliates
Henry Diaz – NOAA Climate Diagnostics Center
Ray Fall – Professor of Chemistry and Biochemistry
Ray E. Habermann – National Geophysical Data Center
Pieter Tans – NOAA/ESRL Global Monitoring Division

Executive Committee
The Executive Committee assists and advises the Director in matters regarding day-to-day management of the institute and makes important decisions and policies affecting CIRES. Members of the Executive Committee include the Associate Directors of the six administrative units for CIRES, two Fellows elected at-large for a two-year term, renewable for one term, and two voting members that are the Members' Council representatives. The Assistant Director for Science, the Associate Director for Administration and the Senior Finance Officer are ex officio members of the committee.

Career Track Committee
This committee is charged with consideration of all nominations for promotion within the CIRES career tracks of Research Scientist, Associate Scientist and Administrative Associate. Nominations are made once yearly, and the committee's recommendations are forwarded to the director for consideration and action. A special committee, organized in early 2005, reviewed and revised the career track descriptions, and clarified the promotion process.

Computing Advisory Committee
The purpose of the CIRES' Computing Advisory Committee (CAC) is to provide expert counsel and recommendations on technical issues, user support, resource allocations and the establishment of computing policies. That advice is available to anyone in CIRES; however, the primary CAC advisees are the Director and Council of Fellows and the CIRES' Computing Facility (CCF) Manager. CIRES staff or the CCF manager submits questions, issues, and recommendations through CAC members, or via a Web suggestion page to the CAC chairperson for committee consideration. CAC also serves as the last resort mediator of disputes between users and the CCF. The CAC membership includes people with the diverse expertise that is required to understand and contribute to the CIRES computing decision-making process, as well as people representing the user groups that are supported by the

CIRES' Computing Facility. The Director of CIRES appoints the Chair of the committee as well as one other Fellow. Additional members are nominated and selected by the CAC. All members serve a three-year term.

Distinguished Lectureship Series
This lecture series was created to bring outstanding scientists and innovative thinkers who have given serious consideration to environmental and Earth system science issues. Coordinators are given the task of putting together this program and hosting the scientists' visit.

External Awards Committee
This group identifies and prepares nominations of CIRES employees for awards offered by the university, professional societies, Federal agencies, national academies, and other organizations.

Fellows Appointment/Reappointment Committee
All CIRES Fellows are subject to periodic review. First-term Fellows are reviewed after two years, and continuing-term Fellows generally every five years thereafter. This committee considers the package of reappointment submitted by the Fellow, which includes a cover letter outlining reasons for continuing as a Fellow and a curriculum vita. The committee prepares its recommendations, which are submitted to the full Council of Fellows for consideration and final vote. This committee is also charged with considering the identification and nomination packages of possible new Fellows within the community of scientists at the University of Colorado and NOAA. Nominations for new Fellows are considered once yearly.

Graduate Research Fellowship Committee
Approximately five graduate research fellowships are awarded to CIRES-affiliated graduate students each year through a CIRES competition. This group serves as the review and selection committee for these fellowships.

Innovative Research Program Committee
This program is designed to stimulate a creative research environment within CIRES and encourage synergy between disciplines and research colleagues. The intent is to provide an uncomplicated mechanism for supporting small research efforts that can quickly provide concept viability. The number of awards each year depends upon the funds available and funds requested, but averages about six.

New Fellows Committee
This committee is charged with considering the identification and nomination packages of possible new Fellows within the community of scientists at the University of Colorado and NOAA. Nominations for new Fellows are considered once yearly.

Space Committee
A continuing problem for CIRES is the limited office and laboratory space for employees. This committee provides advice on the best use and distribution of existing space, provides ideas on improvement of space through renovation, and develops options for planning future space.

Visiting Fellows Committee
This committee is responsible for the review of all applications for CIRES Visiting Fellowships. In the process of this review, the committee makes the decision regarding those best qualified for a fellowship in any given year, and submits that slate to the Fellows Council for final discussion and selection.

Bridge Funding and Sabbatical Leave Committee
This committee is charged with developing guidelines, procedures and selection criteria for a program through which CIRES Research Scientists may apply for bridge funding for support between funded projects, and sabbatical leave to promote interactions with other research groups, to advance their professional development and build new collaborations.

Special Committees
Additional special committees are appointed as needed by the Director. These include Faculty Search committees, the CU Program Review Committee, and others. They are created as a need arises, exist to accomplish a specific task, and are then disbanded.

Members' Council

The CIRES' Members' Council (CMC) was created in 1997 to act as an information and policy conduit between CIRES' leadership and the Institute members (Associate Scientists, Research Scientists, and Administrative Associates). To accomplish this in the most effective manner, the CIRES membership was divided geographically into six groups of approximately equal size. Each group is represented by two people, preferably from two different classifications in the CIRES Career Track. From this Council of twelve, two representatives to the CIRES Fellows' Council and Executive Committee are elected (one PRA representative and one RA representative). The two representatives to the Fellows' Council/Executive Committee serve as the liaison between the Fellows Council/Executive Committee and the Members' Council. The Members' Council, which meets monthly, then serves as a direct line of communication to the Member population at large. During the period of this report, CMC organized the second all-institute Rendezvous science day, administered the ongoing Outstanding Performance Awards, and took over the Adopt-A-Highway program. Additionally, CMC made a significant change in the format of the monthly meetings when, following the suggestion of a CIRES member, they became open meetings. CMC now encourages members to attend monthly meetings, communication has improved, and important issues have been discussed. Since meetings are held sequentially at our three main locations, this has allowed all interested members of the far-flung locations to attend more easily at least every third meeting. Subsequently, CMC has also invited special visitors, like representatives from CU benefits, to attend meetings and respond to questions and concerns about issues important to CIRES members. These issues have then been presented to the Executive Committee and Fellows Council by the CMC representatives. This has encouraged continuing communication throughout the institute on a constant basis, not just at yearly meetings.

Student Diversity Programs

Significant Opportunities in Atmospheric Research and Science Program (SOARS)

SOARS is a model learning community and mentoring program for promoting racial and gender equity in the atmospheric and related sciences. Created by and administered through the National Center for Atmospheric Research, CIRES has formed a partnership with NCAR to participate in this highly regarded program while providing NCAR with a wider range of disciplines in which to place students. It is a multi-summer, four-year undergraduate and graduate program for students majoring in an atmospheric science or a related field such as biology, chemistry, computer science, earth science, engineering, environmental science, mathematics, meteorology, oceanography, physics, or social science. Program information can be found at *http://www.ucar.edu/soars/*.

