CIRES

2012 Annual Report

COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

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Cover image: Ice crystals forming on a window during a cold January morning
Photo by Christopher McNeave, Associate Scientist III, CIRES/NSIDC

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Freeze, Flow, Vaporize related

From the Director

Over the last eight years, under the leadership of Director Konrad Steffen, CIRES has enjoyed steadily increasing research support matched by rising productivity and growth in scientific staff. In July 2012, Director Steffen left CIRES to meet a strong challenge from the Swiss University ETH, which incorporates a number of large research units comparable to CIRES. Dr. Steffen, who is Swiss, will lead the ETH Institute for Forest, Snow and Landscape Research. CIRES feels a great loss but will have continuing research ties with Dr. Steffen.

CIRES now enters a new era in which the Fellows choose a new Director to be reviewed for approval by the University of Colorado. The new Director's appointment will be a natural time for CIRES to consider current issues, including an increasingly difficult funding environment for science. A happy coincidence is that CIRES received in August 2012 from the NOAA Cooperative Institute Program approval for a new cooperative agreement with a five-year term and a scope of work matching that of CIRES in recent years. Under this stimulus, the collaboration between CIRES and NOAA scientists in Boulder will continue to thrive.

Dr. William M. Lewis, Jr.

Achievements of CIRES scientists for FY2012 (July 2011–June 2012) extended over the broad CIRES environmental research agenda, which includes physical, chemical, and biological aspects of environment as well as the human dimension of environmental analysis. Studies of atmospheric chemistry, a special strength of CIRES and its NOAA partner, produced advances in understanding of atmospheric soot, fossil fuel combustion, and bacteria suspended in the air. CIRES and NOAA collaborators continued their intensive collaboration on the study of the effects of the 2010 Gulf of Mexico Deepwater Horizon oil spill on air quality. While the immediate concern of the spill was environmental damage to the aquatic environment, these scientists showed that the strategy of burning oil to remove it from the water surface produced more than 1 million pounds of black carbon in the form of soot. Data produced by these scientists will guide oil spill management in the future as air pollution joins other concerns that determine the response to spills.

CIRES scientists participated in a landmark study of fossil fuel combustion showing, contrary to expectation, that gasoline is less desirable than diesel fuel as a producer of some types of air pollution that are of environmental concern. In addition, CIRES scientists documented the presence of surprisingly high abundances of bacteria derived from dog feces in the urban atmosphere, suggesting the existence of unresolved air pollution problems associated with pets.

Global climate with a focus on ice sheets continued to be a major interest of several working groups within CIRES. CIRES scientists contributed to the conclusion that Arctic sea ice reached its lowest minimum recorded extent in 2012. Long-term detailed studies of the Greenland ice sheet by CIRES scientists showed that movement of the ice sheet toward the Greenland coast may accelerate when increased meltwater reaches the bottom of the ice sheet; water lubricates the movement of ice over rock.

The National Snow and Ice Data Center (NSIDC), which holds a global archive of information on ice and climate related to cold regions, was honored during the past year with Presidential and State awards for its successful commitment to drastic diminution of energy use in support of the massive, power-hungry computing equipment that is necessary for maintenance of global records on ice and climate. A renovation plan that was surprisingly simple in design reduced power use for the NSIDC data center by more than 90 percent.

CIRES scientists presented evidence at the national and state level in a controversy over nutrient (phosphorus, nitrogen) regulation to protect quality of inland waters nationwide. Some scientists have concluded that regulation of nitrogen is not necessary if phosphorus is regulated. Others see evidence, particularly of recent derivation, that nitrogen regulation is critical as well. Individual states have taken varied positions on this regulatory issue. Colorado during 2012, partly in response to evidence presented by CIRES scientists, ruled through its Water Quality Control Commission to proceed with dual regulatory control of nitrogen and phosphorus pollution of waters.

The active Solid Earth Sciences Division of CIRES in 2012 released information on measurements of Earth's crustal movement along the Rio Grande Rift, which extends from Colorado's Rocky Mountains to Mexico. A specialized GPS system that measures crustal movements as small as 1 millimeter over a distance of 1,000 kilometers showed widespread crustal movement around the rift but no indication of strong localized movement, as might be associated with large earthquakes. Small earthquakes will happen, but disasters are unlikely.

CIRES sees well-supported opportunities to advance environmental science in the coming year.

William M. Lewis, Jr.
Interim Director of CIRES

Photo by Christopher McNeave

Freeze...Flow...Vaporize... And Repeat.

From solid to liquid to gas, water is the only natural substance that exists in all three physical states at temperatures normally found on Earth. Its deceptively humble structure—one oxygen and two hydrogen atoms—endows it with unique properties: It expands when frozen, so ice floats instead of sinks; it absorbs large amounts of heat before getting hot, buffering temperatures; its surface tension allows water to move through plant roots and blood through capillaries; and as the "universal solvent," water dissolves more substances than any other liquid. Cycling continuously among its many forms—snow, ice, freshwater, saline, vapor—water sculpts the landscape, moderates the climate, and makes life on Earth possible, while also driving our curiosity about life on planets beyond our own.

Although water covers most of Earth, less than 3 percent is freshwater. Worldwide, changes are occurring that strain the supply and demand structure of this vital resource. The global population now exceeds 7 billion people, 1.1 billion of which lack access to safe drinking water. As our numbers increase, we will need more water for drinking, as well as to grow food and provide sanitation. At the same time, warming temperatures are altering the hydrologic cycle and changing the amount, timing, and quality of freshwater resources.

Understanding freshwater resources is an interdisciplinary problem requiring an interdisciplinary approach. Observing and understanding the processes affecting freshwater systems in the past and in the present; identifying and projecting future stressors; and evaluating the capacity of human and ecological systems to adapt, are all necessary to meet the challenge of sustaining freshwater resources.

CIRES has emerged as an international leader in water research. The FY2012 CIRES Annual Report highlights cutting-edge research by CIRES scientists that focuses on the 21st-century challenge of water.

As has been the practice at CIRES, each Annual Report highlights how CIRES brings interdisciplinary expertise to bear on a specific environmental issue. This Annual Report showcases CIRES research related to sustainability of freshwater resources. Throughout the document, high-impact research is specifically called out. The work and accomplishments profiled are not comprehensive in terms of all the water-related work at the Institute, just the tip of the iceberg, so to speak, but they exemplify the breadth of expertise within CIRES. Watch for the above water-molecule icon, indicating a Water Box, throughout the report.

CIRES: World-Class World Science

Since its inception in 1967, the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder has emerged as an international leader in research that addresses the pressing challenges facing our planet. The scope of scientific accomplishments over fiscal year 2012 (FY2012, July 1, 2011, through June 30, 2012) illustrates the continuation of this tradition, and how CIRES continues to help NOAA support and meet its strategic goals. In support of the NOAA paradigm of Science in Service to Society, CIRES continues to coordinate and communicate relevant research to decision makers and the public.

Vision and Mission

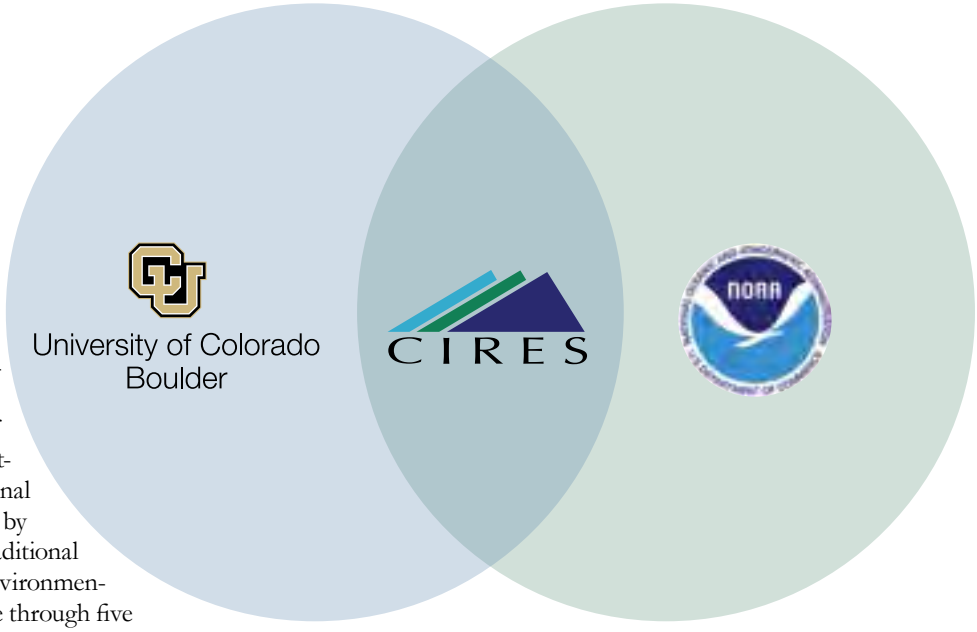
As a world leader in environmental sciences, CIRES is committed to identifying and pursuing innovative research in Earth system science and fostering public awareness of these processes to ensure a sustainable future environment. CIRES is dedicated to fundamental and interdisciplinary research targeted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

Photo by CIRES

A Guide to the CIRES Annual Report FY2012

The scope of research and accomplishments outlined in the CIRES FY12 Annual Report transcends many departments at the University of Colorado, divisions within the NOAA Earth System Research Laboratory, and traditional academic sectors. This Annual Report is an accounting of the collaborative research goals, including those described in the CIRES-NOAA workplan, year two. This report is organized in four main sections. First is the Executive Summary, which includes details about the CIRES organization and highlights FY12 accomplishments. The subsequent sections outline CIRES People and Projects, followed by Theme Reports. The latter are organized by NOAA's six scientific themes as identified in the Cooperative Agreement—advanced modeling and observing systems, climate system variability, geodynamics, planetary metabolism, regional processes, and integrating activities. The final section outlines Measures of Achievements within CIRES, including publications, honors, and important activities.

This Is CIRES



The Cooperative Institute for Research in Environmental Sciences (CIRES) was established in 1967 to facilitate collaboration between the University of Colorado Boulder and the National Oceanic and Atmospheric Administration (NOAA). CIRES's original and continuing purpose is to support NOAA goals by facilitating interdisciplinary studies that crosscut traditional scientific fields and transcend the many facets of environmental research. CIRES fosters interdisciplinary science through five centers—the National Snow and Ice Data Center, the Center for Limnology, the Center for Science and Technology Policy Research, the Climate Diagnostics Center, and the Earth Science and Observation Center. Such interdisciplinary combinations provide unique opportunities for discovery and for application of knowledge to meet societal needs. The work of the CIRES enterprise strengthens the scientific foundation upon which NOAA's many services depend, and allows coordinated studies on a scale that could not be addressed by university research units or by NOAA alone.

University of Colorado Boulder

Aerospace Engineering Sciences

Atmospheric and Oceanic Sciences

Chemistry and Biochemistry

Civil, Environmental, and Architectural Engineering

Ecology and Evolutionary Biology

Electrical and Computer Engineering

Geography

Geological Sciences

Molecular, Cellular, and Developmental Biology

Physics

Environmental Studies

CIRES Divisions

Cryospheric and Polar Processes

Ecosystem Science

Environmental Chemistry

Environmental Observations, Modeling, and Forecasting

Solid Earth Sciences

Weather and Climate Dynamics

Interdisciplinary Research Centers

Climate Diagnostics Center

Center for Limnology

Center for Science and Technology Policy Research

National Snow and Ice Data Center

Earth Science and Observation Center

Programs

Education & Outreach

Western Water Assessment

NOAA at Boulder Earth System Research Laboratory (ESRL)

Chemical Sciences Division

Global Monitoring Division

Global Systems Division

Physical Sciences Division

NOAA Centers

National Geophysical Data Center

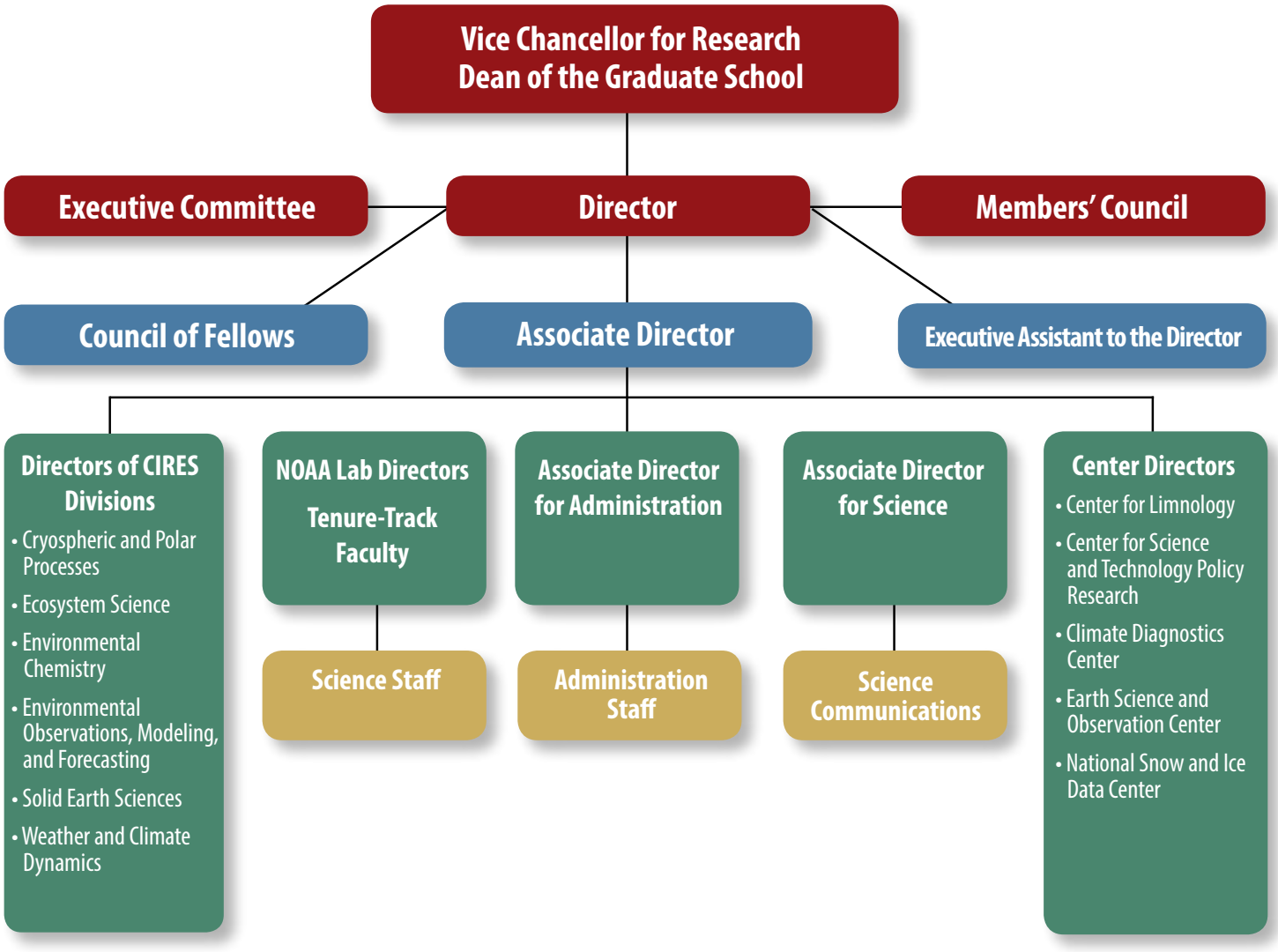
Space Weather Prediction Center

Governance, Management, and Organization

The governance and management of CIRES is provided through its Council of Fellows, an advisory Executive Committee, and the CIRES Members' Council. The CIRES Centers (Climate Diagnostics Center, Center for Limnology, Center for Science and Technology Policy Research, National Snow and Ice Data Center, and Earth Science and Observation Center) link NOAA to 11 different university departments. Coordination among all these entities is facilitated through the Communications group.

The CIRES Team	FY2011	FY2012
Faculty Lines	22	20
CIRES Fellows	47	47
Research Scientists	193	187
Associate Scientists	228	237
Visiting Scientists	29	32
Postdoctoral Researchers	28	26
Administrative Staff	32	38
Graduate Students	96	101
Undergraduate Students	86	76

CIRES Organizational Structure



Council of Fellows

The Council of Fellows (see page 10) 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 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 and 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 spirit 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 seven times during FY12: Sept. 15, Oct. 20, and Dec. 15 of 2011; and Jan. 19, Feb. 9, March 22, and April 26 of 2012.

Executive Committee

The Executive Committee assists and advises the Director in matters regarding day-to-day management of the Institute. Members of the Executive Committee include the Associate Directors of CIRES's six divisions, two Fellows elected at-large for two-year terms (renewable for one term), and two Members' Council members. The Associate Director for Administration, Associate Director for Science, and the Director's Executive Assistant 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.

Fellows Appointment Committee

Fellows of CIRES are selected by two-thirds vote of the Council of Fellows and are appointed or reappointed by the Director of CIRES with the concurrence of the Vice Chancellor for Research and the Dean of the Graduate School. New Fellow nominations are considered by the Council of Fellows once yearly, drawing from the community of scientists at the University of Colorado Boulder and NOAA. Theme leaders present cases for appointment of new Fellows to the Council of Fellows. The initial appointment of any new CIRES Fellow is for two years, and continuing-term reappointments are for five years. Qualifications for reappointment are the same as for the initial appointment, except that the established record of the appointee must show evidence of commitment to the affairs of CIRES.

Diversity Committee

Recent studies highlight that fewer underrepresented minorities are pursuing careers in science, especially in higher education. To increase diversity is a major challenge scientists and educators face, and CIRES has made it a priority to extend its knowledge and community to include more diverse ethnic groups and improve gender balance. Toward that end, the Diversity Committee was created in 2010 and is working to achieve this goal. The Committee works with CIRES Education and Outreach, the Communications group, and scientists and staff to identify opportunities for CIRES to make a difference in this vital work to enrich our science and enhance our mission.

Members' Council

The CIRES Members' Council was created in 1997 to act as an information and policy conduit between CIRES leadership and Institute members. To provide uniform representation, the CIRES membership is divided geographically into eight groups that comprise various divisions and centers across the Institute, with representation reflecting the size of each group. From the council, two delegates to the CIRES Council of Fellows and Executive Committee are elected to serve as the liaison between these governing bodies and the Members' Council. The Members' Council, which meets monthly, then serves as a direct line of communication to the Member population at large. At these meetings, the council hears members' inquiries and concerns, discusses and develops potential solutions to any outstanding issues, and works directly with CIRES leadership to implement these solutions. Additionally, the Members' Council performs regular service to the Institute by, for example, sponsoring the annual Rendezvous Symposium, the Awards Committee for CIRES Outstanding Performance Awards, and the CIRES Bike Share Program.

Special Committees

Additional special committees are appointed as needed by the Director. These include Faculty Search committees, the University Academic Review and Planning Advisory Committee, Award Committee, Faculty Promotion committees, and others. They are created as the need arises, exist to accomplish a specific task, and are then disbanded.

Other CIRES Committees:

Visiting Fellows Committee

Distinguished Lecture Committee

Graduate Student Research Fellowship Committee

Innovative Research Program Committee

Council of Fellows (July 1, 2011–June 30, 2012)

Waleed Abdalati Associate Professor of Geography; Director of the Earth Science and Observation Center

Richard Armstrong CIRES Senior Research Scientist in the National Snow and Ice Data Center (NSIDC); Associate Director of the Cryospheric and Polar Processes Division

Benjamin Balsley Research Professor and CIRES Senior Research Scientist

Stan Benjamin Chief of Assimilation and Modeling Branch, ESRL Global Systems Division

Roger Bilham Professor of Geological Sciences

Maxwell Boykoff Assistant Professor of Environmental Studies

John Cassano Associate Professor of Atmospheric and Oceanic Sciences

Thomas Chase Associate Professor of Civil, Environmental, and Architectural Engineering

Xinzhao Chu Associate Professor of Aerospace Engineering

Shelley Copley Professor of Molecular, Cellular, and Developmental Biology

Joost de Gouw CIRES Senior Research Scientist, ESRL Chemical Sciences Division (CSD)

Lisa Dilling Assistant Professor of Environmental Studies

Randall Dole Deputy Director for Research, ESRL Physical Sciences Division (PSD);

Associate Director of the Weather and Climate Dynamics Division

David Fahey Research Physicist and Program Lead, Atmospheric Composition and Chemical Processes, ESRL CSD

Christopher Fairall Chief, Weather and Climate Physics Branch, ESRL PSD

Lang Farmer Professor and Department Chair of Geological Sciences

Fred Fehsenfeld CIRES Senior Research Scientist, ESRL CSD; Co-Associate Director of the Environmental Chemistry Division

Graham Feingold Research Scientist, ESRL CSD

Noah Fierer Associate Professor of Ecology and Evolutionary Biology

Baylor Fox-Kemper Assistant Professor of Atmospheric and Oceanic Sciences

Timothy Fuller-Rowell CIRES Senior Research Scientist, NOAA Space Weather Prediction Center

Vijay Gupta Professor of Civil, Environmental, and Architectural Engineering

Michael Hardesty Senior Scientist and Program Lead, Atmospheric Remote Sensing, ESRL CSD; Associate Director of the Environmental Observations, Modeling, and Forecasting Division

José-Luis Jiménez Associate Professor of Chemistry and Biochemistry

Craig Jones Associate Professor of Geological Sciences

William M. Lewis, Jr. Professor of Ecology and Evolutionary Biology; Director of the Center for Limnology; Interim Director of CIRES

Peter Molnar Professor of Geological Sciences

Steve Montzka Research Chemist, ESRL Global Monitoring Division

William Neff Senior Scientist and Director, ESRL PSD

Steven Nerem Professor of Aerospace Engineering

David Noone Associate Professor of Atmospheric and Oceanic Sciences

Judith Perlwitz CIRES Research Scientist III, ESRL PSD

Roger Pielke, Jr. Professor of Environmental Studies

Balaji Rajagopalan Associate Professor of Civil, Environmental, and Architectural Engineering

Prashant Sardeshmukh CIRES Senior Research Scientist, ESRL PSD; Director of the Climate Diagnostics Center

Mark Serreze Professor of Geography; Director of the National Snow and Ice Data Center

Anne Sheehan Professor of Geological Sciences; Associate Director of the Solid Earth Sciences Division

Robert Sievers Professor of Chemistry and Biochemistry; Director of the CU-Boulder Environmental Program

Konrad Steffen Professor of Geography; Director of CIRES

Margaret Tolbert Distinguished Professor of Chemistry and Biochemistry; Co-Associate Director of the Environmental Chemistry Division

William Travis Associate Professor of Geography; Director of the Center for Science and Technology Policy Research

Greg Tucker Associate Professor of Geological Sciences

Veronica Vaida Professor of Chemistry and Biochemistry

Rainer Volkamer Assistant Professor of Chemistry and Biochemistry

Carol Wessman Professor of Ecology and Evolutionary Biology; Associate Director of the Ecosystem Science Division

Tingjun Zhang CIRES Senior Research Scientist, NSIDC

Emeritus Fellows

Susan Avery Former CIRES Director; Former Professor of Electrical and Computer Engineering

Roger Barry Distinguished Professor of Geography; Director of the World Data Center for Glaciology

John Birks Professor of Chemistry and Biochemistry

George Reid Senior Scientist, ESRL CSD (deceased)

Doug Robertson Retired NOAA National Ocean Service, National Geodetic Survey

Hartmut Spetzler Professor Emeritus of Geological Sciences

CIRES Centers

The Centers within the CIRES enterprise provide the functional link between NOAA and 11 different departments at the University of Colorado Boulder. The goal is that the Centers provide an environment to develop collaboration and facilitate partnerships between federal and academic entities.

Climate Diagnostics Center

The mission of the Climate Diagnostics Center (CDC) is to improve our understanding of global climate interactions to improve regional climate predictions, and to train the next generation of climate scientists in advanced climate system diagnosis and prediction. Research disciplines include but are not limited to the atmospheric sciences, oceanography, stochastic dynamics and physics, remote sensing, numerical computational methods, computer sciences, data management, and complex dynamical systems analysis. An integration of these disciplines is required to transfer improvements in the understanding of climate processes to improvements in the models and methods used for climate predictions.

CDC Research Highlight

The Twentieth Century Reanalysis (20CR) project was a major international effort led by CDC and NOAA to produce a comprehensive global atmospheric circulation data set spanning the period 1871 to the present. The data set has already proven to be a valuable resource to the climate research community for climate model validations and diagnostic studies. The journal article describing its development and main features has already been cited more than 70 times in the first year since publication, and the data acquired was deemed one of the "Great Long-Term Datasets in all of Science" by *Wired* magazine.

Center for Limnology

The Center for Limnology makes ecologically oriented studies of inland waters: lakes, streams, and wetlands. The goals of the center are to provide visibility and continuity and technical support for interdisciplinary studies involving inland aquatic ecosystems, to maintain undergraduate training programs and individualized undergraduate instruction in the science of aquatic ecosystems, to attract and use research funds for the collection and analysis of data on aquatic ecosystems, to publish and disseminate research findings in the open literature, to participate at the national and international level in the study of important questions relating to aquatic ecosystems, and to help resolve important problems related to either the basic science or applied science of inland waters.

Limnology Research Highlight

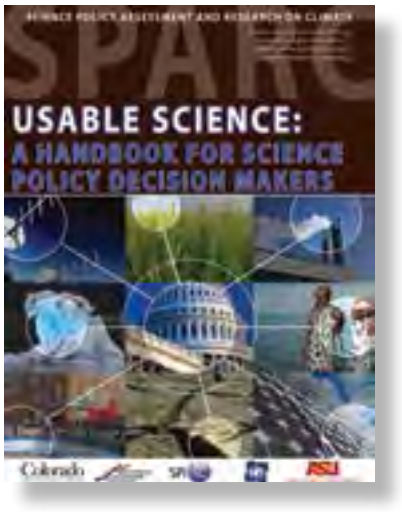
The overgrowth of aquatic plants and algae can strangle a lake or stream—producing toxic algal blooms, depriving fish of oxygen, and tainting the water's smell, taste, and appearance. While phosphorus has received the most attention for fueling that growth, research is shedding light on another equally important nutrient, nitrogen. CIRES scientists from the Center for Limnology presented evidence at the national and state level in a controversy over nutrient (phosphorus, nitrogen) regulation to protect quality of inland waters nationwide. Some scientists have concluded that regulation of nitrogen is not necessary if phosphorus is regulated. Others see evidence, particularly of recent derivation, that nitrogen regulation is critical as well. Individual states have taken varied positions on this regulatory issue. Colorado during 2012, partly in response to evidence presented by CIRES scientists, ruled through its Water Quality Control Commission to proceed with dual regulatory control of nitrogen and phosphorus pollution of waters.

Center for Science and Technology Policy Research

The Center for Science and Technology Policy Research (CSTPR) was established within CIRES in 2001 to conduct research, education, and outreach at the interface of science, technology, and the needs of decision makers in public and private settings. The Center focuses on the intersection of the environment and society, applying the social and policy sciences to problems of environmental change, management, and sustainability. Much of the work at CSTPR poses questions about how people and institutions make decisions under uncertainty; how perception and technical information influence choices; and how, over time, those choices affect the co-evolution of science, technology, and policy.

CSTPR Research Highlight

CSTPR researchers completed a five-year NSF "SPARC" (Science Policy Assessment and Research on Climate) project, which resulted in more than 11 master's theses and dissertations, as well as 200 mostly peer-reviewed publications. Numerous workshops were conducted that directly engaged science policy practitioners from around the world, advancing SPARC's goal of a highly integrated research and outreach agenda. A handbook on usable science was also written for practitioners. The book summarized SPARC research findings and was widely distributed across the community.



National Snow and Ice Data Center

The mission of the National Snow and Ice Data Center (NSIDC) is to advance understanding of Earth's frozen realms: the floating sea ice cover, lake ice, glaciers, ice sheets, snow cover, and frozen ground, collectively known as the cryosphere. Major areas of research at NSIDC include processes driving the downward trend in Arctic sea ice extent; environmental impacts of this sea ice loss both within and beyond the Arctic; the behavior of the Greenland and Antarctic ice sheets; Himalayan glaciers and their contributions to sea level rise; links among snowfall, temperature and streamflow; and the implications of changes in Earth's permafrost. Informatics research includes developing alternative database structures to search vast data volumes to answer science questions; developing technologies to make NSIDC data more visible to more researchers; and enhancing data discovery through semantic interoperability. NSIDC also has a broad scope of education and outreach efforts.

NSIDC Research Highlight

Scientists studying changes in the mass balance of polar ice and its potential contribution to global sea level change can now access data from NASA's IceBridge mission via NSIDC. IceBridge addresses the gap between ICESat-I, which concluded operations in early 2010, and the next satellite, and ICESat-II, which is planned for launch in 2015. Begun in 2009, IceBridge is a six-year campaign of annual flights over the poles. The aircraft carry an array of instruments to map ice surface topography, bedrock topography beneath the ice sheets, and grounding line position. During 2011, NSIDC published more than 40 unique IceBridge data sets, and efforts are ongoing. NSIDC also developed the IceBridge Data Portal, a Web-based tool for easily finding flight reports and science data for a selected flight.

Photo courtesy of Xinzhao Chu

Earth Science and Observation Center

The Earth Science and Observation Center (ESOC) provides a focus for the development and application of modern remote-sensing techniques used in the research of all aspects of Earth sciences at CU-Boulder. The aim is to work on all scales of problems, from technique development in small test sites to understanding pattern and process on regional and global scales. A long-term goal of ESOC research is to investigate problems in global geosciences—questions of global change, in particular—through remote-sensing observations. ESOC had seven faculty associates during FY12, 20 graduate students, eight postdocs, and four visiting fellows.

ESOC Research Highlight

The polar middle and upper atmosphere provides a unique natural laboratory for studying the complex physical, chemical, and dynamical processes in Earth's atmosphere and space environment. However, very little is known in the altitude range of 100 to 200 kilometers because observations are extremely difficult to make. The first lidar discovery of neutral iron (Fe) layers with gravity wave signatures in the thermosphere up to 155 kilometers made by the Chu Research Group at McMurdo, Antarctica, is a breakthrough in the upper atmosphere research. Not only is this the first time for a single instrument to trace gravity waves from 30 to 155 kilometers, but also it enables the first direct measurements of neutral temperatures deep into the E-region, revealing the neutral-ion coupling and aurora-enhanced Joule heating. The new observations of Fe, neutral temperatures, and gravity waves up to 155 kilometers have opened the door to exploring the neutral polar thermosphere with ground-based instruments.

NASA/Jefferson Beck

The sun reflects over thin sea ice and a few floating icebergs near the Denmark Strait off of eastern Greenland, as seen from NASA's P-3B aircraft on April 14, 2012.

Interdisciplinary Programs

A vibrant research environment is fostered through a number of programs and initiatives designed to stimulate interdisciplinary collaborations among CIRES, NOAA, and university departments.

iStock photo

CIRES programs, such as the Western Water Assessment, serve society with timely science. Above: Horseshoe Bend of the Colorado River near Page, Ariz.

Western Water Assessment

The Western Water Assessment (WWA) is CIRES's signature integrating activity, relying on multidisciplinary teams of experts in climate, hydrology, ecology, law, and policy to work with decision makers across the Intermountain West to produce policy-relevant information about climate variability and change. WWA is one of 11 NOAA-funded Regional Integrated Sciences and Assessments (RISA) programs across the country. By building relationships with networks of decision makers, WWA is able to develop practical research programs and useful information products. WWA's mission is to identify and characterize regional vulnerabilities to—and impacts of—climate variability and change, and to develop information, products, and processes to assist decision makers throughout the Intermountain West. WWA addresses 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 U.S. Climate Change Science Program.

wwa.colorado.edu

WWA Research Highlight

As part of the Southwest Climate Alliance, a consortium of research organizations in the Southwest, WWA helped develop a technical input report on the Southwest Region for the USGCRP National Climate Assessment. This effort brought together a diverse set of scientists to craft an IPCC-style, peer-reviewed assessment of scientific findings on climate variability and climate change in the six-state region. WWA researchers served as authors on many chapters and were lead authors on the chapters "Water," "Solutions for a Sustainable Southwest," and "Uncertainty."

Visiting Fellows

CIRES annually conducts a competitive Visiting Fellows program that promotes collaborative research at the forefront of scientific knowledge. Visiting Fellows conduct interdisciplinary research in areas spanning the scope of the CIRES research portfolio. Fellowships of up to one year are awarded to Ph.D. scholars (postdoctoral fellowships) and faculty planning sabbatical leave (sabbatical fellowships). A committee comprised of CIRES Fellows is responsible for the review of all applications for CIRES Visiting Fellowships. The committee chooses those best qualified for a sabbatical or postdoctoral fellowship and submits that slate to the Fellows Council for final discussion and selection. Selections for the Visiting Fellows program are based in part on the likelihood of interactions between the Visiting Fellows and CIRES scientists 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. Since 1967, CIRES has awarded more than 280 Visiting Fellowships. Recipients have included previous CIRES Directors Susan Avery and Konrad Steffen.

cires.colorado.edu/collaboration/fellowships

2012 CIRES Visiting Fellows

Fellow	Sponsor
Jeffrey Amato	L. Farmer
Franco Biondi	T. Chase
Stuart Bradley	W. Neff, M. Hardesty
Lindsay Chapman	W. Lewis, J. McCutchan
Jean-Francois Doussin	V. Vaida
Brian Ebel	G. Tucker
Steven Hansen	A. Sheehan
Mark Hemer	B. Fox-Kemper
Shao-Meng Li	J. De Gouw
Bjorn-Ola Linner	R. Pielke, Jr.
Ben Livneh	C. Wessman
Xian Lu	X. Chu
Ralph Milliff	B. Fox-Kemper
Kyung-Eun Min	F. Fehsenfeld
Arnaud Temme	G. Tucker
Dan Yakir	D. Noone, S. Montzka

Innovative Research Programs

The purpose of the CIRES-wide competitive Innovative Research Program (IRP) is to stimulate a creative research environment within CIRES and to encourage synergy among 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 committee of CIRES Fellows selects the award recipients. The committee reviews all the research proposals and recommends to the CIRES Director for funding those that are the most inventive and bridge boundaries between traditional disciplines. The results of IRP research are presented the following year at a poster reception. For the 14th annual Innovative Research Program, three additional IRP awards were made to support CIRES's Energy and Environment Initiative. This initiative is focused on the environmental effects of the production and use of present and future energy sources. More details on the Energy and Environment Initiative can be found at http://cires.colorado.edu/science/initiatives/ee/.

cires.colorado.edu/science/pro/irp

Innovative Research Program Awards 2012

Project	CIRES and NOAA Investigators
Cropland, soil moisture, and recent heat waves	T Chase, EC Gill, K Wolter, and RJ Pielke Sr.
MiniCam 600-680 nm sensor for the PolarCube Satellite	D Gallaher, T Scambos, and W Meier
Developing an ensemble prediction system for operational space weather forecasting	CA de Koning and G Millward
Testing a silver bullet: Evaluation of mechanisms that link COS and ^{18}O in CO_2 to gross ecosystem uptake of CO_2	D Noone, M Berkelhammer, J Miller, C Sweeney, and D Yakir
Chemopreventive aerosols to reduce dysplasia	RE Sievers and SP Cape
Validating and enhancing airborne lidar snow depth mapping with ground-based lidar	JS Deems
Nighttime aerosol optical depth measurements in the Arctic: Development of a lunar photometer for use in Barrow, Alaska	RS Stone, EG Dutton, J Wendell, and D Longenecker
Emissions of hydrogen sulfide and other air toxics associated with natural gas production using hydraulic fracturing	C Warneke and M Graus
A new approach to NOx: Applications to diesel engines, biofuels, and oil and gas emissions	EJ Williams, WP Dube, PM Edwards, and SS Brown

Graduate Research Fellowships

CIRES supports two prestigious student fellowship programs: the long-established CIRES Graduate Student Research Fellowship (GSRF) and the ESRL-CIRES Fellowship, awarded to prospective master's and doctoral students every other year with the support of NOAA's Earth System Research Laboratory. The fellowships are competitively awarded to new or existing CIRES-affiliated graduate students. A Committee of CIRES Fellows serves as the review and selection committees for both the CIRES GSRF and the ESRL-CIRES Fellowships.

cires.colorado.edu/education/cu/gsrf
cires.colorado.edu/education/cu/esrl

CIRES Graduate Student Research Fellowship Recipients (2012)

Gaddy Bergmann
Ecology and Evolutionary Biology
Advisor: Noah Fierer

Sean Haney
Atmospheric and Oceanic Sciences
Advisor: Baylor Fox-Kemper

Brett Palm
Analytical/Atmospheric Chemistry
Advisor: Jose-Luis Jimenez

Adriana Raudzens Bailey
Atmospheric and Oceanic Sciences
Advisor: David Noone

Joe Rokicki
Molecular, Cellular, and Developmental Biology
Advisor: Shelley Copley

Jessica Weinkle
Environmental Studies
Advisor: Roger Pielke, Jr.

Making a Splash: FY2012 in Review

Contributions to NOAA's Vision

CIRES's fundamental research priority—to enhance the understanding and prediction of Earth's environment—complements NOAA's priorities. CIRES research supports the four Mission Goals identified in the NOAA Strategic Plan: Ecosystems, Climate, Weather and Water, and Commerce and Transportation.

Ecosystem Mission Goal: Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management

CIRES contributes to NOAA's ecosystem mission goal by implementing new approaches to monitoring biotic and abiotic conditions in remote ocean and coastal areas; by improving forecasts for extreme weather events that impact coastal areas; and by developing and archiving new data sets and other information products that can help assess coastal hazards and support seafloor research.

A prime example of CIRES contributions to ecosystem services in FY12 was the novel development, testing, and evaluation of software that automatically identifies ice seals and derives fractal ice characteristics. The software has been successfully applied to more than 50,000 images collected by unmanned aircraft systems over the Arctic. The data can be used to characterize seal habitat and to evaluate changes in populations. Both the executable and source codes for this software are freely available.

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

CIRES is a world leader in climate science research relevant to NOAA's climate mission goal. During FY12, CIRES researchers contributed significantly to all three categories of NOAA's climate-related programs: climate observations and monitoring, climate research and modeling, and climate service development.

CIRES researchers were fundamental to the success of data collected during the CalNex 2010 campaign, as well as subsequent analyses. Measurements from the CalNex campaign provided critical insight into the evolution of aerosol optical properties impacting climate and visibility in Southern California. The results will be used by the California Air Resources Board (CARB) in its efforts to reduce air-quality degradation across the state.

Instruments developed for the CalNex 2010 campaign have also supported a number of additional studies. The instruments were deployed to Barbados to study the optical properties of transported Saharan dust. In addition, they were used by CIRES researchers at the NOAA ESRL site to collect optical property measurements of biomass burning aerosol sampled during the Four-Mile Fire near Boulder, Colo. This data set advances our understanding of the climate impacts of biomass burning emissions.

CIRES researchers are also making headway improving forecasts of aerosol within air-quality models, in direct support of NOAA's goal of having an operational national particulate matter (PM2.5) aerosol forecasting system by 2015. Using measurements made during the 2006 Texas Air Quality Study field mission of aerosols and their precursors, in conjunction with a state-of-the-art air-quality forecast model, researchers were able to assess recent developments in the treatment of secondary organic aerosol formation and its impact on particulate matter aerosol forecasts.

In winter 2012, acidic trace gases in the Uintah Basin in Utah were measured by CIRES collaborators as part of a larger study

iStock photo

that focused on the atmospheric emissions associated with natural gas production and the role these emissions play in atmospheric chemistry. Among the trace gases quantified, measurements of nitrous acid (HONO) were particularly important as HONO can provide a source of free radicals that can potentially initiate ozone chemistry.

Through the NSIDC, CIRES continues to collect and maintain important cryospheric data sets for use by the research community. Ongoing monitoring and analysis of long-term data sets, continue to provide NOAA with valuable information about the nature of short- and long-term change in polar regions.

CIRES research has also provided insights into the drivers of drought, with the ultimate goal of improving predictability. To enhance understanding of the sensitivity of North American drought to tropical sea surface temperature (SST), CIRES researchers evaluated the sensitivity of monsoon regions around the world to tropical SST changes, with particular emphasis on the northeast Asian summer monsoon region. Observations indicate increasing trends of summer precipitation amount, intensity, and frequency of extremes over northeast Asia since the 1960s.

CIRES scientists are also directly engaging in research to support the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5). A specific example is support of the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP). Analyses by CIRES and NOAA partners determined the effects of different Representative Concentration Pathways on the distribution of chemical species and on their deposition at the surface. This will enable improved understanding and modeling of the effect of atmospheric chemical composition on climate.

CIRES's broad research portfolio has also brought the social sciences to bear on NOAA goals, particularly in decision science. CIRES research conducted in FY12 investigated the conditions under which local decision makers in the West decide to adapt to increased climate-related risks and hazards. The results provide insights as to how to best communicate climate information to the public.

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

CIRES researchers support NOAA's mission to provide essential information on weather and water by advancing numerical weather model forecasting through model improvements and assimilation of data collected in observational field campaigns, ongoing monitoring, and from satellite missions.

Weather

From space to the sky, to the oceans and rivers, CIRES continued its legacy of supporting NOAA's forecasting abilities from pure research through transition to operations.

CIRES researchers continued to engage in the fundamental research necessary to provide weather information to support the energy industry. Using a data set of a motion-compensated, high-resolution Doppler lidar offshore wind measurements, CIRES researchers were able to better understand the range of atmospheric conditions—and their spatial and temporal variability—encountered by offshore wind turbines above the surface at the level of the rotor blades. This type of information is critical for

determining optimal siting of wind farms, as well as for short-term projections of wind regimes and, thus, energy production.

CIRES also continued its support of Space Weather Prediction Center (SPWC) efforts to 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 (CME) from the sun, can cause substantial geomagnetic effects leading to the crippling of satellites, disruption of radio communications, and damage to electric power grids. During FY12, CIRES scientists made significant advances in understanding subsurface velocity flows that affect flare production.

In August 2011, the Hurricane-Weather Research and Forecasting model (HWRF v3.4a), which contains the capabilities of the 2011 operational implementation, was released by CIRES and NOAA to the research community. Contributions from the community were incorporated in the revised HWRF operational model implemented in May 2012.

CIRES researchers continued to coordinate worldwide development of the Weather Research and Forecast–Chemistry model (WRF–Chem) as an air-quality prediction tool. In May 2012, real-time forecasts using the WRF/Chem model were used to track wildfire smoke from the Whitewater-Baldy fires in New Mexico as they moved north into Colorado.

Water

CIRES researchers are actively engaged in water resource issues across the Western U.S. and beyond.

During FY12, CIRES researchers began examining the impacts of high dust loads (observed in 2009 and 2010) and climate warming on flow in the Colorado River. Initial modeling results show that even under the strongest warming, timing of runoff is strongly sensitive to radiative forcing by dust. Under scenarios of extreme warming, however, volume of runoff becomes less sensitive to dust deposition. This research is being directly coordinated with the NOAA NWS Colorado River Basin Forecast Center.

The statistical and dynamical down-scaled climate projections for the Colorado River Basin, including data from the North American Regional Climate Change Assessment Program (NARCCAP), particularly as it relates to hydroclimatic processes and variability, were evaluated by a team of CIRES scientists. From this analysis, researchers determined that soil moisture feedbacks were important at high elevations in amplifying warming in summer, and a novel mechanism was proposed for enhanced wintertime warming that involves soil moisture, atmospheric humidity, and snow.

Researchers also continued important work related to extreme events and impacts on water resources. Through the persistent drought of last year, CIRES researchers, in conjunction with the National Integrated Drought Information Service (NIDIS), briefed decision makers in both the Colorado River Basin region and in the Apalachicola-Chattahoochee-Flint Basin about drought and linkages to La Niña.

CIRES also engaged in activities related to flood events. As an example, real-time monitoring of water vapor flux is critical for assessing extreme precipitation events along the West Coast of the United States. In support of the NOAA near-real-time water vapor flux tool, CIRES scientists and colleagues automated software operations for nine different NOAA and cooperative agency sites along the U.S West Coast. In FY12 developments were made to allow users to view Integrated Water Vapor, Total Flux, and Upslope Flux data spatially on Google Maps in near real-time.