Name	Affiliation	Research Mentor	Project Title
Karen Diaz	CIRES	Holger Vomel	Background Measurements in Ozonsondes: re current estimates correct?
Douglas Gavin	CIRES NOAA/ESRL/ PSD	Leslie Hartten	Characteristics of SSTs between 23°C and 24°C West of the Galapagos Islands
Miriam Garcia	CIRES/ Geological Sciences CIRES/ NSIDC	Roger Bilham Francine Coloma	Modeling Vertical Deformation Associated with the 1931 Mach Earthquake, Pakistan
Nancy I. Rivera Rivera	CIRES	Lesley Smith	Meteorological Conditions of Extreme Dust events in the Chihuahuan Desert region of the United States and Mexico

Undergraduate Research Opportunities Program (UROP)

The Undergraduate Research Opportunities Program (UROP) was designed to create research partnerships between faculty and undergraduate students. Research in this context is interpreted as any scholarly or creative activity ranging from traditional scientific experimentation to the creation of new artistic works. UROP awards stipends and/or expense allowances to students who undertake an investigative or creative project in collaboration with a faculty member. Although projects are normally designed around some aspect of the faculty sponsor's research, they may also develop from original ideas of the student, which are endorsed by a faculty sponsor. Whether the context is scholarly or artistic, UROP projects call for significant input on the part of the faculty sponsor. Program information can be found at *http://www.colorado.edu/Research/UROP/*.

Name	Affiliation	Research Mentor	Project Title
Dandavati, Nikhil	CIRES	Fierer, Noah	Comparison of Microbial Enzyme Activities Across a Land-Use Gradient
Seminara, Nicki	CIRES	Docherty, Ken	Analysis of Organic Aerosol Elemental Composition using a Time of Flight Aerosol Mass Spectromet
Fairchild, Sara	CIRES	Tucker, Greg	River Adjustment to Climate Change: Case study from the Colorado Front Range

Personnel Demographics

CIRES Personnel breakdown 2006-2007

Category	Total CIRES Personnel	CIRES Personnel Supported by NOAA Funding			
		TOTAL	*B.S.*	*M.S.*	*Ph.D.*
Research Scientist	182	97			97
Visiting Scientist	18	9			9
Postdoctoral Fellow	14	4			4
Associate Scientist	208	114	50	61	3
Administrative	32	21	17	2	2
TOTAL greater than 50% NOAA support		**245**	**67**	**63**	**115**
Undergraduate Students	44	17			
Graduate Students	80	23	21	2	
Received less than 50 NOAA support		43	8	2	33
TOTAL	578				

Count by OAR Division

CSD	73
PSD	62
GSD	20
GMD	46
TOTAL OAR	**201**
NESDIS/NGDC	33
NWS/SEC	27
TOTAL NOAA	**261**
Obtained NOAA employment within the last year	3

Publications from Calendar Year 2006

CIRES scientists and faculty published 889 peer-reviewed and 177 non-peer-reviewed papers during the preceding calendar year[1]. The table below tabulates publications by affiliation of first author and their peer-review status. The publication count is only one measure of CIRES' impact. Additional information on how CIRES research is extending the boundaries of scientific knowledge is summarized in the Executive Summary, and is also provided in detail throughout this report .

CIRES Lead Author

	2001	2002	2003	2004	2005	2006	*2007*	*2008*
Peer-Reviewed	164	112	177	165	188	388		
Non-Peer-Reviewed	*	*	100	100	161	80		

NOAA Lead Author

	2001	2002	2003	2004	2005	2006	*2007*	*2008*
Peer-Reviewed	43	60	31	56	20	121		
Non-Peer-Reviewed	*	*	10	43	10	7		

Other Lead Author

	2001	2002	2003	2004	2005	2006	*2007*	*2008*
Peer-Reviewed	127	110	183	134	145	380		
Non-Peer-Reviewed	*	*	24	55	38	90		

* Included in peer-reviewed publications

Refereed Publications Published during Calendar Year 2006

Akmaev R.A., 2006. Does the moon also have a tidal effect on Earth's atmosphere? *Scientific American*, 295: no.5, p.108.

Akmaev, R.A., V.I. Fomichev, X Zhu, 2006. Impact of middle-atmospheric composition changes on greenhouse cooling in the upper atmosphere**.** *J. Atmos. Sol.-Terr. Phys.*, 68 (17): p.1879.

Aldener, M., S.S. Brown, H. Stark, E.J. Williams, B.M. Lerner, W.C. Kuster, P.D. Goldan, P.K. Quinn, T.S. Bates, F.C. Fehsenfeld, A.R. Ravishankara., 2006. Reactivity and loss mechanisms of NO_3 and N_2O_5 in a polluted marine environment: Results from *in situ* measurements during New England Air Quality Study 2002. *J. Geophys. Res.-Atmos.*, 111 (D23): Art. No. D23S73.

Alexander, M., J. Yin, G. Branstator, A. Capotondi, C. Cassou, R. Cullather, Y.O. Kwon, J. Norris, J. Scott, I. Wainer, 2006. Extratropical atmosphere-ocean variability in CCSM3**.** *J. Clim.*, 19 (11): p.2496.

Alpert, P., D. Niyogi, R.A. Pielke Sr., J.L. Eastman, Y.K. Xue, S. Raman, 2006. Evidence for carbon dioxide and moisture interactions from the leaf cell up to global scales: Perspective on human-caused climate change**.** *Glob. Planet. Change*, 54: *http://dx.doi.org/10.1016/j.gloplacha*.

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Anastasio, C., B.M. Matthew, 2006. A chemical probe technique for the determination of reactive halogen species in aqueous solution: Part 2 – Chloride solutions and mixed bromide/chloride solutions**.** *Atmos. Chem. Phys.*, 6: p.2439.

Andersen, S.B., E.C. Weatherhead, A. Stevermer, J. Austin, C. Bruhl, E.L. Fleming, J. de Grandpre, V. Grewe, I. Isaksen, G. Pitari, R.W. Portmann, B. Rognerud, J.E. Rosenfield, S. Smyshlyaev, T. Nagashima, G.J.M.

[1] The large increase in the number of publications in 2006 compared with previous years is in part due to the procedure of downloading the journal information from ISI. It was assumed that all ISI downloaded journals were peer-reviewed. Otherwise, the field was defined by the author.

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Anderson, D., A. Anghel, E. Araujo, V. Eccles, C. Valladares, C. Lin, 2006. Theoretically modeling the low-latitude, ionospheric response to large geomagnetic storms. *Radio Sci.*, 41 (5): Art. No. RS5S04.

Anderson, D., A. Anghel, J.L. Chau, K. Yumoto, 2006. Global, low-latitude, vertical ExB drift velocities inferred from daytime magnetometer observations. *Space Wea.*, 4 (8): Art. No. S08003.

Anderson, R.S., P. Molnar, M.A. Kessler, 2006. Features of glacial valley profiles simply explained. *J. Geophys. Res.-Earth Surf.*, 111 (F1): Art. No. F01004.

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Andrews, E, P.J. Sheridan, M. Fiebig, A. McComiskey, J.A. Ogren, P. Arnott, D. Covert, R. Elleman, R. Gasparini, D. Collins, H. Jonsson, B. Schmid, J. Wang, 2006. Comparison of methods for deriving aerosol asymmetry parameter**.** *J. Geophys. Res.-Atmos.*, 111 (D5): Art. No. D05S04.