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

In FY12, CIRES contributed to a streamlined, more fully automated, accessible, and Web-based management and stewardship process for marine geophysical data in support of seafloor research. Since July 2011, 175 multibeam swath sonar surveys (631,896 nautical miles) and 44 trackline (single-beam bathymetry, magnetics, gravity, subbottom, and seismic reflection) surveys (287,000 nautical miles), throughout all of the world's oceans, have been added to the National Geophysical Data Center's (NGDC) global marine geophysical archives by NGDC and CIRES staff. Both national and international organizations contribute to and retrieve marine geophysical data from the interactive databases. Marine geophysical data archived at and delivered by NGDC are currently supporting two specific, ongoing U.S. mapping efforts: the Extended Continental Shelf (ECS) project and the Integrated Ocean and Coastal Mapping (IOCM) program.

CIRES and collaborators also improved public access to a variety of regional and global coastline data sets through development of an interactive map service, including the addition of a new high-resolution community coastline data set developed at NGDC. Such information is mission critical to support maritime navigation.

In December 2011, CIRES researchers completed a formal assessment addressing differences between Rapid Update Cycle (RUC)–derived and Rapid Refresh (RAP)–derived Forecast Icing Potential (FIP) and Current Icing Potential (CIP) icing products for improved aviation safety. An important conclusion of this study is that the new model is more efficient at identifying areas of potential in-flight icing throughout the atmosphere.

CIRES Communications

It has long been a part of CIRES's mission to communicate world-class research in ways that help inform decision makers and the public about how we can best ensure a sustainable future environment. Our communications work is coordinated by the Science Communications Group and involves close collaborations with NOAA, CU–Boulder, our centers, and international colleagues in academic and government institutions. Through a coordinated multimedia approach, the Communications Group uses both traditional and innovative methods to convey the outcomes of key research endeavors to the public. The success of the CIRES communications strategy is exemplified by widespread coverage of our scientific work in, for example: *USA Today*, *Time*, *The New York Times*, *Scientific American*, CBS, *Discovery*, *Discovery News*, *National Geographic*, Nature News BBC, *Business Week*, MSNBC, Fox News, *Science NOW*, *Science News*, *Nature News*, and the *Los Angeles Times*.

Press Releases & Videos

• Press release
▷ Video

2011

July

• New study details glacier ice loss following ice shelf collapse.

August

• Increase in particles high in Earth's atmosphere has offset some recent climate warming.

• Slowing climate change by targeting gases other than carbon dioxide

• Scientists explore link between predator-prey relationships and rainfall patterns.

• Bacteria from dog feces pervade winter air of urbanized areas.

• CIRES expert available to talk about Colorado/Washington, D.C., earthquakes.

September

• Air pollution caused by ships plummets when vessels shift to cleaner, low-sulfur fuels.

• Arctic sea ice reaches minimum 2011 extent, the second lowest in the satellite record.

• Increased crevasse extent in Greenland may dampen ice sheet sliding.

• Gulf spill fires released more than 1 million pounds of sooty black carbon into the atmosphere.

• CIRES scientist available to discuss Antarctic ozone hole recovery paper.

October

• El Niño: Unaffected by climate change in the 21st-century, but its impacts may be more severe.

• Climate change major factor in more frequent Mediterranean droughts.

• Bright city lights affect air pollution.

November

• NSIDC receives award for Green Data Center Design.

▷David Gallaher discusses the design and construction of the Governor's Sustainability Award–winning NSIDC project.

December

• USAID, CU–Boulder, and CIRES partner to study water resources in Asia mountains.

• Gulf oil spill releases a "city's worth" of pollution into the air.

@theCIREStwire | youtube.com/user/CIRESvideos | Facebook/CIRESnews

CIRES Research Highlights

Air Quality Research

Achievements of CIRES scientists for FY12 extended over the broad CIRES environmental research agenda, which includes physical, chemical, and biological aspects of environment as well as the human dimension of environmental analysis. Studies of atmospheric chemistry, a special strength of CIRES and its NOAA partner, produced advances in understanding of atmospheric soot, fossil fuel combustion, and bacteria suspended in the air.

MEDIA:

• Bacteria from dog feces pervades winter air of urbanized areas.

• Gasoline worse than diesel when it comes to some types of air pollution.

• Smoking out an air pollutant's hot spots

Continued Insights Related to Gulf Oil Spill

CIRES and NOAA collaborators continued their intensive collaboration on the study of the effects of the Deepwater Horizon oil spill on air quality. While the immediate concern of the spill was environmental damage to the aquatic environment, these scientists showed that the strategy of burning oil to remove it from the water surface produced more than 1 million pounds of black carbon in the form of soot. Data produced by these scientists will guide oil spill management in the future as air pollution joins other concerns that determine the response to spills.

MEDIA:

• Gulf spill fires released more than 1 million pounds of sooty black carbon into the atmosphere.

• Chemical measurements confirm official estimate of Gulf oil spill rate.

Polar Research: Arctic to Antarctic

Global climate with a focus on ice sheets continued to be a major interest of several working groups within CIRES. CIRES scientists contributed to the conclusion that Arctic sea ice reached its second lowest minimum recorded extent in 2011. Long-term detailed studies of the Greenland ice sheet by CIRES scientists showed that movement of the ice sheet toward the Greenland coast may accelerate when increased meltwater reaches the bottom of the ice sheet; water lubricates the movement of ice over rock.

MEDIA:

• Greenland ice sheet flushing itself away?

• A sea change in the Arctic atmosphere

• Emperor penguins threatened by Antarctic sea ice loss.

Research Relevant to the Region

CIRES's world-class researchers not only bring expertise to bear on global environmental challenges, but also to the issues that hit close to home. Important findings emerging from CIRES during FY12 have implications for regional air, water, and land resources.

MEDIA:

• Colorado mountain hail may disappear in a warmer future.

• Earthquake potential in Colorado and New Mexico

▷What Is Remote Sensing? CIRES Fellows Waleed Abdalati and Steven Nerem explain remote sensing and the need for continued satellite observations.

▷Active Ice. NSIDC Senior Research Scientist Ted Scambos discusses ice ocean interaction and the active nature of ice sheets and glaciers.

2012

January

- Colorado mountain hail may disappear in a warmer future.
- Chemical measurements confirm official estimate of Gulf oil spill rate.
- Earthquake potential in Colorado and New Mexico
- Scientists studying the remote ocean atmospheric environment

February

▷Ozone Mystery: A CIRES and NOAA effort to understand the cause of high winter ozone levels in the Uintah Basin in northwest Utah

March

- Colorado oil and gas wells emit more pollutants than expected.
- Gasoline worse than diesel when it comes to some types of air pollution.

▷Gasoline Worse Than Diesel for Some Types of Air Pollution. Former CIRES scientist Roya Bahreini explains her recent work in Los Angeles looking at fuel types and their link to secondary organic aerosol formation.

- NSIDC scientist leads Nunavut-Nepal exchange.

April

- Thawing permafrost 50 million years ago led to global warm events.
- Greenland ice sheet flushing itself away? New monitoring system clarifies murky atmospheric questions.
- Smoking out an air pollutant's hot spots

▷Breakthroughs in Renewable Energy. CIRES's Suzanne van Drunick and Betsy Weatherhead convened a panel of top minds in renewable energy research at the AAAS annual meeting (2/12).

▷"Putting Scientific Breakthroughs to Work in Support of Renewable Energy" Panel Presentations (4/12). Featuring: Alexander MacDonald (NOAA, ESRL), Dan Arvizu (NREL), Susan Avery (WHOI), Peter Hauge Madsen (Technical University of Denmark), and David Grimes (World Meteorological Organization)

May

- Near-term weather forecasts get powerful boost from new computer model.
- CIRES researchers discover a new type of wave.
- A sea change in the Arctic atmosphere

June

- Emperor penguins threatened by Antarctic sea ice loss.

Spheres

This popular periodic publication highlights the diversity of CIRES research in particular topics. *Spheres* science magazine is CIRES's premier outreach publication, presenting the Institute's research in its divisions and centers. With accessible and entertaining writing and vivid images donated by the scientists themselves, the magazine's mission is to convey the full breadth of research in CIRES to the lay audience.

Each edition carries stories highlighting research funded by the CIRES Innovative Research Program, visiting fellows, and CIRES graduate students. The CIRES Communication Group distributes the magazine to Congressmen, NOAA and CU officials, scientists, high-school students, and potential visiting fellows and graduate students. Staff and scientists also distribute *Spheres* at conferences and local events. *Spheres* editions published FY12:

Air Spheres
Solid Earth Spheres

Caught in the Act

Photo courtesy of Ang Phula Sherpa

For the first time, the often-dramatic changes of supraglacial lakes (which sit atop glaciers) have been captured on camera as they occurred. After rappelling down ice cliffs on Nepal's largest glacier, CIRES graduate student Ulyana Horodyskyj, a recipient of a 2011–2012 CIRES Graduate Student Research Fellowship, installed solar-powered cameras on the moraine to capture time-lapse photography of three lakes' evolution over the course of four months. Her work received widespread media attention from titles such as *National Geographic*, the BBC, and *Scientific American*.

What were some of the biggest changes the cameras captured?

One lake drained at least 10 feet—overnight! It was incredible. Most likely, a crevasse below the lake opened as the glacier moved forward, forming a conduit to the glacier's base. You could just hear the water flushing.

Did any lakes get bigger?

One lake doubled in size during the month due to monsoon rains. Falling ice also raised one lake's water level a total of 28 centimeters, in only two weeks. Ice walls were collapsing almost all the time. Standing near the shore was like being in a shooting gallery. These initial results reveal that these lakes can undergo substantial changes in a very short amount of time.

Why is that important?

When people think about glaciers, they think in terms of advances and retreats, but glaciers are also shrinking vertically. Supraglacial lakes most likely act as catalysts for this vertical ice loss. Understanding how these lakes behave and affect glacier melt is critical—both for estimating the glacier's lifespan and for predicting flooding and water surges in villages down-valley.

Education and Outreach

The research conducted at CIRES provides knowledge that helps society to build a sustainable future. The CIRES Education and Outreach (EO) group builds bridges between CIRES research and educators, communicators, students, and scientists. Its work emphasizes scientific inquiry, access to current research, and foundational concepts in geosciences education. CIRES scientists often partner with CIRES Education and Outreach as part of their research projects, contribute to education projects as presenters, reviewers, and learning-resource providers, and star in scientific video clips. This involvement by scientists helps teachers to have confidence that the resources provided by CIRES EO are scientifically sound and up-to-date.

cires.colorado.edu/education/outreach

Education and Outreach Web Resources:

▷**COSEE (Centers for Ocean Sciences Education Excellence) Teacher Professional Development Lecture Videos.** Covering science topics focusing on the Ocean and Climate. Featuring: Joseph Barsugli, Nolan Doesken, Bob Glancy, Mark Squillace, and Samantha Stevenson (2011); Joseph Barsugli, Tracy Chapman, Brian Ebel, David Noone, Bob Raynolds (2012).

▷**ICEE (Inspiring Climate Education Excellence) Teacher Professional Development Lecture Videos.** Designed to give teachers the tools to teach the complicated topics within Earth and energy science. Featuring: Waleed Abdalati, Joseph Barsugli, Lisa Dilling, Baylor Fox-Kemper, Cheryl Manning, Mark McCaffrey, Walt Meier, Steven Nerem, Susie Strife, Pieter Tans, Amy Wagner, and Jim White.

▷**Water Spotters.** David Noone explains "Water Spotters," a network of middle-school students who observe rain, snow, and weather along Colorado's northern Front Range. Data collected by participating schools contribute to a regional study of Earth's water and energy cycles.

▷**Polar Visions.** An educational film produced by Ryan Vachon explores the causes and effects of climate change in the polar regions of the planet.
http://cires.colorado.edu/education/outreach/polarvisions/

ICEE Community Forum: A forum for educators to discuss climate literacy best practices and current science.
http://iceeonline.org/forum/

▷**Extreme Ultra Violet Variability Experiment (EVE).**

All About EVE	**http://vimeo.com/4480035**
LASP Tour:	**http://vimeo.com/4433858**
Space Science Careers	**http://vimeo.com/4401638**

EO Research Highlight

To provide students with accurate information about climate and energy science, educators require scientifically and pedagogically robust teaching materials. To address this need, the Climate Literacy & Energy Awareness Network (CLEAN) has developed a peer-reviewed digital collection as part of the National Science Digital Library (NSDL). The CLEAN collection is a featured educational resource collection on the NOAA climate.gov portal. The CLEAN Pathways project features teaching materials centered on climate and energy science for grades 6 through 16. Each teaching resource has undergone a rigorous review process and provides expert teaching tips on how to implement the resource in the classroom. All materials are aligned with the Benchmarks for Science Literacy, the Essential Principles of Climate Science, and key energy concepts. CLEAN is funded by grants from the National Science Foundation. **cleannet.org**

Events

CIRES hosts diverse events throughout the year. The CIRES Rendezvous and the Distinguished Lecture Series are among the highlights of the CIRES event portfolio.

CIRES Director Konrad Steffen speaking at the 2012 Rendezvous

David Oonk/CIRES

Rendezvous

More than 400 people attended the seventh annual Rendezvous research symposium of the CIRES Members' Council on April 24, 2012. This half-day, institute-wide symposium featured more than 130 posters showcasing the depth, breadth, and quality of science being conducted by CIRES scientists, and provided a venue for them to share research with each other and NOAA colleagues. Director Konrad Steffen delivered the "State of the Institute" address and presented awards for years in service, the CIRES Outstanding Performance Awards, and awards for other professional achievements.

Distinguished Lecture Series

This lecture series was created to bring in outstanding scientists and innovative thinkers who have given thoughtful consideration to environmental and Earth system science issues. A committee of CIRES Fellows determines distinguished lecture invitees.

September 9, 2011

Brian Toon
Laboratory for Atmospheric and Space Physics, University of Colorado
The Anti-Greenhouse Effect Along the Spiral of Geologic Time

November 4, 2011

Peter Webster
School of Earth and Atmospheric Sciences, Georgia Institute of Technology
Probability, Prediction, and Decisions: A Pathway to the Alleviation of Poverty in the Developing World

March 16, 2012

Diana Liverman
Co-Director of the Institute of the Environment and Regents Professor in the School of Geography and Development, The University of Arizona
Responding to the Challenges of Global Environmental Change: Carbon offsets, climate adaptation, and science for sustainable development

April 6, 2012

Isaac Held
Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration
Global Simulations of Tropical Cyclone Statistics: Interannual variability and the response to global warming

April 13, 2012

A Tribute to Dr. George Reid
Presented by Susan Solomon
From the Mesosphere to the Tropical Tropopause

Achievements and Awards

The breadth and number of achievements by CIRES researchers and staff speak to the quality of research emerging from the Institute. From recognitions of lifetime achievements to acknowledgements of emerging junior talent, CIRES scientists are among the best of the best at what they do. Among the premier awards received by CIRES scientists during FY2012 were the 2011 AGU Ocean Sciences Early Career Medal (Baylor Fox-Kemper) and an NSF CAREER Award (Rainer Volkamer).

CIRES Awards

The CIRES Awards Committee, comprising CIRES Members' Council representatives and members at large, annually reviews nominations and makes recommendations for outstanding professional achievement in the categories of "Science and Engineering" and "Service." This year, CIRES recognized six awards of $2,000 each.

Science and Engineering

Cecelia DeLuca for being the driving force behind the important and novel software development efforts at NOAA's Environmental Software Infrastructure and Interoperability Group (NESII). She guides the group with diverse expertise in high-performance computing, software project management, and Earth sciences, and a vision to bring their efforts to fruition.

Anna Karion, **Tim Newberger**, and **Colm Sweeney** for developing a new atmospheric sampling instrument, the AirCore, which can profile altitude gradients of greenhouse gases. The low-cost, lightweight tool also can be used to validate satellite profiles and may yield new discoveries in stratospheric composition and circulation trends.

Dan Lack for his work putting black carbon emissions inventories for shipping on a sound scientific basis, which has had a major impact on policy decisions for regulation of international shipping.

Troy Thornberry, **Andrew Rollins**, and **Laurel Watts** for designing and demonstrating an airborne chemical ionization mass spectrometer (CIMS) for ultra-low water vapor measurements in the lower stratosphere. Their effort led to unique measurements that will advance our understanding of water vapor in the climate system.

Service

Ken Aiken for his essential work mastering, maintaining, and teaching all things digital. The research of NOAA's Chemical Sciences Division requires multifaceted data collection, manipulation, and presentation, at which Aiken is an unparalleled expert.

Dave Gallaher and **Ron Weaver** for their leadership in data center design and operation with the NSIDC Green Data Center project. The innovative data center redesign slashed energy consumption for data center cooling by more than 90 percent, demonstrating how other data centers and the technology industry can save energy and reduce carbon emissions.

Director's Award for Diversity

Edward Aruajo-Pradere for demonstrating that a distinguished scientific career and regular diversity outreach can be combined to the benefit of both.

Director's Award

Jon Eischeid for his essential work authoring the hydro-climate report "Understanding and Explaining Hydro-Climate Variations at Devils Lake." This key assessment of the climate conditions relevant to the recent rise of Devils Lake elevation supports the Interagency Initiative to Address Flooding Issues at Devils Lake, North Dakota.

Shutterstock

Finance

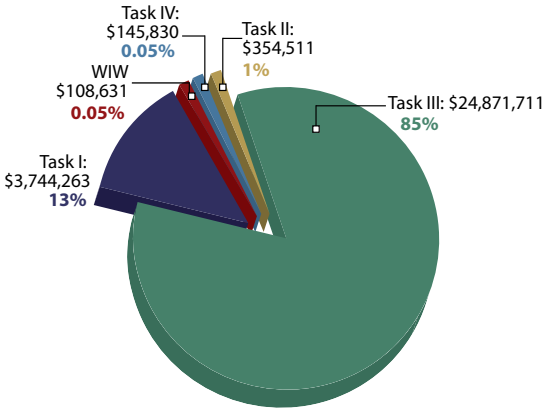
The trend for growth at CIRES continued during the 2011 to 2012 fiscal year. The largest portion of CIRES's expenditures in the past has been through our NOAA Cooperative Agreement (CA) (44 percent). However, during this reporting period, NOAA issued an external award renewing the Western Water Assessment project, so our individual award expenses (50 percent) are now greater than our CA expenses. CIRES researchers continue to have great success in obtaining external research awards. The University's monetary contribution to CIRES primarily covers faculty salaries, and it fluctuates from year to year due to our affiliated University faculty appointments.

Agreement expenditures by task for FY12 are shown in the top figure at right. Task I expenditures include CIRES administration and internal scientific programs, such as the Visiting Fellows and Graduate Student Fellowship programs. Task II provides partial support for data analysis at the National Snow and Ice Data Center, the largest of CIRES's five interdisciplinary scientific centers. Task III funds CIRES's collaboration with NOAA's Earth System Research Laboratory, the National Geophysical Data Center, and the Space Weather Prediction Center, all within Boulder, Colo. Task IV was created to serve as an efficient mechanism for the administration of NOAA research grants and awards, which would otherwise be stand-alone projects outside the Agreement, to CIRES researchers in fields aligned with CIRES's mission. Two Task IV projects have been awarded through our NOAA "shadow" award, NA08OAR4320914.

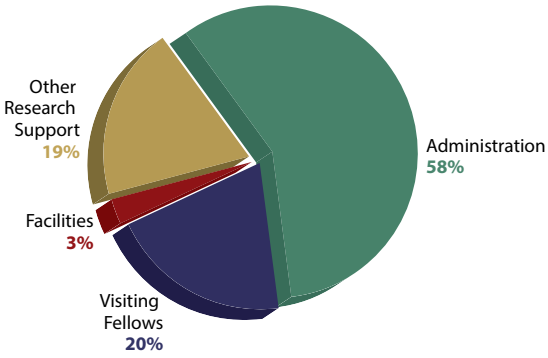
The largest share (58 percent) of Task I base funds support CIRES administration, primarily salaries and benefits for the administrative staff (middle figure at right). The Visiting Fellows program receives the second-largest share (20 percent) of Task I base fund support and is subsidized by other Institute funding as well. Task I also provides partial support of CIRES's Education and Outreach program, other research support, and the physical plant facilities.

Our NOAA Task I base funding is augmented by CIRES's portion of the University's indirect cost recovery (ICR), which is distributed annually to University units as a proportion of indirect costs collected from institutional research grants and awards (bottom figure at right).

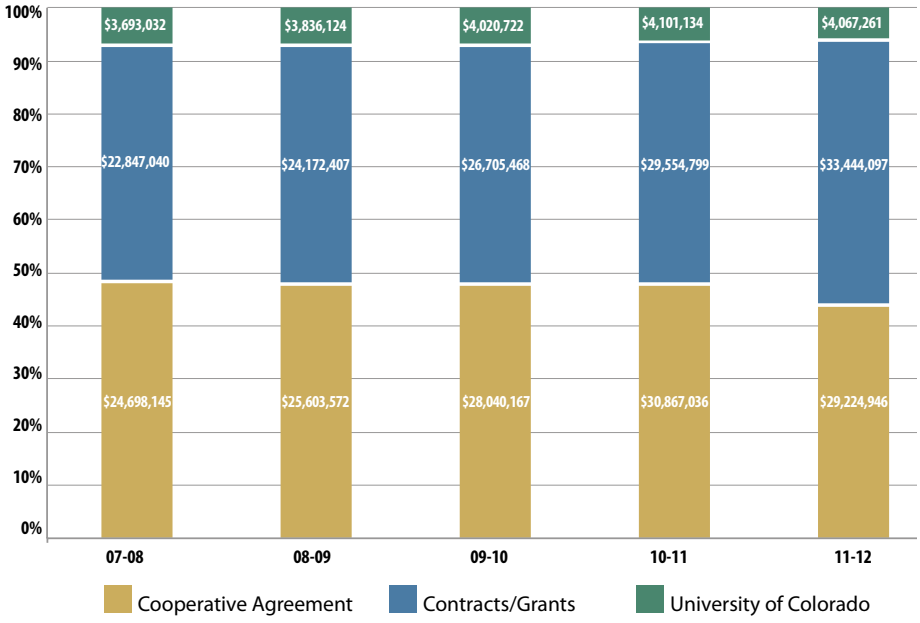
Cooperative Agreement expenditures by task 2011–12



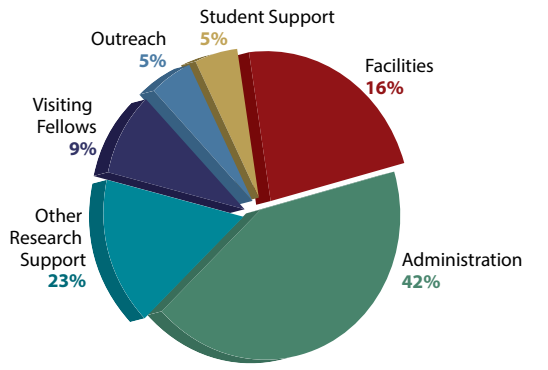
CIRES Task I base fund expenses 2011–12



Expenditures by NOAA Cooperative Agreement, individual awards, and CU funds



CIRES Task I base and ICR-supported expenses 2011–12



People & Projects

CIRES starts with people. Researchers at CIRES all seek to better understand the planet, and they do so from different perspectives that reflect diverse areas of expertise. Fellows, CIRES scientists, students, and outreach professionals work together, forming a network that stretches from the Institute across the globe.

The following pages highlight CIRES's senior investigators and Fellows, interdisciplinary programs, and five centers.

CIRES Senior Investigators

NOAA Scientists

Stan Benjamin
Randall Dole
David Fahey
Christopher Fairall
Fred Fehsenfeld
Graham Feingold
Michael Hardesty
Stephen Montzka
William Neff

CU-Boulder Teaching Faculty

Waleed Abdalati
Ben Balsley
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CIRES Scientists

Richard Armstrong
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Judith Perlwitz
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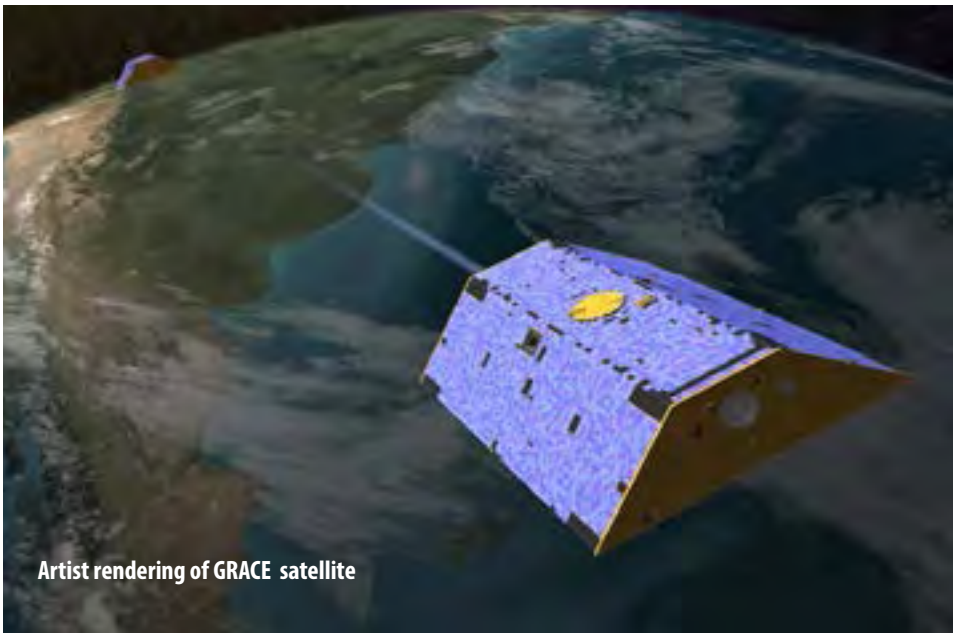
Waleed Abdalati

Studying Ice Sheets from Orbit

Since Jan. 2, 2011, I have been on leave from the University of Colorado to serve as Chief Scientist of the National Aeronautics and Space Administration. Responsibilities of this position include: advising the NASA Administrator on scientific matters related to NASA; interfacing with Congress, the Executive Office of the President, and other federal agencies to ensure alignment among NASA, White House, and Congressional Science priorities; representing NASA's science programs to the public and the scientific community; and serving as a voice for science within the Agency in the areas of Earth Science, heliophysics, planetary science, astrophysics, life sciences, and physical sciences. This continues to be a challenging and fascinating experience, and I look forward to returning to the University and using what I learn in this position to better serve the University community. In the meantime, I keep a hand in the research, working with my graduate students and other colleagues at CU to carry this research forward.

During my absence, I have continued to work with graduate students and research scientists studying changes in Earth's glaciers and ice sheets and developing space-based observation capabilities to carry out such studies. Two key satellite missions of the last decade for studying ice sheets are the Ice Cloud and land Elevation Satellite (ICESat) and the Gravity Recovery And Climate Experiment (GRACE). ICESat measures ice sheet topographic change using laser altimetry, and GRACE measures ice mass change by measuring the temporal evolution of the gravitational field in the vicinity of the ice sheets, all with a view toward understanding ice sheet contributions to sea-level rise. In addition, airborne laser observations of ice topography and ice-penetrating radar observations of thickness have been carried out for the past 20 years in Greenland and 10 years in Antarctica. The airborne laser altimetry provides high-resolution measurements of ice sheet changes to complement those made by satellites to better understand outlet glacier changes. Ice-penetrating radar observations provide information on the geometry of the bedrock over which these glaciers flow, enabling better understanding of the controls on glacier discharge. Other satellite observations provide insights into the ice flow, ice melt, and ice deformation processes.



Artist rendering of GRACE satellite

NASA

Using these tools, as well as in situ measurements, my group seeks to understand the behavior of glaciers and ice sheets and the mechanisms that control them. By combining the multiple observation techniques, we can draw from the strengths of each and overcome the limits of each to provide an optimized estimate for ice change. Our primary focus is on Greenland; however, my research interests are also on the Canadian ice caps and the Antarctic Ice Sheet. In addition, we are working on the future ICESat-2 mission, scheduled for launch in 2016, developing methods for interpreting the ICESat-2 return signals on ice sheets and melt ponds, as well as assessing its potential for determining vegetation canopy height (a proxy for biomass). Our ultimate research objectives are to determine how and why Earth's glaciers and ice sheets are changing, and what the implications are for sea-level rise, as well as how we can use laser altimetry to learn about non-ice-covered surfaces on Earth.

Richard Armstrong

Establishing a Collaborative Effort to Assess the Role of Glaciers and Seasonal Snow Cover in the Hydrology of the Mountains of High Asia

The fundamental objective of this study is to develop a thorough and systematic assessment of the individual contribution of seasonal snow and glaciers to the water resources originating across the Himalaya, Karakoram, Hindu Kush, Pamir, and Tien Shan mountain ranges, referred to here as High Asia. These mountain ranges are located within the countries of Bhutan, Nepal, China, India, Pakistan, Afghanistan, Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan. These countries, containing the headwaters of the Brahmaputra, Ganges, Indus, Syr Darya, and Amu Darya rivers, all posses significant snow and ice resources. While it is generally accepted that a significant component of the High Asian water resources results from the melting of glacier ice and seasonal snow, the actual water volume available from these two individual sources across this region remains generally unknown. The amount, timing, and spatial patterns of snow and ice melt play key roles in providing water for downstream irrigation, hydropower generation, and general consumption.

The improved understanding of these regional water resources is a cross-boundary exercise, and this project will greatly facilitate the international cooperation required for successful water resource management across High Asia. This project is collaborating directly with key Asian research institutions in the countries listed above to develop a consensus regarding the research methodologies to be used to achieve project goals. This effort will include capacity building that will enhance the scientific understanding of the regional hydrology among our Asian partners through collaborative field research and technical training.

Specific project objectives are being accomplished through the application of a suite of satellite remote sensing, reanalysis, and ground-based data as input to specific snow and ice melt models. In addition, we will evaluate the accuracy of the melt model results using innovative isotopic and geochemical tracers to identify and quantify the sources of water flowing into selected rivers representing the major hydro-climates of the study area.

Photo courtesy of Richard Armstrong

Former University of Colorado graduate student and current project research consultant Adina Racoviteanu collecting snow and ice samples for isotopic analysis, Mt. Mera, Nepal

Major river systems, mountain ranges, and glacier cover across High Asia

Ben Balsley

Fine-Scale *In Situ* Measurements to Study Atmospheric Dynamics (0–10 km)

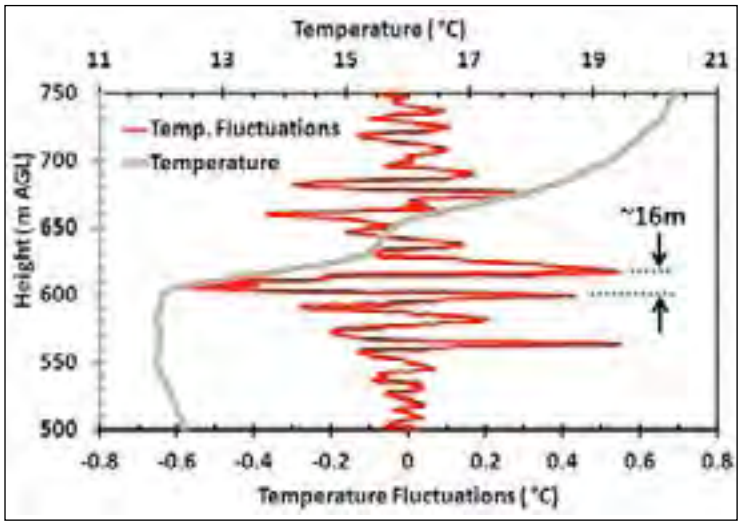
Our primary thrust is to develop systems to measure very fine-scale details of atmospheric dynamic properties throughout the lower atmosphere. We are currently heavily involved in developing and using very small autonomous aircraft to measure such variables as temperature, humidity, wind speed, and turbulence on the scale of seconds (temporally) and meters (spatially). We have flown our CU-designed 'DataHawk' vehicle, designed by the Aerospace Department (Professor Dale Lawrence) and instrumented by CIRES and Aerospace, at a number of locations, including Peru. The DataHawk can be either launched by a 'bungee' technique or carried aloft by a conventional meteorological balloon and then released at altitude. We have obtained data from heights up to 9 kilometers above ground level (AGL).

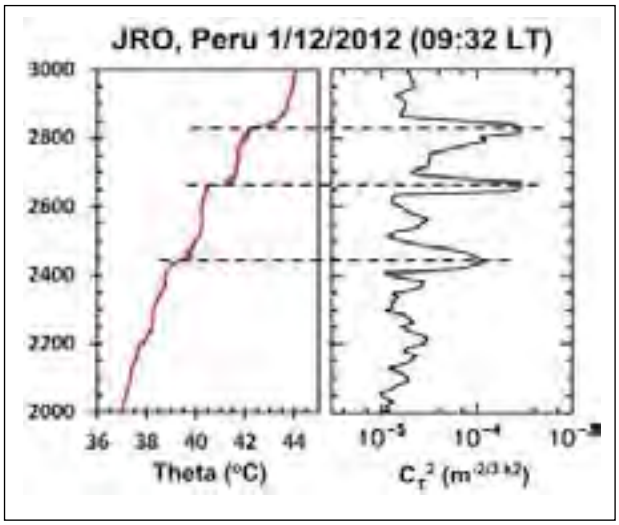
DataHawk details are shown at right. An important feature is the minimal cost of this aircraft. This feature enables us to fly under less-than-optimum conditions, when the more expensive vehicles would be grounded.

- Wingspan.....1 m
- Gross Weight/Payload.....700 g/80 g
- Nominal Airspeed/Flight Time.....14 ms^{-1}/40 min
- Operation.....Autonomous (GPS)
- Modifications (In-flight).....Via 2.4 GHz Telemetry
- Maximum Range.....>10 km
- Unit Cost (approximate).....$1,000

An intriguing example of the type of high-resolution sampling feasible using the DataHawk is shown below (bottom left). This figure shows temperature (gray curve) and temperature fluctuation (red curve) made in the vicinity of the steep inversion region (approximately 650 meters AGL), above the southern coast of Peru in July 2011. The data show the occurrence of quasi-coherent temperature fluctuations having a vertical wavelength of approximately 16 meters. The breakdown of this wave appears to be associated with enhanced turbulence levels at these heights.

A second interesting result obtained in Peru shows a series of 'steps' in the potential temperature profile between 2 to 3 kilometers, where regions of enhanced turbulence (CT2) are identified with the steep 'edges' of these steps (bottom-right). This phenomenon has been predicted by DNS (Direct Numerical Simulation) computer modeling but never confirmed observationally, owing to the small vertical details. These regions, incidentally, are also associated with extremely narrow echoes observed by a nearby VHF radar.





Roger Bilham

Earthquake Hazards in the Kashmir Himalaya

No major earthquakes in the Himalaya have occurred between the 2005 Muzafferabad 7.6-Mw (moment magnitude) earthquake, and the 1905 7.8-Mw Kangra earthquake in the past 450 years. A severe earthquake is known to have occurred in 1555 that damaged structures in the Kashmir Valley, presently home to more than 5 million people. A repeat of this earthquake could have a significant impact on Kashmir.

To characterize future seismicity in the valley better, CIRES scientists, together with the University of Kashmir, have used GPS methods to measure a convergence rate of 10 millimeters per year in the mountains between the Pir Pinjal range and the Zanskar range. Since 1555 the mountains have thus been squeezed by approximately 4.5 meters, which—were this elastic strain released as slip in an earthquake with rupture area measuring 200-by-300 square kilometers—would do so now in a 8.6-Mw earthquake. Two or more earthquakes with smaller area (100-by-150 square kilometers) would register as 8.2-Mw events. Alternative explanations are possible that suggest both lower and higher magnitudes. An extreme possibility is that earthquakes here permit slip in the mountains by up to 20 meters as has been observed nearby in the Himalaya. Should 20 meters of slip be released over the same area, the earthquake could be as large as 9 Mw. It is also possible that the inferred slip potential has been reduced by aseismic processes.

The tectonic history of the Kashmir Valley is partly recorded by the construction and destruction of Kashmir's medieval temples. Temples in the northwest part of the valley have been buried two to four meters by sediments filling the space created by tectonic tilting of the valley since their construction c. 700 AD. ^{14}C samples buried by the partial collapse of megablocks, undisturbed since their fall, record the time of subsequent earthquakes.

Roger Bilham

Bikram Singh Bali inspects tumbled megablocks from the 12th century Sugandhesa Temple, Kashmir.14C samples crushed by earthquake collapse indicated.

Temples on the southwest side of the Kashmir Valley have been raised and those on the southeast side lowered by tectonic processes. Annual floods of the Jhelum form a horizontal flood plane that has drowned the Manasbal Temple at an average rate of 3.3 millimeters per year since its construction in 750–830 AD. Photos show it submerged beneath fields in 1950 and excavated with its base in a pond of water in 2011.

Maxwell Boykoff

Inside the Greenhouse: Creative and Effective Climate Change Communication

The objectives for this project are (1) to generate multimodal compositions on the subject of climate change, (2) to engage with various dimensions and issues associated with sustainability, and (3) to produce and distribute the "Inside the Greenhouse" program.

Co-principal investigator and CU-Boulder Professor Beth Osnes and I worked to deepen our understanding of how issues associated with climate change are and can be communicated, by creating artifacts through interactive theatre, film, fine art, performance art, television programming, and appraising as well as extracting effective methods for multimodal climate communication. The centerpiece of this project is the Inside the Greenhouse (ITG) television program, featuring a high-profile figure engaged in climate and environment issues. As part of the programming, we also feature work produced in an associated undergraduate course at CU-Boulder.

The interdisciplinary approach taken up in this ITG collective seeks to capture, value, and interrogate the complexity of multiscale and contemporary climate science, policy, and politics as well as the challenges of performance and communication of these issues. Our motivations here spring from an expansive view of climate science and policy in society, where more formal scientific and policy work is part of, rather than separate from, public uptake. Representational practices of various sorts play key roles in interpretation, framing climate change for policy, politics, and the public, and drawing attention to how to make sense of the changing world. Mediated portrayals—from television news to live performance—are critical links between people's everyday realities and experiences, and the ways in which these are discussed at a distance between science, policy, and public actors.

Overall, through this project, we have fostered an intentional place for growing new ideas and evaluating possibilities to confront climate change through a range of mitigation and adaptation strategies.

Maxwell Boykoff

University of Colorado students working on a video project

Noah Larsen

Beth Osnes and Maxwell Boykoff illustrating a point during an Inside the Greenhouse class

Maxwell Boykoff

University of Colorado students working on the "Kids Say Climate Things" video

John Cassano

Using Unmanned Aerial Vehicles to Study the Polar Atmosphere

The Cassano Polar Climate and Meteorology group studies the polar atmosphere using a combination of autonomous observing systems and numerical models. Since 2009 we have been using unmanned aerial vehicles (UAVs) to make high space and time resolution observations of the Antarctic atmosphere. In 2009 we used Aerosonde UAVs to observe the atmosphere over the Terra Nova Bay polynya, a region of open water surrounded by sea ice in the western Ross Sea, Antarctica.

In January 2012 the Cassano research group began using Small Unmanned Meteorological Observer (SUMO) UAVs to study the atmospheric boundary layer in the vicinity of McMurdo Station, Antarctica. The SUMOs are a small (80-centimeter wingspan and 0.6 kilogram weight) and inexpensive ($5,000) UAV. The SUMOs require limited logistical support to operate, being hand-launched (shown below) and controlled by a model airplane radio control and a laptop computer. The SUMO UAVs allow us to make detailed local measurements of the atmosphere at any location on the Antarctic continent, requiring no additional support beyond being able to place a two-person field team at the site of interest.

Data from the SUMO UAVs allow us to study the structure of the planetary boundary layer (PBL). The PBL is that portion of the atmosphere that directly interacts with the underlying surface (land, ice sheet, ocean, or sea ice) and as such is critical for controlling coupled atmosphere–climate system processes. Repeat high time resolution observations of the PBL (Figure 1) allow us to study the evolution of the boundary layer and infer the processes acting to control its structure. Data of this type will allow us to more thoroughly evaluate numerical models of the polar atmosphere.

Photo courtesy of John Cassano

A two-person field team (CIRES graduate student Alice DuVivier and CIRES Fellow John Cassano) operates the SUMO UAV in January 2009.

Alice DuVivier

John Cassano launching a SUMO UAV near McMurdo Station, Antarctica

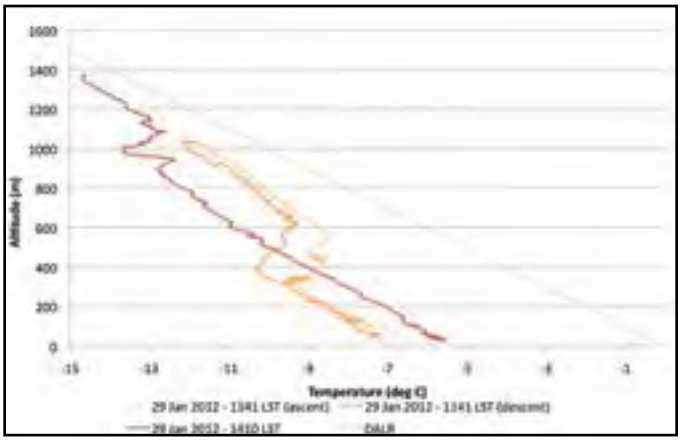
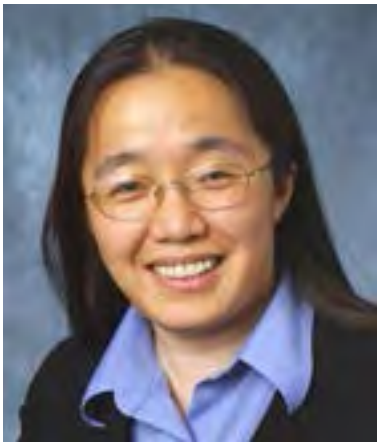


Figure 1. Vertical temperature profiles observed by the SUMO UAV on Jan. 29, 2012. The boundary layer depth increased from 300 m to 1,000 m during the 2.5 hours shown here.



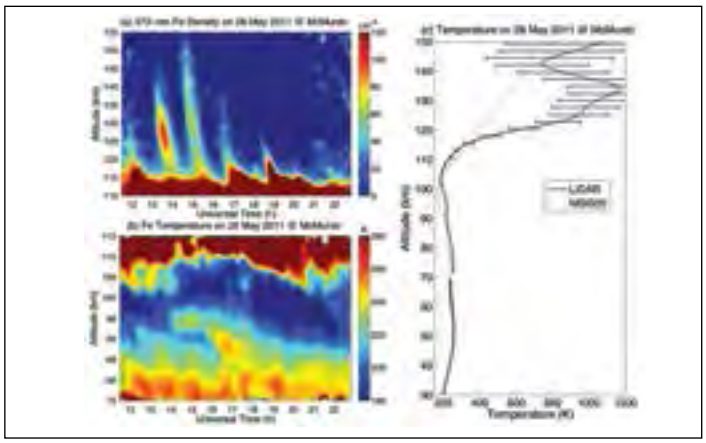
Xinzhao Chu

Discovery of Thermospheric Fe Layer by Lidar in Antarctica

The polar middle and upper atmosphere provides a unique natural laboratory for studying the complex physical, chemical, and dynamical processes in Earth's atmosphere and space environment. However, this region remains one of the least understood regions of the atmosphere. In particular, very little is known about the neutral atmosphere in the altitude range of 100 to 200 kilometers because observations are extremely difficult to make. The first lidar discovery of neutral iron (Fe) layers with gravity wave signatures in the thermosphere up to 155 kilometers made by the Chu Research Group at McMurdo, Antarctica, is a breakthrough in the upper atmosphere research (Chu et al., 2011). Not only is this the first time for a single instrument to trace gravity waves from 30 to 155 kilometers, but also it enables the first direct measurements of neutral temperatures deep into the E-region, revealing the neutral-ion coupling and aurora-enhanced Joule heating. The new observations of Fe, neutral temperatures, and gravity waves up to 155 kilometers have opened the door to exploring the neutral polar thermosphere with ground-based instruments.