Angevine, W.M., J. Hare, C.W. Fairall, D.E. Wolfe, R.J. Hill, A. Brewer, A.B. White, 2006. Structure and formation of the highly stable boundary layer over the Gulf of Maine**.** *J. Geophys. Res. - Atmos*, 111: doi: 10.1029/2006JD007465.

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Araujo-Pradere, E.A., T.J. Fuller-Rowell, P.S.J. Spencer, 2006. Consistent features of TEC changes during ionospheric storms**.** *J. Atmos. Sol.-Terr. Phys.*, 68 (16): p.1834.

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Balsley, B.B., R.G. Frehlich, M.L. Jensen, Y. Meillier, 2006. High-resolution *in situ* profiling through the stable boundary layer: Examination of the SBL top in terms of minimum shear, maximum stratification, and turbulence decrease. *J. Atmos. Sci.*, 63 (4): p.1291.

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Schafer, R., S. K. Avery, K. S. Gage, and G. N. Kiladis, 2006. Seventeen years of wind profiler observations over the central equatorial Pacific. CIRES Member's Council Symposium.

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Tuttle, B.T., C.E. Elvidge, J. Safran, K. Baugh, R. Nemani, C. Milesi, P. Sutton, 2006. Spatial mapping of impervious surfaces associated with urban development. Association of American Geographers Annual Meeting.

Vecherin S. N., V. E. Ostashev, G.H. Goedecke, D. K. Wilson, A. Ziemann, M. Barth, and K. Arnold, 2006. Reconstruction of turbulent fields in acoustic tomography experiments. 12th Intern. Symp. on Long Range Sound Propagation.

Voronovich A.G., and V. E. Ostashev, 2006. Vertical coherence of low-frequency sound waves propagating through a fluctuating ocean. Fourth Joint Meeting Acoustical Society of America and Acoustical Society of Japan.

Weil, J.C., E.G. Patton, and P.P. Sullivan, 2006. Lagrangian modeling of dispersion in the stable boundary layer. AMS 17th Symposium on Boundary Layers and Turbulence, on CDROM.

Westwater, E.R., D. Cimini, V. Mattioli, A. J. Gasiewski, M. Klein, V. Leuski , and J. C. Liljegren, 2006. The 2004 North Slope of Alaska Arctic Winter Radiometric Experiment: Overview and recent results. Proc. of the 16th. ARM Science Team Meeting.

Westwater, E.R., D. Cimini, V. Mattioli, A.J Gasiewski, M. Klein, V. Leuski, J. Liljegren, 2006. The 2004 North Slope of Alaska Arctic winter radiometric experiment: Overview and highlights. 2006 IEEE MicroRad Proceedings 9th Specialist Meeting on Microwave Radiometry and Remote Sensing Applications: p. 77-81.

White, A., C. Senff, A. Keane, D. Ruffieux, and S. McDonnel, 2006. A wind profiler trajectory tool for air-quality transport applications. 14th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, CD.

White, A., C. Senff, L. Darby, A. Keane, I. Djalalova, D. White, D. Ruffieux, and S. McDonnel, 2006. A new wind-profiler prajectory pool for weather and air quality. 7th International Symposium on Tropospheric Profiling: Needs and Technologies.

Wilson D.K., G.H. Goedecke, and V.E. Ostashev, 2006. Quasi-wavelet formulations of turbulence with intermittency and correlated properties. AMS Symposium on Boundary Layers and Turbulence.

Wilson D.K., R. Bey-Hernandez, and V.E. Ostashev, 2006. Statistical characterization of sound-wave scattering in urban environments. 12th Intern. Symp. on Long Range Sound Propagation.

Wilson D.K., R. Bey-Hernandez, and V.E. Ostashev, 2006. Models for fading and coherence of sound in urban environments. Fourth Joint Meeting Acoustical Society of America and Acoustical Society of Japan.

Zavorotny V. U., A.J.Gasiewski, R.J.Zamora, E.M. McIntyre, V.Y. Leuski, V.G. Irisov, 2006. Stationary L-band radiometry for seasonal measurements of soil moisture. Proceedings of IGARSS06.

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Refereed Journals in which CIRES Scientists Published in 2006

Acoustical Physics
Acoustical Society of America, Journal of the
Acustica-Acta Acustica
Advances in Atmospheric Sciences
Advances in Space Research
Advances in Water Resources
Aerosol Science and Technology
Air and Waste Management Association, Journal of the
Ambio
American Chemical Society, Journal of the
American Water Resources Association, Journal of the
Analytical Chemistry
Annales Geophysicae
Annals of Glaciology
Applied Meteorology and Climatology, Journal of
Applied Optics
Aquatic Botany
Astronomy Education Review
Atmospheric and Solar-Terrestrial Physics, Journal of
Atmospheric and Oceanic Technology, Journal of
Atmospheric Chemistry and Physics
Atmospheric Chemistry and Physics Discussions
Atmospheric Environment
Atmospheric Research, Journal of
Atmospheric Sciences, Journal of
Basin Research
BioMed Central Microbiology
Boundary-Layer Meteorology
Bulletin de la Société Géologique de France
Bulletin of the American Meteorological Society
Comptes Rendus Geosciences
Canadian Journal of Forest Research
Chaos, Solitons, & Fractals
Chemical Reviews.
Chromatography, Journal of
Climate Change, Journal of
Climate Dynamics
Climate Research
Climate, Journal of
Cold Regions Science and Technology
Computers and Geoscience
Doklady Earth Sciences
Dynamics of Atmospheres and Oceans
Earth and Planetary Sciences Letters
Earth Interactions
Earth Observer
Earth Planets and Space
Ecological Applications
Ecological Modelling
Ecology
Environmental Science and Technology
EOS Transactions of the AGU
Fluid Mechanics, Journal of
Geoarchaeology
Geochemistry, Geophysics and Geosystems
Geological Society of America Bulletin
Geological Society of America, Journal of the
Geophysical Journal International
Geophysical Monograph Series
Geophysical Research Letters
Geophysical Research, Journal of
Geophysics, Journal of
Geoscience Education, Journal of
Glaciological Data
Global and Planetary Change
Global Biogeochemical Cycles
Global Change Biology
Global Planetary Change
Hazardous Materials, Journal of
Higher Education, Journal of
Hydrologic Engineering, Journal of
Hydrological Processes
Hydrological Sciences, Journal of
Hydrology, Journal of
Hydrometeorology, Journal of
ICES Journal of Marine Sciences
IEEE Journal of Oceanic Engineering
IEEE Transactions on Antennas and Propagation
IEEE Transactions in Geoscience and Remote Sensing
Integrative and Comparative Biology
International Journal of Chemical Kinetics
International Journal of Climatology
International Journal of Geomagnetism and Aeronomy
International Journal of Mass Spectrometry
Journal of Sciences of the Islamic Republic of Iran
Limnologyand Oceanography: Methods
Meteorologische Zeitschrift
Molecular Spectroscopy, Journal of
Monthly Weather Review
NASA XXX
National Weather Digest
Nature
Ocean Modelling
Oceanography
Optical Society of America, Journal of the
Paleogeography Paleoclimatology Paleoecology
Philosophical Transactions of the Royal Society
Photochemistry and Photobiology
Physical Chemistry Chemical Physics
Physics Review
Physics Review Letters
Physical Chemistry, Journal of
Physical Oceanography, Journal of
Proceedings of the National Acadamies of Science
Progress in Physical Geography
Quaternary Journal of the Royal Meteorological Soc.
Quaternary Research
Radio Science