Such a discovery is only a small portion of the rich data sets collected by the lidar team from McMurdo. Many more findings have emerged from the data—for example, the solar effects in the diurnal variations of mesospheric Fe layers; the frequent occurrence of large-amplitude inertia-gravity waves in the mesosphere and lower thermosphere; and extreme events of summer Fe layers and polar mesospheric clouds, etc. We attribute the accomplishment to CIRES students Zhibin Yu and Brendan Roberts for their braving through the harsh Antarctic winters to collect invaluable data, to CIRES researchers Wentao Huang and Weichun Fong for their tireless work during the Antarctic summers, and to Cao Chen for his inventive and comprehensive analysis of the McMurdo lidar data.

The FY12 was also marked by CIRES student John A. Smith's innovation in lidar receiver technologies and CIRES student Bo Tan's publication on the tele-connection of global atmosphere from 15 to 110 kilometers and from the North Pole to the South Pole. It was also an award-winning year: Chihoko Yamashita received a first-place prize in the CEDAR (Coupling, Energetics and Dynamics and Atmospheric Regions) student competition; Weichun Fong and John Smith won AGU (American Geophysical Union) and ILRC (International Laser Radar Conference) travel awards, respectively; and Wentao Huang won a CEDAR grant for the first time as the principal investigator. In addition, Yamashita successfully defended her dissertation and earned her Ph.D. in December 2011. Congratulations to these excellent students and researchers!



Lidar observations of neutral Fe layer with gravity wave signatures in the thermosphere up to 155 km at McMurdo (77.8° S, 166.7° E), Antarctica. Also illustrated are the lidar-derived temperatures (Chu et al., *GRL*, 2011).

Xinzhao Chu

Zhibin Yu (left) and Brendan Roberts (right) braved through the harsh Antarctic winters of 2011 and 2012, respectively. They collected extremely valuable lidar data that enabled many new science discoveries.

Shelley Copley

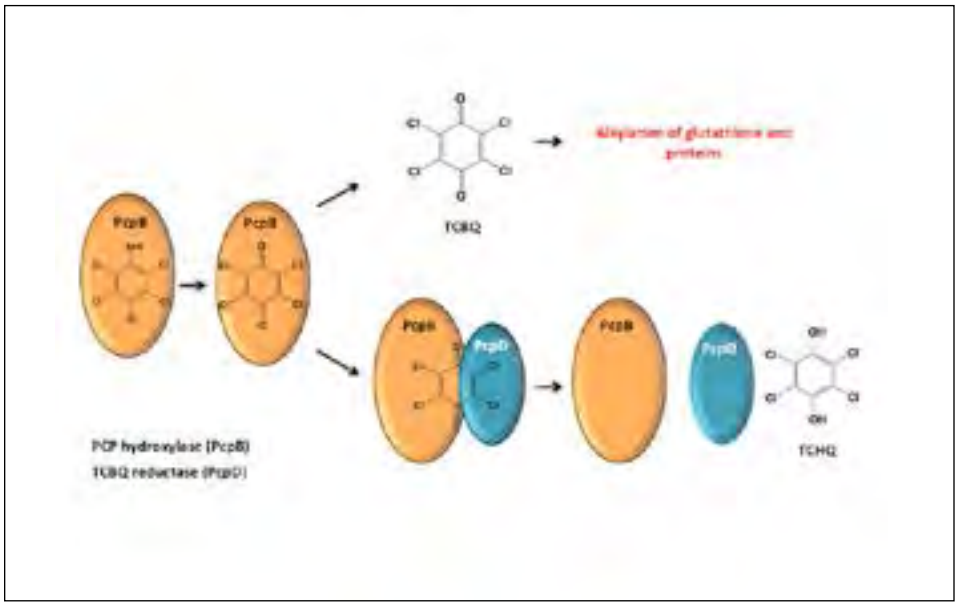
Sequestration of a Highly Reactive Intermediate in an Evolving Pathway Protects Cellular Molecules from Alkylation and Oxidative Damage

Pentachlorophenol (PCP) is an anthropogenic pesticide that was introduced into the environment in large quantities beginning in the 1930s. Despite its recent introduction and high toxicity, some bacteria isolated from contaminated environments can mineralize PCP. The best studied of these is *Sphingobium chlorophenolicum*.

The first enzyme in the PCP degradation pathway in *S. chlorophenolicum* converts PCP to tetrachlorobenzoquinone (TCBQ). TCBQ is a potent electrophile and is more toxic than PCP itself due to its high reactivity. In particular, TCBQ reacts with thiols at nearly the diffusion-controlled rate.

The intermediacy of a dangerous compound such as TCBQ in a newly evolving pathway brings up two interesting questions. First, how does the bacterium protect itself from the toxic effects of TCBQ? And second, does the intermediacy of TCBQ explain the inefficiency of PCP degradation by *S. chlorophenolicum*?

The answer to the first question is provided by molecular studies of purified TCBQ reductase (PcpD). The enzyme uses NADH to reduce TCBQ to tetrachlorohydroquinone. However, its most important function is its ability to physically interact with PCP hydroxylase (PcpB) and reduce TCBQ before it is released to the cytoplasm and wreaks havoc by reacting with cellular thiols. The interaction between PcpB and PcpD appears to be transient, as we were unable to detect an interaction by native gel electrophoresis, gel filtration, or chemical cross-linking.



PCP hydroxylase (PcpB) converts PCP to the highly toxic intermediate tetrachlorobenzoquinone (TCBQ). When TCBQ reductase (PcpD) is present, a transient interaction between the two proteins results in reduction of TCBQ to the less toxic tetrachlorohydroquinone before it can be released to the cytoplasm.

Our recent results provide new insights into the second question. PCP hydroxylase is an unusually inefficient enzyme, with a k_{cat} of only 0.02^{s-1}. If release of TCBQ from the active site of PcpB were faster than the rate of encounter of PcpB and PcpD, the fitness of the cell would be compromised by the damage caused by TCBQ. Thus, there may be a strictly enforced upper limit on the efficiency of PCP hydroxylase that limits the efficiency of degradation.

Joost de Gouw

Sources and Chemistry of Organic Carbon in the Atmosphere

Organic molecules play an important role in the atmosphere. They provide the fuel for the formation of ozone in the troposphere and contribute to organic aerosol formation. Ozone and organic aerosol are important air pollutants and play a role in the climate system: Ozone is a greenhouse gas, and organic aerosol cools the climate through the scattering of sunlight and the formation of clouds.

Organics have important natural and man-made emission sources, but their relative contributions to ozone and, in particular, organic aerosol formation are poorly understood. In 2010, NOAA conducted the CalNex (Research at the Nexus of Air Quality and Climate Change) study in California. An important goal was to study how emissions in the Los Angeles basin, where anthropogenic emissions are large, react to form organic aerosol. We made detailed measurements of organics from a ground site in Pasadena, the NOAA WP-3D research aircraft, and the research vessel Atlantis, which showed significant reductions in trace gas and aerosol concentrations compared with earlier studies in the region. For example, volatile organic compounds have decreased at a rate of approximately 7 percent per year due to introduction of cleaner vehicles. Differences in trace gas composition between weekdays and weekends, when diesel traffic is reduced, proved to be useful to determine the relative importance of emissions from gasoline and diesel vehicles. Formation of organic aerosol was likely dominated by emissions from gasoline vehicles, but a quantitative explanation for these observations remains elusive.

Sara Lance

Haze over mountains northeast of L.A. during the CalNex 2010 field mission

Another important direction in our research is focused on the environmental effects of new energy sources. For example, advances in hydraulic fracturing have increased natural gas production in the last decade, and ethanol made from corn now constitutes approximately 10 percent of gasoline in the U.S. Research is currently underway to determine how these changes have affected the atmospheric environment.

Lisa Dilling

Climate Change, Decision Making, and Managing Risks

My research program focuses on the science-policy nexus, including the processes used to generate policy-relevant science and the use of information in policy-making processes that can help society mitigate or adapt to climate change. I study this area along three major fronts: 1) How do science policies shape the usability of research for decision making?; 2) How do current decision processes incorporate climate-related risk or opportunity?; and 3) What factors shape the adaptive capacity of organizations?

My research in the science-policy arena is focused on one particular type of science policy: programs that are justified as supporting decision making or providing "usable science." With the advent of climate change, it is even more important to discover new ways of conducting research so that it can be available at the time and scale needed. Findings from my current research projects in this area suggest that stakeholder needs related to adaptation in various resource-management areas remain unfulfilled.

The second thrust of my research is on climate policy, or the 'demand' side for climate science. I construe the demand side broadly as decision processes that might affect the mitigation of greenhouse gases or that might manage climate-sensitive resources such as water. I am currently examining the landscape of adaptation-related decision making and information in several contexts such as public lands agencies in the West and water management at the state level across five U.S. states.

My third research focus is to identify the factors associated with policy choices to mitigate weather- and climate-related risks; and to identify the policy barriers that might exist for acting proactively to adapt to climate change. Current research involves urban water management and municipal hazard response.

iStock photo

Lang Farmer

Age and Origin of the REE-Rich Elk Creek Carbonatite, S. Nebraska

Lang Farmer's group began a project in 2011–12 in conjunction with researchers from the University of Nebraska and the U.S. Geological Survey to examine the age and origin of the rare earth element (REE) and niobium (Nb) resources of the Elk Creek carbonatite in southeastern Nebraska. The Elk Creek carbonatite was discovered in 1971 and has since been the subject of periodic exploratory drilling. Much of the core obtained in that drilling (less than 25,000 linear meters) is now held by the State of Nebraska (see right photo of typical "REE" mineralized carbonatite).

Diamond drill cores represent the only samples of the Elk Creek carbonatite available: The carbonatite is covered by 190 meters of soil sediment and rock. The Elk Creek core is probably the largest collection of core in the public domain from a single carbonatite system. There has never been a systematic research program devoted to examining these rocks, despite the importance of both the REE and Nb in various "green" technologies and the fact that this carbonatite represents the largest known U.S. niobium reserve.

Lang Farmer

Our efforts have involved a systematic, detailed description of the petrography and geochemistry of the Elk Creek carbonatite system. The age of the deposit (likely early Cambrian) is also a major unknown, and we are undertaking uranium-lead zircon age determinations, samarium-neodymium and argon-argon mineral isochrons to measure the age of the carbonatite, and related metasomatic alteration. We are also using stable and radiogenic isotope data to identify the sources of the carbonatite components and REE endowment.

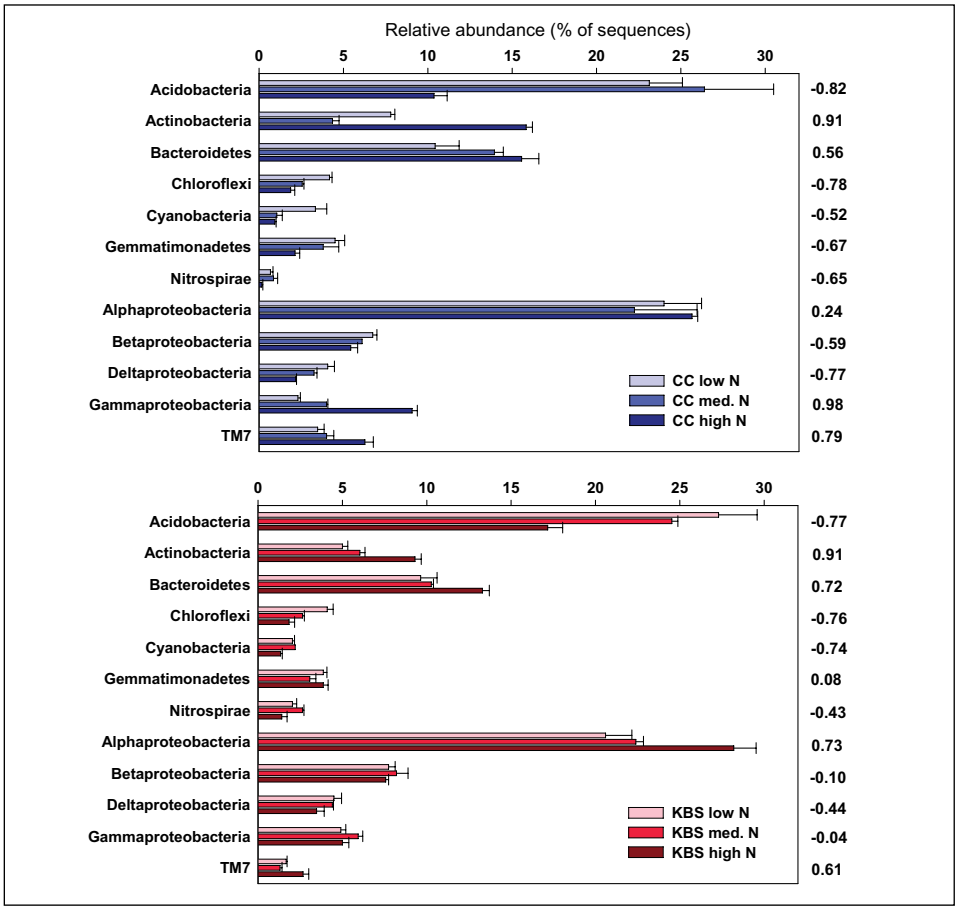
Noah Fierer

Soil Microbes and Global Change

Although they are miniscule, soil microbes play critical roles in the functioning of terrestrial ecosystems, the maintenance of ecosystem productivity, and terrestrial carbon dynamics. Even small changes in the rates at which microbes break down soil organic matter can have profound influences on the terrestrial carbon cycle and its responses to global change factors. Our recent work has focused on how soil microbial communities and processes are affected by increases in nitrogen (N) availability, a key global change factor given that terrestrial ecosystems across the globe are receiving elevated inputs of N due to the direct or indirect activities of humans.

Although the impacts of the increases in nutrient availability on plant productivity and diversity have been reasonably well studied, the responses of belowground microbes to nutrient additions are poorly understood. In a series of laboratory-based studies and long-term field experiments, we have leveraged newly developed DNA sequencing–based analyses to gain unprecedented insight into the structure and function of soil microbial communities and their responses to elevated N inputs. We have found that N additions consistently reduce soil microbial biomass and microbial CO_2 production by 10 percent to 30 percent regardless of the form of N applied, the type of soil, or the biome in question.

The consistency of these patterns is striking given that it is counterintuitive; we would expect microbes, like plants, to respond to N fertilization by increasing biomass and activity. However, we have found that the decreases in microbial biomass and activity with increases in N are likely a product of changes in the types of microbes found in soil: N additions favor 'weedy' microbial taxa that are less proficient at breaking down soil organic matter. Together these results highlight that the widespread increase in N inputs to terrestrial ecosystems can change microbial diversity in a predictable manner and that these changes may contribute to an increase in the rates at which carbon is stored in terrestrial systems.



Bar graph showing changes in the relative abundances of soil bacterial taxa under different levels of nitrogen fertilization. The top panel shows data from experimental plots located at the Cedar Creek Ecosystem Science Reserve in Minnesota (successional grasslands), while the bottom panel shows data from experimental plots located at the Kellogg Biological Station in Michigan (cultivated fields).

Baylor Fox-Kemper

Improving Ocean Climate Models

The Fox-Kemper group studies ocean models, data, and theory with an end goal of improving the ocean component of climate models. From adding new physics to models to finding new ways to validate models and discover unknown biases, my students, collaborators, and I consider a broad range of approaches toward our goal.

In the past couple of years, two topics have been foremost in our efforts. The first is the centennial variability of the El Niño/Southern Oscillation climate pattern, and the second is upper ocean turbulence.

Our El Niño work was largely led by recent CU Ph.D. student Samantha Stevenson, now in a postdoctoral position at the University of Hawaii. Unexpectedly large El Niño or La Niña events can have economic impacts worldwide. Our work focused on finding ways to compare models, observations, and paleoproxy records of El Niño variability to determine if there were any measurable connection between the strength of El Niño variability and increasing atmospheric carbon dioxide. Interestingly, we were able to demonstrate statistically significant connections but only over long timescales—we do not expect to see changes to the variability of El Niño itself in the 21st century. However, a warmer, wetter atmosphere responds differently to an El Niño event, and we may already be seeing the effects of changes to the atmospheric teleconnections.

Our upper ocean turbulence work has expanded to cover all of the scales from 4 meters to 400 kilometers. Over that range of scales, many different dynamical processes occur and affect the air-sea exchange of heat, gasses, and momentum. Working with satellites and reanalysis has revealed important and persistent short timescale errors in both models and conventional understanding of upper ocean turbulence and its forcing. The group has already added parameterizations to the IPCC/CMIP5 models presently being analyzed for the next IPCC (Intergovernmental Panel on Climate Change) report; our research is directed toward improving the CMIP6 models as well.

Photo by Anne Kemper

Timothy Fuller-Rowell

Connections Between Terrestrial and Space Weather

My main interest is space weather. The term "space weather" was coined several years ago and refers to the impacts of the space environment on technological systems. These include, for example, the disruption of radio signals traveling through Earth's ionosphere and the impact on satellite communication and navigation; or changes in mass density of the upper atmosphere that impact orbital drag, satellite positioning, and collision avoidance. At NOAA's Space Weather Prediction Center, there is a need to understand the physical system to a level where accurate predictions can be made, which can hopefully mitigate these detrimental impacts. Until now, the conventional wisdom was that all space weather comes from the sun. Certainly this is the case during big solar events, when there is a solar flare or when plasma from the sun, in the form of a coronal mass ejection (CME), strikes Earth, and the ensuing geomagnetic storm dominates the impact on these technological systems.

However, these big solar events are rare, and we now know that regular terrestrial weather down here in the troposphere can also have a big impact on space weather. It has long been understood that the lower atmosphere is a source of variability for the ionosphere, but a coherent connection between a particular atmospheric event and space weather was elusive. A recent breakthrough has revealed that a change in large-scale atmospheric dynamics, such as during a sudden stratospheric warming (SSW), imparts a coherent change in thermospheric dynamics, electrodynamics, and ionospheric structure in the upper atmosphere.

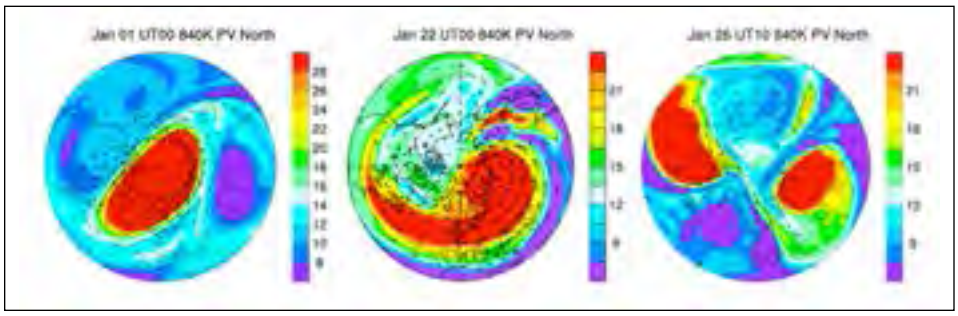


Figure 1.

We now have a whole atmosphere weather model extending from the ground to the top of the atmosphere that can model these events. Figure 1 shows a simulation of the January 2009 period, which included a particularly intense SSW, where the stratospheric polar vortex split into two. The change in the atmospheric dynamics had a dramatic effect on winds in the lower thermosphere dynamo region and drove very different electrodynamics and ionospheric structure.

What we also discovered was that the structure and variability in the large-scale dynamics and electrodynamics in the whole atmosphere model were sufficient to spawn ionospheric irregularities in the Boston College high-resolution model, shown in Figure 2. What was unique and transformational was that, for the first time, the irregularities grew naturally from the physical conditions in the simulation, without the need for artificial seeding. These atmospheric conditions can be forecast hours or days ahead, so there is a real possibility of predicting the impact on operational systems.

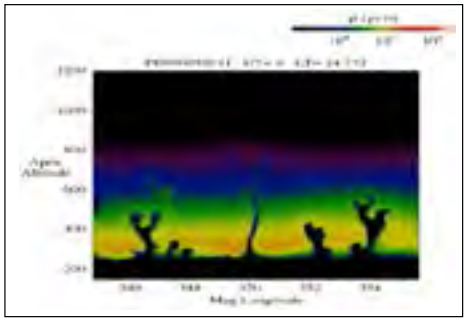


Figure 2. First simulation of plasma bubble formation without the need for artificial seeding (John Retterer, Boston College, irregularity model)

William M. Lewis, Jr.

A Nutrient Controversy for Surface Waters

Thousands of bioassay experiments on lakes, streams, and wetlands have shown that the dominant plants in these ecosystems, which may be either aquatic vascular plants or algae, show strong growth response to the addition of nitrogen and phosphorus. The experiments also show that the addition of other elements such as potassium, calcium, or sulfur almost never causes growth responses. The general conclusion is that phosphorus and nitrogen are the key elements limiting the growth of aquatic autotrophs (photosynthesizers).

William M. Lewis, Jr.

A lake under the influence of nutrient pollution (N, P). Algal scum shows in the foreground.

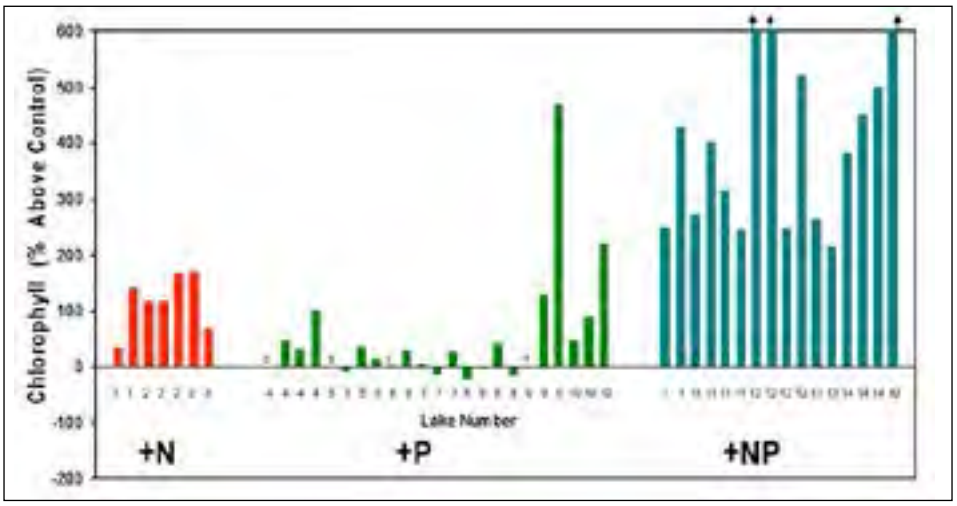


Figure 1. Results of nutrient enrichment experiments on whole lakes worldwide. Chlorophyll response indicates degree of algal growth.

Excessive growth of autotrophs is a worldwide problem that impairs the usefulness of water and alters the natural characteristics of aquatic ecosystems (photo at left). From the viewpoint of water use, some practical problems include production of taste and odors that cause treatment problems for domestic water supply, production of powerful toxins by certain types of algae, loss of transparency and aesthetic appeal, and replacement of species that either have aesthetic or sport value by other species that lack these desirable characteristics.

In the United States, Canada, and Europe, this problem is being addressed through the development of regulatory limits on the amounts of phosphorus and nitrogen that can be released as a byproduct of human activity. The regulatory system begins with control of nitrogen and phosphorus in wastewater effluents, which all cities produce. Because humans mobilize large amounts of nitrogen and phosphorus through their own metabolism, food waste, or detergents, municipal effluents contain concentrations of nitrogen and phosphorus that may be as much as 100 or even 1,000 times above the background concentrations in the water that received municipal discharges. Effluent concentrations of nitrogen and phosphorus can be reduced by implementing known technologies for this purpose. This action can increase capital costs and operating costs for cities or other entities that process municipal waste or other waste that carries a high concentration of phosphorus and nitrogen.

Underlying the effort to control nitrogen and phosphorus is a scientific controversy about the relative importance of these two elements. While both elements are being targeted for reg-

ulation by North American and European governments, phosphorus has consistently received higher priority in regulatory efforts, and some scientists have argued that control of nitrogen is not essential as long as phosphorus is properly regulated.

The controversy about relative importance of phosphorus and nitrogen depends partly on the interpretation of field data involving experiments with both nutrients together and each nutrient separately. A growing body of evidence shows that natural waters are equally likely to be limited by nitrogen or phosphorus. The experiments also show that the addition of the two nutrients together causes a larger growth response than either element individually (Figure 1, page 37). These two observations suggest that a nutrient control strategy based on phosphorus alone is inadequate. For example, allowing nitrogen pollution to continue will stimulate plant growth in aquatic ecosystems that have predominately nitrogen limitation. While previous arguments have been made that this is not often the case, current evidence suggests otherwise. Furthermore, some evidence suggests that nitrogen in excess, even under conditions of phosphorus limitation, may cause changes in aquatic communities in that some kinds of organisms respond to high nitrogen-to-phosphorus ratios, whereas others do not. Thus the advisability of regulating both nutrients seems to be strong.

The State of Colorado recently held hearings before the Water Quality Control Commission on the issue of dual nitrogen and phosphorus limitation. The Center for Limnology at CIRES offered scientific testimony that phosphorus and nitrogen should be regulated together in Colorado. Commissioners chose to pursue a dual nitrogen and phosphorus control strategy. Scientific information was the key to the decision of the Commissioners.

Clearing the Waters

The overgrowth of aquatic plants and algae can strangle a lake or stream—producing toxic algal blooms, depriving fish of oxygen, and tainting the water's smell, taste, and appearance. While phosphorus has received the most attention for fueling that growth, research is shedding light on another equally important nutrient, nitrogen. Dr. William M. Lewis, Jr., director of the CIRES Center for Limnology, explains.

Why has phosphorus consistently received higher priority than nitrogen in regulatory efforts?

Early studies of the statistical relationships between nutrients and abundance of algae in inland waters showed that phosphorus is more tightly correlated with algal abundance than nitrogen. Recent studies have shown that the strength of such correlations is not an accurate indicator of nutrient control. A warning that all scientists are taught as they learn statistics was proven in this case: Correlation does not necessarily correspond to causation.

Why has nitrogen's role in lake eutrophication been so murky (no pun intended)?

A large portion of the total nitrogen in water is unavailable for uptake by algae. This is a contrast with phosphorus, for which the unavailable fraction is very small. Therefore, interpretation of nitrogen concentrations in relation to growth of algae has been confusing, but now is becoming clearer (no pun intended).

What are the main sources of nitrogen discharge into lakes, streams, and wetlands?

All lakes, streams, and wetlands have natural nitrogen sources that support the growth of algae and other aquatic plants even in the absence of pollution. Three categories of pollution are associated with nitrogen enrichment of water: (1) Point sources, which consist of all wastewater flows that enter inland waters by pipes or canals; (2) non-point sources, which contribute nitrogen through widely distributed underground or overland flows, as in the case of nitrogen applied to land as fertilizer for plants; and (3) atmospheric deposition (wet precipitation and dryfall), which in industrialized areas may carry large amounts of nitrogen capable of stimulating the growth of algae and other aquatic plants.

The Center for Limnology testified before the Colorado Water Quality Control Commission in support of dual control. What was this process like and how much do you think it influenced the commission's decision?

The Water Quality Control Commission, which is appointed by the Colorado governor, is composed of individuals with varied backgrounds. As would a jury, the Commissioners hear the opinions of specialists or experts and also hear the opinions of the Water Quality Control Division staff. Commissioners often ask questions and may openly express skepticism or enthusiasm for a given argument (unlike a jury). They ultimately adopt one or more resolutions reflecting their majority opinion. For the experts, the experience is tense, as each expert attempts to be persuasive but, unlike some attorneys in legal cases, also try to avoid showing strong bias in evaluating quantitative evidence. It is a thrill to win the Commission's approval for an argument and very disappointing to be found unconvincing.

What can be done to reduce nitrogen discharge into lakes?

Point sources of nitrogen such as municipal or industrial effluent can be removed by biological and chemical treatment processes. Use of this technology is now being required by the Water Quality Control Commission in Colorado. Non-point discharge, as in the case of fertilizers, is more difficult to control but can be reduced partly by modification of farming practices. Atmospheric deposition of nitrogen has been reduced, but not completely eliminated, by use of catalytic converters for vehicles and use of removal technologies for fossil fuel emissions from power plants.

Peter Molnar

Mountain Topography, Erosion, Tectonics, and Climate Change

I devoted a part of this research effort in 2011 to synthesizing topography, climate, and tectonics of mountain belts around Earth to isolate the roles of active tectonics and climate change in erosion and mountain topography (Champagnac et al., 2012).

Most geologists follow the 100-year-old school of William Morris Davis, who divided mountain landscapes into Youth, Maturity, and Old Age, with high relief in youthful ranges, and low relief in those of old age. This approach, however, ignores the potential role of climate change in altering erosion rates, for instance, by enhanced glaciation since approximately 3 million years ago; stormier climates beginning near the same time; increased climate variability on 20,000-to-40,000-year time scales, if not shorter ones, etc. Because high relief can be found in active ranges like the Himalaya, dead ones like the Rocky Mountains, and senile ranges like the Swiss Alps, the question of whether active tectonics affects relief more or less than climate change remains controversial.

We examined the topography of 69 ranges by considering relief on different scales (averaged over regions with radii of approximately 1 kilometer to approximately 15 kilometers) and average heights, above both sea level and local base level (Denver basin for the Front Range), and we regressed these against average shortening rates across the ranges, measured with GPS, mean annual precipitation, and, as a surrogate for the likelihood of glaciation, the cosine of the latitude. All three account for some variance in relief or elevations, but none accounts for even 25 percent of them, and together they account for less than half of the elevations or relief (Figure 1).

Of course, other factors, such as total convergence across ranges, variability in precipitation, or direct measures of glaciation, surely contribute to both elevations and relief, but a main deduction from this work is that active tectonics is overrated as a factor contributing to mountain topography.

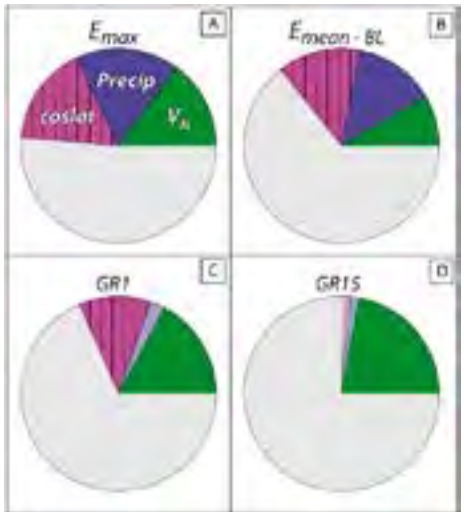


Figure 1. Pie charts showing the contributions of active tectonics (Vh), mean annual precipitation (precip), and cosine of latitude (coslat)—a surrogate for glacial activity—to (A) maximum elevation along ridge crests, (B) difference between maximum ridge crest elevation and base level, (C) relief averaged over radii of approximately 1 km, and (D) relief averaged over radii of approximately 15 km

R. Steven Nerem

Performance Simulations for Future Satellite Gravity Missions

The GRACE (Gravity Recovery And Climate Experiment) satellite mission has precisely measured temporal variations in 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. And yet the GRACE mission is limited in terms of the spatial resolution it can provide. We investigated what additional performance might be gained by flying two GRACE missions at the same time.

It is expected that future satellite missions dedicated to recovering temporal gravity variations will be limited in their performance by temporal aliasing errors, which is a form of aliasing related to the GRACE temporal/spatial sampling characteristics. We investigated the performance of two pairs of GRACE-like satellites, one pair in a polar orbit at 320 kilometers altitude, and a second pair at 72° inclination and 290 kilometers altitude. Both of these orbits repeat every 13 days. We found that the spatial resolution and accuracy of hydrologic and ice signals were significantly improved when two pairs of satellites were employed (Figure 1). On average, when no post-processing is applied to the gravity solutions, two pairs of satellites offer an 80 percent reduction in error in determining mass variations in the basins over the year. After the single satellite pair solutions have been destriped and smoothed and mass has been restored using an appropriate scale factor, two pairs of satellites (with no post-processing) still, on average, provide a 25 percent to 40 percent reduction in errors in determining mass variations in the hydrological basins and a 55 percent to 75 percent reduction in errors in determining mass variations in the Greenland basins over the year.

The GRACE mission, launched in 2002, has been tremendously successful but has left scientists wanting better accuracy for the estimated surface mass variations. Our study has shown that much better accuracy can be obtained if two pairs of satellites are flown in optimally selected orbits. The primary advantage of this is that for a spatial resolution of about 300 kilometers, no post-processing (e.g., destriping), which might remove real signals, is required when two satellite pairs are used. This opens up new possibilities for the future. We are investigating what performance might be obtained if additional pairs of GRACE-like satellites were added to the mix, and what orbits these satellites might be targeted for. GRACE has shown the unique ability to measure where water is on the surface of Earth with roughly monthly temporal resolution—our research is directed toward improving this capability for future missions.

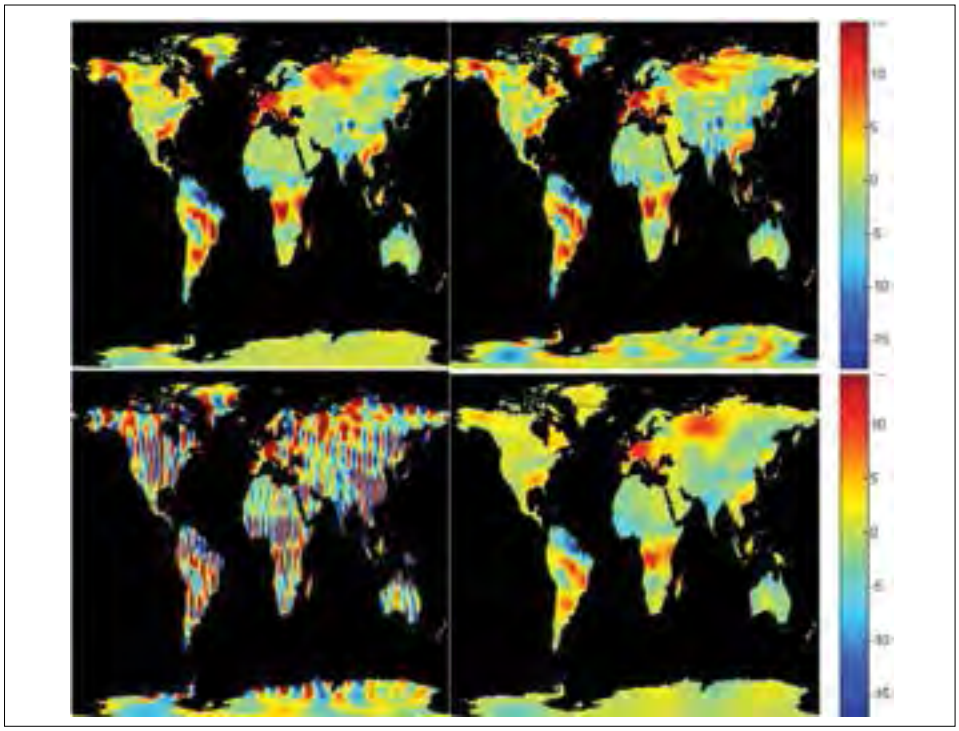


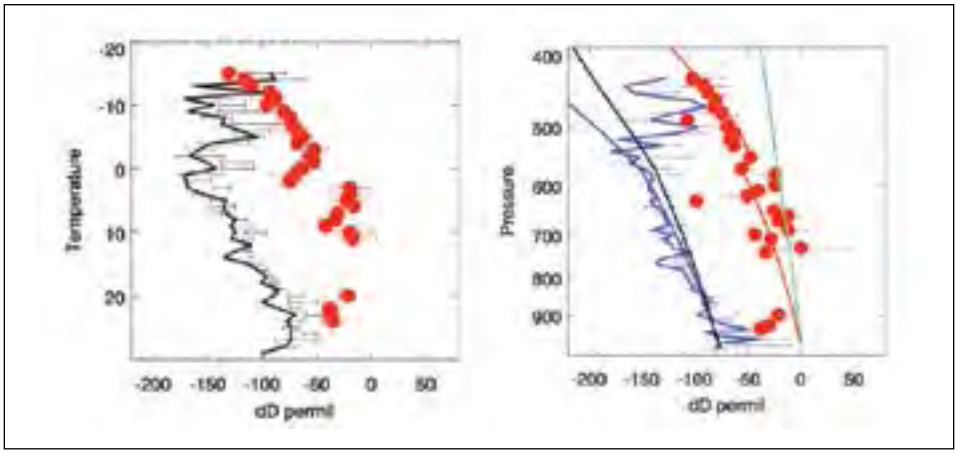
Figure 1. Simulated recovery of temporal variations of the gravity field from GRACE-like satellite gravity missions. Truth hydrology and ice signals (top left); recovery from two pairs of GRACE-like satellites (top right); recovery from a single pair of GRACE-like satellites (bottom left); and recovery from a single pair of GRACE-like satellites after destriping and smoothing (bottom right) (Wiese et al., 2011). Color bar units are in millimeters of equivalent water.

David Noone

Aircraft Studies of Cloud Microphysical Controls on Tropical Humidity

Water vapor is the most abundant greenhouse gas in the atmosphere. The distribution of water vapor is dependent on patterns of evaporation, atmospheric motions, and clouds. Significant uncertainties exist in treatment of clouds in climate models, and these uncertainties give rise to dispersion between future projections of the rate of warming from different climate models under greenhouse gas emission scenarios. In an endeavor to better understand the behavior of tropical clouds and the mechanisms by which convective clouds moisten the atmosphere, measurements of the isotopic composition of water air near and within clouds were obtained to test assumptions about clouds that are typically employed in climate models. The isotopic composition of water is useful for understanding the water movements and phase change because the abundance of heavy isotopologues (HDO and $H_2{}^{18}O$) relative to normal H_2O ($H_2{}^{16}O$) changes during evaporation and condensation. Specifically, the lighter H_2O molecules preferentially evaporate while the heavier HDO and $H_2{}^{18}O$ molecules preferentially condense, and lighter molecules diffuse faster than the heavier ones.

Observations of the $^{18}O/^{16}O$ and D/H isotope ratios were made in July 2011 on 13 research flights of the NCAR C130 aircraft during the ICE-T (Ice in Clouds Experiment–Tropical) field campaign near St. Croix, Virgin Islands. Values were determined using the Wave-Length Scanning Cavity Ring Down approach that was optimized for high speed and precise measurements of the isotope ratio of liquid and ice cloud condensate by coupling a gas analyzer to the NCAR Counter flow Virtual Impactor inlet. The inlet system provides a particle enhancement while rejecting vapor, and its use is an important technical advance needed to exploit isotope information to understand cloud microphysics. Results in the figure show that the cloud condensate has high isotope ratios (presented in the standard "delta" notation) relative to the environmental vapor. Changes in the microphysical properties of the cloud are detected at the onset of glaciation above the freezing level, and the clouds are fully glaciated below about minus 10°C. Moistening of the atmosphere by detrainment of condensate, which dominates the total water detrainment, is seen above 500 hPa (hectopascal) where the environmental values are seen to approach the values of the condensate found inside the cloud. These results place constraints on both the rate of rain production in clouds and the characteristics of detrainment in the mid-troposphere, which are otherwise poorly constrained within models.



Left panel shows isotopic measurements of water vapor (black) and condensed cloud water (red dots) binned by temperature as an average of many clouds near St. Croix. A distinct change in the isotope of the condensate is associated with glaciation of the cloud. Right panel shows that the measurements can be reasonably well constrained using a simple plume model once the plumed is tuned to have the correct rain production rate. There is evidence for moistening of the atmosphere where the cloud vapor values (blue) approach the cloud condensate values around 500 hPa and above.

Judith Perlwitz

Exploring Mechanisms by which the Stratosphere Influences Climate

Over the past two decades, observational and modeling studies have fundamentally changed our understanding of the role of the stratosphere in surface weather and climate. While we now have multiple evidence for a two-way interaction between troposphere and stratosphere, the mechanisms by which the stratosphere can affect tropospheric climate are still under investigation.

In a paper published in 2003, we established observational evidence that planetary waves that are generated in the troposphere and that are propagating into the stratosphere can be reflected back into the troposphere where they modify the tropospheric flow. However, the tropospheric climate features of reflective events have not been determined.

During the last year, we studied the life cycle of Northern Hemisphere downward coupling between the stratosphere and troposphere via wave reflection. We showed that the evolution in the troposphere that follows a reflective event in the stratosphere involves a shift toward a positive phase of the North Atlantic Oscillation (NAO). The pattern develops from a large westward propagating wave-1 anomaly in high-latitudes that causes a negative geopotential height anomaly in the Atlantic sector. Subsequent equatorward propagation leads to a positive anomaly in midlatitudes. The evolution of the near-surface temperature and mean sea level pressure anomalies are consistent with the shift toward a positive NAO phase.

Finally, we analyzed winter seasons dominated by extreme wave coupling events. The largest impacts in the troposphere occur during seasons with multiple wave reflection events that produce a positive NAO phase and during weak vortex seasons with major sudden stratospheric warmings that produce a negative NAO phase. The results suggest that the dynamical coupling between the stratosphere and NAO involves distinct dynamical mechanisms.

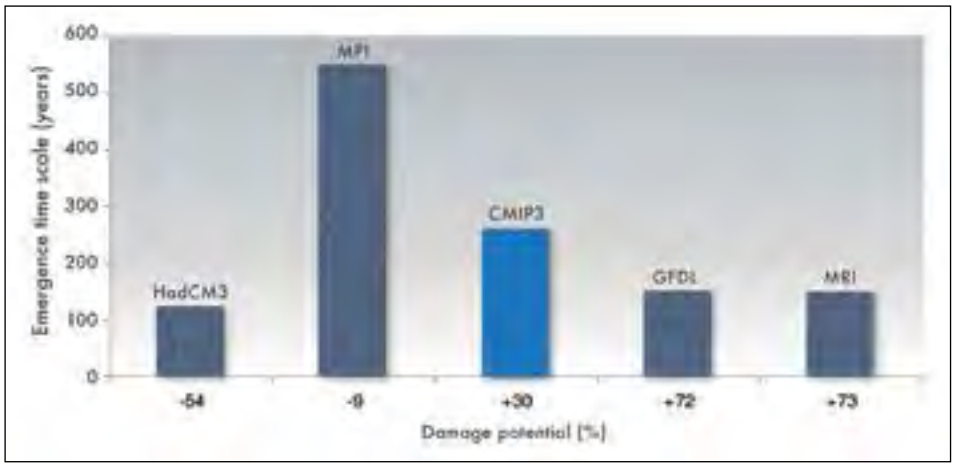
NASA

Roger Pielke, Jr.

Emergence Timescales for Detection of Anthropogenic Climate Change in U.S. Tropical Cyclone Loss Data

Recent reviews have concluded that efforts to date have yet to detect or attribute an anthropogenic climate change influence on Atlantic tropical cyclone (of at least tropical-storm strength) behavior and concomitant damage. However, the possibility of identifying such influence in the future cannot be ruled out. Using projections of future tropical cyclone activity from a recent prominent study, we estimate the time that it would take for anthropogenic signals to emerge in a time series of normalized U.S. tropical cyclone losses. Depending on the global climate model(s) underpinning the projection, emergence timescales range between 120 and 550 years, reflecting a large uncertainty. It takes 260 years for an 18-model, ensemble-based signal to emerge. Consequently, under the projections examined here, the detection or attribution of an anthropogenic signal in tropical cyclone loss data is extremely unlikely to occur over periods of several decades (and even longer). This caution extends more generally to global weather-related natural disaster losses.

Our results do not support using abnormally large losses from individual Atlantic hurricanes or seasons as either evidence of anthropogenic climate change or to justify actions on greenhouse gas emissions. However, policy making related to climate necessarily must occur under uncertainty and ignorance. Our analysis indicates that such conditions will persist on timescales longer than those of decision making, strengthening the case for expanding disaster risk reduction in climate adaptation policy.