Remote Sensing of the Environment
Review of Scientific Instrument
Revista Brasileira de Agrometeorologia
Scanning
Science
Science Education
Scientific American
Seismological Research Letters
Space Science Reviews
Space Weather
Tectonics
Tellus
Turbulence, Journal of
Volcanology and Geothermal Research, Journal of
Water Resources Research
Weather
Weather and Forecasting, Journal of
Zeitschrift für Gletscherkunde und Glaziogeology

Honors and Awards: Calendar Year 2006

CIRES/NOAA Bronze Medal

In 2006, NOAA presented its 2006 Bronze Award to NOAA employees for demonstrating the usefulness of unmanned aircraft systems in accomplishing NOAA's mission, including operational and research goals. Several CIRES members were integral members of this stellar team, and in April 2007, CIRES presented them each with plaques recognizing their contributions. These CIRES members are ***Dale Hurst*** (GMD), ***Fred Moore*** (GMD), ***Geoffrey Dutton*** (GMD) ***David Nance*** (GMD), ***Brian Vasel*** (GMD), ***Marian Klein*** (formerly PSD) ***Vladimir Leuski*** (formerly PSD), ***Eric Ray*** (CSD

Akmaev, Rashid
Career track promotion to Senior Research Scientist.

Bauer, Robert
Antarctic Service Medal of the United States National Science Foundation

Barry, Roger
2006 Goldthwait Polar Medal Byrd Polar Research Center, Ohio State University
Atmospheric Science Librarians International (ASLI) Choice Award for 2005 The Arctic Climate System: by M C Serreze and R G Barry, Cambridge University Press.
Zayed International Prize for the Environment Second Prize to Contributors to the Millennium Ecosystem Assessment
NASA Group Achievement Award EOSDIS Data Centers Customer Support Team

Cape, Stephen
2006 Kalpana Chawla Outstanding Recent Graduate Award CU-Boulder Alumni Association

Cassano, Elizabeth
Career track promotion to Associate Scientist III.

Chu, Xinzhao
Director, Technology Center for the Consortium of Resonance and Rayleigh Lidars, National Science Foundation

Clifford, Steven
Member, National Academy of Engineering
Fellow, of the Acoustical Society of America
Fellow, of the Optical Society of America
Senior Member, of the IEEE
Meritorious Presidential Rank Award winner.

Coloma, Francine
NASA Group Achievement Award to EOSDIS Data Centers Customer Support Team.
Certificate of Appreciation, UNAVCO's Research Experience in Solid Earth Sciences for Students (RESESS) program

Cooper, Owen
Career track promotion to Research Scientist III

Dempsey, Karen
Outstanding Department Liaison University of CO Colorado Combined Campaign

Disterhoft, Patrick
EPA Stratospheric Ozone Protection Award

Dubé, William
CIRES Outstanding Performance Award CIRES

Duerr, Ruth
Hubert Wenger award Polar Libraries Colloquy

Frauenfeld, Oliver
Association of American Geographers 2006 John Russell Mather Paper of the Year Award, awarded by the Climate Specialty Group of the Association of American Geographers (for Frauenfeld, O. W., R. E. Davis, and M. E. Mann, 2005: A Distinctly Interdecadal Signal of Pacific Ocean-Atmosphere Interaction. J. Climate, 18(11), 1709–1718)
Board of Directors (Secretary) United States Permafrost Association

Golden, Joseph
The Thunderbird Award Weather Modification Association Award given occasionally for sustained contributions to the advancement of weather modifications science and technology, second-highest award from the Association.

Gupta, Vijay
Member, International Advisory Board J. Hydrologic Eng. ASCE
Member, IIHR Advisory board University of Iowa

Hartman, Michael
CIRES Outstanding Performance Award
NASA Group Achievement Award for the EOSDIS Data Centers Customer Support Team's exceptional customer service to a diverse community of Earth system science data users.

Hartten, Leslie
Significant Opportunities in Atmospheric Research and Science (SOARS) acknowledges 5 years of service as a SOARS Science Mentor.

Howard, Allaina
SRMA Board Member, Society of Rocky Mountain Archivists Program Coordinator
Frank B. Sessa Continuing Professional Education Scholarship Beta Phi Mu

Hurst, Dale
NOAA Oceanic and Atmospheric Research Outstanding Scientific Paper of 2005 NOAA OAR

Husted, Lindsay
NASA Group Achievement Award to Earth Observing System Data and Information System (EOSDIS) Data Centers

Klein, Roberta
CIRES Outstanding Service Award CIRES

Korn, David
NASA GSFC Customer Service Award

Leon, Amanda
NASA Group Achievement Award for the EOSDIS Data Centers Customer Service Support Team

Maslanik, James
Lead editor for Journal of Geophysical Research

Massoli, Paola
Boulder Lab Postdoc Symposium award DOC-Boulder Laboratories

Maurer, John
"Art in Science | Science in Art" juried exhibition selection University of Colorado
Career track Promotion to Associate Scientist III

McAllister, Molly
NASA Group Achievement Award to the EOSDIS Data Centers Customer Support Team

Meier, Walter
Science and Engineering Visualization Challenge NSF and AAAS Honorable Mention award in the Non-Interactive Media category for the NASA Scientific Visualization Studio "Tour of the Cryosphere" animation DVD.

Morrill, Carrie
Elected Councilor for Paleoclimatology American Quaternary Association

Nacu-Schmidt, Ami
CIRES Outstanding Performance/Service Award

Naranjo, Laura
NASA Group Achievement Award to EOSDIS Data Centers Customer Support Team

Nerem, Steven
2006 Geodesy Section Award American Geophysical Union

Neuman, Jonathan
Career track Promotion to Research Scientist III

Nowak, John
Career track promotion to CIRES Research Scientist II.
AOC Safety Medallion NOAA Aircraft Operations in Tampa, FL

Parsons, Mark
Career track promotion to Senior Associate Scientist
Co-Chairmanship IPY Data Policy and Management Subcommittee ICSU/WMO Joint Committee for IPY
Member National Research Council (NRC) Committee on Archiving Environmental and Geospatial Data at National Acadamy of Science

Pendergrass, Linda
CIRES Outstanding Performance Award

Pielke Jr., Roger
Eduard Brueckner Prize for Outstanding Achievement in interdisciplinary Climate Research

Pincus, Robert
Career track promotion to Research Scientist III

Ray, Eric
UARS Science Team NASA Group Achievement Award

Savoie, Matthew
NASA Group Achievement Award for exceptional customer service to a diverse community of Earth system science data users.