Emergence timescale of anthropogenic signals in normalized damage versus the percent change in damage potential after 80 years

	Emergence timescale (years)	Change in damage potential (%)		Simulated mean change in damage (%)	
		After 80 years	At emergence timescale	After 80 years	At emergence timescale
CMIP3 ensemble	260	+30	+94	+30	+106
GFDL	150	+72	+135	+71	+138
MRI	150	+73	+137	+74	+138
MPI	550	−9	−62	−9	+41
HadCM3	120	−54	−81	−54	−82

Emergence timescale, change in damage potential, and the simulated mean change in damage after 80 years and at the emergence timescale

Balaji Rajagopalan

with graduate student Lisa Wade and CIRES WWA Researcher Jeff Lukas

Paleohydrology Reconstructions for the Lower Colorado River Basin

The Colorado River Basin (CRB) is a critical surface water source in the Southwest (Figure 1). Since the Upper CRB provides 80–90 percent of the total CRB annual flow and a smaller contribution comes from the Lower CRB flows, and also since the Gila River Basin isn't explicitly incorporated in the legal and management structure governing the rest of the CRB, Lower Basin flows have typically been left out of CRB water-supply modeling. But as demand on the CRB system approaches supply, the LCRB's 10–20 percent contribution becomes more critical. For these flows to be incorporated into a planning framework, it's important to understand their long-term variability and develop robust simulation methods that can capture the variability. These research needs motivated the present study and led to two streamflow reconstruction methods.

The first method clusters tree ring chronologies from the Southwest into coherent spatial regions; the leading modes of variability from each region were used with a local polynomial model to fit observed natural streamflows. We applied this to reconstruct natural flows on the Gila River and LCRB (Figure 2), offering a robust counterpart to the widely used reconstructions of the UCRB at Lees Ferry, Ariz. The second method introduces extreme value analysis (EVA) to streamflow reconstruction. Underlying this method is the premise that trees respond better to moisture exceeding some threshold. The EVA models the probability of threshold exceedance and the magnitude of exceedances; it is especially suited for reconstructing intermittent streamflow. This was applied to reconstruct natural flows on the highly intermittent Gila River at the Colorado River confluence. We find including Gila River flows provides water-supply risk mitigation capability and reduces Colorado River system risk by 4–17 percent. The new reconstruction methods coupled with the demonstration of their utility in assessing water-supply risk provide an attractive framework to studying water-supply management and planning in other river basins especially in semi-arid regions.

Figure 1. Upper CRB is area above Lees Ferry gauge (red dot), Lower CRB is below Lees Ferry, and Gila River Basin lies within the black boundary.

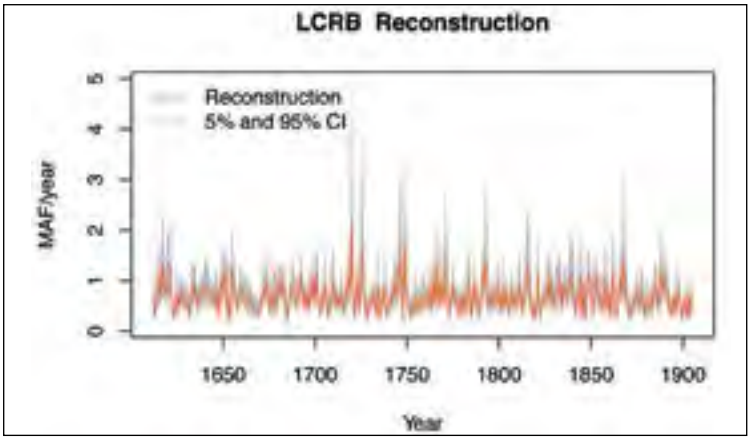


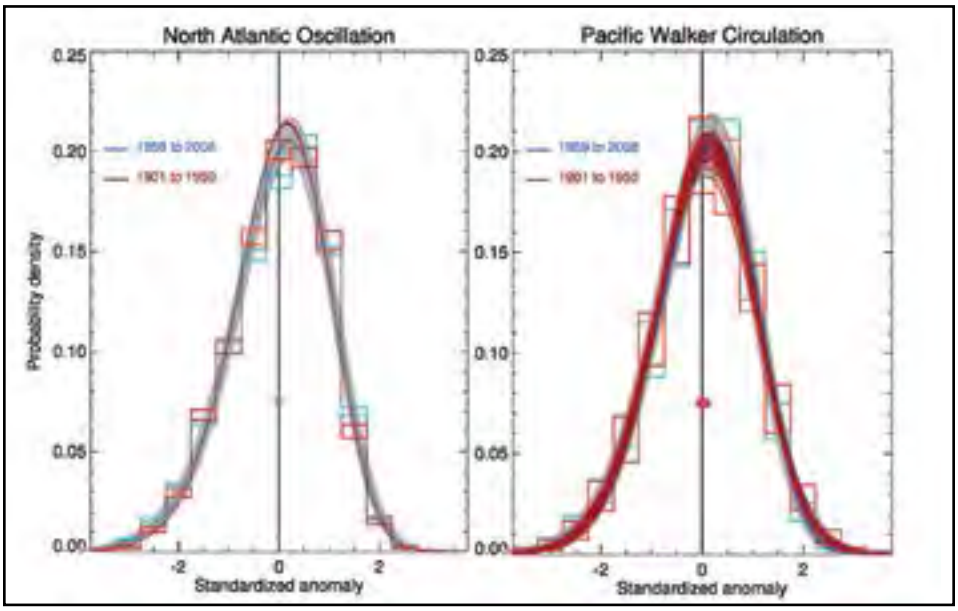
Figure 2. Reconstruction of the Lower Colorado River Basin

Prashant Sardeshmukh

Has Global Warming Significantly Affected Atmospheric Circulation Variability?

Although the anthropogenic influence on 20th-century global warming is well-established, the influence on the atmospheric circulation, especially on regional scales at which natural variability is relatively large, has proved harder to ascertain. This may be because the influence is actually small, a "second order" effect associated with the fact that a nearly spatially uniform surface warming cannot directly induce large changes in atmospheric jet structure and intensity and the statistics of daily weather. Indeed the "first order" theory of global warming's effect on the global pattern of precipitation minus evaporation, which assumes that there's no effect on the atmospheric circulation but mainly an effect on atmospheric humidity through the temperature increase, is quite successful in explaining the gross features of the precipitation response to global warming obtained in climate models.

Has there been a significant change in the atmospheric circulation over the 20th century? Many assertions are made to this effect, especially in the media whenever an extreme warm, cold, dry, or wet spell occurs and is tied to an apparent trend in the associated large-scale atmospheric circulation pattern. We have begun to address this important issue using the longest available global atmospheric circulation data set, an ensemble of 56 equally likely estimates of the atmospheric state within observational error bounds every six hours from 1871 to the present generated by the Twentieth Century Reanalysis (20CR) project, a major international effort led by the CIRES Climate Diagnostics Center (CDC) and NOAA. In the paper describing the data set (Compo et al, *QJRMS,* 2011), we presented evidence that long-term trends in the indices of several major modes of atmospheric circulation variability, including the North Atlantic Oscillation (NAO) and the tropical Pacific Walker Circulation (PWC), were weak or nonexistent over the full period of record. We have since investigated the possibility of a change in the probability density function (PDF) of daily values of these indices from the first (1901 to 1950) to the second (1959 to 2008) half of the 20th century, and found no statistically significant change. This was done taking into account the generally skewed and heavy-tailed character of these PDFs, and using both raw histograms and fitted "SGS" probability distributions (whose relevance in describing large-scale atmospheric variability was demonstrated in Sardeshmukh and Sura, *J. Climate*, 2009) to perform the assessment. Our finding of no significant change in the PDFs of the NAO and the PWC has important implications for how global warming is influencing atmospheric circulation variability and extreme anomaly statistics, and to what extent climate models are correctly representing those influences.



PDFs of standardized anomalous daily indices of the NAO and PWC. The PDFs are estimated for two 50-year periods (1901–1950, red, and 1959–2008, blue) both as raw histograms (rectangles) and as fitted "SGS" PDFs (curves). Results are shown for each of the 56 members of the 20CR ensemble. There are, thus, 56 red and 56 blue curves in each plot. Upper and lower segments of the red and blue rectangles show the range of counts for each anomaly size bin. The gray swath indicates 95% confidence intervals on the PDFs associated with using limited 50-year records, estimated using Monte Carlo simulations. The spread among the red and blue curves measures observational uncertainty, and the gray swath measures sampling uncertainty. The figure shows that the PDFs for the two 50-year periods are not statistically different, for both the NAO and the PWC.

Mark Serreze

Understanding and Predicting Arctic Change

The Arctic is in the midst of pronounced change encompassing the ocean, lands, and the atmosphere. Work over the past year has focused on understanding these changes, what they imply for the future of the Arctic, and how they will affect the rest of our planet. While I work closely with CIRES colleagues Julienne Stroeve, Walter Meier, Andrew Barrett, and John Cassano, as well as CIRES graduate students, the highly interdisciplinary nature of Arctic change has fostered connections with colleagues across the world. While much of my work involves analysis of satellite data, atmospheric data, and results from climate models, it also takes me to the field. For the past five years, I have been involved in a study of Arctic snow conditions on the North Slope of Alaska. In September 2011, Arctic sea ice extent barely missed setting a new record low, reinforcing the strong downward trend in ice extent observed over the satellite data record.

The rate of ice loss appears to be outpacing expectations from even the most advanced global climate models; why this is so remains to be resolved. Correct representation of sea-ice thickness is likely part of the answer and is the focus of an ongoing study making use of thickness data from aircraft and satellites. While it has been well established that sea-ice loss is a major contributor to the very strong warming of the Arctic, work over the past year established that this is also helping to make the Arctic atmosphere moister. It is increasingly clear from our work and that of others that continued loss of the sea-ice cover will have impacts on patterns of weather and precipitation not just within the Arctic, but well beyond. There is disturbing evidence that such impacts have already occurred.

Kelly Elder

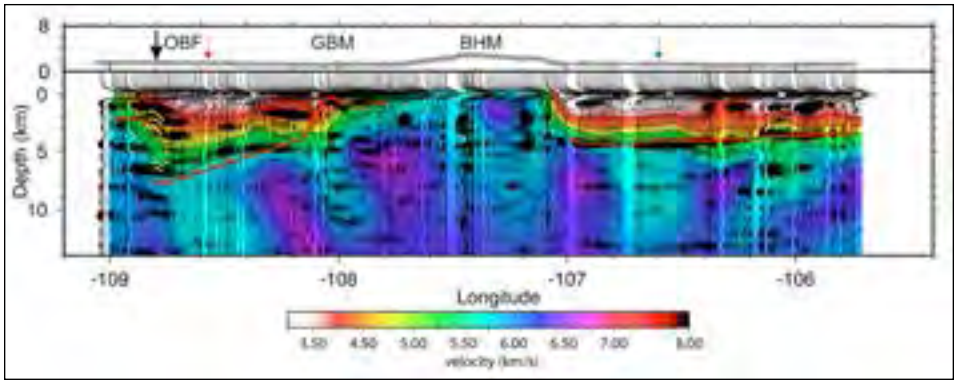
Traveling across the Alaskan Arctic tundra as part of a snow survey in April 2012

Anne Sheehan

Passive Seismic Imaging of Rocky Mountain Foreland Arches and Sedimentary Basins

Basement-involved arches—characteristic of the Laramide orogeny that formed the Rocky Mountains 60 million years ago—are uplifts of deep crystalline basement rocks, which are rocks beneath what is often several kilometers or more of sedimentary cover. They're typically flanked by deep sedimentary basins, which often host significant energy resources. A range of hypotheses for the formation of basement-involved arches predict different lower crustal and crust-mantle boundary geometries beneath foreland arches. These hypotheses and others are being tested by combining the near-surface geology of northern Wyoming's Bighorn Arch with a combined active/passive source EarthScope Flexible Array seismic experiment. The Bighorn Arch was chosen because it is minimally affected by pre- and post-Laramide tectonic events, preserving the sedimentary sequence. The sedimentary sequence gives key information on the timing and extent of deformation events. The Bighorn Arch has a relatively planar, west-dipping backlimb inclined into the Bighorn Basin and a more abrupt, east-dipping forelimb facing the Powder River Basin.

The passive seismic experiment uses naturally occurring seismic sources, such as earthquakes and ambient noise. The active-source experiment includes the use of controlled sources, 20 single-fired shots ranging from 500 to 2,000 pounds in size. The seismic experiment was a three-phase deployment with a 15-month deployment of 41 broadband seismometers; a six-month deployment of 170 three-component short-period seismometers; a four-month deployment of three five-element seismic arrays; an active-source experiment with 20 single-fired shots recorded on 1,800 geophones; and a passive-source geophone deployment with 850 geophones deployed in passive-source mode for 12 days. The combination of these approaches is being used to develop structural crustal images at high resolution at all levels of the crust.



Ongoing analysis includes the use of seismic mode-converted waves to map out subsurface interfaces such as the crust-mantle boundary. Vertical component multiply-reflected waves from distant earthquakes (teleseisms) have been used to map sedimentary basin structure. This is the first time to our knowledge that recordings of teleseisms on a dense array of industry-style geophones have been used to map sedimentary basin structure. This technique shows great promise; as passive-source seismology is applied increasingly in oil, gas, and geothermal reservoir modeling, the reverberation image method could be used to extract structural information from passive data. Ambient noise surface wave tomography analysis has been performed and provides constraints on crustal shear velocity.

The figure above shows the merging of active and passive source seismology. Teleseismic virtual source reflection (TVR) profile made from teleseisms recorded on single-component geophones, superimposed upon (color backdrop) P wave velocity tomography from active source shots. Data are from Wyoming's EarthScope Flexible Array Bighorn Arch Seismic Experiment (BASE). The west-east profile crosses the Bighorns at 44.6° N. Geophones are shown by triangles plotted at station elevation. The image is created by deconvolving the P-wave source pulse from high-frequency vertical component recordings, leaving the underside reflection from the phase PdPdp, which acts as a virtual source for subsequent P-wave reflection off crustal interfaces. The profile is made by stacking deconvolved PdPdp of three small (magnitude 5.2–5.4) teleseisms (two from Argentina, one from the Aleutians). Red lines mark the top of the Tensleep geologic formation determined from well and industry data (T. Riley, unpublished). Yellow lines are for multiple reflectors near the Oregon Basin Fault, which appear in industry seismic reflection data (Stone, 1985). (BHM, Bighorn Mountains; GBM, Greybull Monocline; OBF, Oregon Basin Fault.) This analysis illustrates the utility of using teleseisms recorded on active source geophones to determine sedimentary basin structure.

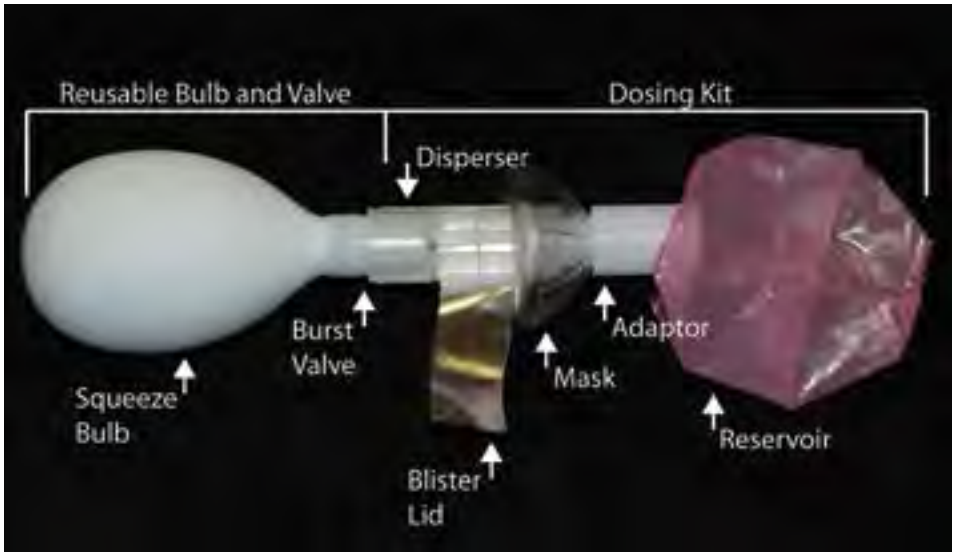
Robert Sievers

Improving Global Health Even as Climate Changes

Increased stability and safety of vaccines are goals of the CIRES team effort in Global Health. Last year the Sievers Research Group broadened the vaccines and delivery methods studied to include administration of measles, human papilloma virus, and hepatitis B vaccines by one or more of sublingual, inhalation, or subcutaneous injection, following stabilization and drying by the CIRES-patented CAN-BD (Carbon dioxide Assisted Nebulization with a Bubble Dryer) process. We have demonstrated that the measles vaccine powder formulation is stable and satisfies the World Health Organization's short-term stability requirement at 37°C. It also possesses good stability characteristics over a much longer period (less than 1 log loss of potency after about four years of storage at 2–8°C). In addition, CIRES's collaborators in Pune, India, have established room-temperature stability of our dry powder aerosol vaccine for six months.

The stabilization of the other vaccines and storage behavior are still under study. The FNIH-supported Sievers team from Aktiv-Dry LLC, CU–CIRES, the Serum Institute of India, Sristek Private Ltd., Centers for Disease Control and Prevention (CDC), Johns Hopkins University, and BD Technologies plans to continue research focused on vaccinations for children. Achievements include reformulating with myo-inositol (a newly discovered stabilizer) an existing measles vaccine as a potent live attenuated virus vaccine and developing two inhalation devices for administering the vaccine powder to children in the developing world. CIRES patent applications have been submitted. European Patent No. 1 185 248 B1, "Supercritical Fluid-Assisted Nebulization and Bubble Drying," recently was granted to Sievers, Sellers, and Carpenter, with 37 allowed claims.

The Global Health Group, under Dr. Stephen Cape's guidance, is characterizing sublingual pellets and films of dried excipient stabilizers, which are expected to dissolve rapidly in water for sublingual delivery of vaccines.



PuffHaler® dry powder inhaler invented by the CIRES Global Health Group to administer aerosol measles vaccine to human volunteers in Phase I clinical trials in India

Konrad Steffen

with graduate student Dan McGrath

Basal Crevasses on the Larsen C Ice Shelf, Antarctica

The break up of the Larsen B Ice Shelf in 2002—an event in which approximately 3,200 square kilometers of floating ice fractured and subsequently floated away from Antarctica—was a dramatic example of the rapid changes occurring on the Antarctic Peninsula (AP). This narrow and tall mountain range, with cascading glaciers toeing into the Southern Ocean, has witnessed some of the most dramatic warming of anywhere on the planet—some 2.5°C since 1950—and subsequently, some of the most significant changes. Following the collapse of the ice shelf, the outlet glaciers that previously fed it increased their flow more than four-fold, subsequently adding more than 25 cubic kilometers per year of ice to the ocean.

This research is focused on assessing the stability of the Larsen C Ice Shelf, the largest ice shelf on the AP, in the context of the observed warming climate. Four field seasons, three weather stations, too many rations of delicious British military food, and more than 1,500 kilometers of in situ ice-penetrating radar surveys have revealed some exciting and important insights to the future stability of the ice shelf. First, numerous and very large basal crevasses were found on the ice shelf—some of these crevasses extend more than 230 meters into the ice column (approximately 66 percent of total ice thickness) and extend laterally for tens of kilometers (Figure 1). Further, the ice shelf surface deforms to compensate for the reduced ice thickness, creating a perfect depression to pond meltwater. Lastly, surface crevasses subsequently form on the flanks of these depressions, in response to the increased bending/tensional stresses induced by the new geometry (Figure 2).

Together, these features represent a major structural flaw in the ice shelf, one that may play an important role in its future stability. Meltwater-driven crevasse hydrofracture, the process by which a surface crevasse can fracture down through ice, is believed to have been a major contributor to the final collapse of Larsen B in 2002. Thus, for Larsen C, basal crevasses create locations to pond meltwater, induce surface crevasses, and create a section of the ice shelf one-third of its original thickness—together, these create an environment conducive to this breakup mechanism. While Larsen C is not displaying many of the other characteristics seen as precursors to collapse, our research has revealed these large structural flaws, which have important implications for ice-shelf stability in a warming climate.

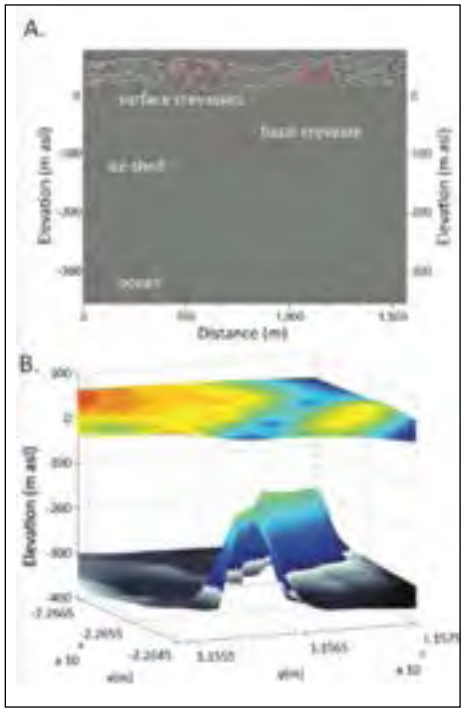


Figure 1. (a) 25-megahertz radar profile across basal and surface crevasses. Surface elevations have been corrected to reflect ice-shelf topography. Note down-warping of firn above basal crevasse and hyperbolas on the flanks, highlighted in red, interpreted as surface crevasses; (b) three-dimensional view of the basal crevasse penetrating into the ice shelf. Surface and basal interface interpolated from GPS and ground-penetrating-radar profiles, respectively.

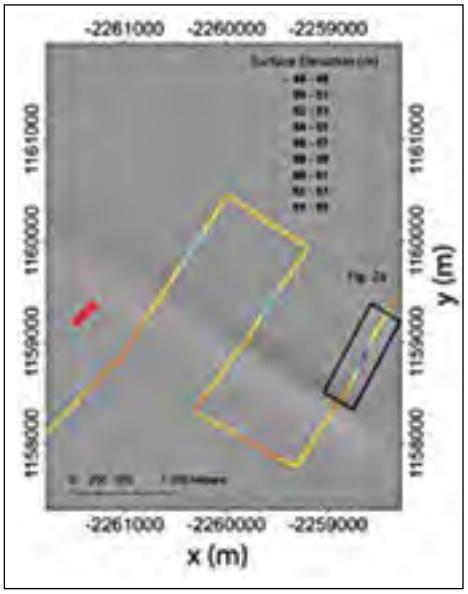


Figure 2. High-resolution (0.5-meter) visible imagery of surface depressions and surface crevasses, located on flanks of the depressions. Red arrow is aligned with flow direction and identifies bridged surface crevasses.

Margaret Tolbert

Laboratory Studies of Cirrus Clouds: Nucleation from the Inside Out

Although cirrus clouds are ever-present in the upper troposphere, the precise mechanisms governing their formation have eluded scientists for many years. The particles available for ice nucleation are complex, and ice concentrations are low (less than one in 10,000 particles nucleate ice), making direct measurements difficult. Thus, there's a high degree of uncertainty associated with the impact of cirrus clouds on global climate. Understanding the precise mechanisms governing cirrus cloud formation is critical to our understanding of how natural processes and anthropogenic activities impact cloud origination and global climate.

It has recently become apparent that ice nucleation in the atmosphere often occurs via heterogeneous nucleation. In heterogeneous nucleation, a solid particle can help the critical ice germ form at lower relative humidity levels than would be possible without the solid nucleus. Three important types of heterogeneous nucleation are illustrated schematically in Figure 1. On the left, a solid particle within a liquid droplet provides the seed for nucleation. The center illustrates contact nucleation, while the right illustrates vapor deposition on a solid particle. While known to be important, it is not clear which solid particles provide the best ice nuclei, nor is it understood which nucleation mechanisms dominate. This limits our ability to predict future cirrus cloud abundances in the atmosphere.

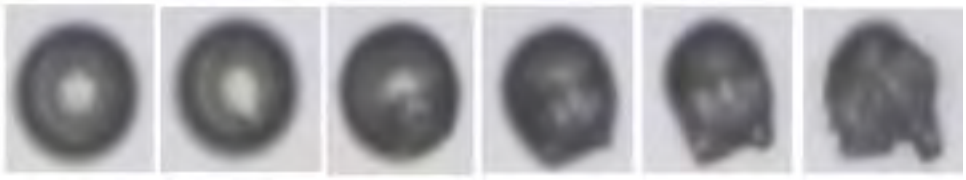


Figure 1. Schematic of different types of heterogeneous ice nucleation

We are developing new techniques for the study of heterogeneous ice nucleation in the laboratory. In our National Science Foundation project, we are using Raman microscopy to study heterogeneous ice nucleation one particle at a time. In Figure 2, we show a sequence of ice nucleation for a solid ammonium sulfate crystal coated by an organic layer (similar to Figure 1 above). Here we see ice nucleation occurring from inside the particle as water vapor diffuses through the organic to nucleate on the ammonium sulfate inside. Ongoing studies are examining other complex particle morphologies with different salts and organics.

We are also studying contact nucleation in a new project funded by a CIRES Innovative Research Project with Sara Lance at NOAA. Here we are building a new apparatus to trap single liquid aerosol particles using a Bessel beam. We then plan to study contact nucleation by passing a solid particle over the trapped particle and imaging the resulting ice formation.

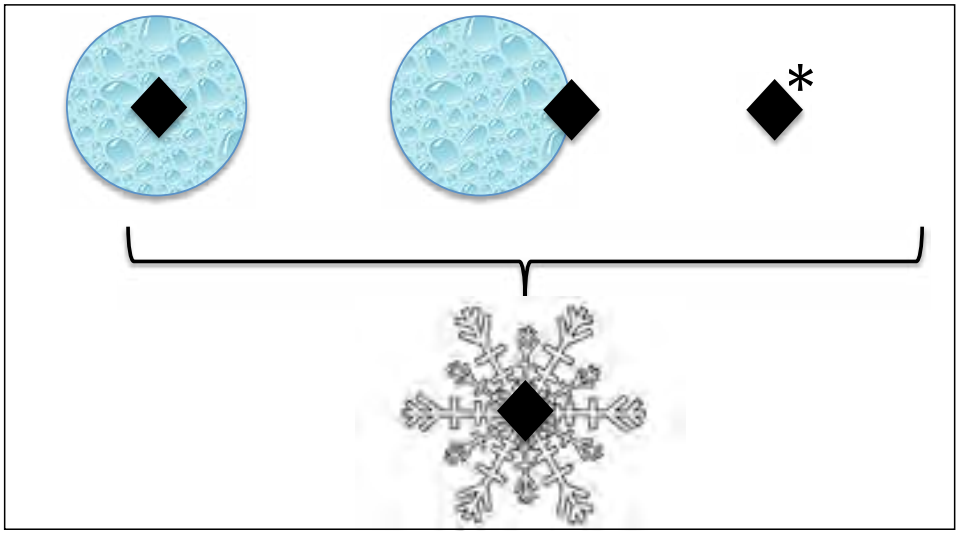


Figure 2. Ice nucleation on a solid ammonium sulfate particle coated with an organic overlayer. The beginning of ice nucleation is observed in the second panel. Ice growth continues, and the organic layer is stretched over the growing ice crystal. A complex ice crystal results and is shown in the final panel.

William Travis

Understanding Adaptation Decision Making Under Climate Uncertainty

Colleagues and I study the processes by which people make decisions in adapting to climate variability and change. With support from NOAA, the Western Water Assessment, and CIRES, we have combined several software tools into an "adaptation test bed" that allows us to test hypotheses about adaptation in modeled systems, such as agriculture and species conservation. Our main focus is on the role of extreme events; although extreme events are often seen as opportunities to advance adaptation, we found that extremes can trip premature and inefficient adaptation on a wheat farm facing a worsening climate (Figure 1).

Though the adaptation test bed is built around decision simulation models, an important aspect of our work is to balance normative, quantitative decision-analysis with qualitative, empirical studies of the choices and policy contexts faced by actual decision makers. So, recent master's graduate Kristin Gangwer interviewed ranch families in the Rockies to build a rich roster of the options, constraints, and incentives they face in adapting to drought. Their options are extraordinarily complex, including adjustments in herd size, grazing patterns across a wide range of ecological and land tenure types, technological inputs, labor, finance, and marketing. We then bring these insights to decision simulations; recent master's graduate Mary Huisenga is using a decision and risk analysis tool, Analytica, developed at Carnegie Mellon University, to simulate ranchers' decisions in the face of uncertainty about both climate and other ranchers; the analysis uses game theory to assess the likelihood that other ranchers will also cull their herds when drought lowers range productivity and raises the feed prices, thus depressing cattle prices. This study paralleled national news coverage during the summer of 2012 on how drought was forcing ranchers to sell off their herds.

One constraint on decision-making is lack of information, and we're integrating data analysis tools into the test bed to develop dashboards that can inform both researcher and decision maker. For example, we create data visualizations with Tableau, a business analytics software. Our first application of this tool was to develop drought impact dashboards with support from the National Integrated Drought Information System (NIDIS).

Another key element of adaptation science is projection into the future. As part of CU Prof. Lisa Dilling's NOAA-funded study of the interaction of drought adjustment and climate change adaptation in water management, we are developing storylines that explore the tradeoffs between adapting to the current climate and developing resilience to a range of future conditions. The work specifically challenges the notion that better adaptation today offers a "low-regret" strategy for absorbing future climate change. This bridge between current and future adaptation inevitably leads to questions about the rate and nature of climate change over time. So, the next step in our evolving adaptation test bed is to integrate future climate scenarios with impact models. We're doing this with the SimCLIM climate assessment tool developed at the University of Waikato. Our goal is not to predict the future, but to use scenarios especially to conduct failure analysis: When would the type of adaptive decisions now available to resource managers fail to counter growing negative impacts and push the system from incremental to transformative adaptation?

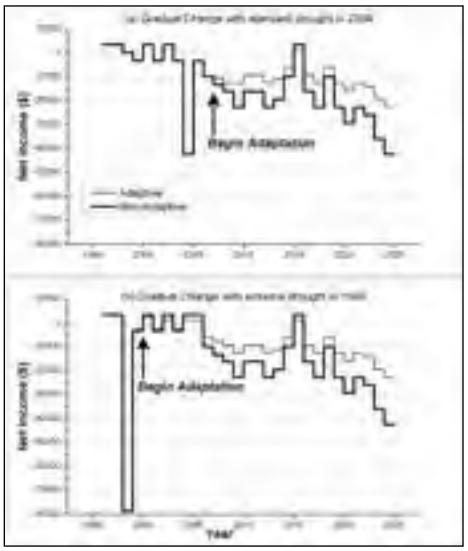


Figure 1. An extreme drought causes adoption of conservation tillage whenever it occurs, perhaps too early for it to pay off in adaptation to underlying climate change.

Greg Tucker

From Peaks to Prairie: Two Natural Experiments in Decadal Landscape Evolution

Numerical models of landscape evolution play a vital role in geomorphology, but there remains a pressing need to test these models against field data. We are developing two case studies for model-data comparison testing. The two case studies are sites of rapid decadal landscape change. The decadal scale is particularly important because: It is a critical time scale for societal adaptation to rapid environmental change; it is short enough to take advantage of historical records; and models of longer-term landscape dynamics should be consistent with shorter-term behavior.

The study pairs two very different environments: a low-relief, semi-arid, soft-rock setting dominated by rapid gully erosion and scarp retreat, and a steep, montane, forested, crystalline-rock setting responding to a 1996 wildfire. The first site, located on the high plains of eastern Colorado, provides a unique opportunity to reconstruct erosion rates and channel growth patterns over a 70-year period. The second site, in the Colorado Front Range, contains an extraordinarily rich 14-year database of post-fire geomorphic response, thanks to intensive monitoring efforts by the U.S. Geological Survey.

The project relies on a variety of methods, including aerial photo analysis, reservoir sediment volumes, 137Cs measurements, lidar DEM analysis, and oral history interviews. Modern hydrology and geomorphology are documented with a network of rain gauges and flow sensors, combined with biennial tripod-laser scans to measure rates of channel-head retreat (estimated at approximately 0.5 meters per year). The two data sets are used to test a physically based numerical model of landscape evolution using a Monte Carlo calibration method.

Francis Rengers (CU) and John Moody (USGS) at the Spring Creek, Colo., wildfire site

Left: A typical gully head near the West Bijou Escarpment. Right: Cross-sections of the gully head obtained with a ground-based laser scanner, showing morphologic change over a 14-month period

Veronica Vaida

Light- and Water-Mediated Chemistry in Earth's Atmosphere

Our program explores water- and sunlight-mediated processes in planetary atmospheres including the contemporary and prebiotic Earth. My approach uses fundamental chemical physics to address complex problems where atmospheric measurements and models disagree, aiming to provide new inputs for models of atmospheric chemistry and climate.

In response to observations of high radical concentrations with the Sun near the horizon, our group—using red-light-initiated photochemistry in our lab and through collaborations with NOAA and environmental chamber studies—pointed to the role of water in catalysis and/or suppression of atmospheric reactions. This chemistry resulted in mechanisms connecting volatile organic compounds to aerosol nucleation and growth.

Properties of atmospheric aerosols are highly nonlinear, resulting in uncomfortably large uncertainties in aerosol effects on climate. Inspired by atmospheric measurements, which established that aerosols have a large organic content, we proposed that a significant population of organic aerosols consists of an aqueous core with an organic surface film and pointed to the profound consequences to their morphology and optical and chemical properties. Our research group investigates the fundamental physical chemistry of interfacial organic films and, using theoretical models, explores the consequences of these results to environmental water.

To bring this research to a broader community, I have included environmental chemistry topics in teaching chemistry at all levels. Simultaneously, I developed lectures, which have been delivered to public and academic audiences nationwide during my tenure as Sigma Xi Distinguished Lecturer. Recent research collaborations and student exchanges developed abroad include Canada (University of Toronto), Brazil, France, and Romania (University Babes-Bolyai).

Photo courtesy of Veronica Vaida

The Vaida group with Professor Jean-François Doussin and the environmental chamber at Université Paris Est, LISA, France

Rainer Volkamer

The TORERO Project (Tropical Ocean tRoposphere Exchange of Reactive halogens and Oxygenated voc)

Oceans cover 70 percent of Earth's surface, yet the open ocean marine atmosphere is one of the most poorly probed atmospheric environments of our planet. Reactive halogen species and organic carbon sources from the ocean are important in the atmosphere because they modify HOx radical abundances, influence the reactive chemistry and lifetime of climate active gases (e.g., ozone, methane, dimethyl sulfide), and affect the atmospheric reaction cycles of mercury.

The Tropical Ocean tRoposphere Exchange of Reactive halogens and Oxygenated voc (TORERO) Project was conducted from Jan. 19, 2012, until Feb. 29, 2012, to investigate the role of reactive halogens, like bromine and iodine oxide radicals, as well as short-lived oxygenated hydrocarbons on the oxidative capacity of the tropical free troposphere. Figure 1 shows recent first measurements of iodine oxide (IO) radicals and glyoxal (CHOCHO) in the tropical free troposphere over the central Pacific Ocean by means of the University of Colorado Airborne MAX-DOAS (Multi AXis Differential Optical Absorption Spectroscopy). The presence of IO is relevant in the free troposphere because it destroys heat-trapping ozone and modifies the abundance of OH and bromine radicals.

The TORERO mission conducted 17 research flights aboard the NSF/NCAR GV aircraft in early 2012 over the eastern tropical Pacific Ocean. TORERO comprises collaborators from 15 institutions in five countries, including CIRES collaborators in the Earth System Research Laboratory's Physical Sciences Division and Chemical Sciences Division. The project was conceived, initiated, and is coordinated by Prof. Volkamer at CIRES/CU Boulder.

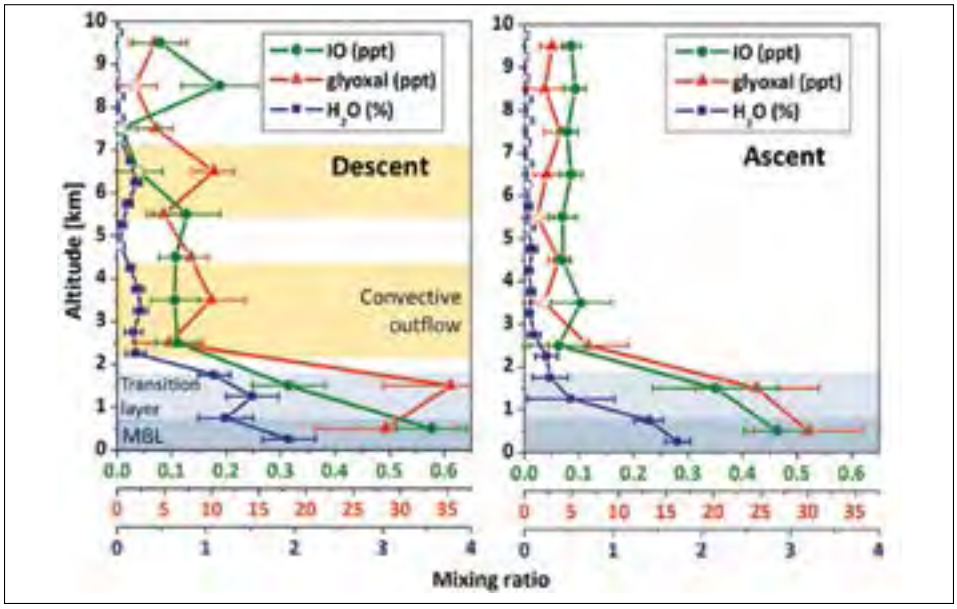


Figure 1. Vertical profiles of iodine oxide (IO) and glyoxal (CHOCHO) over the Central Pacific Ocean

Michael Lechner

Participants during the 2nd TORERO Science Team meeting hosted at CIRES from July 23–25, 2012

Tingjun Zhang

Degrading Permafrost on the Qinghai-Xizang (Tibet) Plateau

The Qinghai-Xizang (Tibet) Plateau has an average elevation of greater than 4,000 meters above sea level (a.s.l.) and is known as "The Roof of the World." As a result, permafrost is well-developed over the majority of the plateau's area. Due to the impacts of climate warming and human activities, such as the newly constructed Qinghai-Tibet Railroad, permafrost on the plateau is experiencing significant warming and degradation during the past few decades. Changes in permafrost conditions would have dramatic impact on local and regional ecosystems, hydrological and carbon cycles, landscape, and, importantly, engineering infrastructure. In collaboration with Professor Qingbai Wu and his colleagues from the Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, we established in the past few years a long-term permafrost-monitoring network, which is still expanding, along the Qinghai-Xizang (Tibet) Railroad.

The preliminary results indicate that among the 28 monitoring sites along the network, average active-layer thickness is about 3.1 meters with a range from about 1.2 meters to 4.9 meters. From 2006 through 2010, active-layer thickness has increased at a rate of about 6.3 centimeters per year. Permafrost temperature at the depth of zero amplitude (i.e., mean annual ground temperature, MAGT) ranges from about minus 3.0°C to minus 0.1°C (Figure 1). Although permafrost along the network is relatively warm, permafrost temperature at the depth of zero amplitude is increasing at a rate of about 0.01°C per year over the past five years. The magnitude of permafrost-temperature increase is greater for relatively colder perma¬frost (MAGT of less than minus 1.0°C) than for relatively warm permafrost (MAGT less than minus 1.0°C). This is consistent with observations in the Arctic, primarily due to the effect of latent heat as unfrozen water content increases with permafrost temperature increase. This permafrost monitoring will continue for the next 10 years.

Figure 1: (a) Site elevation; (b) mean annual ground temperature (MAGT) at depth of zero amplitude; and (c) active layer thickness (ALT) along the Qinghai-Xizang (Tibet) Railroad.

CIRES Centers

The Centers within the CIRES enterprise provide the functional link between NOAA and 11 different departments at the University of Colorado Boulder. The goal is that the Centers provide an environment to develop collaboration and facilitate partnerships between federal and academic entities.

The **Center for Limnology** makes ecologically oriented studies of inland waters: lakes, streams, and wetlands. The staff and students of the Center for Limnology during 2011 worked on several projects related to Colorado lakes and streams.

Graduate student Thomas Detmer and Center Associate Director James McCutchan extended their studies of the effects of fish on aquatic communities in the lakes of Rocky Mountain National Park. Prior to the mid-19th century, many lakes in the Colorado Rockies lacked fish entirely. The popularity of fishing for trout at high elevation led the State of Colorado, like many other states, to conduct extensive stocking of fishless lakes, first by carrying young fish in milk cans by mule train to remote lakes and, in later years, by stocking lakes by airplane. Stocking continues today.

Detmer's fieldwork on several of the mountain lakes during 2011 turned up a surprising result. It has been known for some time that the presence of fish reduces the average size of invertebrates because the fish prefer larger prey and even eliminate some of the larger classes of invertebrates through this preference. It has been postulated that a byproduct of this community shift is reduced production of invertebrates in lakes that have fish. Detmer's data show that the removal of larger prey does, indeed, occur but is accompanied by an increase in the ratio of production (growth) to biomass because smaller invertebrates grow more rapidly than larger ones. The higher production per unit biomass compensates for the reduction in biomass caused by the loss of larger prey. Thus, the ecosystem conserves production, even as it shifts in composition. This is a new example of ecosystem homeostasis as a byproduct of the interaction between fish and invertebrates (Figure 1).

Under the leadership of James McCutchan, the Center also worked on Grand Lake during the summer. This lake, which is the largest and deepest natural lake in Colorado, has been the subject of great controversy. The Alva Adams Tunnel, which was completed in 1947, draws water from Grand Lake and sends it through the continental divide to the East Slope where it provides water for domestic and agricultural use to supplement the natural supplies on the East Slope. Water withdrawn from Grand Lake is replaced by water from two reservoirs, Shadow Mountain and Granby. Since this practice began, the transparency of Grand Lake has been notably lower than it was previously. A documented connection between the pumping operations and the transparency of the lake has been missing, however.

A collaboration between the Northwest Colorado Water Conservancy District and Grand County has produced a water quality study program operated by the Center for Limnology. The first months of fieldwork produced a surprising map of the distribution of fine sediments in Shadow Mountain Reservoir, which is a direct water supply for Grand Lake. The initial hypothesis was that Shadow Mountain Reservoir, which is shallow, shows wind-generated suspension of fine sediment that then affects the transport of fine sediment to Grand Lake. Sediment mapping, however, showed that the highest concentrations of fine sediment are located in the center of Shadow Mountain Reservoir rather than around the edges (Figure 2). The distribution pattern, when followed to the water source for Shadow Mountain Reservoir, implicates the Upper Colorado River as the main supply of fine sediment to Shadow Mountain Reservoir and conpresumably to Grand Lake. This preliminary result raises several questions yet to be answered. First, does the sediment transferred from the Colorado River to Shadow Mountain Reservoir account quantitatively for the amount of sediment transferred to Grand Lake? In addition, is the sediment load of the Colorado River natural, i.e., susceptible to geologic and hydrologic explanations, or is it somehow augmented by disturbances

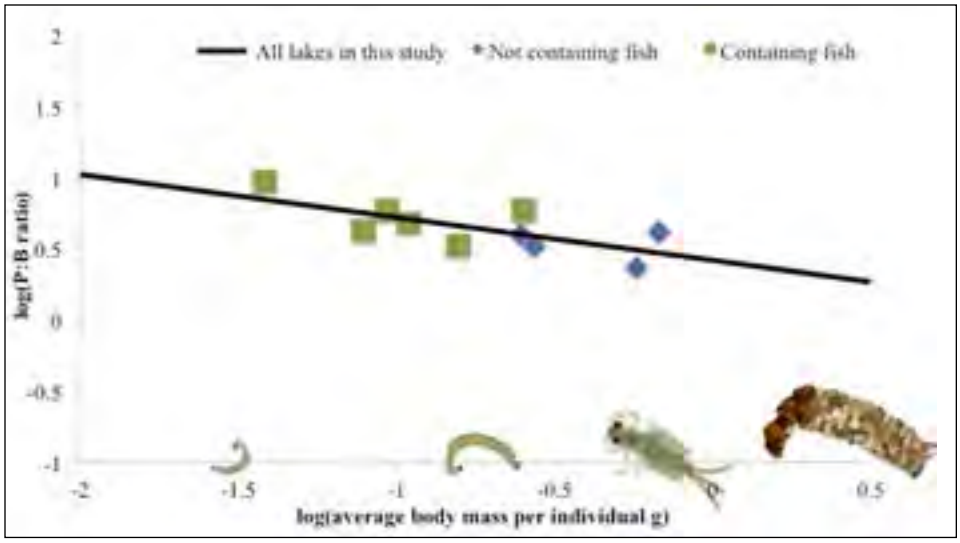


Figure 1. Production to biomass ratio (P:B ratio) as a function of average body size for all Rocky Mountain National Park lakes containing and not containing fish. The decrease in body size caused by fish is related to the increase in P:B ratio.

upstream? These questions will be answered by further study.

A third study conducted by the Center for Limnology in 2011 was of the mixing of a domestic effluent with a river. In some cases, the junction of an effluent discharge with a receiving water leads to nearly instantaneous mixing. In other cases, however, the effluent source is much smaller in volume than the receiving water. A plume then develops below the point of discharge. The plume shows gradual downstream mixing with the receiving water until mixing is complete. The mixing process may take tens of meters or even several kilometers, depending on the circumstances.

A Center for Limnology field study in 2011 quantified the mixing of a permitted effluent discharge from the Pueblo Wastewater Treatment Facility to the Arkansas River. The State of Colorado, through a mixing zone policy, allows a certain area (regulatory mixing zone) for mixing to occur. If full mixing does not occur within that area, the limits for regulated substances in the effluent are reduced in order to compensate for the lack of complete mixing.

The field study involved use of rhodamine dye to determine the size and shape of the physical mixing zone for effluent entering at time of low flow, when mixing conditions are least advantageous. There was a plume, as expected (Figure 3), and expansion of the plume occurred over a distance of approximately 1,200 meters below the location of the effluent discharge. The size of the mixing zone was determined by the width of the channel, as specified by the State of Colorado. At the bottom of the regulatory mixing zone, rhodamine dye had mixed completely over the cross section and volume of the Arkansas River. Therefore, in this case the discharge permit limits were not affected by a mixing zone restriction because the regulatory mixing zone was large enough to allow full mixing of the effluent plume with the river. In other cases, the reverse might be true.

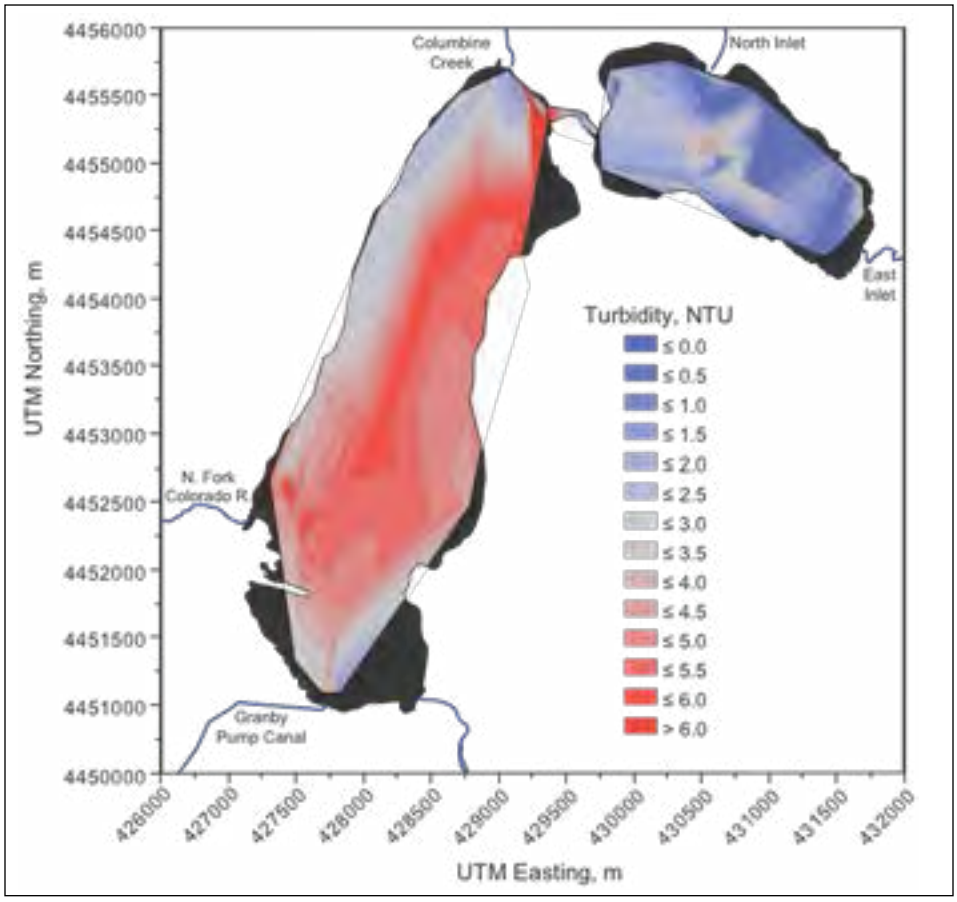


Figure 2. Contour plot of turbidity (particles) in Shadow Mountain Reservoir and Grand Lake, June 2012

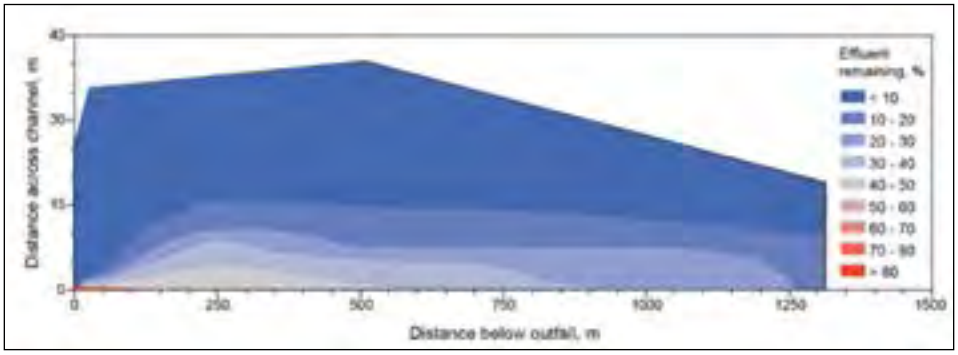


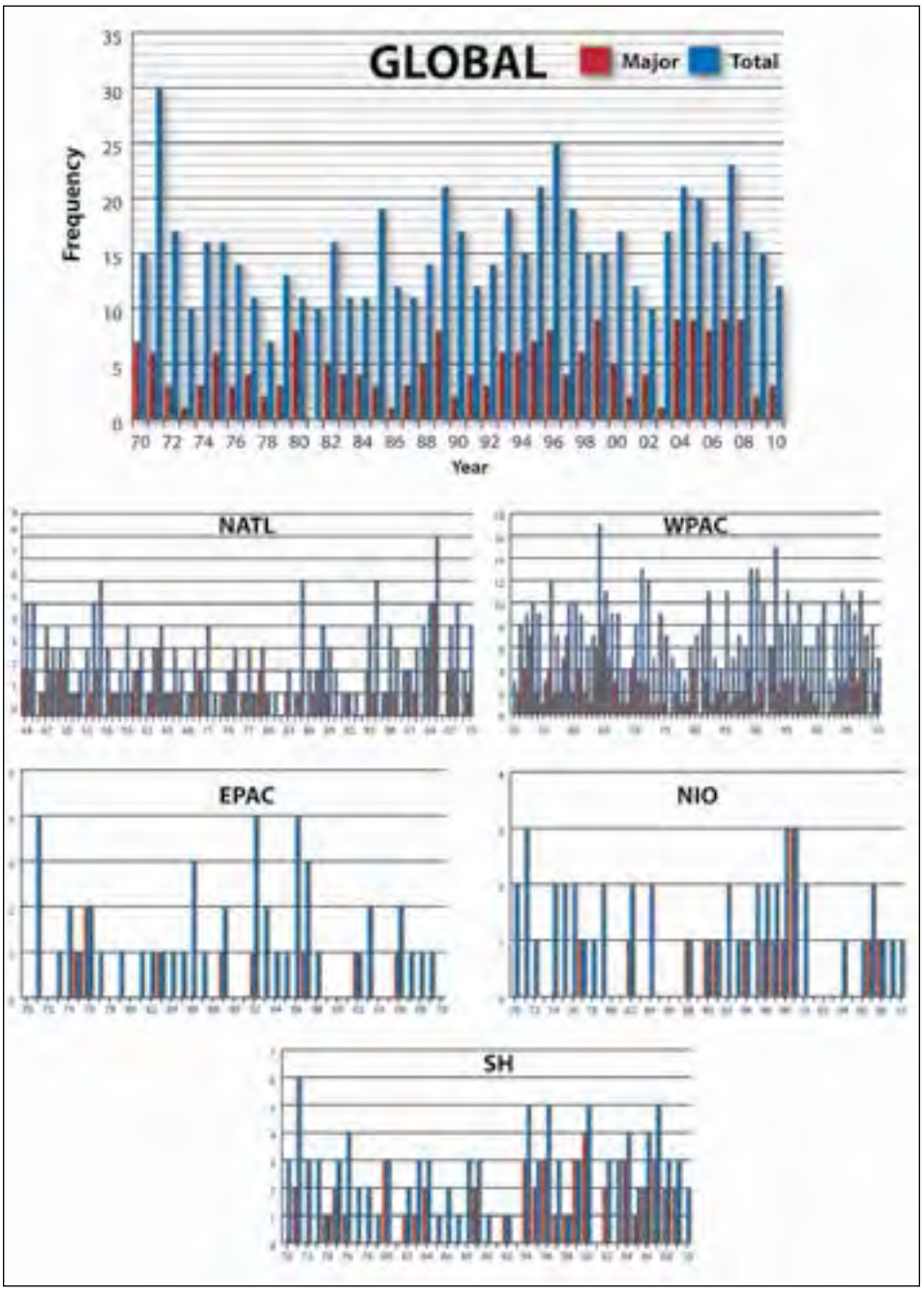
Figure 3. Contour map of a mixing zone in the Arkansas River as determined with rhodamine dye

A policy center discussion with U.S. Congressman Jared Polis about decision making in Washington, D.C.

The **Center for Science and Technology Policy Research (CSTPR)** was established within CIRES in 2001 to conduct research, education, and outreach at the interface of science, technology, and the needs of decision makers in public and private settings. The Center focuses on the intersection of the environment and society, applying the social and policy sciences to problems of environmental change, management, and sustainability. The Center's research is integrated with the ongoing activities of CIRES, NOAA, CU-Boulder, and the broader science and technology community.

Much of our work poses questions about how people and institutions make decisions under uncertainty; how perception and technical information influence choices; and how, over time, those choices affect the co-evolution of science, technology, and policy. Outcomes of particular interest to Center faculty include trends in natural disaster losses and their underlying causes; factors affecting the supply and demand of climate science; trends in media coverage of climate change; and ethics and trends in environmental management and policy, including efforts to limit greenhouse gases in the atmosphere, manage natural hazards, and adapt to environmental change.

Current projects include decision modeling that is testing hypotheses about whether extreme events might act as pacemakers of adaptation to underlying trends such as climate change in farming, flood management, and other climate-sensitive sectors; a study of how drought policies interact with both short-term drought and long-term climate change; an investigation of why some local decision makers choose to adapt to climate-related stress and risk while others do not; and a look at analogs from other areas of research to understand under what circumstances we might want to apply extra scrutiny to proposed geo-engineering research and



Weinkle, Maue, and Pielke, Jr., 2012, Historical global tropical cyclone landfalls, *Journal of Climate*

Global and basin hurricane landfall annual frequencies of storms of major (red) and both major and minor (blue) hurricane intensity at landfall for North Atlantic (NATL), North Eastern Pacific (EPAC), Western North Pacific (WPAC), Northern Indian Ocean (NIO), and the Southern Hemisphere (SH) regions

for what reasons. Our work is reported via research articles, books, reports, and several outreach methods, including a regular newsletter, briefings for decision makers, faculty blogs, news media, and frequent seminars and workshops.

Recent highlights include completion of the five-year NSF "SPARC" (Science Policy Assessment and Research on Climate) project which resulted in more than 11 master's theses, dissertations, as well as 200 mostly peer-reviewed publications; numerous workshops that have directly engaged science policy practitioners from around the world and have advanced SPARC's goal of a highly integrated research and outreach agenda; and publication of a handbook on usable science written for practitioners that summarized SPARC research findings and was widely distributed across the community. Other highlights include publication of Max Boykoff's new book *Who Speaks for the Climate? Making Sense of Mass Media Reporting on Climate Change*, which analyzes media reporting on climate change; a completed Ph.D. thesis examining whether an anthropogenic climate change signal can be identified in natural disaster loss trends; research publications about the history of building damage and loss of life due to bushfire in Australia since 1925 and about how public-lands decision makers are incorporating climate change into their decisions about forests, biofuels, and grazing; and a special journal issue on reconciling the supply of and demand for research in the science of science and innovation policy.

Our work is reported via research articles, books, reports, and several outreach methods, including a regular newsletter, briefings for decision makers, faculty blogs, news media, and frequent seminars and workshops.

The mission of the **Climate Diagnostics Center (CDC)** is to improve our understanding of global climate interactions to improve regional climate predictions, and to train the next generation of climate scientists in advanced climate system diagnosis and prediction. CDC's goal is to establish the causes of regional climate variations around the globe on time scales of weeks to millennia, by 1) developing and applying new diagnostic techniques to global observations and model simulations; 2) developing new observational data sets and performing new climate model integrations as needed for this purpose; and 3) developing new techniques to diagnose and reduce climate model errors.

Research disciplines include but are not limited to the atmospheric sciences, oceanography, stochastic dynamics and physics, remote sensing, numerical computational methods, computer sciences, data management, and complex dynamical systems analysis. An integration of these disciplines is required to transfer improvements in the understanding of climate processes to improvements in the models and methods used for climate predictions.

In 2011–2012, CDC published 26 peer-reviewed papers on topics that included:

• The Twentieth Century Reanalysis (20CR) project, a major international effort led by CDC and NOAA to produce a comprehensive global atmospheric circulation data set spanning the period 1871 to the present, and using it to assess changes in worldwide storminess since 1871.

• Demonstrating the critical influence of the pattern of tropical oceanic warming trends on climate trends around the globe, and also the inability of the models used in the 2007 IPCC report to represent both the amplitude and spatial structure of such trends over the second half of the 20th century.

• Developing an empirical model of tropical ocean dynamics and using it to diagnose the significance of 20th-century changes in tropical sea surface temperatures (SSTs).

• Constraining estimates of global climate sensitivity to increases of greenhouse gas by giving relatively greater weights to a subset of climate models that are better at simulating the 20th-century climate.

• Distinguishing natural and anthropogenic decadal climate variability and predictability.

• Explicitly accounting for clouds in atmospheric data assimilation.

• Recent developments in the understanding and predictability of the South American monsoon system.

• Assessing the prospects for improving subseasonal predictions in the tropics and the northern hemisphere.

• Using high-resolution regional models to assess potential changes in hail and flood risk over the Colorado mountains.

Additionally, CDC continued the development of several observational and atmospheric circulation data sets and forecast products, and provided scientific input to international programs, including:

• Making the 20CR data set for 1871 to the present widely available through a web interface (http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_Rean.html). The data set is currently being extended further back to 1851 through a DOE-sponsored project.

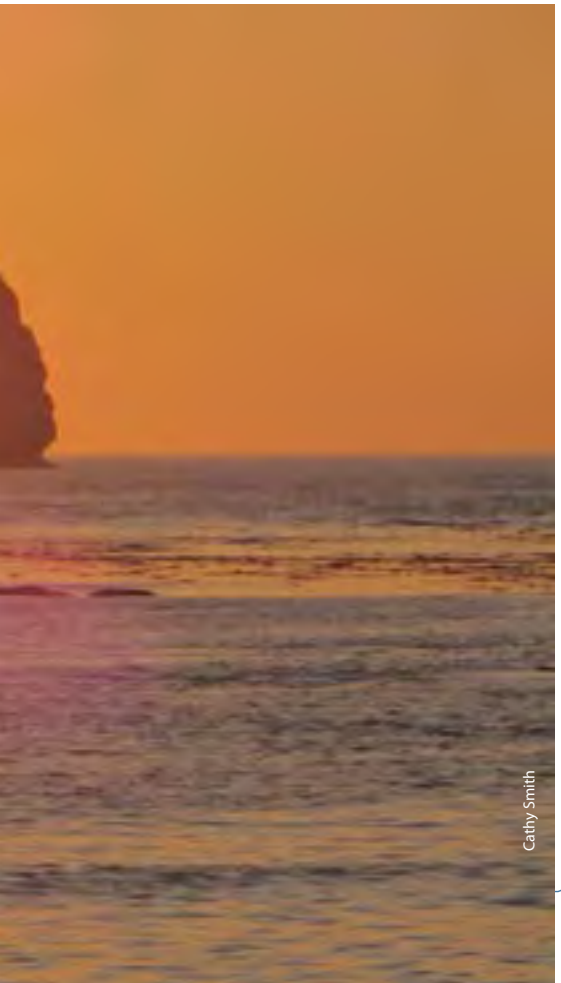
• Providing leadership in the international Global Climate Observing System Surface-Pressure Working Group, to promote the development of long-term, high-quality surface-

pressure data sets.

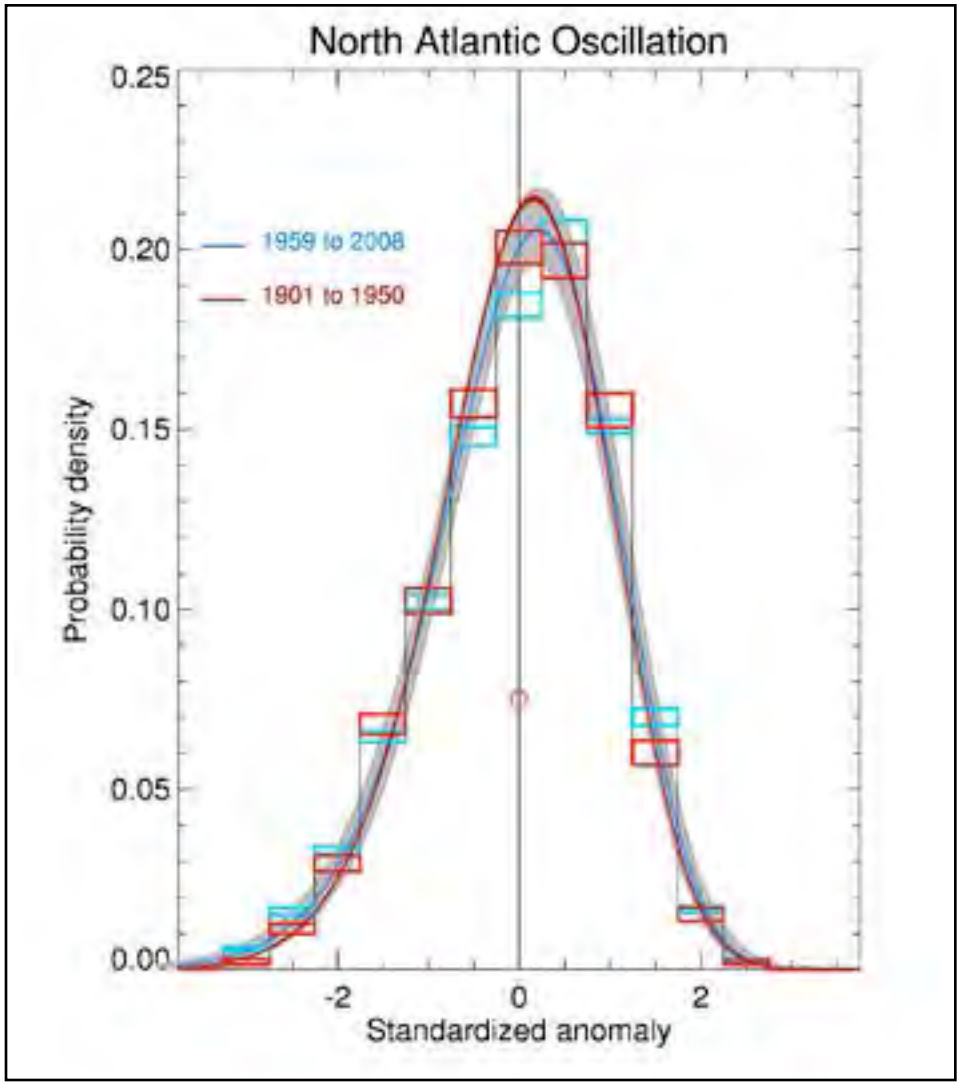
• Providing leadership in the U.S. CLIVAR Working Group on Decadal Predictability.

• Developing and releasing a new experimental forecast product (jointly with NOAA ESRL's Physical Sciences Division) for subseasonal tropical forecasts based on a coupled linear inverse model of weekly tropical SSTs and outgoing longwave radiation variations. More: see http://www.cdc.noaa.gov/forecasts/clim/.

The completion, publication, and worldwide distribution of the 20CR data set are major contributions. The data set has already proven to be a valuable resource to the climate research community for climate model validations and diagnostic studies. The journal article describing its development and main features has already been cited more than 70 times in the first year since publication, which is likely an all-time record for a CIRES–NOAA contribution. Some surprising aspects of the data set are already evident. For instance, the long-term trends of indices representing the North Atlantic Oscillation and the tropical Pacific Walker Circulation are weak or non-existent over the full period of record (1871 to the present). Indeed a rigorous analysis reveals no statistically significant differences between the (generally skewed and heavy-tailed) probability distribution functions of the daily values of these indices between the first and second halves of the record. These results have important implications for how global warming is influencing atmospheric circulation variability, and to what extent climate models are representing (or misrepresenting) those influences.



Cathy Smith



Probability Density Functions (PDFs) of standardized daily anomalies of the North Atlantic Oscillation (NAO) index in northern winter, based on the sea level pressure difference between Azores and Iceland. The PDFs are estimated for two 50-year periods, 1901 to 1950 (red) and 1959 to 2008 (blue), both as raw histograms (rectangles) and continuous PDFs (curves) belonging to a class of skewed and heavy-tailed PDFs identified by Sardeshmukh and Sura (*J. Climate,* 2009) as being especially relevant in the atmosphere. The results are derived using each one of the 56 members of the 20th Century Reanalysis ensemble (Compo et al, 2011) as a possible realization of the atmosphere within observational error bounds. There are actually 56 red and 56 blue curves in the plot, obtained from each of these 56 possible realizations, and the red and blue rectangles actually show the range of counts obtained in each anomaly size bin. The gray swath indicates 95% confidence intervals on the PDFs associated with estimating them from limited 50-year records. Thus, the spread among the red and blue curves and boxes indicates observational uncertainty, whereas the gray swath indicates sampling uncertainty. The figure shows there is not only no difference in the mean of the NAO index in the first and second periods (indicated by the completely overlapping red and blue circles at the center of the plot), but also that there is no statistically significant difference in the entire PDF.

CIRES Centers

The **Earth Science and Observation Center (ESOC)** provides a focus for the development and application of modern remote-sensing techniques used in the research of all aspects of Earth sciences at CU-Boulder. Our aim is to work on all scales of problems, from technique development in small test sites to understanding pattern and process on regional and global scales. A long-term goal of ESOC research is to investigate problems in global geosciences—questions of global change, in particular—through remote-sensing observations. ESOC had seven faculty associates during FY12, 20 graduate students, eight postdocs, and four visiting fellows. Below, ESOC accomplishments and activities are summarized by topic.

Cryospheric change

We continued to monitor the climate on the Greenland Ice Sheet using 15 automatic weather stations, including two permanent research sites at the ice sheet interior. This data set is the longest in situ meteorological time series capturing the recent climate warming in the ice sheet. Other activities within ESOC's cryospheric-change research group include the development of an ice model to study the englacial effect of meltwater, the development of a glacio-hydrological model, and the study of a moulin system in the ablation region close to Swiss Camp. In the Southern Hemisphere this year, we concluded our NSF International Polar Year project on the Larsen C ice shelf on the Antarctic Peninsula. We completed 1,400 kilometers of radar surveys on the ice shelf, focusing on important structural features, including basal crevasses and marine flow bands. Ongoing research is focused on integrating in situ observations from the past four years with a broader remote-sensing effort.

This year we also developed a novel application of the Gravity Recovery And Climate Experiment (GRACE) satellite data to determine the spatial distribution of mass changes on the Greenland ice sheet. Movement of terrestrial-based ice into the ocean creates changes in Earth's gravity field that are detected by the GRACE mission but with spatial resolution that is too coarse for direct comparisons to changes assessed by other methods such as altimetry. We have been developing an inverse statistical approach to infer the most likely pattern of ice-sheet mass change that is responsible for the cryosphere-attributed mass change fields isolated from satellite gravimetry. By constraining the inferred mass changes to only occur within irregularly shaped ice-covered areas, this inverse statistical approach moves us one step closer to being able to directly compare gravimetry and altimetry observations and surface balance models. Higher performance computing resources for this project are being provided by the Janus supercomputer at the University of Colorado Boulder.

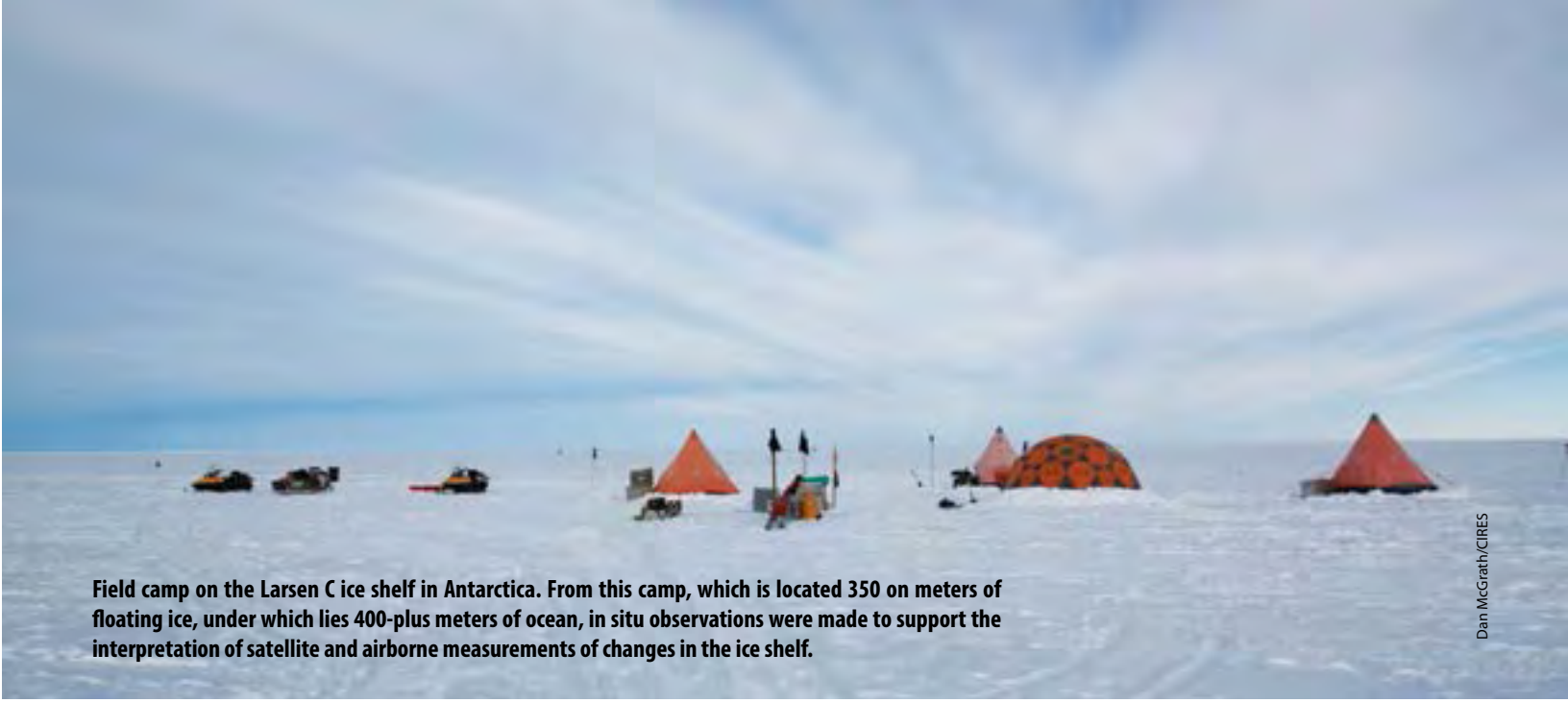
Ecology

In 2011, we initiated a cross-disciplinary project with colleagues in CIRES at WWA in an effort to use a suite of modeling and field work techniques to better understand drivers of snow accumulation and melt in the Upper Colorado River Basin (UCRB). The overall aim of the project is to improve NOAA NWS Colorado Basin River Forecast Center forecasts, if possible. Water managers in the Intermountain West rely on streamflow forecasts to plan reservoir operations in any given year. Unfortunately, recent forecasts in the UCRB, especially for peak flow and daily flow, have shown greater-than-normal errors, posing significant challenges to water managers. These forecast errors may be related to unusual spatio-temporal patterns of snow water equivalent (SWE), which researchers only recently have begun to model in any detail. Snowpack perturbations (e.g., regional warming, dust radiative forcing, and forest cover changes associated with fire and mountain pine beetle infestation) add an additional layer of complexity and are a potential source of error in water supply forecasting. This year, time series of Moderate-Resolution Imaging Spectroradiometer phenology metrics and leaf area index (LAI) were completed and assessed for eventual incorporation in the hydrology model. 2002–2010 trends in both mean and max summer LAI were correlated with increasing density of insect mortality. Distribution of forests experiencing declining LAI was spatially coherent with areas of cumulative mortality from beetle infestation. Interestingly, areas mainly experiencing insect kill early in the decade (2002–2004) appeared to be on the road to recovery (in terms of LAI). The phenology relationship with beetle kill was also significant but with less predictive power; the best relationship was found between the large integral of yearly Normalized Difference Vegetation Index and insect mortality.

We also began an NSF-funded project aimed to improve understanding of the potential effects and consequences of multiple disturbances on carbon sequestration in forests. This research takes advantage of a complex of four disturbance events in a Colorado subalpine forest (wind, logging, beetles, and fire; Routt National Forest) to evaluate impacts of disturbances, singularly and in combination, on carbon sequestration. The two primary components are: (1) field research and laboratory analysis that collect the data necessary for modeling carbon stocks, and (2) simulation of carbon stocks using an individual tree growth model (USFS Forest Vegetation Simulator). The first field season (summer 2011) was completed as proposed, and early modeling was initiated.

Atmospheric lidar development and application

The polar middle and upper atmosphere provides a unique natural laboratory for studying the complex physical, chemical, and dynamical processes in Earth's atmosphere and space environment. However, this region remains one of the least understood regions of the atmosphere. In particular, very little is known about the neutral atmosphere in the altitude range of 100 to 200 kilometers because obser-



Field camp on the Larsen C ice shelf in Antarctica. From this camp, which is located 350 on meters of floating ice, under which lies 400-plus meters of ocean, in situ observations were made to support the interpretation of satellite and airborne measurements of changes in the ice shelf.

Dan McGrath/CIRES

vations are extremely difficult to make. The first lidar discovery of neutral iron (Fe) layers with gravity wave signatures in the thermosphere up to 155 kilometers, made by the Chu Research Group at McMurdo, Antarctica, is a breakthrough in the upper atmosphere research. Not only is this the first time for a single instrument to trace gravity waves from 30 to 155 kilometers, but also it enables the first direct measurements of neutral temperatures deep into the E-region, revealing the neutral-ion coupling and aurora-enhanced Joule heating. The new observations of Fe, neutral temperatures, and gravity waves up to 155 kilometers have opened the door to exploring the neutral polar thermosphere with ground-based instruments.

Such a discovery is only a small portion of the rich data sets collected by the lidar team at McMurdo. Many more findings have emerged from the data, e.g., the solar effects in the diurnal variations of mesospheric Fe layers, the frequent occurrence of large-amplitude inertia-gravity waves in the mesosphere and lower thermosphere, and extreme events of summer Fe layers and polar mesospheric clouds, etc.

Water cycle and climate processes

The Climate Processes Research Group in ESOC has developed and maintained state-of-the-art measurements and models to evaluate the way in which changes in climate modify, and are linked to, water and carbon cycles. Locally, we continue to make measurements at the 300-meter-tall tower at the Boulder Atmospheric Observatory of the transport of water from the land surface to the atmosphere to air in order to improve models of the atmospheric boundary layer and surface processes. During 2011 measurements were made from the NCAR C130 research aircraft to evaluate the Colorado snow cloud formation and how water is exchanged between the Colorado land surface and the overlying atmosphere. This study complemented a study from the previous year based on the Caribbean and Hawaii regions where profiles of water vapor, temperature aerosols, and the isotopic composition of water vapor were used to investigate boundary layer exchanges, to test theories, and improve climate models.

In the Colorado Rockies we have established a new instrument platform at the Niwot Ridge Long Term Ecological research station to measure the isotopic composition of water and water vapor though the alpine forested canopy to test the way in which the alpine ecosystems used water that is scarcely available. The 2011 growing season was particularly productive due to high wintertime snow pack, providing a strong contrast to the summer of 2012, which followed a winter with very little snow. These contrasts allow the sensitivity of ecosystems to changes in the hydro climate of the region to be assessed. The use of isotopic information allows the water that falls as snow or summertime rain to be differentiated and tracked through plants to evaluate how the ecosystems of Colorado and other locations use water under changing climate.

In polar regions, we use a suite of advanced meteorological sensors installed at Summit station to understand the water balance of the Greenland ice sheet. We use laser-based spectroscopic analyzers to measure the isotopic composition of water vapor and snow. This study is critical to interpret the history of the hydrologic balance of ice sheets and evaluate the mechanisms responsible for imprinting signatures of climate change in ice cores. These studies complement modeling work with global-scale models that seek to evaluate the connectivity among oceanic areas, land areas, and the polar regions that are separated by space and differ by the various types of atmospheric and land processes that dominate in each region.

Satellite and aircraft missions

We continue to play an important role for NASA's Ice Cloud and land Elevation Satellite-2 (ICESat-2) laser altimetry mission, planned for launch in 2016. We are members of the science team, defining mission requirements that will drive ICESat-2's capabilities in measuring ice sheets, sea ice, and vegetation, and provide input to NASA and the ICESat-2 project on scientific matters. We are actively involved in the planning of NASA's IceBridge aircraft mission to survey the Arctic and Antarctic land and sea-ice cover, providing scientific and technical guidance on measurement approaches and priorities. We work extensively with data from NASA's GRACE mission; the Total Emission Spectrometer (TES) on the Aura Spacecraft; and MODIS. This year, we continued our work (begun last year) in detection of potential geothermal heat sources using high-resolution thermal infrared data from Landsat, MODIS, and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer). We partnered with Flint Geothermal, LLC, on a $5 million grant, and the second phase of the project, identification of sites for drilling, is underway.

CIRES Centers

The mission of the **National Snow and Ice Data Center (NSIDC)** is to advance understanding of Earth's frozen realms: the floating sea ice cover, lake ice, glaciers, ice sheets, snow cover, and frozen ground, collectively known as the cryosphere. NSIDC advances its mission through:

- Managing, distributing, and stewarding cryospheric and related data from Earth orbiting satellites, aircraft missions, and surface observations;
- Researching major elements of the cryosphere, increasingly focused on understanding how and why the cryosphere is changing and the implications of these changes;
- Conducting informatics research to find better ways to discover, integrate, and distill the vast and growing volume of cryospheric and climate data;
- Educating the public about the cryosphere, the changes that are being observed, and their implications.

NSIDC makes hundreds of scientific data sets accessible to researchers worldwide. Our data management practices ensure the physical and scientific integrity of the data we manage and disseminate. We manage data under sponsorship from NASA, NOAA, and the National Science Foundation.

Major areas of research at NSIDC include processes driving the downward trend in Arctic sea ice extent;

- Environmental impacts of this sea ice loss both within and beyond the Arctic;
- The behavior of the Greenland and Antarctic ice sheets and Himalayan glaciers and their contributions to sea level rise;
- Links between snowfall, temperature, and streamflow; and
- The implications of changes in Earth's permafrost.

Informatics research includes:

- Developing alternative database structures to search vast data volumes to answer science questions;
- Developing technologies to make NSIDC data more visible to more researchers; and
- Enhancing data discovery through semantic interoperability.

NSIDC's education and outreach efforts are wide-ranging. NSIDC scientists are in high demand by the media to lend their expertise on environmental issues involving cryospheric change. Arctic Sea Ice News and Analysis (http://nsidc.org/arcticseaicenews/index.html) provides daily updates of Arctic sea ice extent, along with scientific analysis of evolving conditions that is both accurate and accessible to a wide audience. The NSIDC "About the Cryosphere" site (http://nsidc.org/cryosphere/) provides a range of information and basic science about Earth's snow and ice.

Selected 2011 NSIDC highlights

IceBridge data: Scientists studying changes in the mass balance of polar ice and its potential contribution to global sea level change can now access data from NASA's IceBridge mission via NSIDC. IceBridge addresses the gap between ICESat-I, which concluded operations in early 2010, and the next satellite, ICESat-II, planned for launch in 2015. Begun in 2009, IceBridge is a six-year campaign of annual flights over the poles. The aircraft carry an array of instruments to map ice surface topography, bedrock topography beneath the ice sheets, and grounding line position. During 2011, NSIDC published more than 40 unique IceBridge data sets, and efforts are ongoing. NSIDC also developed the IceBridge Data Portal, a Web-based tool for easily finding flight reports and science data for a selected flight.

Green Data Center: NSIDC renovated its computing facility to dramatically lower its carbon footprint. The NSIDC Green Data Center, a first-of-its-kind system, has cut the energy required to cool its computing center by more than 90 percent and stands as a model for others to reduce energy consumption.

The Center used to consume more than 300,000 kilowatt-hours of electricity per year, enough to cool 34 average U.S. homes. NSIDC Technical Services Manager David Gallaher and partners at the National Renewable Energy Laboratory and at Colorado companies Coolerado Corporation and RMH Group designed a new data center, using energy-sipping indirect evaporative units. The project was funded in part by a grant from the National Science Foundation under its Academic Research Infrastructure Program.

The design takes advantage of Boulder, Colorado's dry climate. Evaporative cooling works best in low-humidity conditions; plus, during cool weather, the new system can draw in and filter outside air for cooling. The Coolerados function as chillers in the summer and humidifiers in the winter. The system went operational in fall 2011. Taking advantage of Boulder's sunny climate, an array of solar panels mounted on NSIDC's roof charges the backup batteries and feeds energy back to the grid.

The project received the 2011 Colorado Governor's Award for High-Impact Research. For more information, visit NSIDC's Green Data Center page (http://nsidc.org/about/green-data-center/).

NASA MEaSUREs data: Numerous NASA satellites measure an astounding range of phenomena, from the soot particles from a forest fire, to the movement of Earth's crust. Put together, the data constitute a long-term record of observations on Earth's environment and climate for the last 50 years. NASA is ensuring these data, called Earth science data records (ESDRs), remain valid across old and new satellite missions and a myriad of sensors. The NASA Making Earth Science Data Records for Use in

Is Earth Losing Its Cool?

Many people know that Arctic sea ice is melting, but what they don't realize is that this has present-day ramifications far beyond the Arctic, says Mark Serreze, director of CIRES's National Snow and Ice Data Center (NSIDC).

How much has sea ice declined?

Since 1979, Arctic sea ice extent has declined by more than 30 percent in summer months. It hit a record low in 2005, and then broke that record by 23 percent only two years later, in 2007. We now set a new record low in sea ice in August this year.

How has this affected Arctic dwellers?

Without protective ice cover, shorelines are eroding, forcing entire towns to move. This has disrupted longstanding patterns of travel and hunting and made them more dangerous. Ice loss is also affecting the ocean food chain from the level of phytoplankton all the way up to polar bears and walruses.

What are the ramifications for lower latitudes?

The Arctic sea ice acts as an air conditioner for the northern hemisphere. The white ice reflects more sunlight than the darker oceans, so it keeps the underlying water and surrounding land masses cooler. As the sea ice melts, the sun's rays heat up more of the exposed water, causing ripple effects throughout the northern seas. Researchers also have found links between declining sea ice cover and extreme weather events in North America. Recent studies suggest that having less ice in the fall, for example, could contribute to cold air outbreaks in other parts of the northern hemisphere. This is because the ice loss helps to warm the Arctic, which in turn influences the jet stream patterns in the atmosphere. So what we are realizing is that the change in Arctic sea ice is not just a problem for the Arctic but for all of us.

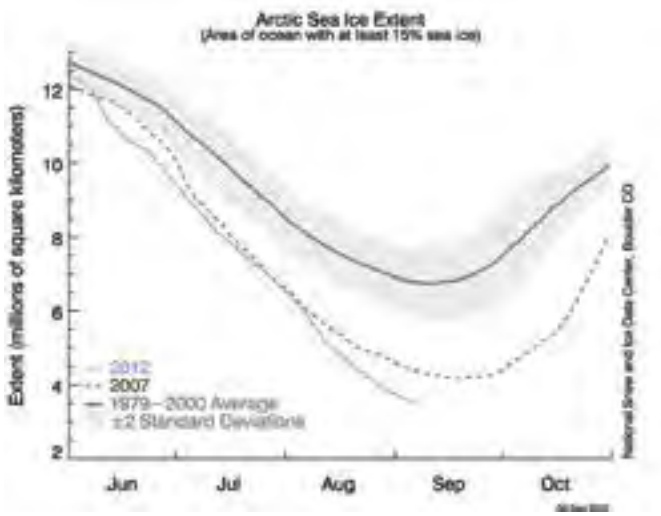


Table courtesy of the National Snow and Ice Data Center

Research Environments (MEaSUREs) program supports scientists who make these long-term ESDRs in their area of specialty. During 2011, NSIDC began making some of these data sets available to other researchers.

For example, Ian Joughin at the Applied Physics Laboratory at the University of Washington has been producing ice velocity maps of the Greenland Ice Sheet for nearly a decade. The data show how rapidly the ice is moving, from the ice sheet summit toward the ocean; in recent years, many areas have seen increased velocity as a result of warmer ocean water and more surface melt. The new data will be a huge help to researchers interested in ice sheet dynamics, indicating how well models of ice sheets are doing in predicting ice flow and their net contribution to the oceans. Ultimately, these data will help in understanding climate warming and its impacts, such as the potential for sea level rise. For more information and to access the data, see NASA MEaSUREs Data at NSIDC (http://nsidc.org/data/measures/).

A Climate Data Record for sea ice: NSIDC produced a Climate Data Record (CDR) for sea ice concentration, an important indicator of sea ice health and Arctic climate. A CDR is a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. Because of the strong decline in Arctic sea ice, some of NSIDC's most used products are sea ice records from passive microwave remote-sensing instruments on U.S. Defense Meteorological Satellite Program (DMSP) satellites. These products provide ice concentration and extent information since late 1978, based on two algorithms developed by scientists at the NASA Goddard Space Flight Center (GSFC). Each algorithm utilizes scientific expertise to manually pull out spurious areas of ice, and the resulting data products have different strengths and weaknesses.

As interest in sea ice and climate data has increased, there is also a much broader community of users, such as researchers in other areas of climate science, modelers, biologists, ecologists, sociologists, and civilian and military government planners. These users are not familiar with the science behind the data or the subtleties of different data sets. As a result, they may not understand the limitations of the data and can easily misuse the data.

NSIDC created a new data product by reprocessing the original satellite data with both algorithms, adding several features to meet CDR criteria. The CDR provides a consistent, daily time series of sea ice concentrations from July 9, 1987, through Dec. 31, 2007. Additional years of data will be released as processing permits.

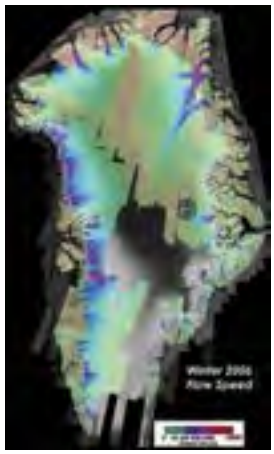


Image courtesy Ian Joughin/APL

This map shows the different speeds at which ice was flowing from the Greenland ice sheet toward the ocean during the winter of 2005 to 2006. The fastest velocities can be found in the outlet glaciers (magenta), seen near the western, northern, and eastern coasts.