Scambos, Theodore
Career track promotion to Senior Research Scientist
Keynote speaker Gordon Research Conference: Polar Marine Science

Scott, Michon
People's Voice Winner for Education 10th Annual Webby Awards For http://earthobservatory.nasa.gov
2006 Gallery: Brilliant Display Nature For http://earthobservatory.nasa.gov
Website of the Week Voice of America For http://earthobservatory.nasa.gov
Internet Guide Selection Britannica Online For http://www.strangescience.net
NASA Group Award Goddard Space Flight Center for EOSDIS Data Centers Customer Support Team

Shah, Anju
NASA Group Achievement Award - EOSDIS Data Centers Customer Support Team

Sheehan, Anne
Incorporated Research Institutions for Seismology/Seismological Society of America (IRIS/SSA), Distinguished Lecturer
Kansas State University Women in Engineering and Science Program, Distinguished Lecturer
CU Faculty Fellowship
Emerging Leaders Program Fellow University of Colorado, Office of the President

Sheffield, Elizabeth
NASA Customer Service award NASA/GSFC received certificate for helping NASA achieve an excellent customer service rating.

Shupe, Matthew
Career track promotion to Associate Scientist III

Simons, Craig
CIRES Outstanding Performance Award CIRES

Smirnova, Tatiana
Outstanding Scientific Paper NOAA Award for the research paper:
"An Hourly Assimilation-Forecast Cycle, THe RUC", published in Monthly Weather Review, v.132, pp. 495-518, 2004.

Solomon, Amy
Associate Editor Journal of Geophyscial Research-Atmospheres AGU

Thornberry, Troy
Career track promotion to Research Scientist II.

Vaida, Veronica
Sigma Xi Distinguished Lecturer 2007-2008

Veale, Anthony
NASA Group Achievement Award to the members of EOSDIS Data Centers Customer Support Team.

Vukicevic, Tomislava
Fulbright International Scholar Fulbright foundation

Wahr, John
2006 Recipient of The Charles A.Whitten Medal of the American Geophysical Union Awarded at the Fall Meeting of the AGU

Williams, Christopher
CIRES Outstanding Performance Award CIRES

Service: Calendar Year 2006

CIRES members serve the scientific communities within the University of Colorado and NOAA, and beyond through participation in professional societies; organization of meetings and special sessions at conferences; review of journal publications and proposals from funding agencies, and service on editorial boards for major journals and committees. Following is a selected list of such memberships and activities, reflecting CIRES employees' service and dedication to their diverse fields of expertise. It is impossible to list all the organizations which benefit from CIRES' involvement, but we have tried to include an overview here. For the sake of brevity, service to CIRES, the University of Colorado, and NOAA are not included as the aim is to illustrate the global reach of CIRES expertise and contributions. Also omitted is the considerable list of services CIRES members contribute to the greater Boulder/Denver community.

Professional Memberships

Acoustical Society of America
Alexander von Humboldt Association of America
American Association for the Advancement of Science
American Association of Geographers
American Association of Pharmaceutical Scientists
American Chemical Society
American Indian Science and Engineering Society
American Meteorological Society
American Soceity for Information Science & Technology
American Society for Limnology and Oceanography
American Society of Mass Spectrometry
American Society for Quality
American Society of Parasitologists
American Water Resources Association
American Water Works Association
American Geophysical Union
Association for Computing Machinery
Boulder Writers' Alliance
China Society of Glaciology and Geocryology
Climate and Weather of the Sun-Earth System
Colorado Association of Science Teachers
Colorado Water Congress
Computer Professionals for Social Responsibility
Deutsche Gesellschaft fuer Polarforschung
Deutsche Physikalische Gesellschaft
EcoHealth
Ecological Society of America
European Geophysical Society
European Geophysical Union
Geological Society of America
Geoscience Education & Public Outreach Network
Human Factors and Ergonomics Society
Institute of Electrical and Electronics Engineers
Intergovernmental Panel on Climate Change
International Association for Geomagnetism and Aeronomy
International Association for Mathematical Physics
International Association for Mathematical Geology
International Facilities Management Association
International Glaciological Society
International Society on General Relativity and Gravitation
Morris K. Udall Foundation
National Association of Science Writers

National Center for Science Education
National Marine Educators Association
Permafrost Young Researchers Network
Rocky Mountain Climate Organization
Science Communications and Marine Public Information Network
Society for Advancement of Chicanos and Native Americans in Science
Society of American Archivists
Society of Research Administrators
Society of Rocky Mountain Archivists
Tsunami Society
Urban and Regional Informations Systems Association
U.S. Permafrost Association
World Meteorological Organization

Editorial Service

Arctic, Antarctic and Alpine Research
Climate Research
Cold Regions Science and Technology
Express Letters of the Journal of the Acoustical Society of America
Journal of Applied Meteorology
Journal of Atmospheric Chemistry
Journal of Geophysical Research
Journal of Glaciology and Geocryology
Journal of the Counstical Society of America
Journal of Volcanology and Geothermal Research
Mathematical Geology
World Meteorological Organization/Global Atmosphere Watch Report

Organizer/Convenor

1st Asian Conference on Permafrost, Lanzhou, China: Special session: Climate and Environmental Controls of the Cryosphere
1st Asian Conference on Permafrost, Lanzhou, China: Special session: Permafrost Hydrology
10th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans and Land Surface
AGU Special session: International Polar Year
AGU: Special session: Climatological Variations in the Upper Atmosphere and Ionosphere
AGU: Special session: Creating Usable Science in the 21st Century: Strategies for more effectively connecting science to societyal needs
AGU: Special session: Outstanding Issues in Seasonal to Interannual Climate Prediction
AGU: Special session: Toward High-resolution Greenhouse Gas Emission Inventories for Fossil Fuel Combustion
AGU: Western Pacific Geophysics Meeting, Beijing, China: Special session on Tropical Air-Sea Interaction
American Meteorological Society Middle Atmosphere Conference
Association of American Geographers: Special session: Land Cover/Land Use Change I and II
European Geophysical Union session on education and outreach
International Polar Year IceFest
Virtual Globes Conference
WCRP/Global Climate Observing System Surface Pressure

Review Papers and Proposals for:

Acoustical Society of America, Journal of the
Advances in Space Research
American Water Resources Association, Journal of the
Annals of Glaciology
Applied Meteorology, Journal of
Applied Meteorology and Climatology, Journal of
Arctic, Antarctic, and Alpine Research