Interdisciplinary Programs

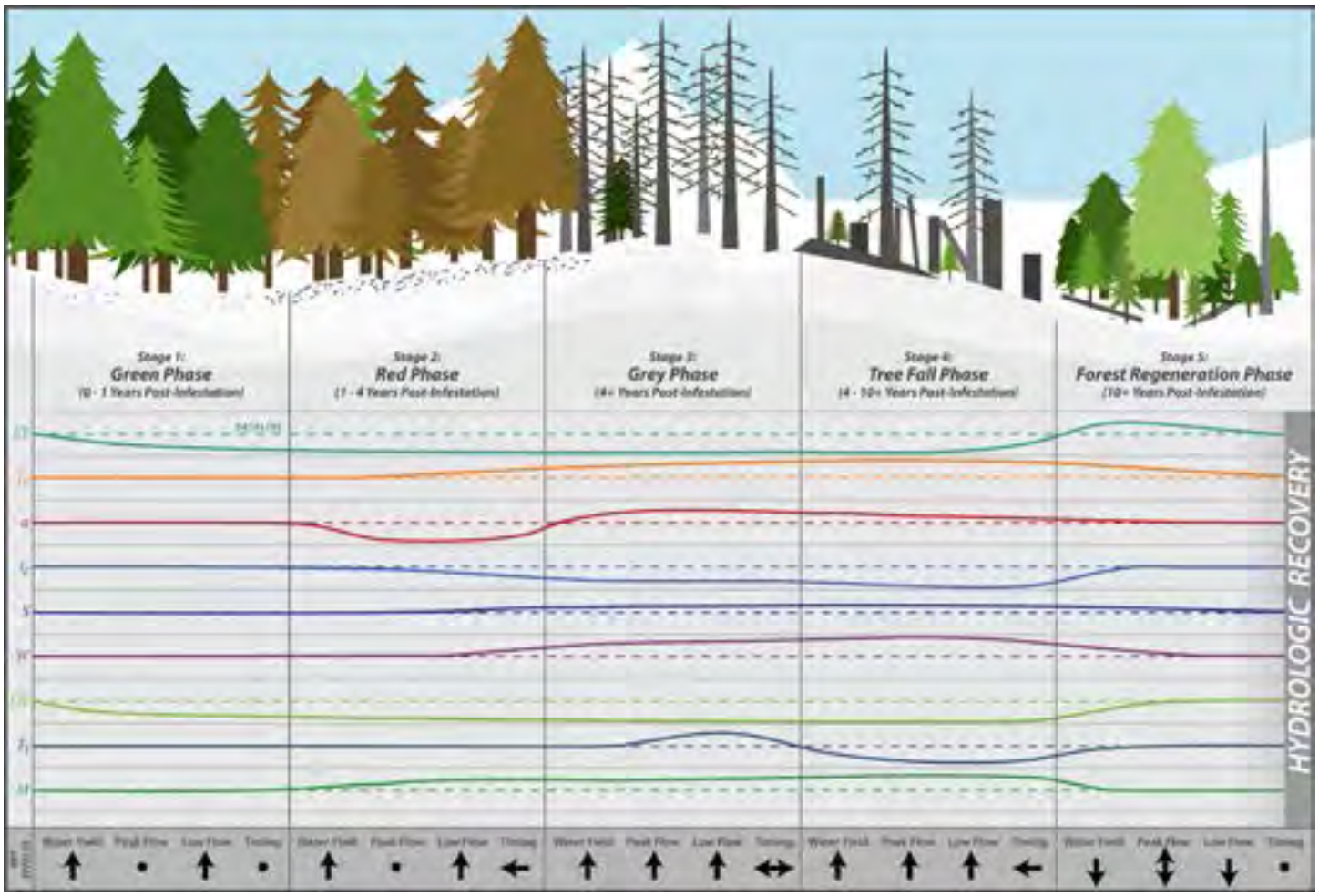
A vibrant research environment is fostered through a number of programs and initiatives designed to stimulate interdisciplinary collaborations among CIRES, NOAA, and university departments.

The **Western Water Assessment (WWA)** is one of 11 NOAA-funded Regional Integrated Sciences and Assessments (RISA) programs across the country. Using multidisciplinary teams of experts in climate, water, ecology, law, and the social sciences, the WWA team works with decision makers across the Intermountain West to produce policy-relevant information about climate variability and change. By building relationships with networks of decision makers, WWA is able to develop practical research programs and useful information products.

In FY12, the WWA research team continued its research and decision-support products in three major thematic categories:
1) Decision Support for the Colorado River Basin and Headwaters; 2) Ecological Vulnerabilities, Impacts, and Adaptation, and 3) Emerging Initiatives and Adaptation Strategies to Inform Climate Services. WWA's ongoing projects and newer initiatives were well-received by a broad community of federal, state, local, and private stakeholders, and several major endeavors emerged as particularly important efforts.

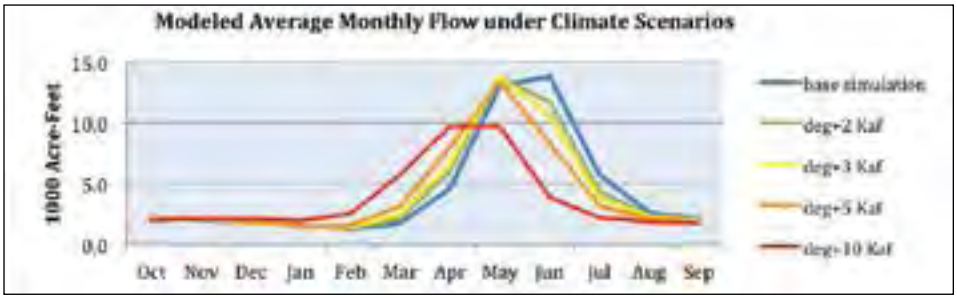
Science synthesis of hydrologic impacts of widespread bark beetle infestations

In FY12, WWA researchers continued their efforts to help water managers and forest managers throughout the Intermountain West understand the impacts of the ongoing bark beetle infestation, which has affected more than 4 million acres of forest across Colorado and nearly 150 million acres across North America since the mid-1990s. Because much of the research on this topic is still in



Conceptual model showing changes in ecohydrologic processes during various stages of tree mortality following bark beetle infestation (Pugh and Gordon, 2012)

progress, WWA previously held two research symposia on beetle-water impacts to let researchers across the West share ongoing work and help us develop useful synthesis products for stakeholders. Leveraging those efforts, in December 2011 WWA held its first workshop expressly intended to help guide water and forest managers in their understanding of water-related impacts on beetle infestations, and more than 100 people attended in person or via webcast. In addition, WWA researchers synthesized existing knowledge into a conceptual model of the impacts of beetle infestations on multiple ecohydrologic processes, in a paper published by *Hydrological Processes* in early 2012 (Pugh and Gordon, 2012).



Projected change in average monthly streamflow in the Big Cottonwood Creek under four scenarios of future warming, as modeled for the Salt Lake City Department of Public Utilities

Climate adaptation for local municipalities

WWA researchers were closely involved with multiple efforts to help municipalities in the Intermountain West understand future climate impacts and prepare to adapt to them. For Boulder County, Colorado, WWA assessed the state of existing science relating to possible future climate changes in the geographically diverse county and provided a policy-oriented analysis of how water managers in the county could make additional preparations for uncertain climate shifts as part of the Boulder County Climate Change Preparedness Plan. For the Salt Lake City Department of Public Utilities, WWA researchers collaborated with NOAA's Colorado Basin River Forecast Center to provide initial assessments of changes in runoff volume and timing under future scenarios of changing temperature and precipitation. Finally, WWA researchers have surveyed municipal officials across Colorado, Wyoming, and Utah in order to better understand the factors that drive preparation for climate-related natural hazards in those communities.

Southwest region technical input to the National Climate Assessment

As part of the Southwest Climate Alliance, a consortium of research organizations in the Southwest, WWA helped develop a technical input report on the Southwest Region for the National Climate Assessment. This effort brought together a diverse set of scientists to craft an IPCC-style, peer-reviewed assessment of scientific findings on climate variability and climate change in the six-state region. WWA researchers served as authors on many chapters, including "Water" (Udall; lead), "Uncertainty" (Averyt; lead), "The Changing Southwest" (Travis and Gordon; contributing), "Weather and Climate" (Gillies; contributing), "Evolving Weather and Climate Conditions" (Lukas and Wolter; contributing), "Projections of Mean Climate" (Barsugli; contributing), and "Solutions for a Sustainable Southwest" (Dilling, lead; Gordon, contributing).

Ongoing stakeholder engagement and collaborations

WWA also supported its longstanding reputation with stakeholders and decision makers as a trusted source of climate information. Collectively, WWA researchers gave more than 65 talks and seminars; published 16 articles, reports, and book chapters; were cited or quoted by the media numerous times; and served as members of many committees and organizations.

Interdisciplinary Programs

The **CIRES Education and Outreach (EO)** group is active across the spectrum of geosciences education, including teacher and scientist professional development, digital learning resources and courses, graduate student fellowships, and more.

Climate education

CIRES and NOAA climate scientists make our climate education projects possible. CIRES climate scientists partner with CIRES Education and Outreach as part of their research projects, contribute to education projects as presenters, reviewers, and learning resource providers, and star in scientific video clips. This involvement by scientists helps teachers to have confidence that the resources provided by CIRES EO are scientifically sound and up-to-date.

To provide students with accurate information about climate and energy science, educators require scientifically and pedagogically robust teaching materials. To address this need, the Climate Literacy & Energy Awareness Network (CLEAN) has developed a peer-reviewed digital collection as part of the National Science Digital Library (NSDL). The CLEAN collection is a featured educational resource collection on the NOAA climate.gov portal. The CLEAN Pathways project features teaching materials centered on climate and energy science for grades 6 through 16. Each teaching resource has undergone a rigorous review process and provides expert teaching tips on how to implement the resource in the classroom. All materials are aligned with the Benchmarks for Science Literacy, the Essential Principles of Climate Science, and key energy concepts. CLEAN is funded by grants from the National Science Foundation.

Lesley K. Smith

Colorado State climatologist Nolan Doesken observes the Bubble Bottle station with teachers during the 2012 COSEE workshop.

ICEE (Inspired Climate Education Excellence), funded through a NASA Global Climate Change Education grant, complements CLEAN as a professional development program for science educators. The ICEE project supports teachers to use best-practices teaching strategies in their climate science instruction, including knowing how to integrate solutions into instruction and how to forestall controversy. ICEE staff have provided webinars and workshops for multiple educator communities, including undergraduate faculty, environmental educators, and secondary science teachers. The project has benefited multiple NOAA educator groups, including environmental educators through the Chesapeake Bay office and the NOAA Climate Stewards. Current ICEE resources include a discussion forum and list serve, videos and study guides on iTunesU, video resources on YouTube and Vimeo, a resource site aligned with climate literacy principles, a book club around climate and energy themes, and an upcoming online course.

The COSEE (Centers for Ocean Sciences Education Excellence) West Colorado Collaborative is a NSF-funded teacher professional development program that aims to demonstrate the important connection that inland regions have with the global oceans and vice versa. CIRES, the University of Southern California, and the University of California at Los Angeles partner together to provide teachers from Colorado and the Los Angeles Unified School District content knowledge and classroom activities that revolve around a new topic each year. In FY12, experts from CIRES, the CIRES Western Water Assessment, the United States Geological Survey, the Denver Museum of Nature and Science, Colorado State University, and CU's Department of Geography illustrated how California and Colorado are linked via the oceans and the Colorado River during the Water in the West course. The impacts of climate change on local ecosystems were also explored. A

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teacher exchange program is an important component of this workshop and provides the exchange of ideas and perspectives of inland and coastal teachers and secondary science students.

Sun-Earth connections

CIRES Outreach provides teacher professional development and classroom kits. The CIRES team involved with the project has collaborated with other Solar Dynamics Observatory (SDO) teams to create lessons using SDO data. CIRES is developing solar science lessons for SMART board technologies so teachers may use them in their classrooms and for teacher professional development.

Graduate student education

CIRES Outreach leads an NSF-funded grades K-12 program to place a dozen science graduate students in classrooms within the Boulder Valley School District (BSVD). The project enhances the acquisition of STEM (Science, Technology, Engineering, and Math) skills by fourth- and fifth-grade and middle-school students in the more socioeconomically diverse BVSD schools by studying the ecology of extreme environments. Graduate student "Fellows" assist teachers while still conducting their own research. Some of the K-12 students will be the first in their family to graduate from high school, and Fellows are able to help them understand what it's like to be a scientist and to know more about what it's like to be at a university.

Jeffrey Morton

Fifth-grade students from Eisenhower Elementary School make observations of a creek flowing near the school in preparation for invertebrate sampling.

Emily Kellagher/David Oonk

Education products for the Solar Dynamics Observatory include a multimedia classroom kit for use in after-school environments

Visiting Fellows

With partial sponsorship by NOAA, CIRES offers visiting fellowships at the University of Colorado Boulder. Every year, CIRES awards several fellowships to visiting scientists at many levels, from postdoctoral to senior. These fellowships promote collaborative and cutting-edge research. Since 1967, 267 people have been visiting fellows at CIRES, including previous CIRES Directors Susan Avery and Konrad Steffen.

Jeffrey Amato

Sabbatical
Ph.D., Stanford University
Project: Using Hf isotopes and U-Pb ages of detrital zircons to characterize the provenance of Cambrian and Grenville-age sandstones in the Cordillera

Jeffrey Amato is a professor at New Mexico State University in Las Cruces. His main research interests are structural geology, tectonics, geochronology, and isotope geochemistry.

While at CIRES, Amato is working with Lang Farmer to use the age and isotopic composition of zircons (a type of mineral) to match sediment to its source region. "If we can determine the source areas of sediment, it will significantly improve our understanding of the paleogeography during the early Paleozoic," he says. "One possible implication of the work is that we may be able to improve our ability to determine the transportation directions of ancient rivers, as well as evaluate longshore drift directions on the coastline 500 million years ago." Amato is also studying the origin of the distinctive 1080 Ma (mega-years) and 510 Ma igneous rocks in the western U.S.

Sponsor: Lang Farmer

Franco Biondi

Sabbatical
Laurea (Italian Doctorate), Università di Firenze
Ph.D., University of Arizona
Project: Using tree-ring records to quantify spatial and temporal patterns of dry and wet episodes

Franco Biondi is a professor in the Department of Geography at the University of Nevada, Reno, where he is also the DendroLab Director. His main areas of research include ecoclimatology (which studies the relationship between living organisms and their climatic environment); forest and landscape dynamics; spatial processes; and environmental change.

While at CIRES, he will work with Balaji Rajagopalan and Tom Chase, along with Roger Pielke, Sr.'s research group and Jeff Lukas at Western Water Assessment (WWA). He is investigating how to best combine proxy records of climate at annual to seasonal timespans with instrumental observations and models used to manage environmental resources, especially water. Additionally, he is studying how to incorporate long-term perspectives in the analysis (and management) of disturbance effects on tree-dominated ecosystems. "Proxy records, such as tree-ring chronologies, can help improve regional assessments of environmental (and societal) vulnerability to future environmental changes," he says.

Sponsor: Thomas Chase

Stuart Bradley

Sabbatical
Ph.D., The University of Auckland, New Zealand
Project: Remote sensing of turbulent generated acoustic noise

Stuart Bradley is a professor of physics at The University of Auckland, New Zealand. His research focuses on atmospheric boundary layer processes, particularly using sound to remotely sense atmospheric turbulence and winds for applications such as wind energy.

Working with the Special Projects Group and Multiscale Interactions researchers, Bradley is conducting research into the background noise—much of it likely caused by turbulence—that affects the quality of acoustic 'radars' known as sodars, which are used in remote sensing of the atmosphere. "I am modeling and measuring this noise with the objectives of improving acoustic remote sensing using sodars," Bradley says. "I'm also investigating whether the spectral signatures of this noise allow for a new, entirely passive, microphone-based method of profiling atmospheric turbulence." The results of his work may provide the basics for a leap forward in acoustic remote sensing of atmospheric winds and turbulence.

Sponsors: William Neff and Mike Hardesty

Lindsay Chapman

Postdoctoral
Ph.D., Florida State University
Project: Application-of the eddy correlation technique to shallow running waters: A test of the fate of organic carbon in Colorado plains rivers

Lindsay Chapman is working with the Department of Limnology to evaluate the use of the eddy correlation method for estimating oxygen metabolism in shallow rivers. She will then use these measurements to investigate the fate of organic matter transported by rivers. "This research will help to answer questions related to the fate and global cycling of carbon and nitrogen and contribute to our understanding of how changes in climate, human population, and land use will affect the delivery of carbon to the world's oceans," she says.

Sponsors: William M. Lewis, Jr., and James McCutchan

Jean-Francois Doussin

Sabbatical
Ph.D., University of Paris 7
Project: Interaction between water and carbonyls: A multiphase approach of the isoprene chemistry contribution to secondary organic aerosol formation in the atmosphere

Jean-Francois Doussin is a professor in chemistry at the University of Paris East at Créteil. He studies atmospheric chemistry, specifically the experimental simulation of organic carbon's atmospheric fate.

While at CIRES, he is working with Veronica Vaida's group to investigate production of secondary organic aerosol (SOA)—a type of air pollution—from the multiphase oxidation of the compound isoprene. Produced by plants, isoprene is the major volatile organic compound (VOC) emitted on a global scale. In the atmosphere, isoprene can react with the sun and ozone to yield other compounds such as water-soluble VOCs. These secondary compounds can lead to the formation of significant additional amounts of SOA. This may "deeply modify the current yield estimation of SOA on the global scale and its climatic impact," Doussin says. His work will lead to a better account of isoprene's contributions to air pollution.

Sponsor: Veronica Vaida

Brian Ebel

Postdoctoral
Ph.D., Stanford University
Project: From ridgetops to rivers: Advancing understanding of hydrologically driven sediment transport following wildfire

Brian Ebel is working with Greg Tucker's group to investigate the water-driven transport of sediment following wildfire. The principal field site is the 2010 Fourmile Canyon Fire outside of Boulder, Colo. Wildfire is one of the most significant disturbances in mountainous landscapes and commonly leads to major sediment loads into streams, Ebel says. These enhanced sediment loads impact stream ecology and the built environment. "I feel fortunate to have the opportunity to improve our understanding and predictive capability of natural hazards such as flash floods and debris flows," Ebel says.

Sponsor: Greg Tucker

Steve Hansen

Postdoctoral
Ph.D., University of Wyoming
Project: Investigation of the North American lithosphere with receiver function imaging

Steve Hansen is earning a doctorate in geophysics at the University of Wyoming. He is working with Anne Sheehan's group and also collaborating with Craig Jones's and Peter Molnar's groups. Using seismic data recorded from distant earthquakes, he will image the structure of North America's subsurface. Hansen is particularly interested in the mantle lithosphere and lithosphere-asthenosphere boundary (LAB), which is the mechanical boundary between the rigid plates and the deep convecting mantle. "The LAB is critical to the theory of plate tectonics and yet is poorly understood," Hansen says.

Sponsor: Anne Sheehan

Mark Hemer

Sabbatical
Ph.D., University of Tasmania, Australia
Project: Surface wave driven feedbacks in the coupled climate system

Mark Hemer is a research scientist at the Centre for Australian Weather and Climate Research and is based in Hobart, Tasmania. His research focuses on how wind-waves behave in a variable climate system.

Hemer is working with Baylor Fox-Kemper's research group and also collaborating with researchers at NOAA and NCAR. He is working to couple a spectral wind-wave model with a global climate model. Current models do not adequately account for wind-wave effects on climate. "We hope that

Visiting Fellows

parameterization of wind-wave dependent processes in global general circulation models reduces model biases—improving climate simulations and understanding of how wind-waves influence the climate system," he says.

Sponsor: Baylor Fox-Kemper

Shao-Meng Li

Sabbatical
Ph.D., Florida State University/National Center for Atmospheric Research Advance Study Program

Project: Volatile organic compounds off the coast of California: Results from the CalNex 2010 studies

Shao-Meng Li is a senior research scientist for the Canadian government, working in the Air Quality Research Division, based in Toronto, for the Department of Environment. Li's main research interest is regional air quality, primarily in aerosol chemical composition and its various impacts.

While at CIRES, Li is working with Joost de Gouw's group to investigate volatile organic compounds (VOCs) over California's coastal areas. Li will use data gathered from the CalNex 2010 (Research at the Nexus of Air Quality and Climate Change) field study. Li is particularly interested in the VOC compositions over the area where there has been a well-documented methane seepage from underwater coal deposits off the coast of Santa Barbara and will compare the data with NOAA's results from over the Deepwater Horizon oil spill. "Increased explorations for fossil fuels to meet increased demands have increased public awareness about potential environmental impacts these days, and among them, the emissions into the atmosphere have the potential to cause regional air quality problems, health issues, and related climate effects," Li says. "Better fingerprinting and better quantifications of these emissions will enable models to better predict the consequences of the increased emissions, allowing for assessment of existing and/or new policies regulating the industry."

Sponsor: Joost de Gouw

Björn-Ola Linnér

Sabbatical
Ph.D., Linköping University

Project: Science, politics, and the Green Revolution

Björn-Ola Linnér is a professor in water and environmental studies at the Centre for Climate Science and Policy Research, Linköping University, in Sweden. His research focuses on international policy-making on climate change, food security, and sustainable development.

While at the CIRES Center for Science and Technology Policy Research, Linnér is unraveling and contextualizing the lessons of the Green Revolution for how we think about innovation policy—in agriculture and beyond. The world is seeking to provide massive quantities of energy by mid-century while at the same time dramatically reducing the carbon intensity of the global economy. "To have any chance of succeeding will require a sustained and intensive commitment to energy innovation," Linnér says. "We believe that the notable successes in sustained improvements in agricultural productivity gains over the past half-century offer fruitful lessons for energy policy innovation." Linnér and his colleagues' analysis has direct relevance to policies for agriculture, which seek to produce enough food for more than 9 billion people by 2050, while at the same time reducing the environmental footprint of those practices.

Sponsor: Roger Pielke, Jr.

Ben Livneh

Postdoctoral
Ph.D., University of Washington

Project: Hydrology modeling of desert dust and mountain pine beetle disturbance under current and future climate scenarios

Ben Livneh is working with the Environmental Observations, Modeling and Forecasting Division and also in close collaboration with the Cryospheric and Polar Processes Division and the Ecosystem Science Division. His research addresses crucial aspects of water-resource management in the Colorado River Basin. Specifically, he is investigating dust deposition on snow and its impact on snowpack evolution and the onset of spring snowmelt under current and future climates. "The findings will have implications for freshwater resources within the region," he says. Livneh is also studying the drivers behind the anomalously large runoff experienced by the Colorado headwaters region in 2010.

Sponsor: Carol Wessman

Xian Lu

Postdoctoral
Ph.D., University of Illinois at Urbana-Champaign

Project: Lidar and modeling studies of atmospheric wave dynamics in Antarctica

Xian Lu is working with Xinzhao Chu's research group and also collaborating with Timothy Fuller-Rowell in NOAA's Space Weather Prediction Center. Using lidar, radar, and satellite data, she is investigating the characteristics of gravity waves and thermal tides from the lower to the upper atmosphere at the McMurdo Station in Antarctica. She will then compare them with the Whole Atmosphere Model simulations and examine their impacts on the polar dynamics. "Gravity waves and tides are the two most dominant wave activities, which drive the whole middle atmosphere away from the radiative equilibrium and affect its momentum budget and mean circulation," she says. "Due to this importance, insufficient observations of gravity waves make it challenging to parameterize their effects and difficult to realistically simulate the middle atmosphere in climate and space weather models." This project will provide new knowledge of gravity waves and tides in Antarctica and the observational validations

of climate and space-weather models.

Sponsor: Xinzhao Chu

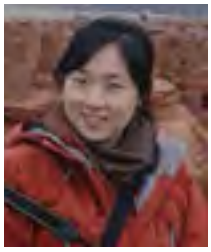
Ralph Milliff

Sabbatical
Ph.D., University of California, Santa Barbara
Project: Development of the TropSat Observatory

Ralph Milliff is an adjunct associate professor with the Atmospheric and Oceanic Sciences Department at the University of Colorado Boulder and a senior research scientist at Colorado Research Associates (CoRA). Milliff's research interests focus on air-sea interaction processes on regional and global scales.

Milliff is the science team lead for a new earth-observing satellite mission concept called the TropSat Observatory. TropSat is intended to measure properties of convective-system evolution in the mesoscale (meaning weather systems measuring horizontally five to several hundred kilometers and often involving heavy rainfall, wind, hail, and lightning)—system by system—throughout the global maritime tropics. This is achieved in part by a very low-inclination orbit and broad-swath design.

Sponsor: Baylor Fox-Kemper



Kyung-Eun Min

Postdoctoral
Ph.D., University of California at Berkeley
Project: Development of a broadband cavity enhanced spectroscopy (BBCES) instrument to characterize wavelength-dependent optical properties of brown carbon

Kyung-Eun Min is working with Fred Fehsenfeld, Steve Brown, and Rebecca Washenfelder. She is developing an instrument for measuring how an aerosol, a particle suspended in the atmosphere, scatters and absorbs light, specifically short-wavelength light. Light extinction (meaning scattering and absorption of light) by atmospheric aerosols represents the single largest uncertainty in researchers' understanding of Earth's radiation balance. And recent work has shown that some organic aerosols, so-called "brown carbon," may absorb ultraviolet light, which was previously unknown. "This finding adds additional uncertainty to estimates of aerosol radiative forcing as brown carbon's optical properties are poorly constrained," Min says. "Through this project, I'm expecting to improve our understanding of the role of brown carbon aerosols in Earth's radiation budget."

Sponsor: Fred Fehsenfeld

Arnaud Temme

Sabbatical
Ph.D., Wageningen University in the Netherlands
Project: Digging deeper—Adding soil formation to landscape evolution models

Arnaud Temme is an assistant professor in soil geography and geomorphology at Wageningen University in the Netherlands. While at CIRES, he is working with Greg Tucker to study the relation between geomorphic processes (for instance, landslides) and soil formation in the high Rockies. Soil and landscape change are intimately related, Temme explains, not only in lowland deltas such as the Netherlands, but also in high mountain areas, where hillslope processes alter soil parent material and soil formation alters erodibility and opportunities for vegetation to grow. "If we understand how soils and landscapes interact, we will be better able to predict soil patterns in high mountain regions," he says. "This allows better estimates of water retention and ecological succession in these areas."

Sponsor: Greg Tucker

Dan Yakir

Sabbatical
Ph.D., Hebrew University of Jerusalem
Project: Exploring the links between COS and ^{18}O-CO_2 in biosphere-atmosphere exchange—Combining process understanding and atmospheric observations

Dan Yakir is a professor of biogeochemistry at the Weizmann Institute of Science in Israel. His main research interests are biogeochemistry and plant-atmosphere interactions.

While at CIRES, Yakir is working with David Noone, Steve Montzka, and Jim White, director of INSTAAR. Yakir is investigating two tracers (a radioactive atom present in a material and used to study the material's distribution and pathway)—oxygen-18 content in CO_2 and carbonyl sulfide—and how they can be used to better estimate the exchange of CO_2 between land vegetation and the atmosphere. "Accurately estimating carbon uptake by land vegetation will improve estimates of the rate of global warming and climate change," Yakir says. "Tracing specific fluxes of CO_2 between the atmosphere and the land vegetation will also provide a powerful tool to understand the process underlying the biosphere response to climate change."

Sponsors: David Noone and Steve Montzka

Graduate Research Fellowships

CIRES supports two prestigious student fellowship programs, the ESRL-CIRES Fellowship, begun in 2008 with the support of NOAA's Earth System Research Laboratory, and the long-established CIRES Graduate Student Research Fellowship. For 2011–2012, CIRES awarded CIRES Graduate Student Research Fellowships to six students. This year's recipients are exploring topics ranging from the influence of fish-stocking in mountain lakes to an investigation into the sources of ambient aerosol and chemical transformations in the atmosphere.

2011–2012 CIRES Graduate Student Research Fellowship Recipients

CIRES Graduate Student Research Fellowships attract outstanding students at the outset of their graduate careers, and let current students emphasize the completion and publication of their research results. Support ranges from a summer stipend to tuition, stipend, and partial health insurance for 12 months. Fellowships are restricted to doctoral graduate students advised by a CIRES Fellow, or any prospective or current graduate student who might be advised by a CIRES Fellow. Evaluation by a committee of CIRES Fellows is based on the candidate's university application, academic achievements, and the likelihood of his or her contribution to environmental science. Independence, passion for science, and the ability to communicate are also considered.

Adriana Raudzens Bailey

CIRES Ph.D. Student: Atmospheric and Oceanic Sciences

Advisor: David Noone

Raudzens Bailey is studying the vertical moisture exchange through the convective boundary layer in the atmosphere.

Gaddy Bergmann

CIRES Ph.D. Student: Ecology and Evolutionary Biology

Advisor: Noah Fierer

Bergmann is studying the community of bacteria that inhabits the bison digestive tract and how it varies among different herds across the Great Plains.

Sean Haney

CIRES Ph.D. Student: Atmospheric and Oceanic Sciences

Advisor: Baylor Fox-Kemper

Haney's research focuses on improving global climate models by better accounting for the ocean mixed layer and its interactions with the atmosphere.

Brett Palm

CIRES Ph.D. Student: Analytical/Atmospheric Chemistry

Advisor: Jose-Luis Jimenez

Palm's research focuses on the application of a Rapid Secondary Aerosol Formation Measurement Tool for laboratory and field studies.

Joe Rokicki

CIRES Ph.D. Student: Molecular, Cellular, and Developmental Biology

Advisor: Shelley Copley

Rokicki is investigating the *Sphingobium chlorophenolicum* bacterium and the genetic regulation of enzymes that degrade the environmental toxin pentachlorophenol.

Jessica Weinkle

CIRES Ph.D. Student: Environmental Studies

Advisor: Roger Pielke, Jr.

Weinkle's research involves a policy evaluation of Florida's Citizens Property Insurance Corporation with the goal of informing the process of forecasting, negotiating understanding, and democratically governing hurricane risk.

Diversity and Undergraduate Research

CIRES engages in many important efforts to educate undergraduate students and involve them in hands-on research. The two programs highlighted below are the Significant Opportunities in Atmospheric Research and Science Program (SOARS) and the Undergraduate Research Opportunities Program (UROP).

Significant Opportunities in Atmospheric Research and Science Program (SOARS)

This is a learning community and mentoring program for promoting ethnic and gender equity in the atmospheric and related sciences. The National Center for Atmospheric Research (NCAR) created and administers the highly regarded program, and CIRES partners with NCAR to provide a wider range of research options for students, called protégés. SOARS provides four years of mentorship—and summer research experience—for undergraduate and graduate protégés majoring in atmospheric science or a related field.
More: http://www.ucar.edu/soars/

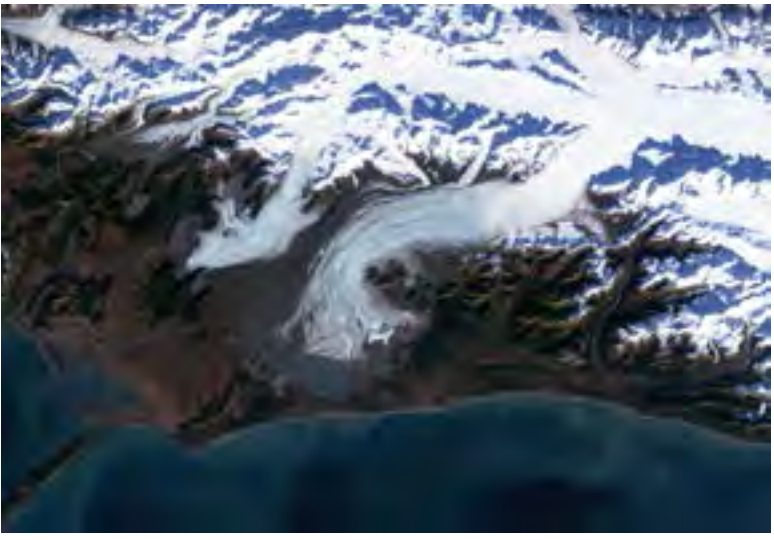
2011–12 SOARS Protégés

Javier Lujan

Research: Understanding profiler observations of the stratocumulus-topped marine boundary layer with the assistance of ceilometer data
CIRES Mentors: Leslie Hartten and Paul Johnston

Ma'Ko'Quah Jones

Research: Statistical analysis of relations between monthly teleconnection indices
CIRES Mentors: Leslie Hartten and Cecile Penland



NASA

Bering Glacier surge is just one of the topics being studied by UROP students.

Undergraduate Research Opportunities Program (UROP)

The Undergraduate Research Opportunities Program (UROP) funds research partnerships between faculty and undergraduate students. UROP-supported work is diverse, including traditional scientific experimentation and the creation of new artistic works. The program awards research assistantships, stipends, and/or expense allowances to students who undertake an investigative or creative project 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, endorsed by a faculty sponsor.
More: http://enrichment.colorado.edu/urop/

2011–12 UROP Students

Kelsey Bickham

Project: Ecological response to disturbance interactions in subalpine forest
Faculty or CIRES Sponsor: Carol Wessman

David Chen

Project: Sublingual vaccine delivery
Faculty or CIRES Sponsor: Robert Sievers

Sean O'Grady, Matthew Goo, and Alexander Weltman

Project 1: Bering Glacier surge: Analysis of an environmental catastrophe
Project 2: Connecting glaciologic data analysis and modeling
Faculty or CIRES Sponsor: Ute Herzfeld

Brooke Regan

Project: Effects of salvage logging on soil properties in beetle-killed forests
Faculty or CIRES Sponsor: Carol Wessman

Emily Wilson

Project: How is soil moisture related to extreme temperature anomalies
Faculty or CIRES Sponsor: Thomas Chase

Theme Reports

Office of Oceanic and Atmospheric Research Earth System Research Laboratory

National Environmental Satellite, Data, and Information Service

National Weather Service Space Weather Predication Center

Other Projects

ADVANCED MODELING AND OBSERVING SYSTEMS

AMOS-01: Instrumentation Design, Prototyping, and Analysis

- CSD-01 Instrumentation for Atmospheric Observation and Analysis
- PSD-08 Sensor and Technique Development

CSD-01 Instrumentation for Atmospheric Observation and Analysis

FEDERAL LEADS: MICHAEL HARDESTY, STEVEN BROWN, AND DAN MURPHY
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

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

Milestone 1. Develop and test a new, fully automated instrument to measure water vapor on board a high-altitude research aircraft. Impact: The new instrument will include in-flight calibration to ensure that water vapor measurements made over a wide dynamic range (1-200 parts per million) have known, high accuracy.

Efforts this year have focused on (1) analysis of the data collected with the chemical ionization mass spectrometry (CIMS) water vapor instrument during the MACPEX (Mid-Latitude Airborne Cirrus Properties Experiment) campaign and (2) development of a new, compact, tunable diode laser (TDL)-based instrument for measurement of water vapor and total water in the upper troposphere and lower stratosphere (UT/LS).

(1) One goal of the deployment of the CIMS water vapor measurement during the MACPEX campaign was to participate in a comparison of *in situ* UT/LS water vapor measurements in order to investigate the potential sources of measurement error that have contributed to significant measurement discrepancies at low water vapor mixing ratio over the past decades. The ability to conduct *in situ* background determinations and calibrations under flight conditions is unique among UT/LS water vapor instruments and represents an important diagnostic that has been lacking. Overall, the agreement among water vapor measurements during MACPEX was better than in previous missions, but systematic differences remained. Analysis of the data from other instruments along with the CIMS measurements indicates that previously unrecognized background signals under flight conditions are responsible for the measurement disagreements.

(2) The need for reliable, accurate water vapor measurements in the UT/LS has led us to begin development of a new, TDL-based water instrument that will have the calibration capabilities of the CIMS instrument in a compact, lightweight package capable of being deployed on a number of different high-altitude research aircraft platforms. The instrument has two channels for the simultaneous measurement of water vapor and total (vapor plus condensed-phase) water.

Milestone 2. Construct and deploy a three-wavelength, photoacoustic/cavity ring-down combination to measure single scattering albedo. Impact: Single scattering albedo controls whether the direct radiative effect of aerosols is a warming or cooling. This instrumentation will make measurements of single scattering albedo with better sensitivity, higher accuracy, and fewer artifacts than previous instrumentation.


Bill Dubè

CIRES scientist Rebecca Washenfelder and the cavity enhanced absorption spectroscopy instrument

Initial development of the three-wavelength cavity ring-down and photoacoustic instruments and their first field deployment during CalNex 2010 were completed last year. This year's efforts have focused on:

(1) Analysis of data collected during CalNex 2010. Measurements from the CalNex campaign formed the basis of a study examining the evolution of aerosol optical properties impacting climate and visibility in the Los Angeles urban plume (Langridge et al., *JGR*, 2012). Data from the instruments during this campaign have also supported a number of additional studies (currently four publications).

(2) Instrument characterization. Data from the CalNex mission, combined with significant laboratory testing, formed the basis of two further papers describing the instruments and their performance (Langridge et al., *AS&T*, 2011; Lack et al., *AS&T*, 2012).

(3) Instrument modifications and improvements. Initial field and laboratory studies provided numerous ideas for improvements, primarily to the instrument flow system, calibration system, and electronic/software systems. Improvements in these areas have been successfully implemented over the course of this year.

(4) Continued instrument deployments. The instruments were deployed to Barbados to study the optical properties of transported Saharan dust. In addition, they were used to sample emissions from a local fire that occurred during the year. This provided a rich and unique data set with which to examine the optical properties of biomass burning emissions and specifically the importance of brown carbon and coatings for aerosol absorption. These data have been analyzed and submitted for publication (Lack et al., *PNAS*, 2012).

Milestone 3. Develop and test cavity enhanced absorption spectroscopy (CEAS) instruments for glyoxal, nitrous acid, and nitrogen dioxide. Impact: Both glyoxal ($C_2H_2O_2$) and nitrous acid (HONO) are reactive intermediates in atmospheric chemistry that serve as photochemical radical sources and, in the case of glyoxal, may participate

in secondary organic aerosol formation. Understanding their abundances is important to both regional air quality and climate.

(1) During 2010, we designed and constructed a new CEAS field instrument to measure nitrous acid, glyoxal, and nitrogen dioxide. We deployed this instrument at the ground site in Pasadena, Calif., during the CalNex campaign in 2010. We used the CalNex data to quantify the contribution of glyoxal to organic aerosol budget of Los Angeles and to determine the role of HONO and $ClNO_2$ in the radical budget of Los Angeles.

(2) We extended this work by constructing a laboratory CEAS instrument to measure the weak absorption cross sections of ozone and hydrogen peroxide. This work was completed in collaboration with a graduate student and postdoctoral fellow from the University of Colorado and resulted in two published papers.

(3) We modified the laboratory CEAS instrument to measure aerosol optical properties as a function of wavelength in the UV and near-visible spectral regions. A manuscript describing the results from this work is in preparation.

PSD-08 Sensor and Technique Development

FEDERAL LEAD: JIM JORDAN
CIRES LEAD: ANDREY GRACHEV

NOAA Goal 3: Weather and Water

Project Goal: 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 1. Write reports on the use of roving calibration standard for ship flux measurements on two University-National Oceanographic Laboratory System (UNOLS) ships.

Reports were written for the Research Vessel (R/V) Hi'ialakai (Bariteau, et al., Evaluation of meteorological observation systems on the R/V Hi'ialakai, 2011 WHOTS-8 Field Program).

Milestone 2. Perform laboratory study on crosstalk and sensitivity of new fast carbon dioxide (CO_2) sensor.

The new CO_2 was deployed in DYNAMO2011 cruise for field-testing purposes (about four months). The original design of the instrument was redesigned to operate with a longer sampling line. A publication is in preparation.

Milestone 3. Install and make test flights of PSD W-band radar on NOAA WP-3D aircraft.

Same status as last year due to delay in the availability of the aircraft.

AMOS-02 Data Management, Products, and Infrastructure Systems

- NGDC-01 Geospatial Technology for Global Integrated Observing and Data Management Systems
- NGDC-02 Marine Geophysics Data Stewardship
- SWPC-03 Information Technology and Data Systems
- NGDC-09 Space Environment Data Algorithm and Product Development
- GSD-07 High Performance Computing Systems (HPCS)
- NGDC-08 Improve Integration of Coastal Data to Support Community Resiliency
- CSD-11 Processes in the Marine Boundary Layer

NGDC-01 Geospatial Technology for Global Integrated Observing and Data Management Systems

FEDERAL LEAD: RAY (TED) HABERMANN
CIRES LEAD: DAVID NEUFELD

NOAA Goal 3: Weather and Water

Project Goal: 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 Federal Geographic Data Committee (FGDC) and International Standards Organization (ISO) 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 1. Design, develop, and demonstrate systems to support data set discovery, documentation, lineage, and usage (metadata) using international standards.

NOAA collects, stores, and distributes one of the world's largest collections of environmental data sets. Increasing the usability and availability of these data sets requires high-quality documentation. This emphasis was recently highlighted by a new NOAA directive that states: "Environmental data will be visible, accessible, and independently understandable to users." Documenting our data, products, and services is a significant task. For this reason, CIRES and the National Geophysical Data Center have developed and deployed a new Enterprise Metadata System (EMS) to facilitate and speed this documentation effort. EMS includes the following features:

Web Accessible Folders (WAF)—Groups of related metadata records that share information and are managed as a collection in folders on the web and harvested together into portals.

Record Services—Schema and schematron validation, xlink checking, component resolution, translation to multiple HTML views, and evaluation services (rubrics) that operate on single metadata records.

Component Management—Creation, recognition, and retrieval of metadata components (i.e., people, citations, and sources) that are used in multiple records for consistency and efficient maintenance.

Collection Services—Schema and schematron validation, xlink checking, consistency checking, component resolution, translation between standards (i.e., FGDC to ISO), and evaluation services (rubrics) that

operate on collections of records in web accessible folders.

CIRES is working with partners like the World Meteorological Organisation (WMO) on their metadata holdings. This work will yield important improvements for both WMO and their data documentation efforts, as well as allowing NGDC and CIRES to continue to enhance EMS.

Milestone 2. Design, develop, and demonstrate systems that provide integrated access to and visualization of *in situ* and satellite environmental observations. Employ Open Geospatial Consortium (OGC) standards as well as emerging international approaches to ensure interoperability across systems.

CIRES staff led the effort to deploy a new data discovery system for NGDC. Collaborating with ESRI on their open source Geoportal software, CIRES was able to integrate both existing FGDC metadata along with more detailed documentation based on emerging international standards (ISO 19115-2). The ISO standards allow more detailed information to be captured related to a data set's geographic and temporal extents along with sensor level and provenance documentation, which is critical for researchers to be able to reliably use the data. All three NOAA data centers now have an operational Geoportal allowing federated searches based on the Open Geospatial Consortium (OGC) Catalog Service for the Web (CSW) standards. The implementation of CSW for data discovery across data centers ensures interoperability and integrated access to both NOAA's *in situ* data holdings as well as remotely sensed or satellite based environmental data sets.

Milestone 3. Design, develop, and demonstrate systems to support *in situ* and satellite data set ingest, archival, and data quality monitoring.

The primary data holdings at NGDC are too large to all be held on disk drives for rapid access (also known as 'online' or 'spinning disk'). Some portion of the data are written to tape and are not normally kept as files on disk drives—these are copied back to disk when needed and may be erased after use so that the disk space can be reused for other files.

A web service known as the Archive Retrieval Server has been developed by CIRES staff at NGDC to automate and control access to these data holdings on tape. This software is sometimes referred to as an API (Application Programming Interface) since this is a web service intended to be used by other programs. A major software infrastructure project at NGDC is now beginning to interface with this Archive Retrieval Server. By serving as a single access point for data retrievals, this system manages load, priorities, and controls access to private files for data orders. Completed orders are bundled, and email notifications provide a download link to finished orders. Web pages also provide order- and system-monitoring capabilities.

Milestone 4. Enhance the Comprehensive Large Array Stewardship System (CLASS) to meet NGDC archive requirements. This involves working with scientific, contract, and federal teams to understand, document, and define CLASS capabilities for scientific data stewardship. This milestone will result in a system that houses and manages NGDC data using CLASS technology.

Three distinct types of CLASS services are required to support NOAA data center operations: data ingest, data management tools, and data access. CLASS ingest at NGDC uses a pre-ingestor to prepare and submit files to CLASS, as well as to monitor their ingest. Data management tools support data managers in their stewardship of archived files by maintaining metadata, validating files, and reporting on holdings. Data discovery and ordering services are undergoing a transition from being provided by CLASS to being provided by data centers. This is redefining CLASS data access as a machine-to-machine (M2M) interface connecting public-facing data center applications with CLASS.

CIRES staff implemented an initial pilot version of the pre-ingestor that currently ingests GNSS (Global Navigation Satellite System) data from a network of Continuously Operating Reference Stations (CORS). An update to this basic functionality is currently underway, and a high-level summary of the ingest process is shown in the figure.

As part of the pilot, CLASS services supporting data access were specified by CIRES, and subsequently implemented by CLASS. One outcome from the pilot project was that it identified a need to change direction in order to better support an upcoming migration of the bulk of data center holdings to CLASS. CIRES staff have worked to define how this more streamlined form of ingest might work, and to help NGDC communicate these ideas to CLASS. An update to the pre-ingestor supporting these capabilities is underway.

NGDC-02 Marine Geophysics Data Stewardship

FEDERAL LEAD: SUSAN MCLEAN
CIRES LEAD: BARRY EAKINS

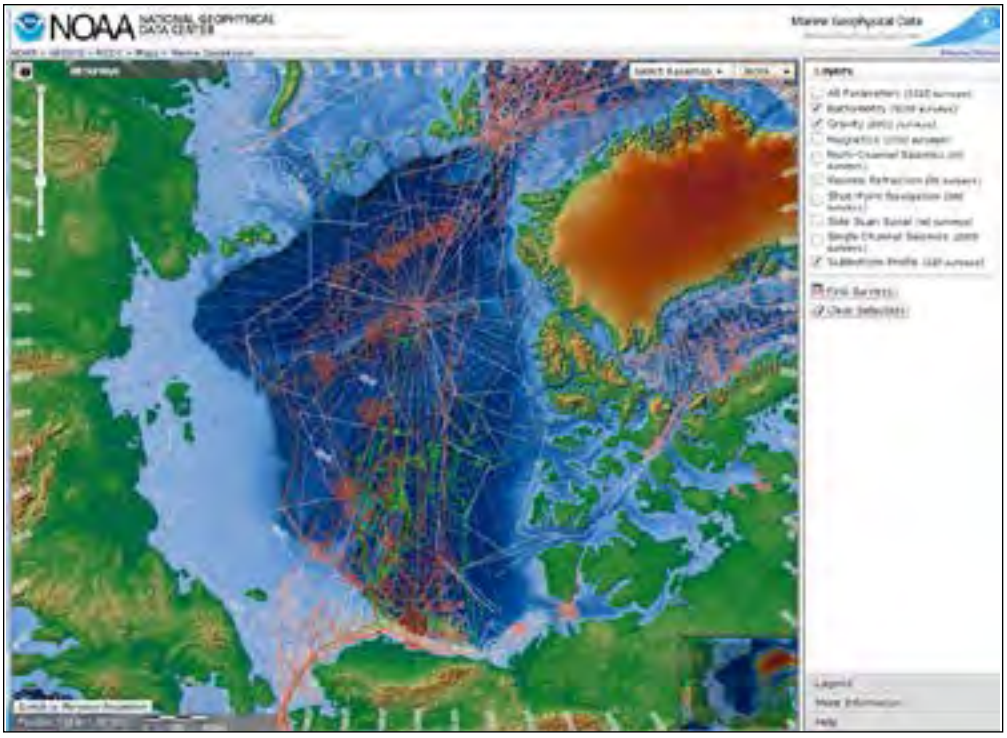
NOAA Goal 4: Transportation

Project Goal: 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 1. Search, target, acquire, and provide access to new and historical marine geophysical data (e.g., bathymetry, gravity, seismic, and magnetics) from the global oceanographic community.

Since July 2011, 175 multibeam swath sonar surveys (631,896 nautical miles) and 44 trackline (single-beam bathymetry, magnetics, gravity, subbottom, and seismic reflection) surveys (287,000 nautical miles), throughout all of the world's oceans, have been added to the National Geophysical Data Center's (NGDC) global marine geophysical archives

NGDC's interactive Trackline Geophysics Data Viewer. Lines represent ship tracks in the Arctic Ocean with publicly available single-beam bathymetric, gravity, and subbottom profile data.



NGDC's interactive "ECS Data Inventory." Polygons represent gridded bathymetric products in the Pacific Ocean around the Mariana Islands.

by NGDC and CIRES staff. Both national and international organizations contribute to and retrieve marine geophysical data from the interactive databases. Marine geophysical data archived at and delivered by NGDC are currently supporting two specific, ongoing U.S. mapping efforts: the Extended Continental Shelf (ECS) project and the Integrated Ocean and Coastal Mapping (IOCM) program. NGDC provides long-term archiving, stewardship, and delivery of data to scientists and the public by utilizing standard metadata, spatially enabled databases, robotic tape archive, and standards-based web services.

Milestone 2. Improve metadata content and data discovery capability for marine geophysical data in support of the U.S. Extended Continental Shelf and Integrated Ocean and Coastal Modeling projects, including a "Data Inventory" that enables comment and access to a variety of marine geophysical data in a geographically distributed environment.

In the past year, CIRES and NGDC staff have focused their efforts on the design and implementation of an interface to the ECS Database, referred to as the "ECS Catalog." This is a direct response to the charge NGDC was given to serve as the Data Management lead and archival location for all data related to this project. The Catalog allows a project team member to access any ECS-related data (through a secure log-in). A newly developed map interface (ECS Data Inventory) has been created to show the spatial coverage of all ECS-related data and products that have been uploaded in to the ECS Catalog. This includes geophysical surveys from a variety of federal government and academic sources and products from preliminary analyses conducted by ECS Project scientists.

Collaboration has continued with scientists and data experts from several U.S federal agencies and academic science data centers on improving common metadata standards for cruise level data for both the U.S. ECS project and the IOCM program. Staff have worked on generating cruise-level metadata for all ECS-funded cruises and have made these records available to the public through the NGDC ECS Data Access webpage (http://www.ngdc.noaa.gov/mgg/ecs/cruises.html).

Milestone 3. Improve access to a variety of regional and global coastlines through development of an interactive map service and updating of other online services to provide the most direct and up-to-date links to various vector shoreline data, including a new high-resolution community coastline data set developed at NGDC.

Updated online services by improving NGDC's shorelines homepage (http://www.ngdc.noaa.gov/mgg/shorelines/shorelines.html). Information provided at this site is now based on the most Frequently Asked Questions (FAQs) received at coastline.info@noaalgov from the coastline community.

SWPC-03 Information Technology and Data Systems

FEDERAL LEAD: STEVEN HILL
CIRES LEAD: DAVID STONE

NOAA Goal 3: Weather and Water

Project Goal: Determine the necessary research data systems and infrastructure required to successfully implement the empirical and physical scientific models of the space environment, such as those envisioned in SWPC-01 and SWPC-02 with fast and efficient access to appropriate data sources.

Milestone 1. Support ongoing development of the Geostationary Operational Environmental Satellite (GOES) NOP series ground data system (GDS). Continue to enhance the GOES-NOP data processing systems and support GOES-N and GOES-O operationally used products. Provide analysis and technical support to algorithm development, instrument checkout, and data verification for GOES-P as it completes post-launch testing. Facilitate planning for the transition of GOES-NOP GDS operations to the National Environmental Satellite, Data, and Information Service (NESDIS).

Expanded the GOES-NOP Preprocessor (PP) in support of operational and science requirements through a disciplined change control process that saw the completion of more than 37 documented change requests. Upgraded all system components of the GOES-NOP PP and backing data store, and replicated the system in order to support a backup forecasting center, per our lab's new Continuity of Operations (COOP) plan.

The Preprocessor is capable of subscribing to and ingesting high bandwidth telemetry into its component magnetometer, particle, extreme ultraviolet, X-ray sensor, and SXI instrument raw data. It uses database-configurable logic to convert this data into space weather products for distribution to NOAA, NASA, and the United States Air Force.

Milestone 2. Assist Space Weather Prediction Center (SPWC) efforts to modernize data processing and distribution systems that are currently hosted on legacy systems. Provide development, transition, and mentoring support for contracts to outsource modernization efforts. Implement specific portions of the modernization that will not be outsourced. Improve legacy replacement systems that now exist and support new modernization projects as they are identified.

Served as technical lead for the transition of the Wang-Sheeley-Arge (WSA)-Enlil model into formal operations status at the National Weather Service's (NWS) SWPC. This effort included developing, installing, and compiling all model codes on NWS supercomputers and developing runtime operational scripts for NWS staff implementation. Finished development and testing of the GUI-based Coronal Mass Ejection (CME) Analysis Tool (CAT) for analysis of coronagraph images to provide CME inputs to the WSA-Enlil system. Also supervised the development of the web-based tools for job submission for model run storage and retrieval, and delivered the latest version of the system to the Air Forces Research Laboratory (AFRL).

Assisted in the development of the software for processing data from the Atmospheric Composition Explorer (ACE) satellite. This software was ported by contractors using processing code running on the lab's legacy systems. Deployed this software to operations and performed bug fixes.

Completed a beta-level implementation of the new GOES-R Solar Ultraviolet Imager (SUVI) Thematic Maps Generation system as specified by the GOES-R algorithm development team.

Provided operational support for the Real-Time Ground Magnetometer (RTGM) processing system.

NGDC-09 Space Environment Data Algorithm and Product Development

FEDERAL LEAD: STEVEN HILL
CIRES LEAD: MARY SHOULDIS

NOAA Goal 3: Weather and Water

Project Goal: Explore new techniques for analyzing and modeling Geostationary Operational Environmental Satellite (GOES) space environment data, and develop and validate new algorithms and products.

Milestone 1. Development of the algorithm and software tool for specifying satellite anomaly hazards from GOES energetic particle data shall be completed and put into operational test mode during the work plan timeframe. Research and development of five algorithms for Phase 2 of the GOES-R project shall be completed in this time period. Research and development of the six Phase 3 algorithms will be started and shall progress through preliminary design and into critical design in this time period.

The SEAESRT (Space, Environmental Expert System Real Time) algorithm to specify satellite anomaly hazards was modified and tested for use at the National Geophysical Data Center (NGDC). The interface to the algorithm was enhanced and improved to make it more user-friendly. Also, the output was improved to include graphical displays. The algorithm is operational-ready and will be implemented at NGDC when their resources are available.

Requirements definition and research of viable solutions have been completed for four of the seven Phase 3 algorithms. Preparations are underway for the Preliminary Design Review (PDR) on all seven of the algorithms. Also, the team completed a major effort by developing the Space Weather Instruments and Data portions of the GOES-R Calibration and Validation Plan. Another major task completed this year was the Metadata Model for all of the Space Weather instruments.

The GOES-R team was moved from the Space Weather Prediction Center to NGDC during this time period. This move necessitated a need for better documentation of requirements between the two organizations. An effort is underway to document all functional and performance requirements for all of the Phase 1, 2, and 3 algorithms.

GSD-07 High-Performance Computing Systems (HPCS)

FEDERAL LEAD: SCOTT NAHMAN
CIRES LEAD: CRAIG TIERNEY

NOAA Goal 2: Climate

Project Goal: Provide systems research support for high-performance computing (HPC) efforts and assistance to the user community; provide HPCS communications equipment and software research; and provide research support for high-performance file systems.

Milestone 1. Conduct technical study of latest hardware architectures to support future NOAA procurements.

We continue to evaluate latest-generation technologies that are appropriate for high-performance computing (HPC). Over the last year, we have had opportunities to test and implement latest-generation CPU technologies (Intel Sandy Bridge) as well as accelerator technologies (Intel Phi). Intel's newest CPU, Sandy Bridge, provides a huge speedup over previous-generation technologies. For one of our primary weather applications, Weather Research Framework (WRF), application speed has increased approximately 60 percent per core over previous systems, and on a per node basis, the performance increase is more than 2.25 times. This new technology provides not only a huge performance gain, but also huge gains in price performance.

We continue to investigate and test next-generation HPC accelerator technologies. Intel is planning a release of its Phi architecture. This technology is based on a many-core x86_64 architecture. While we cannot provide specific results at this time, the technology looks promising.

Milestone 2. Investigate tools to automate the use of Graphical Processor Units (GPU) co-processors within existing GSD codes.

Progress on this milestone has been limited due to other priorities. Some work has been covered under Milestone 1, but minimal work has been done with the automation. Lack of progress in this milestone is actually good. When we first started research in this area, there were no commercially available tools to do these things. Now, there are many commercial tools available (Portland Group, CAPS HMPP) along with multiple open standards that allow for portable programming models (OpenACC, OpenCL, OpenMP).

Milestone 3. Support investigations of large, core-count model scalability in heterogeneous computing environments.

Due to time constraints (see Milestone 1), minimal work has proceeded in this investigation.

NGDC-08 Improve Integration of Coastal Data to Support Community Resiliency

FEDERAL LEAD: SUSAN MCLEAN
CIRES LEAD: BARRY EAKINS

NOAA Goal 3: Weather and Water

Project Goal: Improve integration of coastal data and develop new products that promote community resiliency through better assessments of hazards, coastal vulnerability, and risk. Research goals include the development of seamless, accurate, high-resolution digital elevation models (DEMs) to improve the accuracy of coastal inundation modeling; the development and expansion of historic events databases and tsunami deposits databases; and hazard assessments.

Milestone 1. Produce nine to 14 seamless, integrated, bathymetric–topographic digital elevation models of select U.S. coastal communities to support tsunami forecast and warning, hurricane storm-surge modeling, and coastal inundation mapping.

CIRES staff at the National Geophysical Data Center (NGDC) developed 13 seamless, integrated, bathymetric–topographic DEMs of U.S. communities for coastal states, including in Alaska and Hawaii. These high-resolution coastal DEMs serve as a base layer for a variety of uses including: (1) modeling of coastal processes (storms, tsunamis, ocean currents, sediment transport, sea-level rise, etc.); (2) ecosystems management and habitat research; (3) coastal and marine spatial planning; and (4) community hazard preparedness and disaster mitigation. The coastal DEMs are used by NOAA's Tsunami Warning Centers, the NOAA Center for Tsunami Research, Coast Survey Development Laboratory, and the National Tsunami Hazard Mitigation Program for computing inundation from tsunamis and hurricane storm-surge.

CIRES staff at NGDC also developed a Catalog of unstructured grids of the Gulf of Mexico (https://www.ngdc.noaa.gov/mgg/dem/ugc/). This Catalog is a searchable geospatial database that has been developed by different Federal agencies to support hydrodynamic modeling and is intended to be a community resource for researchers to either access and use existing grids, or to contribute and share new grids with others.

CIRES staff also provided technical support and DEMs to other researchers and the public, including providing bathymetry of the Great Lakes used by the National Geographic Channel for its television program "Drain the Great Lakes."

Milestone 2. Investigate the effects of different gridding algorithms and near-shore morphologic features on integrated bathymetric–topographic digital elevation models, and their impacts on coastal inundation that result from tsunami modeling.

The development of integrated bathymetric-topographic DEMs requires extreme interpolation across large distances between sparse bathymetric measurements in order for the model to retain the resolution of dense coastal topographic data, particularly lidar. Accordingly, we have investigated the accuracy of three common interpolative gridding algorithms used to develop bathymetric DEMs of Kachemak Bay, Alaska, from sparse bathymetric measurements: inverse distance weighting (IDW), spline, and triangular irregular networks (TIN). More specifically, the relationship among interpolation deviations from measured depths and sample density, distance to the nearest depth measurement, and terrain characteristics has been quantitatively and qualitatively assessed.

A split-sample method was implemented in which a percentage of measured depths were omitted, an interpolative gridding algorithm was applied, and the interpolation deviations from the original measured depths were quantified. It was determined that the accuracy of the three evaluated gridding algorithms decreases in areas of high surface curvature, at greater distances from the nearest measurement, and at smaller sampling densities. Furthermore, spline was the most accurate interpolation method at all sampling densities. Predictive equations of interpolation uncertainty derived from the quantification of interpolation deviations in relationship to sample density and distance to the nearest depth measurement were also developed. These predictive equations of uncertainty in DEMs introduced by interpolative gridding can aid mitigation efforts for coastal communities prone to tsunami by improving the understanding of the propagation of uncertainty into the modeling of coastal processes such as tsunamis that rely on integrated bathymetric-topographic DEMs.

Milestone 3. Develop techniques and software to process raw Deep-ocean Assessment and Reporting of Tsunamis (DART) data with various time discretization and record lengths to produce high-quality data sets for climate and tsunami research.

All high-resolution DART buoy high-resolution observations are processed, and data for selected significant tsunami events, including the Honshu Island tsunami in March 2011, are now available through new National Geophysical Data Center (NGDC) web pages. To improve the quality of the processed data, an additional "QA" program module was developed to fix instrumental issues, to suppress high-frequency noise, and to analyze the spectral energy characteristics of traveling tsunami waves. A paper was published in a special tsunami issue of *Pure and Applied Geophysics* describing

NGDC-08, Milestone 4

in detail all aspects of data processing and the collaboration with the NOAA National Data Buoy Center and Pacific Marine Environmental Laboratory. NGDC staff developed tsunami event pages to deliver summaries of the tsunami event, including socio-economic impacts, tsunami travel time maps, photos showing the damage sustained in coastal communities, and to provide raw observations, de-tided residuals, and spectra of the tsunami signal and wavelet. These pages are integrated with the NOAA Global Historical Tsunami Event Database and show the maximum wave height based on tide gauge or observations. These data are essential to tsunami researchers and educators in providing a more complete record of tsunamis and their propagation in the open ocean.

Milestone 4. Enhance online and offline access and delivery of hazards data.

CIRES staff at NGDC have improved data discovery and access to hazards data. NGDC's map services and viewers have been maintained and improved over the past year. The Natural Hazards Viewer, an interactive map that allows access to the Historical Tsunami Database, has been improved by adding new search functionality and new basemaps and by modifying the underlying code to improve performance.

NGDC's map services and viewers are now more discoverable, by being advertised more widely through online catalogs such as ArcGIS Online and the new NOAA Geoplatform. These platforms allow users to easily view and design their own maps, and to mix and match different map services from various sources. Find an example for the Natural Hazards map service at: http://www.arcgis.com/home/item.html?id=fbb119ce92514d589265919515801978.

Discovery and access to coastal DEMs have been improved with a new map service that displays a single 'seamless' shaded relief visualization of all DEMs available at NGDC, using a constant color palette. In addition, both Esri (ArcGIS Online) and Google Maps/Google Earth have included many of NGDC's DEMs in their bathymetry basemaps, further increasing the visibility and utility of the DEM products at NGDC.

CIRES staff supported NOAA's Tsunami Awareness Week (March 25-31, 2012) by creating a set of educational materials: posters, graphics, maps, and an interactive Google Earth display. These materials highlighted NGDC's role as stewards of historical hazards and water level data, and were displayed in the lobby of the David Skaggs Research Center.

CSD-11 Processes in the Marine Boundary Layer

FEDERAL LEAD: ROBERT BANTA
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Understand dynamic processes in the marine boundary layer, such as the distribution of wind flow characteristics, including development of nocturnal low-level jets, the primary source of wind resources for offshore wind farms.

Milestone 1. Develop a detailed analysis of spatial and temporal variability of the offshore boundary layer wind flow characteristics using past experiment Doppler lidar measurements in the Atlantic off the coast of the northeastern United States. Impact: This research will advance the understanding of the spatial and temporal variability of wind flow characteristics responsible for mixing and transport processes in the offshore boundary layer, ultimately providing accurate estimates of wind resources at the heights where multi-megawatt wind turbines operate. The results can also be used for validation of satellite estimates of wind flow characteristics and in numerical models.

A wind turbine at the National Wind Technology Center south of Boulder, Colo.

The existing data set of a motion-compensated, High-Resolution Doppler Lidar offshore wind measurements was used to better understand the range of atmospheric conditions— and their spatial and temporal variability—encountered by offshore wind turbines above the surface at the level of the rotor blades. A sampling of data from the 2004 New England Air Quality Study (NEAQS) shows the kind of analyses and information available. Examples include time-height cross sections, time series, profiles, and distributions of quantities such as mean winds and shear. These analyses show strong spatial and temporal variability to the wind field in the marine boundary layer.

The lidar observations also show that near-surface winds often do not see many of the changes in the flow aloft, some of which were significant. Thus near-surface measurements, or even low-resolution profile measurements, often produce misleading results when extrapolated to hub height. Such results can lead to significant error in estimates of turbine power output. Winds near the coast show diurnal behavior, and frequent occurrences of low-level jet structure are evident especially during nocturnal periods. Persistent patterns of spatial variability of the flow field due to coastal irregularities should be of particular concern for wind-energy planning, because this affects the representativeness of fixed-location measurements and implies that some areas would be favored for wind energy production, whereas others would not.

AMOS-03 Prediction, Model Development, and Evaluation

- CSD-02 Chemical Transport Model Research
- GSD-03 Verification Techniques for the Evaluation of Aviation Weather Forecasts
- NGDC-03 Space Weather
- SWPC-01 Solar Disturbances in the Geospace Environment
- SWPC-02 Modeling the Upper Atmosphere

■ GSD-01 Numerical Weather Prediction
■ GSD-05 Numerical Prediction Developmental Testbed Center (DTC)
■ PSD-16 Raindrop Size Distributions
■ GSD-06 Environmental Information Systems
■ PSD-17 Environmental Modeling and Prediction

CSD-02 Chemical Transport Model Research

FEDERAL LEAD: MICHAEL TRAINER
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 3: Weather and Water

Project Goal: 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 1. Conduct a detailed study of the California ozone budget during the CalNex field study in the spring of 2010. Impact: This CIRES research will result in the first measurement-based tropospheric ozone budget for California. The findings will enable scientists and air-quality mangers to quantify the contribution of baseline ozone to the exceedances of ozone air-quality standards in California.

Much of the analysis for this milestone was completed prior to July 1, 2011. However, the results were published in *JGR-Atmospheres* in December 2011 and describe the first measurement-based quantification of the California ozone budget (Cooper et al., 2011). The ozonesonde profiles collected during the 2010 CalNex experiment have proven to be a highly valuable and unique data set with application for several additional studies of the California and western North America ozone budget.

Langford et al. (2012) show that springtime stratospheric intrusions can impact the surface of southern California and combine with local pollution to push ozone-mixing ratios above the National Ambient Air Quality Standard (NAAQS). Lin et al. (2012) used a high-resolution global chemical transport model to simulate the transport of Asian pollution plumes to the surface of the western United States. The model indicated that the Asian ozone combines with local pollution and enhances surface ozone in the southwestern USA such that half of the NAAQS exceedances would not have occurred in the absence of Asian influence. The ozonesonde data will also be applied to an upcoming regional model intercomparison study of the influence of Asian emissions on western U.S. surface ozone.

Coordinated by the United Nations–mandated Task Force on Hemispheric Transport of Air Pollution, the goals are to: (1) understand how well regional scale models replicate the transport processes that bring Asian pollution to the surface; and (2) quantify the improvement in accuracy that is gained by employing regional scale models over coarser-resolution global scale models.

Milestone 2. Use existing inventories, available field and satellite measurements, and models to improve the emission inventories for chemical transport models; and initiate a multiagency effort to coordinate U.S. research on emissions and enhance access to emission data sets and tools for their evaluation. Impact: These comparisons will provide an evaluation of the status of the most recent inventories and the temporal trends in emissions that have been seen over the last decade. The multiagency initiative will strengthen the research relationships among the inventory development, observations, and modeling communities.

Dan Lack

The NOAA P3 research aircraft gathered air chemistry data during the Deepwater Horizon oil spill.

Task 1: We completed our evaluation of U.S. Environmental Protection Agency (EPA) 2005 National Emission Inventory (NEI2005) estimates of air pollution emissions. The NEI2005 have deficiencies in representing NO_x, ethylene, and propylene emissions from Houston's petrochemical industry and NO_x emissions from Houston's in-port commercial shipping. Newly developed emission inventories that are based on our evaluations and inversion models improved the model's ability to simulate secondary ozone and formaldehyde in the city's pollution plumes. The several results from this project were published in major journals. After the completion of the project, we started to examine the emissions and air quality in California during the CalNex 2010 field campaign.

Task 2: The Community Initiative for Emissions Research and Applications (CIERA) kept a good partnership of the U.S. EPA, NOAA, the Federation of Earth Science Information Partners (ESIP), Department of Energy (DOE), International Global Atmospheric Chemistry (IGAC), NCAR, several academic institutions, and the private sector. Activities by CIERA were presented through major scientific conferences and IGAC newsletters, and there was good progress in the development in the CIERA web portal.

Milestone 3. Use measurements of aerosols and their precursors made during the 2006 Texas Air Quality Study field mission in conjunction with a state-of-the-art air-quality forecast model to assess recent developments in the treatment of secondary organic aerosol formation and their impact on particulate matter (PM2.5) aerosol forecasts. Impact: This CIRES research contributes to improved forecasts of aerosol within air-quality models and directly supports NOAA's mission of having an operational national PM2.5 aerosol forecasting system by 2015.

This work incorporated recent laboratory and theoretical advances in SOA (secondary organic aerosol) formation within a regional photochemistry/aerosol model. A new SOA formation mechanism based on the Carnegie-Mellon Volatility Basis Set (VBS) approach was applied to the WRF/Chem model, and evaluated for the summer 2006 using PM2.5 composition measurements from three national networks and the Texas Air Quality Study, and published in early 2012 (Ahmadov et

al., 2012). Critical evaluations show the new SOA module compares well with available organic aerosol measurements and provides statistical skill in predicting organic aerosol (OA). The model code was submitted to the publicly accessible WRF model repository and incorporated within the WRF/Chem (version 3.4) release of March 2012.

During the 2010 Deep Water Horizon (DWH) oil spill disaster in the Gulf of Mexico, the NOAA WP-3D aircraft sampled upwind and downwind of the spill site on two separate days (see photo). WRF/Chem simulations were used to characterize the photochemical conditions during these flights (de Gouw et al., 2011) and provide a platform for hypothesis testing of OA measurements. The SEARCH aerosol network (Southeastern Aerosol Research and Characterization) also observed organic aerosol from the DWH at two sites in Mississippi during the disaster. WRF/Chem simulations using the VBS mechanism for SOA formation were applied to May and June 2010 and compared to these surface observations. Results showed the VBS mechanism accurately predicted the timing and concentrations of the DWH OA plume, providing a model estimate for assessments of health impacts from the disaster (Middlebrook et al., 2011).

GSD-03 Verification Techniques for the Evaluation of Aviation Weather Forecasts

FEDERAL LEAD: JENNIFER MAHONEY
CIRES LEAD: ANDREW LOUGHE

NOAA Goal 3: Weather and Water

Project 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 1. Develop a verification plan for assessing the quality of the Graphical Turbulence Guidance Product (GTG) version 3 and the GTG Product Nowcast.

The GTG Product Nowcast project has been delayed by the Federal Aviation Administration (FAA), and so a verification plan is not required at this point.

The GTG Product version 2.5 evaluation was completed and reported to the FAA. The verification plan for GTG Product version 3 will be submitted to the Product Development Team in July and will include the incorporation of an additional eddy dissipation rate (EDR) platform, the inclusion of mountain wave turbulence, and the extension of the analysis down to the surface. In addition, further work is being performed on the EDR data in order to learn more about the nature of atmospheric turbulence.

Milestone 2. Provide assessment report summarizing the findings from an evaluation of the Current Icing Potential and the Forecast Icing Potential.

A formal assessment addressing differences between Rapid Update Cycle (RUC)–derived and Rapid Refresh (RAP)–derived Forecast Icing Potential (FIP) and Current Icing Potential (CIP) icing products for improved aviation safety was completed and presented to sponsors in December 2011. An important conclusion of this study regarding the analysis product (CIP) was that analyzed icing from the new, operational RAP meso-scale model performs in a manner similar to that of the older RUC model, but the new model is more efficient at identifying areas of potential in-flight icing throughout the atmosphere. Icing production at night is more in line with observations, and is greatly reduced in the newer model.

While the detection rate for icing was found to be comparable between the two models, the new model performs slightly better at correctly identifying areas of 'no icing.' Regarding the forecast product (FIP), a significant finding was a large decrease in super-cooled large droplets in the new RAP model. There was a problem detected in the relative humidity interest maps of the old model, and once corrected in the RAP, this desirable effect was measured and then reported. The forecast product from the RAP was also determined to have a higher detection rate for icing and a similar rate of detection for non-icing events. The take-home point from this report is that both diagnosed and forecast icing potential from the new RAP model will perform in a similar matter to the model it is replacing, and the new model is more efficient at correctly identifying areas of icing throughout the U.S.

Milestone 3. Provide a comprehensive assessment of the Consolidated Storm Prediction for Aviation (CoSPA) forecast algorithm in support of the Federal Aviation Administration FY10 demonstration.

The 2011 CoSPA evaluation experiment was completed in FY11 with a formal report completed in early FY12. The CoSPA evaluation utilized many of the techniques from the 2010 evaluation demonstration; however, the 2011 one contained more stratifications and more event-driven analyses that were useful for FAA management. The 2011 results were contrasted with the 2010 findings and presented to FAA Aviation Weather Research Program management as well as members of the other product development teams. In addition to summary statistics presented at the end of the convective season, monthly reports were available with selected days highlighted for important case studies.

NGDC-03 Space Weather

FEDERAL LEAD: ERIC KIHN
CIRES LEAD: JUSTIN MABIE

NOAA Goal 4. Transportation

Project 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 1. Add new features to the Space Physics Interactive Data Resource (SPIDR), including the work flow system, data dashboard, and collaboration on new web service interface development with colleagues at the Russian Academy of Sciences, Geophysical Center.

SPIDR was updated to include additional web service features to provide programmatic access to both its data and metadata. One recent addition this year was a catalog service that allows data customers to determine what is available for all data sets within SPIDR, at a very fine-grained level. This service is currently used externally by NASA's/George Mason University's AutoPlot software to expose SPIDR's data along with its own to its entire user base. This would not have been possible without the catalog service.

Milestone 2. Develop an operational version of the D-Region Absorption Prediction (DRAP) Modeling System on the National Geophysical Data Center (NGDC) website, which will generate model outputs that are available from, and archived at, NGDC.

The DRAP project currently exposes preselected events for download by data customers, but the second portion of the project—to create a dynamic/on-request model run application—was postponed. The task of porting the existing Microsoft centric software to NGDC's Linux environment, as well as the maintenance that implies, was put on hold. The current static site and data are how this project will remain for the time being.

Milestone 3. Develop a 'Geomag Tracking Database' to track geomagnetic data holdings at NGDC in order to modernize the geomagnetic data stewardship program and provide a tool that will help correct past difficulties in data stewardship and dissemination.

MIRRMAG (MIRror of online MAGnetic data) Ingest system was developed and implemented. The system retrieves data from the data provider and launches loading routines to make the data publically available on the NGDC website and load the data into the Space Physics Interactive Data Resource. This task is complete, and a new milestone must be developed for FY2013.

Milestone 4. Develop a MIRRMAG data (MIRror of online MAGnetic data) ingest system that will ingest available, online geomagnetic data into NGDC databases. Once ingested, the system will perform any needed format processing, load the data into the SPIDR database, port the data to the NGDC FTP site, and port the data to the tape library ingest staging area.

MIRRMAG system is complete and operational. Tasking has been changed to focus on solar data products and indices. A new task must be formulated for FY2013.

SWPC-01 Solar Disturbances in the Geospace Environment

FEDERAL LEAD: VIC PIZZO
CIRES LEAD: ALYSHA REINARD

NOAA Goal 3: Weather and Water

Project 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 (CME) 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 1. In collaboration, SWPC will modify and test the empirical relationship linking helicity and future flaring potential of a given active region, and will evaluate its potential as a forecasting tool for solar flares.

At this point we have made strong progress toward our goals. We have gone back to basics to understand the subsurface velocity flows that affect flare production. This analysis will help in our collaboration with active region modelers who will use our results as inputs to their models of CME/flare eruptions.

We have started an in-depth study of a single active region to relate subsurface flows to CME and flare eruptions. We have done a comparison between eruptive (CME-associated) and non-eruptive flares to see if the subsurface signatures are different for CMEs and flares, and we have found essentially no difference between the two populations. We have looked at the timing of vorticity changes and found differences between the shallower layers and the deeper layers. Finally, we have been working to improve our input data by reducing effects from systematic variations in subsurface flows with active region position on the disk.

SWPC-02 Modeling the Upper Atmosphere

FEDERAL LEAD: MICHAEL CRUMLY
CIRES LEAD: TIMOTHY FULLER-ROWELL

NOAA Goal 3: Weather and Water

Project 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 1. Quantify the impact of sudden stratospheric warmings (SSW) on the upper atmosphere. Recent observations suggest that SSWs impact the dynamics and electrodynamics of the lower thermosphere and change the diurnal variation of total electron, which is an important component of space weather. The recently developed Whole Atmosphere Model (WAM) simulates SSW naturally so will be used to quantify their impact on the thermosphere and ionosphere.

A suite of physical models were used to addressed the question: Does a sudden stratospheric warming warm or cool the thermosphere? If it warms, then one would expect to see a neutral density increase and an increase in satellite drag. Observations during the record-breaking January 2009 warming, however, appeared to indicate a cooling during the period of 30 percent, and papers had already been published using CHAMP satellite data indicating such a response. However, when careful simulations were performed with the coupled thermosphere ionosphere physical model (CTIPe) and the information was extracted from the MSIS empirical model, the models showed the cooling was very likely due to a decrease in geomagnetic activity that happened to coincide with the startwarm.

The correlation of the CTIPe physical model neutral density response with CHAMP observation was very high, 0.9, indicating high confidence that the apparent decrease in temperature and density had little to do with the SSW. The extremely low solar activity at the time made the thermosphere particularly sensitive to geomagnetic activity.

On the contrary, the whole atmosphere model (WAM) suggested a slight warming in the upper thermosphere of about 5 percent globally. However, it would be difficult to detect this modest warming in the CHAMP observations due to the accompanying changes in solar and geomagnetic activity. It also appeared that subtle changes and shifts in the amplitude and phase of the diurnal variation could further have masked the response along the CHAMP satellite orbit.

GSD-01 Numerical Weather Prediction

FEDERAL LEAD: GEORG GRELL
CIRES LEAD: CURTIS ALEXANDER

NOAA Goal 3: Weather and Water

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

Milestone 1. Conduct and evaluate a summer 2010 and 2011 convection forecast exercise with other Aviation Weather Research Product Development Teams (Convective Weather, in particular) in which the High Resolution Rapid Refresh (HRRR) run at convection-resolving resolution over the conterminous United States plays a dominant role. The goal of this exercise is to evaluate the potential effectiveness of the HRRR in predicting high-impact aviation weather, particularly convection, three to 12 hours in advance.

The HRRR model remains a foundational component of the 2010-2012 CoSPA forecast system used as convective weather guidance in both tactical and strategic flight planning in the national airspace.

Prior to the summer 2012 season, the underlying Weather Research and Forecasting (WRF) model of the HRRR and the parent Rapid Refresh model (RAP) were updated to include the official version 3.3.1 release. Model enhancements were introduced in the RAP and HRRR to increase the accuracy of the model dynamics and physics including higher order vertical advection, more frequent calls to the shortwave radiation driver, improved damping of vertical motion near the model tops, updated fractional land use information for the land surface model, and an improved model reflectivity diagnostic consistent with the updated microphysics.

In addition to RAP and HRRR model enhancements, numerous improvements were made in the RAP data assimilation to reduce a moist bias observed in 2011 RAP and HRRR forecasts, including excessive soil moisture, dewpoints, precipitation, and convective initiation, particularly in the first few forecast hours of each model cycle. Data assimilation enhancements included additional emphasis of surface dewpoint observations in mixed boundary layers, soil moisture adjustments to correct for excessive latent heat flux, removal of snow hydrometeor specification from radar observations in the warm season, limited water vapor increments from precipitable water observations, and increased atmospheric stability during cloud building. These changes have resulted in improved RAP and HRRR convective forecasts in 2012 with higher skill scores and a reduced moist bias.

Milestone 2. Progress toward construction of an Earth System Research Laboratory (ESRL) Earth system model by coupling an icosahedral formulation of the global Hybrid Coordinate Ocean Model (currently under development within ESRL) with the global Flow-following finite-volume Icosahedral atmospheric Model (FIM) on an identical horizontal grid. Test this coupled model on individual cases, and in real time if adequate computing resources and initial data are available.

Disclaimer: While Milestone 2 qualifies as a numerical weather prediction project, this work is rather unrelated to the topics described above under 'Project Goal.' In terms of temporal and spatial scales, Milestones 1 and 2 are diametrically opposed. Unlike Milestone 1, whose focus is well-described in the project write-up, Milestone 2 deals with global prediction issues and year-to-year atmospheric circulation anomalies, i.e., climate variability. This distinction should be clarified in the next round of project descriptions.

There has been incremental progress on the technical side of model development. The ESRL Earth System Model at present consists of only two components, an ocean and an atmosphere. Both work well, even though there are concerns regarding the dynamic viability of an ocean model that uses unstructured grids in all three dimensions (icosahedral in the horizontal and hybrid-isopycnic in the vertical). Attempts to conduct decadal coupled simulations have highlighted problems common to virtually all climate simulation efforts: sea surface temperature drifts due to an erroneous geographic distribution of light-reflecting clouds and insufficient 'tuning' of global cloudiness to achieve a net-zero radiation flux at the top of the atmosphere. Efforts to resolve these issues will continue for some time.

GSD-05 Numerical Prediction Developmental Testbed Center (DTC)

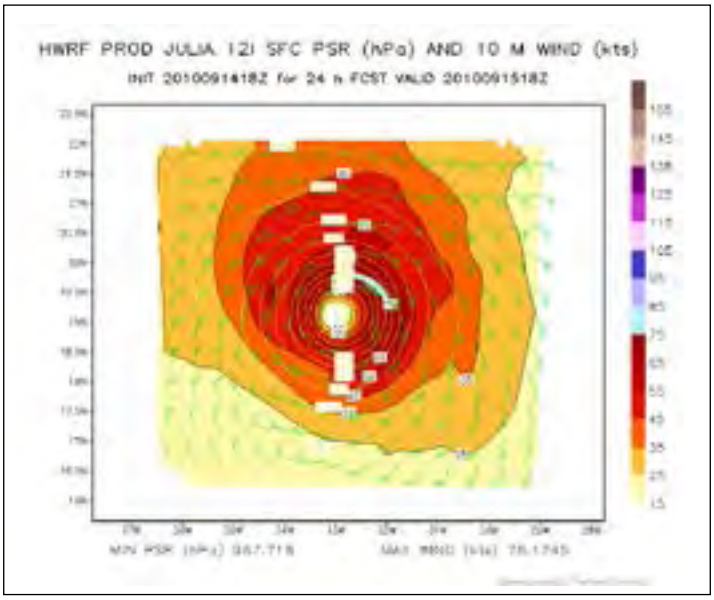
FEDERAL LEAD: ZOLTAN TOTH
CIRES LEAD: LIGIA BERNARDET

NOAA Goal 3: Weather and Water

Project Goal: Transition new developments from research to operations in the Gridpoint Statistical Interpolator (GSI) data assimilation system and the Hurricane Weather Research and Forecasting (HWRF) modeling system through the Developmental Testbed Center (DTC).

Milestone 1. Upgrade the community Hurricane-Weather Research and Forecasting model (HWRF) code to contain new developments used by NOAA's National Centers for Environmental Prediction (NCEP) for the 2010 operational hurricane season and run extensive tests to assure that the community HWRF is performing as well as operational HWRF, enabling a transition of the community code to NCEP for the 2011 hurricane season.

The Hurricane-Weather Research and Forecasting model (HWRF)



GSD-05, Milestone 1

code used for operations at NOAA's National Centers for Environmental Prediction (NCEP) has been kept synchronized with the community code used for research. In August 2011, HWRF v3.4a, which contains the capabilities of the 2011 operational implementation, was released to the research community. Conversely, contributions to the community were incorporated in the revised HWRF operational model implemented in May 2012. Those include the use of the Princeton Ocean Model for Tropical Cyclones (POM-TC) for the Eastern North Pacific basin (previously run in uncoupled atmosphere-only mode) and advancements in the physics and initialization of the atmospheric model.

In order to keep the code synchronized, tests are constantly conducted to assure the integrity of the code, to confirm that the code continues to work on multiple platforms, and to ascertain that contributions that do not intend to alter the answer of the default configuration indeed do not alter it. As part of these tests, a significant bug was found in the convective parameterization code, and an emergency fix was implemented in HWRF in the middle of the 2011 hurricane season. Extensive runs were also conducted to benchmark the community HWRF system, in order to create a control against which future innovations can be compared.

Milestone 2. Maintain the code repositories for Gridpoint Statistical Interpolation (GSI) and Hurricane-Weather Research and Forecasting model (HWRF) and provide user support for both codes (helpdesk, website, code distribution, and documentation).

The code repositories for the Gridpoint Statistical Interpolator (GSI) and the Hurricane Weather Research and Forecast (HWRF) have been maintained to incorporate contributions from research and operations. For GSI, research contributions have been received in the areas of assimilation of aerosol data and surface PM2.5 observations for regional air-quality forecasting, and in enhancements of the surface data analysis and cloud analysis for the Rapid Refresh (RAP) application. For HWRF, contributions include the use of the Princeton Ocean Model for Tropical Cyclones (POM-TC) for the Eastern North Pacific basin (previously run in uncoupled atmosphere-only mode) and advancements in the physics and initialization of the atmospheric model.

The community GSI repository was regularly synchronized with the operational one. Every proposed code change to the operational trunk was thoroughly tested before being committed to make sure the change can be successfully run on multiple platforms.

Release and support of the GSI v3.0 and HWRF v3.3a community systems have been done through the Developmental Testbed Center. User support involves maintenance of a website where users can obtain updated documentation, code downloads, data sets, and case studies. There are currently 550 and 410 registered users for GSI and HWRF, respectively. In addition to the community releases, all components of the experimental HWRF system (GSI data assimilation, atmospheric model, ocean model, etc.) have been made available to developers so that collaborations can be established toward next year's operational implementation.

PSD-16 Raindrop Size Distributions

FEDERAL LEAD: TIMOTHY SCHNEIDER
CIRES LEAD: CHRISTOPHER WILLIAMS

NOAA Goal 3: Weather and Water

Project Goal: Improve ground-based, airborne, and space-borne radar rainfall estimates through increased understanding of the number and size of raindrops in precipitating cloud systems.

Milestone 1. A vertical air motion estimation technique will be developed using collocated 50- and 920-megahertz (MHz) radar observations to isolate the vertical air motion resolved in the 50-MHz radar observations. These columnar dual-frequency vertical air motion

Rain Catchers

David Noone has more than 200 talented research assistants—they just happen to be in middle school. Through the CIRES Education & Outreach Program, Noone has partnered up with students in the St. Vrain Valley School District to collect rainwater from school rooftops and data from weather stations as part of his research into the water cycle. By looking at the samples' chemistry, he can learn where the water came from (for example, the Gulf of Mexico or the Pacific) and where it's going. And he couldn't do this work without the help of his scientists-in-training.

What can we gain from this research?

Understanding how water moves around in the air—the water cycle—will help us know how to use water more effectively for agriculture, environmental sustainability, and recreation. One of the greatest challenges in adapting to climate change is anticipating changes to water availability. Our research seeks to improve the ability to understand and predict changes in how water on the landscape and in the atmosphere varies.

Where do the kids come in?

For our work in Colorado, we need information from the region. Some of our detailed measurements are only made at a single point, in Erie, but we need the wider network to understand the context. Obtaining the data to provide this context is not really possible without making use of citizen science—in this case, the help of students. We gain extensive data and a network perspective on the precipitation patterns in the region.

The students, in turn, get valuable learning opportunities both in regard to learning about their local and global environments and in the types of research being done in the science community. One aim of our work is to encourage students to think about science and technology as an important part of their future careers. We help the students, and the students help us. It's a win-win.

How have the students responded?

Good question! At the moment we're still in the spin-up phase. Mostly we've been working with teachers. We're rolling out curriculum packages shortly.

estimates will provide reference measurements for simultaneous dual-Doppler scanning radar estimates.