Army Office of Scientific Research
Astrophysics and Space Sciences
Atmospheric Chemistry, Journal of
Atmospheric Chemistry and Physics
Atmospheric Environment
Atmospheric Sciences, Journal of
Atmospheric and Solar-Terrestrial Physics, Journal of
Boundary-Layer Meteorology
Bulletin of the American Meteorological Society
Canadian Journal of Fisheries and Aquatic Sciences
Canadian Journal of Zoology
Chemical Geology
China Society of Glaciology and Geocryology Journal
Chinese Academy of Sciences Journal
Climate Dynamics
Climate Research
Climate, Journal of
Cold Regions Science and Technology
Computational Acoustics, Journal of
Department of Commerce
Environmental Chemistry
Environmental Modeling and Software
Environmental Science and Policy
Environmental Science & Technology
Geophysical Research Letters
Geophysical Research, Journal of
Global and Planetary Change
Hydrometeorology, Journal of
IEEE Transactions on Geoscience and Remote Sensing
International Journal of Climatology
International Journal of Parasitology
Limnology and Oceanography
Marine Ecology Progress Series
Marine and Freshwater Research
Mass Spectrometry, Journal of
Meteorologische Zeitschrift
Monthly Weather Review
NASA
Natural Sciences and Engineering Research Council of Canada
Nature
Netherlands Organisation for Scientific Research (Dutch Research Council)
NOAA
North American Benthological Society, Journal of the
NSF
Ocean Modeling
Oceanography, Tokyo, Journal ofOecologia
Paleoclimatology
Physical Chemistry, Journal of
Physical Oceanography, Journal of
Polar Geography
Proceedings of the Royal Society (London)
Quarterly Journal of Mechanics and Applied Mathematics
Quarterly Journal of the Royal Meteorological Society
Quaternary Research
Quaternary Science Reviews
Radio Science

Remote Sensing of the Environment
Royal Meteorological Society
Tellus
Wave Motion
Weather and Forecasting

Acronyms and Abbreviations

A/Q	Air Quality
AAAR	American Association for Aerosol Research
AARI	Arctic and Antarctic Research Institute
ADCC	ARCSS Data Coordination Center
AFCCC	Air Force Combat Climatology Center
AFWA	Air Force Weather Agency
AGCM	Atmospheric Global Circulation Model
AGDC	Antarctic Glaciological Data Center
AGU	American Geophysical Union
AIRS	Advanced Infra Red Sounder
AMF	Air Mass Factor
AMIE	Assimilative Mapping of Ionospheric Electrodynamics
AMIP	Atmospheric Model Intercomparison Project
AMMA	African Monsoon Multidisciplinary Analysis
AMOS	Advanced Modeling and Observing Systems (CIRES scientific theme)
AMS	American Meteorological Society
AMSU	Satellite microwave sensor
ANOSIM	Analysis Of Similarities
ANTCI	Antarctic Tropospheric Chemistry Investigation
AOD	Aerosol Optical Depth
AOS	Aerosol Observation System
APEX	Geomagnetic field coordinate system
ArcIMS	Arc Internet Map Server
ARCSS	Arctic System Science
ARM	Atmospheric Radiation Measurement
ARW	Advanced Research WRF
ASCE	American Society of Civil Engineers
ASD	Analytical Spectral Devices
ASD-FR	Analytical Spectral Devices Field Spectroradiometer
ASG	Automated Spectro-Goniometer
ASR	Arctic System Reanalysis
ASLI	Atmospheric Sciences Librarians International
ATOC	Atmospheric and Oceanic Sciences (CU academic department)
AVE	Aircraft Validation Experiments
AXS	Avalanche X-ray Spectrometer
BBH	Brightband Height
BCM	Billion Cubic Meters
B-RAMS	Brazilian-Regional Atmospheric Modeling System
BSRN	Baseline Surface Radiation Network
CAC	Computing Advisory Committee
CAFS	CCD-based Actinic Flux Spectroradiometers
CAM	Community Atmosphere Model
CAN-BD	Carbon Dioxide-Assisted Nebulization with a Bubble Dryer®
CASES	Cooperative Atmosphere-Surface Exchange Study-99
CCD	Comparative Climate Data
CCF	CIRES Computing Facility
CCMC	Community Coordinated Modeling Center
CCSM	Community Climate System Model
CDC	Climate Diagnostics Center
CDMP	Climate Database Modernization Project
CDPW	Climate Diagnostics and Prediction Workshop
CDR	Climate Data Record
CDSS	Colorado Decision Support System
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions

CET	Center for Environmental Technology (CU Center)
CGCM	Coupled Global Circulation Model
CHAMP	CHAllenging Minisatellite Payload
CHASM	Chameleon Surface Model
CHILD	Channel-Hillslope Integrated Landscape Development model
CILER	Cooperative Institute for Limnology and Ecosystem Research
CIMS	Chemical Ionization Mass Spectrometry
CIRES	Cooperative Institute for Research in Environmental Sciences
CIRPAS	Center for Interdisciplinary Remotely-Piloted Aircraft Studies
CISM	Solar wind model
CLASIC	Cloud and LAnd Surface Interaction Campaign
CliC	Climate and Cryosphere
C-LIM	Coupled empirical-dynamical Linear Inverse Model
CLM	Community Land Model
CMAP	CPC Merged Analysis of Precipitation
CMCC	Community Coordinated Modeling Center
CME	Coronal Mass Ejection
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COARE	Coupled Ocean-Atmosphere Response Experiment
CONUS	Continental United States
CORS	Continuously Operating Reference Stations
CPASW	Climate Prediction Applications Science Workshop
CPC	Climate Prediction Center
CPC	Condensation Particle Counter
CPO	Climate Program Office
CPP	Cryospheric and Polar Processes
CR-AVE	Costa Rica Aura Validation Experiment
CRD	Cavity Ring-Down Spectroscopy
CRRL	Consortium of Resonance and Rayleigh Lidars
CRSS	Colorado River Simulation System
CRTM	Community Radiative Transfer Model
CSD	Chemical Sciences Division (ESRL)
CSES	Center for the Study of Earth from Space
CSIRO	Australian Commonwealth Scientific and Research Organization
CSPHOT	Cimel SunPHOTometer
CSTPR	Center for Science and Technology Policy Research
CSU	Colorado State University
CSV	Climate System Variability (CIRES scientific theme)
CTC	Consortium Technology Center
CTIPe	Coupled-Thermosphere-Ionosphere-Plasmasphere-electrodyamics
CU	University of Colorado
CUCF	Central UV Calibration Center
CVI	Counterflow Virtual Impactor
DAAC	Distributed Active Archive Center
DAFM	Dynamical Area Fraction Model
DAHLI	Discovery and Access of Historical Literature of the IPYs
DEM	Digital Elevation Model
DFI	Digital Filter Initialization
DLESE	Digital Library for Earth System Education
DLR	German Space Agency
DMS	Dimethyl-Sulfide
DMSP	Defense Meteorological Satellite Program
DOAS	Differential Optical Absorption Spectroscopy
DOC	Department of Commerce
DOD	Department of Defense

DOE	Department of Energy
DOTLRT	Discrete Ordinate Tangent Linear Radiative Transfer
DPI	Dry Powder Inhaler
DSD	Drop Size Distribution
DU	Dobson Units
EASE-GRID	Equal-Area Scalable Earth grid
EB	Environmental Biology (CIRES Division)
EBIO	Ecology and Evolutionary Biology (University Department)
EC	Environmental Chemistry (CIRES Division)
EC	European Commission
ECMWF	European Center for Medium Range Weather Forecasts
EEJM1	Equatorial Electrojet Model
EIS	Environmental Impact Statement
EIT	Extreme Ultraviolet Imaging Telescope
EMM-06	Extended Magnetic Field Model
ENLIL	A time-dependent 3D MHD solar wind model of the heliosphere
ENSO	El Niño/Southern Oscillation
EO	Education and Outreach
EOMF	Environmental Observations, Modeling and Forecasting (CIRES Division)
EOSDIS	Earth Observing System Data and Information System
EPIC	Eastern Pacific Investigations of Climate
ERA-40	ECMWF Re-Analysis
ERB	Earth's Radiation Budget
ESRL	Earth Systems Research Laboratory
ETH	Eidgenössische Technische Hochschule (Swiss Federal Institute of Technology)
EUVS	Extreme Ultraviolet Spectrometer
EVE-MESA	Extreme ultraviolet Variability Experiment – Mathematics, Engineering, Science, Achievement
FEMA	Federal Emergency Management Agency
FGDC	Frozen Ground Data Center
FIP	Forecast Icing Product
FLEXPART	Lagrangian particle dispersion model
FRAMES	Fire Research And Management Exchange System
FTE	Full Time Equivalent
FTIR	Fourier Transform Infrared (spectroscopy)
FTP	File Transfer Protocol
FY	Fiscal Year
GAIM	Global Assimilation of Ionospheric Measurements
GaP	Gallium Phosphide
GCM	Global Circulation Model
GCOS	Global Climate Observing System
GCSM	Global Climate System Model
GDSIDB	Global Digital Sea Ice Data Bank
GEM	GEostationary Microwave imager/sounder
GEO	Geodynamics (CIRES scientific theme)
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	Global Forecast System
GIF	Graphics Interchange Format
GIP	Global Ionosphere Plasmasphere
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GITM	Global Ionosphere-Thermosphere Model
GLDAS	Global Land Data Assimilation Systems
GLIMS	Global Land Ice Measurements from Space
GLOBEC	Global Ocean Ecosystem Dynamics
GMD	Global Monitoring Division
GNSS	Global Navigation Satellite Systems

GOES	Geostationary Operational Environmental Satellite
GoMACCS	Gulf of Mexico Atmospheric Composition and Climate Study
GOMECC	Gulf of Mexico and East Coast Carbon Cruise
GPCP	Global Precipitation Climatology Project
GPS	Global Positioning System
GPS-MET	Ground-based GPS Meteorology
GRACE	Gravity Recovery and Climate Experiment
GSD	Global Systems Division (ESRL)
GSFC	Goddard Space Flight Center
GSI	Gridpoint Statistical Interpolation
HCO	Formyl radicals
HD	High Definition
HIRS	High-Resolution Infrared Radiation Sounder
HMT	Hydrometeorological Testbed
HIRS	High-resolution Radiation Sounder
HRDL	High Resolution Doppler Lidar
HWRF	Hurricane Weather Research and Forecasting
HYCOM	Hybrid Coordinate Ocean Model
IA	Integrating Activities (CIRES scientific theme)
IAGA	International Association of Geomagnetism and Aeronomy
IARC	International Arctic Research Center
ICARTT	Int'l Consortium for Atmospheric Research on Transport and Transformation
I-COADS	International Comprehensive Ocean-Atmosphere Data Set
ICR	Indirect Cost Recovery
ICSU	International Council for Science
IDEA	Integrated Dynamics through Earth's Atmosphere
IEEE	Institute of Electrical and Electronics Engineers
IGRF	International Geomagnetic Reference Field
IGS	International GNSS Service
INMARTECH	International Marine Technician
INSTAAR	Institute of Arctic and Alpine Research
IOP	Intensive Observation Period
IOZDM	Indian Ocean Zonal Dipole Model
IPCC	Intergovernmental Panel on Climate Change
IPE	Ionosphere-Plasmasphere-Electrodynamics
IPY	International Polar Year
IPYDIS	IPY Data and Information Service
IR	Infrared
IRIS	Incorporated Research Institutions for Seismology
IRP	Innovative Research Program
ISA	Impervious Surface Area
ISM	index sequential method
ISO	International Standards Organization
IT	Information Technology
ITCT	Intercontinental Transport and Chemical Transformation
ITCZ	Intertropical Convergence Zone
JCSDA	Joint Center for Satellite Data Assimilation
JHT	Joint Hurricane Testbed
KML	Keyhole Markup Language
KPP	Kinetic PreProcessor
LASP	Laboratory for Atmospheric and Space Physics
LHF	Latent Heat Flux
LIM	Linear Inverse Model
LPAS	Laser-Photo-Acoustic Spectroscopy
LST	Local Standard Time
MAG	Magnetometer (NEAR data set)

MBBDB	MultiBeam Bathymetric Data Base
MCI	Mid-Continent Intensive
MEI	Multivariate ENSO Index
METAR	A format for reporting weather information (from French)
MFRSR	Multi-Filter Rotating Shadowband Radiometer
MHD	Magnetohydrodynamic
MHW	Mean High Water
MIRRION	Mirrored Ionosonde database
MJO	Madden-Julian Oscillation
MLO	Moana Loa Obervatory
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectroradiometer
MONA	Measurements of Ozone over North America
MOST	Method of Splitting Tsunami
MRE	Major Research Equipment grant
MRI	Major Research Instrumentation grant
MRS&S	MDL (Multi-Use Data Link) Receive System and Server
mVOC	Microbial Volatile Organic Compounds
N_2O	Nitrous Oxide
NAAQS	National Ambient Air Quality Standards
NACP	North American Carbon Program
NAM	North American Monsoon
NAME	North American Monsoon Experiment
NAO	North Atlantic Oscillation
NARR	North American Regional Reanalysis
NASA	National Aeronautics and Space Administration
NASM	North America Summer Monsoon
NAVDAT	North American Volcanic and intrusive ignious rock DATabase
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCS	National Critical Systems
NDGPS	National Differential GPS Service
NEAQS	New England Air Quality Study
NEAQS2k4	New England Air Quality Study 2004
NESDIS	National Environmental Satellite, Data, and Information Service
netCDF	network Common Data Form
NGDC	National Geophysical Data Center
NGO	Non-Governmental Organizations
NGS	National Geodetic Survey
NH_3	Ammonia
NIC	National Ice Center
NIDIS	National Integrated Drought Information System
NIST	National Institute of Standards and Technology
NO	Nitrogen Oxide
NOAA	National Oceanic and Atmospheric Administration
Noah	Land surface model: N: National Centers for Environmental Prediction (NCEP) O: Oregon State University (Dept of Atmospheric Sciences) A: Air Force (both AFWA and AFRL - formerly AFGL, PL) H: Hydrologic Research Lab - NWS (now Office of Hydrologic Dev -- OHD)
NOS	National Ocean Service
NOSB	National Ocean Sciences Bowl
NOx	Nitrogen oxides
NRLC	Natural Resources Law Center
NSAW	National Seasonal Assessment Workshop

NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
O_3	Ozone
OAI	Open Architectural Initiative
OAR	Oceanic and Atmospheric Research
ODS	Ozone Depleting Substances
OGCM	Oceanic General Circulation Model
OLR	Outgoing Longwave Radiation
OLS	Operational Linescan System
OMB	Office of Management and Budget
OMI	Ozone Monitoring Instrument
OPAL	Ozone Profiling Atmospheric Lidar
OSU	Ohio State University
OWS	Ocean Weather Station
PAGES	Past Global Changes
PASSCAL	Program for the Array Seismic Studies of the Continental Lithosphere
PBL	Planetary Boundary Layer
PCP	Pentachlorophenol
PCR	Polymerase Chain Reaction
PDO	Pacific Decadal Oscillation
PFA	Perfluoroalkoxy (Teflon tubing)
PM	Planetary Metabolism (CIRES scientific theme)
PMEL	Pacific Marine Environment Laboratory
PMH	Protocol for Metadata Harvesting
PNA	Pacific-North America
POMME	Geomagnetic field model
PRP	Program Review Panel
Prt	Prandtl Number
PSD	Physical Sciences Division (ESRL)
PSR	Polar Scanning Radiometer
PTR-MS	Proton-Transfer-Reaction Mass Spectrometry
PTR-ITMS	Proton-Transfer-Reaction Ion Transfer Mass Spectrometry
QPE	Quantitative Precipitation Estimate
QPF	Quantitative Precipitation Forecast
R/V	Research Vessel
ReSciPE	Resources for Scientists in Partnerships with Education
RH	Relative Humidity
RISA	Regional Integrated Sciences and Assessments
rivmSHIC	Software to improve comparability of data sets obtained with different spectral instruments
RL	Residual Layer
RP	Regional Processes (CIRES scientific theme)
RR	Rapid Refresh
RTVS	Real-Time Verification System
RUC	Rapid Update Cycle
SAC-C	Satelite de Aplicanciones Cientificas-C
SARP	Sector Applications Research Program
SBL	Stable Boundary Layer
SDO	Solar Dynamics Observatory
SEARCH	Study of Environmental Arctic Change
SEC	Space Environment Center
SEISS	Space Environment In-Situ Suite
SEM	Space Environment Monitor
SEMS	Scanning Electrical Mobility Sizer
SES	Solid Earth Sciences (CIRES Division)

SHEBA	Surface Heat Budget of the Arctic Ocean
Si	Silicon
SiB	Simple Biosphere Model
SIFT	Short-term Inundation Forecasting for Tsunamis
SII	Serum Institute of India
SIMM	Simple Inner Magnetosphere Model
SIPNET	Simple Photosynthesis and Evapotranspiration
SM	Soil Moisture
SMART-R	Shared Mobile Atmospheric Research and Teaching Radar
SMMR	Scanning Multichannel Microwave Radiometer
SNEP	Sierra Nevada Ecosystem Project
SO_2	Sulfur Dioxide
SOARS	Significant Opportunities in Atmospheric Research and Science
SOF	Solar Occultation Flux
SOHO	Solar and Heliospheric Observatory
SOLAR	Solar activity On-Line Activity Resources
SOM	Self-Organizing Maps
SPARC	Science Policy Assessment and Research on Climate
SPIDR	Space Physics Interactive Data Resource
SPIE	International Society for Optical Engineering
SPMAP	South Platte Mapping and Analysis Program
SPRAT	South Platte Regional Assessment Tool
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
STEREO	Solar Terrestrial Relations Observatory
STRATUS	Surface mooring component of the CLIVAR Long Term Evolution and Coupling of the Boundary Layers in the Stratus Deck Regions study
SURFRAD	Surface Radiation
SWA	Space Weather Analysis
SWDS	Space Weather Data Stores
SWE	Snow Water Equivalent
SWF	Shortwave Flux
SXI	Solar X-ray Imager
TAF	Terminal Aerodrome Forecast
TAO	Tropical Atmosphere Ocean
TCHQ	Tetrachlorohydroquinone
TEC	Total Electron Content
TECQ	Texas Commission on Environmental Quality
TES	Tropospheric Emission Spectrometer
TexAQS	Texas Air Quality Study
TLS	Tethered Lifting System
TM5	Transport Model
TMO	Table Mountain Observatory
TMTF	Table Mountain Test Facility
TOMS	Total Ozone Mapping Spectrometer
TOPAZ	Tunable Optical Profiler for Aerosol and oZone
TOPEX	Ocean Topography Experiment
TRMM	Tropical Rainfall Measurement Mission
TWP-ICE	Tropical Western Pacific-International Cloud Experiment
UAS	Unmanned Aircraft System
UNAVCO	University NAVSTAR Consortium
UNESCO	United Nations Educational, Scientific and Cultural Organization
UROP	Undergraduate Research Opportunities Program (CU)
USADCC	U.S. Antarctic Data Coordination Center
USAF	U.S. Air Force
USBR	U.S. Bureau of Reclamation

USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
UV	Ultraviolet
UVB	Ultraviolet Broadband
VIC	Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model
ViRBO	Virtual Radiation Belt Observatory
VO	Virtual Observatory
VOC	Volatile Organic Carbon
VOCALS	VAMOS Ocean Cloud Atmospheric Land Study
WAM	Whole Atmosphere Model
WCD	Weather and Climate Dynamics (CIRES Division)
WCS	Web Coverage Service
WDC	World Data Center
WDI	World Development Indicators
WDMAM	World Digital Magnetic Anomaly Map project
WGA	Western Governors' Association
WGS	World Geodetic System
WHO	World Health Organization
WMM	World Magnetic Model
WMO	World Meteorological Organization
WMS	Web Mapping Service
WRF	Weather Research and Forecasting
WRF/Chem	Weather Research and Forecasting/Chemistry
WSA	Wang-Sheeley-Arge
WSR-88D	Weather Surveillance Radar 88 Doppler
WWA	Western Water Assessment
XRS	X-Ray Sensor
XSLT	Extensible Stylesheet Language Transformations
YES	Yankee Environmental System