A manuscript describing how the Doppler velocity spectra from two collocated vertically pointing profilers can be used to retrieve an unbiased vertical air motion estimate during precipitation has been accepted for publication in the *Journal of Atmospheric and Oceanic Technology* (Williams, 2012: Vertical air motion retrieved from dual-frequency profiler observations. Early online release available at http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-11-00176.1). The photo shows the antennas for the two profiling radars used in this study located near Darwin, Australia. The 920-MHz profiler antenna is in the foreground, and it is a two-by-two-meter square antenna under a water-protective radome. The 50-MHz profiler antenna is in the background and is a 100-by-100-meter square antenna.

Three different collaborators have used the dual-frequency vertical air motions. The first study evaluated the accuracy of ice terminal fall speeds derived from vertically pointing radar measurements. This study is published (Protat and Williams, 2011). The second study used the dual-frequency vertical air motions as validation data for a scanning radar dual-Doppler vertical air motion retrieval method. A manuscript describing this work has been submitted (Scott Collis, Alain Protat, Peter May, and Christopher Williams, submitted).

The third study divided the dual-frequency vertical air motions based on cloud regimes to document the vertical air motions in shallow convective clouds, stratiform clouds, and deep convective clouds. A manuscript describing this work is in preparation (Courtney Schumacher, Stephanie Stevenson, and Christopher Williams, in preparation).

GSD-06 Environmental Information Systems

FEDERAL LEAD: PATRICIA MILLER
CIRES LEAD: LEON BENJAMIN

NOAA Goal 3: Weather and Water

Project Goal: Develop information systems that deliver atmospheric observation data and environmental products to users of weather, water, and climate information.

Milestone 1. Complete Final Operating Capability of the Meteorological Assimilation Data Ingest System (MADIS) at the National Weather Service.

The MADIS transition to Final Operating Capability (FOC) is progressing well. We spent the last year growing the number of stations in MADIS, hardening the operational processing, and re-engineering the system FOC design. A new Letter of Agreement was signed in April 2012 between the National Weather Service (NWS), the Office of Oceanic and Atmospheric Research (OAR), and the National Environmental Satellite, Data, and Information Service (NESDIS) and provides guidance for the transition of MADIS from initial operating capability (IOC) to FOC and beyond. FOC is scheduled for fiscal year 2014 with the production system under National Centers for Environmental Prediction (NCEP) and NESDIS. OAR will provide level-three support and code updates.

This past year MADIS added 2,800 new surface stations; increased the number of surface and upper-air sites processed per hour by 9,000; reached servicing 1 million customer data requests per day; and added more than 200 new MADIS data users accounts. We started the knowledge transfer from OAR to NCEP for real-time operations, including

GSD-06, Milestone 3

user accounts maintenance, and troubleshooting processing issues. We submitted more than a dozen request-for-change (RFC) for improvements to our operational processing. We answered more than 3,000 data users and providers information requests.

Milestone 2. Port FX-Collaborate drawing tool software to AWIPS II.

The port of FX-Collaborate (a weather collaboration program) functionality to the Advanced Weather Interactive Processing System II (AWIPS II) involves the addition of a drawing tool in order to allow weather forecasters the ability to produce annotated products. The latter might include, for example, a cold front line, text explaining various features, shaded shapes representing warning areas, etc. The previous-generation AWIPS system required that forecasters use a standalone tool, FX-Collaborate, in order to create such annotated products. This project integrates drawing capability into the core AWIPS II software.

In the last year, the previously existing near-production-ready AWIPS II drawing tool was further refined. In addition to a number of bug fixes, successive upgrades of the drawing tool were required in order to match new capabilities and limitations of new versions of the core AWIPS II software suite as the latter became available. New functionality was also added, including better Google Earth integration; refinements to text annotations; and the addition of a properties palette, enabling users to quickly see and modify multiple glyphs' properties simultaneously.

The result is a CAVE (Common AWIPS Visualization Environment) plug-in providing nearly all of the functionality of the FX-Collaborate drawing tool, as well as considerable enhancements not present in the original, fully integrated into the core AWIPS II software. At this stage, the only plans with regard to further development are to fix bugs as they are revealed. If funding is forthcoming for further augmentation in the future, this will be pursued as well.

Milestone 3. Develop an AWIPS II collaboration prototype as part of the AWIPS II.

Raytheon Co., the developer of the Advanced Weather Interactive Processing System II (AWIPS II) weather forecasting system, is integrating collaboration into the core AWIPS II software. This will allow real-time collaboration between weather forecasters at different sites by allowing them to share weather products, drawings, and other data within the AWIPS II environment. The work done by CIRES researchers on collaboration within the AWIPS II environment now serves as a prototype for Raytheon's ongoing implementation.

A number of different approaches to the implementation of collaboration, utilizing different technologies (simple desktop sharing,

open-source conferencing [similar to WebEx], and dedicated AWIPS II plug-in), were investigated. The resulting findings were submitted to Raytheon as input as to the strengths and weaknesses of various approaches, in order to assist them in moving forward with implementing AWIPS II collaboration.

Furthermore, the existing code from last year's work on the collaboration prototype was further refined to fix bugs, and to provide more synchronization between collaborators. The prototype was then submitted to Raytheon as a functioning implementation of collaboration within the AWIPS II environment. Said prototype uses XMPP (Extensible Messaging and Presence Protocol) messages passed between participating AWIPS II clients, and Openfire (an open-source server responsible for coordinating the session) to exchange information about products each client has loaded. Raytheon has chosen to use the same technologies successfully demonstrated by the prototype (XMPP via an OpenFire server and an AWIPS II plugin) in their production implementation of collaboration.

PSD-17 Environmental Modeling and Prediction

FEDERAL LEAD: GARY WICK
CIRES LEAD: DARREN JACKSON

NOAA Goal 3: Weather and Water

Project Goal: Improve the performance of numerical weather and climate models through model process evaluation using data streams from focused observational campaigns and spaceborne measurements.

Milestone 1. Assess the representation of water vapor content and transport in the new Flow-following finite-volume Icosohedral Model during wintertime precipitation events along the U.S. West Coast using satellite observations, and compare with that of other operational models.

The work on this task has focused on the application of an objective, automated technique for the identification and characterization of atmospheric river events to corresponding satellite observation and model forecast fields to evaluate the performance of the models. A manuscript describing the development and validation of the technique has been accepted for publication in the *IEEE Transactions on Geoscience and Remote Sensing*.

The technique was applied to three cool seasons (October–March) of satellite data and five different operational numerical weather prediction models including those from NOAA, the European Center for Medium Range Weather Forecasting (ECMWF), the UK Met Office, the Japanese Meteorological Agency, and Canadian Meteorological Center. Intercomparisons of the models' representation of water vapor content are currently being completed, and a second manuscript is in preparation and due to be submitted by Oct. 1, 2012.

AMOS-04: Observing Facilities, Campaigns, and Networks

- GMD-02 Surface Radiation Network
- PSD-10 Cloud and Aerosol Processes
- PSD-11 Water Cycle
- GSD-04 Unmanned Aircraft Systems

GMD-02 Surface Radiation Network

FEDERAL LEAD: JOSEPH MICHALSKY
CIRES LEAD: GARY HODGES

NOAA Goal 2: Climate

Project 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 1. Using SURFace RADiation (SURFRAD) databases, complete and publish an analysis of spectral albedo at the Table Mountain, Colo., SURFRAD station and present the results in conferences.

No progress was reported for this Milestone.

PSD-10 Cloud and Aerosol Processes

FEDERAL LEAD: TANEIL UTTALTIM SCHNEIDER
CIRES LEAD: MATTHEW SHUPE

NOAA Goal 2: Climate

Project 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 1. Produce cloud macrophysical and microphysical data sets describing the clouds at Arctic atmospheric observatories. These data sets will include information on cloud occurrence, vertical distribution, boundaries, phase, and microphysical properties.

There continues to be ongoing work to develop and evaluate Arctic cloud products. Recent efforts have focused on new measurements as part of the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project wherein a comprehensive suite of atmosphere and cloud-sensing instruments has been installed at Summit Station, Greenland, on top of the Greenland Ice Sheet. Initial work has been started to develop cloud occurrence fraction, liquid water path, and temperature data sets. Many of the initial results have been summarized in a paper that has been submitted to the *Bulletin of the American Meteorological Society*.

Additionally, cloud retrieval products from the Arctic group have been used in a number of model evaluation and retrieval evaluation studies (Zhao et al., 2012; Birch et al., 2012; de Boer et al., 2012; Fridlind et

al., 2011; Solomon et al., 2011; and Du et al., 2011).

Milestone 2. Utilize ground-based, multi-instrument, remote-sensor measurements, aircraft *in situ* observations, and high-resolution mesoscale models to study the role of cloud dynamical-microphysical processes in the Arctic cloud life cycle. Specific observations will come from various sites, including NOAA's Study of Arctic Environmental Change, SEARCH; the DOE's ARM sites, and the Surface Heat Budget of the Arctic, SHEBA; Arctic Summer Cloud Ocean Study, ASCOS; and Arctic Mechanisms of Interaction between the Surface and Atmosphere, AMISA, field campaigns.

A number of activities have occurred under this milestone. Observationally, a retrieval method for deriving turbulent dissipation rate from cloud radar measurements has been evaluated via comparisons with aircraft observations from the DOE ARM site and tethered balloon measurements from the Arctic Summer Cloud Ocean Study (ASCOS) showing that the radar method is able to provide important information on profiles of turbulence in clouds (Shupe et al., 2012).

Additionally a study was conducted that utilized the Weather Research and Forecasting (WRF) model to examine in high resolution an Arctic mixed-phase stratocumulus cloud. That study specifically focused on the important role the moisture inversions play as a source for cloud moisture and the transport of the moisture into the cloud layer. The vertical structure of moist static energy and entrainment processes has also been examined. These model studies have been summarized in Solomon et al. (2011). Building on this concept of moisture inversions, an observational study was also conducted that examined these moisture inversions using radiosonde measurements at multiple Arctic locations and related them to the presence of cloud water inside of temperature inversions that typically reside at the top of low-level Arctic clouds (Sedlar et al., 2012). This characteristic of many Arctic clouds is not observed at lower latitudes, and the processes responsible are still under investigation.

Milestone 3. Participate in the Northwest Tropical Atlantic Salmon, NTAS; PIRATA Northeast Extension, PNE; and CalNex research cruises in 2010. Deploy cloud radar, radiometer, and flux systems to measure key surface marine boundary layer parameters, low cloud macrophysical, microphysical, and radiative properties. Conduct initial analysis focused on the associations between low clouds and the boundary layer structure.

The CIRES–NOAA team participated in the Air Quality and Climate Change Field Study in California in 2010 (CalNex 2010). Results have been used in data workshop and a publication has been submitted: McBride, PJ, KS Schmidt, P Pilewskie, A Walther, AK Heidinger, DE Wolfe, CW Fairall, S Lance (2012), A CalNex climatology of cloud optical properties retrieved from a ship-based spectrometer and comparisons with satellite and aircraft retrieved cloud properties, *J. Geophys. Res.*, submitted.

PSD-11 Water Cycle

FEDERAL LEAD: MARTY RALPH
CIRES LEAD: DAVID KINGSMILL

NOAA Goal 3: Weather and Water

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

Milestone 1. Plan and execute the 2011 Hydrometeorology Testbed, HMT-West field campaign, an annual series of field efforts conducted in the northern California American River basin, located in the Sierra Nevada Mountains west of Lake Tahoe and east of Sacramento. CIRES investigators will be key participants and contributors to these activities.

HMT-West field operations for the 2011–2012 cool-season focused on data collection from autonomous instrumentation operating at sites across northern and central California, as well as sites in the Pacific Northwest and Colorado River Basin. There were no intensive observing periods (IOPs) and no staffing of sites in the HMT-West domain; thus there was no need for daily field operations coordination calls. This strategy allowed for greater attention to deployment of the HMT-West Legacy Network, as well as analysis of past data and development of new tools.

The goals of data collection for the 2011–2012 cool-season included:

- Calibration of the KPIX C-band radar and quantitative precipitation estimation (QPE) studies using data collected from KPIX, surrounding NEXRAD radars, and rain gauges;
- Testing autonomous operations of the SkyWater radar at the Lincoln, Calif., field site;
- Ongoing implementation of the HMT-West Legacy Network in Calif.

Milestone 2. Develop and test an approach for a synergetic use of C-band scanning polarimetric radar (C-POL) and vertically pointing 8-millimeter wavelength radar (MMCR) for simultaneous retrievals of parameters in stratiform precipitating systems at the Tropical Western Pacific (TWP) Darwin Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF). This remote-sensing approach will aim to estimate liquid cloud water path and rainwater path in the liquid hydrometer layer and simultaneously retrieve an ice water content profile and ice water path in the same vertical atmospheric column. In addition to measurements from radars that are currently available at the Darwin ACRF, the ground-based rain gauge and disdrometer data will be used to constrain retrievals. The suggested remote-sensing approach will be tested using data from a number of experimental events. The retrieval uncertainties will be evaluated.

The approach for the synergetic use of the 5-centimer (C-band) scanning polarimetric (C-POL) and the vertically pointing 8-millimeter (Ka-band) radars was enhanced. The enhancement included correcting for the attenuation of C-band radar signals in rainfall using differential phase shift measurements, so better quality estimates of non-attenuated profiles of reflectivity over the MMCR site can be obtained when the C-Pol performs range-height indicator scans. As a result, the improved retrievals of the total rain water content and cloud liquid content (as well as ice water content profiles above the Darwin ACRF site) can be obtained. The enhanced retrieval approach was applied for several priority cases observed during the field intensive operation period. The retrieval results were given to the model community for comparisons with model outputs.

Milestone 3. Apply a CloudSat method for simultaneous retrievals of mean rain rate and ice water path in stratiform precipitating systems to multi-year data sets collected during the CloudSat overpasses in the vicinity of the ARM Southern Great Plains Climate Research Facility (ACRF). The CloudSat retrievals will be analyzed for possible correlations between parameters of the ice parts of precipitating systems (e.g., ice water path) and the resultant rainfall. The satellite retrievals will be also compared to the ARM retrievals, so a consistency

Milestone 5. The CalWater experiment is a multi-year effort supported by NOAA and the California Energy Commission to study the impact of anthropogenic aerosols and climate change on precipitation and associated water supply in California. Aerosol and meteorological observing instruments will be deployed in key locations in California. Part of this effort will be to diagnose the vertical structure of the precipitating cloud systems in the context of collocated aerosol observations. Another part of this effort will entail analysis of meteorological observations to characterize the Sierra barrier jet, its modulation by atmospheric rivers, and the resultant spatio-temporal distribution of precipitation.

CalWater efforts were focused on documenting the kinematic and thermodynamic structure of the Sierra Barrier Jet (SBJ). Observations from scanning and profiling Doppler radars, balloon soundings, and GPS integrated water vapor retrievals were used to document the kinematic and thermodynamic structure of SBJs and associated Atmospheric Rivers (ARs) that occurred during Feb. 14–16, 2011. Results from this analysis include:

- SBJs extend westward from the Sierra across the entire Central Valley of California.
- ARs ride over stable air associated with SBJs and slope upward from southwest to northeast.
- The height of SBJs increases from southwest to northeast, especially over the windward side of the Sierra where it has a terrain-following character.

The climatological representation of the SBJ and its impact on water vapor transport was tested in reanalysis data sets and reanalysis downscalings, through comparison with the observations—primarily wind profiler data—collected during CalWater (and HMT). It was found that only very high resolution (less than 10-kilometer grid spacing) numerical models can represent this terrain-generated dynamical feature. In addition, SBJ representation within the highest resolution data set, WRF-RD, was found to be sensitive to stability within the Central Valley: WRF-RD's boundary layer was overly mixed, resulting in reduced stability compared with observations and reduced SBJ amplitudes during the strongest wind events. Meteorological characteristics during SBJ events that were well-represented within WRF-RD are currently being investigated.

PSD-11, Milestone 4

between space-borne and ground-based estimates of hydrometeor parameters in precipitating cloud systems will be investigated.

The CloudSat method for simultaneous retrievals of mean rates and ice water path was modified and extended for the use in moderate-to-heavy precipitation observed in land-falling hurricanes and hurricane remnants as they move inland. The enhanced retrieval method was applied to observations of hurricanes Gustav and Ike (2008), which had landfall in Louisiana and Texas, correspondingly. The total ice content of the hurricane systems in their active stage was shown to reach 20 kilograms per square meter. In the decaying stage, these hurricane systems observed inland (including regions close to the ARM Southern Great Plains Climate Research Facility) produced total ice contents and rain rates that were comparable to typical synoptic systems.

Milestone 4. Maintain configurations and web access to the real-time water vapor flux tool for use by researchers and weather forecasters to assess and monitor extreme precipitation events along the West Coast of the United States.

In support of the near-real-time water vapor flux tool, which is used by researchers and forecasters to help monitor and study extreme orographic precipitation events, automated software operations and configurations were developed, enhanced and maintained for nine different NOAA and cooperative agency sites along the U.S West Coast. This year developments were made to allow users to view Integrated Water Vapor, Total Flux, and Upslope Flux data spatially on Google Maps in near real-time. (http://www.esrl.noaa.gov/psd/data/obs/sitemap/psd-mapdata/)

This new display also allows users to view other data types including NexRAD data to help show areas of interest during precipitation events. Enhancements, developed by Dan Gottas, were also made to the existing water vapor flux time-height product to allow for expanded time coverage from 24 hours to 48 hours. The maintenance and configuration of software to distribute the tool's numerical flux data was also performed. Lastly, monitoring of data and product quality, as well as near-real-time availability, was accomplished on a daily basis to support research and forecasting efforts during the NOAA HMT campaigns.

GSD-04 Unmanned Aircraft Systems

FEDERAL LEAD: SARA SUMMERS
CIRES LEAD: ELIZABETH WEATHERHEAD

NOAA Goal 3: Weather and Water

Project Goal: Test and evaluate a variety of unmanned aircraft systems to collect scientifically valuable environmental data. The tests will be carried out in a variety of situations in support of multiple scientific goals. Results of funded unmanned aircraft projects will be provided in written reports that can be shared within NOAA and the general scientific community.

Milestone 1. Analyze sea ice images collected from satellite to automatically identify ice seals and derive fractal ice characteristics.

Seal identification software has been successfully developed and applied to more than 50,000 images collected in the Arctic of ice and seals. Images from Canadian missions have been collected to augment the initial 27,000 images collected by NOAA. The software was developed with an international team of environmental and computer scientists. Ice characteristics were characterized, and more than 100 individual seals were identified. Preliminary results were presented at the 2011 International Conference of Marine Mammalogy and the American Geophysical Union Annual meeting.

The software was developed by University of Colorado researchers including the principal investigaor, Betsy Weatherhead, as well as Jim Maslanik and Ute Herzfeld. External partners who contributed to this effort include Gwen Duclos from France, Trevor Clarke from Ball Aerospace, and Amanda Hodgson from Australia. International researchers have started to ask for collaboration on using the software for other applications, including looking for other environmental features collected by unmanned aircraft.

To summarize products, three sets of software have been developed to assist in the identification of seals on sea ice. The first set of software categorizes types of sea ice using a number of different criteria. The second set of software helps identify and describe potential seals. The third set of software acts as a graphical user interface to allow researchers to determine which potential seals are actually seals and which are not. Both the executable and source codes for this software are freely available. A process under which one can request the software is currently being developed.

GSD-04, Milestone 1

CLIMATE SYSTEM VARIABILITY

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

- GMD-03 Climate Trend Analysis
- PSD-04 Decadal Climate and Global Change Research
- NGDC-04 Paleoclimatology—Understanding Decadal- to Millennial-Scale Climate Variability

GMD-03 Climate Trend Analysis

FEDERAL LEAD:: SAMUEL OLTMANS
CIRES LEAD: IRINA PETROPAVLOVSKIKH

NOAA Goal 2: Climate

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

Milestone 1. Analyze ground-based, balloon, and aircraft *in situ* ozone measurements for long-term trends in the troposphere and at the surface.

All 18 surface ozone sites continued to collect data in 2011 and 2012. The most recently established NOAA surface-ozone-measurements site in the Arctic is near Tiksi, Russia. The Hydrometeorological Observatory of Tiksi (since 2010) and NOAA's Barrow, Alaska, Observatory (since 1973) are in the Arctic Circle at similar latitudes of 71.6° N and 71.3° N, respectively. Their locations provide a unique opportunity for measurement comparison due to minimization of solar zenith angle differences. Both stations show surface ozone depletion events during 2011, likely due to high bromine originating in nearby ice leads.

Polar surface ozone depletion events (ODEs), which are characterized by exceptionally low ozone in the spring, were first reported in the Arctic in the 1980s (Oltmans, 1981; Bottenheim et al., 1986). Bromine released during sea ice melting enters into a photochemical process that destroys surface level ozone. Younger ice is saltier, so intensifies this release of bromine and the frequency of ODEs. Over the last four decades of Barrow surface ozone observations, ODE frequency has increased during March.

Transport factors also contribute to the frequency of ODEs (i.e., wind from land directions results in fewer events observed). However, the increase of newer, thinner, saltier ice present in the Arctic is likely the cause of the increase in ODE frequency over the years (Oltmans et al, 2012). Tiksi has more land-based wind flow than Barrow. Tiksi's ice melting season begins later than Barrow's, so its spring depletion events begin in late April and extend through May (Patrick et al, 2012).

Milestone 2. Continue to assess and improve quality of column and

profile ozone measurements for climate trend analysis and satellite validation.

The improvement of the Dobson and Brewer ozone profile retrieval algorithm has continued. The Umkehr data acquired in 2011–2012 by the NOAA Dobson and NEUBrew Brewer ozone ground-based network have been processed and archived. Verification/quantification of the instrumental changes (caused 5 percent error in retrieved ozone at 40 kilometers) found in the Dobson Umkehr retrieved ozone data at Mauna Loa (MLO), Hawaii, in 2005 were performed through the comparisons against the climatological data, and long-term time-series of co-incident measurements taken by lidar and microwave instruments at MLO, and ozone-sounding at Hilo, Hawaii. Corrections were applied, and the new data set is available for submission to the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) archive.

The study to assess the sensitivity of Dobson and Brewer Umkehr retrieved ozone profiles to the choice of the ozone absorption cross section (Bass and Paur, 1985; Daumont, 1992), the out-of-band stray light (OOB) error, and stratospheric temperature variability was published (Petropavlovskikh et al., 2011). The coherence of stratospheric ozone time series was investigated for ground-based (lidar, Dobson Umkehr, balloon ozonesonde) and satellites overpass measurements at Haute–Provence Observatory (OHP, 43.93° N, 5.71° E): SBUV(/2) satellite, SAGE II, HALOE, MLS (UARS and Aura), and GOMOS (Nair et al., 2012). A detailed statistical study of the relative differences of ozone observations was performed to detect any specific drifts in the data. On average, all instruments showed their best agreement with lidar at 20 to 40 kilometers, where deviations are within ±5 percent.

PSD-04 Decadal Climate and Global Change Research

FEDERAL LEAD: RANDALL DOLE
CIRES LEAD: PRASHANT SARDESHMUKH

NOAA Goal 2: Climate

Project Goal: Improve understanding of long-term climate variations through analysis of observations and hierarchies of General Circulation Model (GCM) experiments. Seek dynamical explanations of oceanic variability and changes through observational analysis and GCM experiments. Provide attribution for long-term regional climate changes.

Milestone 1. Investigate the relative contributions of El Niño Southern Oscillation (ENSO)–related and ENSO-unrelated tropical sea surface temperature (SST) variations on global climate changes over the last 130 years.

Large discrepancies exist between 20th-century tropical Indo-Pacific sea surface temperature (SST) trends determined from current reconstructions. These discrepancies prevent an unambiguous verification and validation of climate models used for projections of future climate change. In a paper to appear in Nature Climate Change, we demonstrated that a more consistent and robust trend among all the reconstructions is found by filtering each data set to remove ENSO, which is represented not by a single index time series but rather by an evolving dynamical process. That is, the discrepancies appear largely the result of different estimates of ENSO variability in each reconstruction.

The robust ENSO-residual trend pattern represents a strengthening of the equatorial Pacific temperature gradient since 1900, due to a systematic warming trend in the warm pool and weak cooling in the cold tongue. Similarly, the ENSO-residual sea level pressure trend represents no weakening of the equatorial Walker circulation over the same period. Additionally, none of the disparate estimates of post-1900 total eastern equatorial Pacific SST trends are larger than can be generated by statistically stationary, stochastically forced empirical models that reproduce ENSO evolution in each reconstruction.

NGDC-04 Paleoclimatology—Understanding Decadal- to Millennial-Scale Climate Variability

FEDERAL LEAD: DAVE M. ANDERSON
CIRES LEAD: CARRIE MORRILL

NOAA Goal 2: Climate

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

Milestone 1. Expand the database of transient climate change during the last 21,000 years to include terrestrial temperature reconstructions and stable isotope records from speleothems and ice cores. Also, add raw age model data to the database to allow users to generate new age models as dating and calibration methods are refined.

Following our addition of temperature and stable isotope records, along with their raw age model data, to the database, we have produced a composite data set of speleothem (cave deposit) oxygen isotope measurements spanning the last 21,000 years. Oxygen isotope measurements from cave deposits provide some of the highest-resolution and best-dated information about past fluctuations in temperature and precipitation. Our compilation includes quality-controlled values from 60 cores at 36 sites, for a total of 27,975 oxygen isotope values. These time series span part or all of the last deglaciation and Holocene, and are provided on a common age scale and with common measurement units.

The main data file provides all oxygen isotope values, along with site metadata, in comma-separated values format. Also available for each core are machine-readable text files, which give more complete information about site-specific metadata, dating methods, and all raw data. These data address key scientific questions surrounding climate sensitivity to greenhouse gas concentrations, nonlinear responses and thresholds in the climate system, and the skill of state-of-the-art climate models in reproducing states different from the present one.

Milestone 2. Expand the last millennium temperature database to include gridded climate reconstructions. These gridded reconstructions will complement the point reconstructions already included in the database and will provide a template for the eventual addition of climate model simulations.

We expanded our last millennium temperature database by partnering with the Past Global Changes (PAGES) 2K Network. This network is an international collaboration of scientists and data managers tasked with collecting the best time series and spatial reconstructions of important state variables of the climate system, including temperature, for the last 2,000 years, in order to analyze them in combination with ensemble runs of Earth System Models. We are assisting them by providing easy access to data already in our database, by ingesting additional temperature data sets identified by the PAGES 2K Network, and

by acting as the long-term stewards for the data.

This ongoing collaboration has added numerous data sites and expanded the spatial coverage of the point reconstructions and proxy data in the database. We have also included NOAA's Merged Land-Ocean Surface Temperature Analysis (MLOST v3b) global gridded (5°x5°) surface temperature anomalies data as part of the database, allowing additional linkages to be made between the paleoclimatic records and the modern instrumental observations, and adding to the available tools researchers can use to calibrate and make temperature reconstructions.

The NOAA P3 research aircraft takes off during the 2010 CalNex field study.

CSV-02 Mechanism and Forcings of Climate Variability

- CSD-03 Chemistry, Radiative Forcing, and Climate
- PSD-01 Modeling of Seasonal to Inter-Annual Variability
- PSD-02 Understanding and Predicting Subseasonal Variations and Their Implications for Longer-Term Climate Variability
- GMD-04 Climate Forcing
- CSD-12 Emissions and Atmospheric Composition
- CSD-13 Kinetics and Photochemical Studies

CSD-03 Chemistry, Radiative Forcing, and Climate

FEDERAL LEADS: THOMAS B. RYERSON, KAREN ROSENLOF, STEVEN BROWN, AND DAN MURPHY
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

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

Milestone 1. Add ice habit information to cloud parcel modeling. Impact: Ice formation and growth is a critical and highly uncertain process for both precipitation and the radiative properties of clouds. A better description of ice habits will allow better calculations of both ice crystal growth and sedimentation.

The fundamental physical processes that maintain supercooled liquid in observed Arctic mixed-phase clouds are poorly constrained. Over the past years, many laboratory experiments have produced ambiguous results in terms of the description of the freezing behavior and surface properties of various ice nuclei.

In our study, we adapted data from a single laboratory study and showed, by using a combination of box and parcel models, that the consistency of different nucleation schemes (single or many nucleation sites, time-dependent or time-independent freezing) that could all reproduce observed freezing behavior in laboratory experiments leads to greatly diverging properties of mixed-phase clouds (ice number concentration, ice mass, cloud life time) over a wider range of conditions as compared to the narrow range in the corresponding experiments. These results clearly show the need to better constrain surface properties of ice nuclei so physically based approaches can be developed to be used in models of various scales.

The different schemes included both time-dependent and time-independent approaches. Our model study showed that in particular these approaches can lead to very different results. Future work will include a more careful analysis of the conditions under which time independent predictions of ice nucleation might be appropriate and in agreement with the physically based classical nucleation theory. Such work will help to bridge laboratory results to ambient data by developing laboratory-based, computationally efficient approaches to interpret ambient ice number concentrations in mixed-phase clouds.

Milestone 2. In the CalNex 2010 field campaign, survey a wide variety of different sources of directly emitted gas and aerosol species (e.g., carbon dioxide, methane, nitrous oxide, halocarbons, and particle-phase soot) that affect atmospheric radiative forcing. Impact: The planned suite of measurements includes both short-lived and long-lived forcing agents and will provide survey data for anthropogenic, agricultural, biogenic, and geologic sources of these radiatively important trace species. These data will provide additional independent evaluation of newly developed greenhouse gas inventories in California and better define source sector emissions strengths for directly emitted greenhouse gases.

The principal focus of CIRES scientists involved in the CalNex 2010 study over this period was continued data analysis and write-up of findings. A significant number of publications are in press or in preparation. The primary area of investigation for climate variability during CalNex is on characterization of direct emissions and impacts of climate forcing agents, such as CO_2 (Neuman et al.), CH_4 (Peischl et al.-1, Peischl et al.-2), N_2O (Xiang et al.), and aerosols (Bahreini et al., Cappa et al., Lack et al., Langridge et al., Nowak et al.).

The trend in short-lived climate forcing agents, notably ozone, is also being evaluated (Pollack et al.). These results will be used in planned modeling studies that will evaluate existing greenhouse gas emissions

inventories using a top-down approach to verify and/or improve those inventories. These results will be further summarized in a scientific synthesis document that will provide information for the California Air Resources Board (CARB) to use in its efforts to reduce air quality degradation across the state.

Milestone 3. Investigate the climate impact of changes in stratospheric ozone and water vapor concentrations using the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM) with the slab ocean component (SOM), using time slice simulations and sensitivity studies and making use of new and improved ozone and water vapor data sets. Impact: The experiments aim to quantify the importance of these gases to both the modeled stratospheric and tropospheric climates. Also, the results will show the effect of using improved ozone data as a model boundary condition, which will be of great use and interest to the global modeling community.

Since last year, the planned write-ups have expanded to include four manuscripts: one describing the NIWA (National Institute of Water and Atmospheric Research) ozone data set (Bodeker et al.); one comparing the different stratospheric ozone data sets (Hassler et al.); one looking at the NCAR CAM model simulations (Young et al.); and one looking at lower stratospheric ozone in particular (Solomon et al., submitted to *Geophys. Res. Lett.*). It is intended to have all these manuscripts submitted by the end of the year and to have the main ozone-related goals of this milestone completed.

The latest NCAR model will soon be available on the new NOAA supercomputer, which will be used to further probe the climate impacts of stratospheric ozone, as well as stratospheric water vapor. Time slice and continuous experiments have been planned, which will be complementary to the Atmospheric Chemistry and Climate Hindcast experiment.

PSD-01 Modeling of Seasonal to Inter-Annual Variability

FEDERAL LEADS: RANDALL DOLE AND
MARTIN HOERLING
CIRES LEAD: PRASHANT SARDESHMUKH

NOAA Goal 2: Climate

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

Milestone 1. Determine the sensitivity of North American drought to tropical sea surface temperature (SST) changes at different locations, and identify the optimal anomalous tropical SST pattern for maximizing drought.

To deepen our understanding of the sensitivity of North American drought to tropical sea surface temperature (SST) changes highlighted in our previously published study, we performed a similar study of the sensitivity of monsoon regions around the world to tropical SST changes, with particular emphasis on the northeast Asian summer monsoon region. Observations indicate increasing trends of summer precipitation amount, intensity, and frequency of extremes over northeast Asia since the 1960s.

Climate models are generally able to simulate such increases of precipitation over northeast Asia over the second half of the 20th century and project continuations of these trends in response to the projected warming of the tropical Indo-Pacific Warm Pool, especially around the Philippines and the South China Sea. The principal basis for confidence in these projections is the simplicity and robustness of the mechanisms involved. In essence, the warming of these waters enhances the northward moisture transport from the tropics to northeast Asia, leading to an increase of the northeast Asian precipitation. Warming of these waters also affects the North American precipitation but through a different set of mechanisms.

PSD-02 Understanding and Predicting Subseasonal Variations and Their Implications for Longer-Term Climate Variability

FEDERAL LEADS: RANDALL DOLE AND
JEFFREY WHITAKER
CIRES LEAD: PRASHANT SARDESHMUKH

NOAA Goal 2: Climate

Project 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 1. Compare the Week Two and Week Three atmospheric circulation forecast skill of state-of-the-art global atmosphere-ocean coupled models with that of simple Linear Inverse Models (LIMs) based on lag-correlations of the northern hemispheric circulation and tropical convection fields. Assess the prospects for further skill improvement by performing a predictability analysis based on the relative magnitudes of the forecast signal and forecast noise.

The Week Two and Week Three forecast skill of two global coupled atmosphere-ocean models recently developed at NASA and NOAA was compared with that of much simpler LIMs derived from observed time-lag correlations of atmospheric circulation anomalies in the northern hemisphere and outgoing long-wave radiation (OLR) anomalies in the tropics. The coupled models were found to beat the LIMs only slightly, and only if an ensemble prediction methodology was employed.

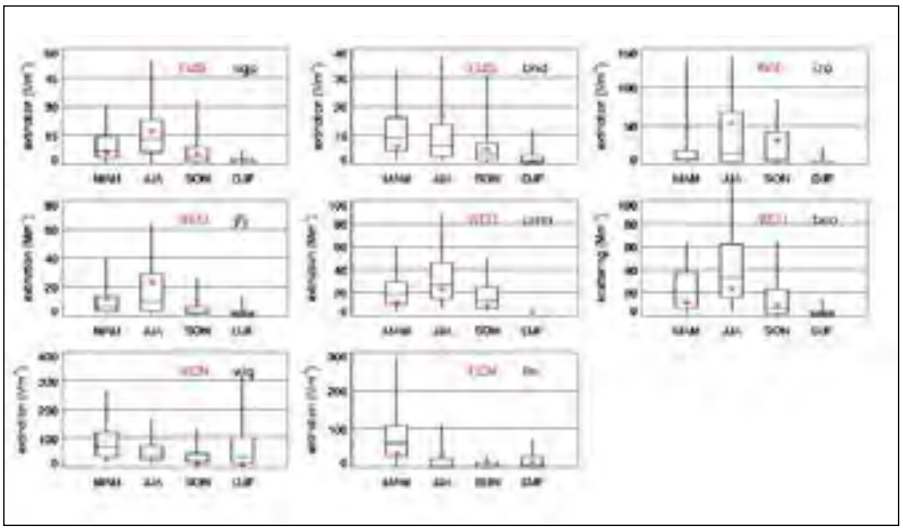
To assess the potential for further skill improvement, a predictability analysis based on the relative magnitudes of forecast signal and forecast noise in the LIM framework was conducted. Estimating potential skill by such a method was argued to be superior to using the ensemble-mean and ensemble-spread information in the coupled-model ensemble prediction system. The LIM-based predictability analysis yielded relatively conservative estimates of the potential skill, and suggested that outside the tropics, the average coupled-model skill may already be close to the potential skill, although there may still be room for improvement in the tropical forecast skill. This work was presented at several national and international meetings on predictability at the Weather-Climate interface.

GMD-04 Climate Forcing

FEDERAL LEAD: JOHN OGREN
CIRES LEAD: ANNE JEFFERSON

NOAA Goal 2: Climate

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



GMD-04, Milestone 1

Milestone 1. Use data from 12 high-altitude observatories to develop a climatology of free tropospheric aerosol radiative properties.

A paper has been published (Andrews et al., 2011) describing the climatology of aerosol optical properties measured at high-altitude sites. The results suggest that the amount of aerosol in the free troposphere increases from west (Mauna Loa, Hawaii) to east (Mt. Waliguan, China). The seasonal cycle of aerosol extinction derived from the in-situ measurements was consistent with those obtained from the space-based CALIOP lidar.

The figure shows a comparison of average seasonal CALIPSO ambient extinction values at 3 km (purple) 532 nm with seasonal in-situ extinction (at 550 nm, low RH, and STP). Surface sites indicated in lowercase letters: sgp = Southern Great Plains, Okla.; bnd = Bondville, Ill.; iza = Izana, Spain; jfj = Jungfraujoch, Switzerland; cmn = Monte Cimone, Italy (cmn data at 520 nm, low RH, and STP); beo = Bulgarian Environmental Observatory, Bulgaria (beo plot shows in-situ scattering); wlg = Mount Waliguan, China; and

Dust on Snow

White snow, brown snow, deep snow, no snow. CIRES research has revealed that dust-covered snowpacks melt about three weeks sooner than normal. This deprives the Colorado River—the lifeblood of the American Southwest—of 5 percent of its average annual runoff. The findings serve as both a warning—and an opportunity—for the West, says CIRES scientist Jeff Deems.

Where does the dust come from?

From deserts and drylands to the west and southwest of the Rocky Mountains. Gusty spring storms deposit the dust on the mountain snowpack, turning it red or brown.

Photo by Chris Landry

And this accelerates snow melting?

Yes, dark, dust-covered snow absorbs more sunlight and melts faster than white snow. The effect is readily observed: If you were to scrape a dusty patch of snow free of dust, then come back in the afternoon, you'd see an elevated patch of snow because the dusty snow around it melted faster [similar to the effect seen in the above photo].

How does the early melt reduce the Colorado River flow?

Earlier snowmelt leads to a longer snow-free season, and snow-free ground and vegetation lose more water to the atmosphere through evaporation and transpiration than does snow. Our study showed this extra evaporation decreases the annual flow in the Colorado River by more than 250 billion gallons on average.

Is that significant?

Yes. That's twice Las Vegas's annual usage and would provide 18 months of water for Los Angeles. Colorado River flow is also being reduced by growing demand, drought, and climate warming.

Is there a silver lining to your findings?

This could be an opportunity to help ease stresses on the Colorado River. If we can reduce the amount of dust on snow through restoration and improved land management practices in the dust source regions, this could put billions of gallons back into the river.

Do your results apply elsewhere?

Yes. We've seen both anecdotally and in observations that dust production from drylands is on the rise worldwide, and we're seeing dust deposited on mountain snow cover and glaciers in regions such as the Tien Shan in China, the Zagros Mountains, the Himalaya, and the Antarctic Peninsula. So while the numbers we produced in our current work may not be directly applicable to other regions, the physical processes and science certainly are.

lln = Mount Lulin, Taiwan. CALIPSO values come from Yu et al. (2010). EUS is eastern U.S. profile; NAF is northern Africa profile; WEU is western Europe profile; WCN is western China profile; and ECN is eastern China profile.

Milestone 2. Establish one new tall tower site in the NOAA Earth System Research Laboratory (ESRL) Carbon America tall tower network to help reduce the uncertainty of carbon uptake by the North American continent and to better characterize regional terrestrial carbon flux estimates.

Milestone was completed and reported on in FY10 Annual Report.

Milestone 3. Complete development of a field-operational temperature/humidity/GPS system to augment current trace gas vertical profile measurements in the NOAA/ESRL Carbon America aircraft network (a prototype system exists and is in use currently at five network sites; the system allows for automated measurements of the ambient temperature and humidity and the position and altitude associated with each sample in a vertical profile).

Milestone was completed and reported on in FY10 Annual Report.

Milestone 4. Analyze balloon-borne measurements of water vapor in the upper troposphere–lower stratosphere (UTLS) to reveal multiple-year trends and attempt to attribute them to geophysical processes.

Monthly soundings were made at three globally distributed sites (Boulder, Colo.; Lauder, New Zealand; and Hilo, Hawaii) to continue the long-term monitoring of water vapor in the UTLS. The Boulder data record has now surpassed 32 years; by mid-2012 the Lauder and Hilo records were 8.7 and 1.6 years in length, respectively. By combining a tropical site with a middle-latitude site in each hemisphere, we now can examine UTLS water vapor trends on a more global basis. Stratospheric water vapor continued its upward trend at all three sites. The increases have restored stratospheric mixing ratios to the levels observed just prior to the rapid 0.5 parts per million by volume (10 percent) decrease in 2001.

CSD-12 Emissions and Atmospheric Composition

FEDERAL LEAD: KAREN ROSENLOF
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Improve understanding of past and projected future anthropogenic and natural emissions of atmospheric trace gases that influence climate and climate variability.

Milestone 1. Evaluate anthropogenic and natural surface emissions of atmospheric chemical compounds during the past two decades by making detailed comparisons of available emissions inventories, and evaluate the consistency between global and regional emissions, and the impact on the composition of the atmosphere. Impact: This study will provide information used as inputs in climate models, focusing on the chemical compounds detected from space (CO, NO_2, and ozone) and on hydrocarbons from natural and anthropogenic origins.

Several different inventories of global and regional anthropogenic and biomass burning emissions have been assessed for the 1980–2010 period. The species considered last year were CO, NO_x, SO_2, and black carbon, and we have started this year to gather many different emission inventories providing global and regional distributions of the emissions of methane, organic carbon, non-methane volatile organic compounds, and ammonia. The Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) historical emissions developed in support of the simulations for the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) are also considered. Emissions from the Representative Concentration Pathways (RCPs) are included in this analysis.

Large discrepancies between the global and regional emissions are identified for all regions of the world, more particularly for China and India, where uncertainties larger than a factor of two have been determined for several compounds. The range of the emissions for all these compounds has been established, and this information is now included in two chapters of the ongoing IPCC AR5 report. In order to better understand the origin of the discrepancies, we have started to analyze the emissions reported for different sectors. Since the sectors used in the regional and global inventories differ, we have started to focus this study on traffic emissions.

Milestone 2. Evaluate the evolution of the chemical composition of the atmosphere during the next two to three decades, using the different emissions scenarios developed in support of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) to assess different Representative Concentrations Pathways (RCPs). Impact: This research will support the IPCC AR5 report by determining the effects of different RCPs on the distribution of chemical species and on their deposition at the surface, which will enable improved understanding and modeling of the effect of atmospheric chemical composition on climate.

The proposed work has started with an evaluation of the capability of chemistry-transport models to reproduce past trends in air quality. Documenting these strengths and weaknesses on the basis of historical simulations is essential before the models can be used to assess future air-quality projections. Different regional and global models have been used to simulate the evolution of air quality during the 1997–2008 period.

The analysis has so far focused on ozone and nitrogen dioxide, for which surface as well as satellite observations are available. A paper was published at the end of 2011, which focuses on the results obtained for the European region. The analysis of the model results has shown that the year-to-year interannual changes in the distributions of the constituents are rather well reproduced, although capturing the more moderate trends of chemically produced species such as O_3 is more challenging.

Simulations for the 2010–2030 period were also performed, using different sets of emissions scenarios, based on the emissions provided by the RCPs. Another set of scenarios developed as part of the Global Energy Assessment was used. This study, which is currently under review in the *ACPD* journal, showed that air pollution mitigation measures are the main factors leading to an improvement of air quality, but an additional cobenefit of at least 40 is brought about by the climate policy.

CSD-13 Kinetics and Photochemical Studies

FEDERAL LEAD: JIM BURKHOLDER
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Determine the rates of climate-relevant processes, and evaluate the lifetimes and radiative properties of atmospheric species (gases and particles) that influence climate.

Milestone 1. Measure rate coefficients for the chlorine monoxide self-reaction (ClO + ClO + M) over a range of temperatures and pressures relevant to polar stratospheric photochemistry. Impact: This research will provide data needed to reduce uncertainties in atmospheric model calculations of polar ozone loss. This research has implications for stratospheric ozone chemistry and climate-chemistry coupling.

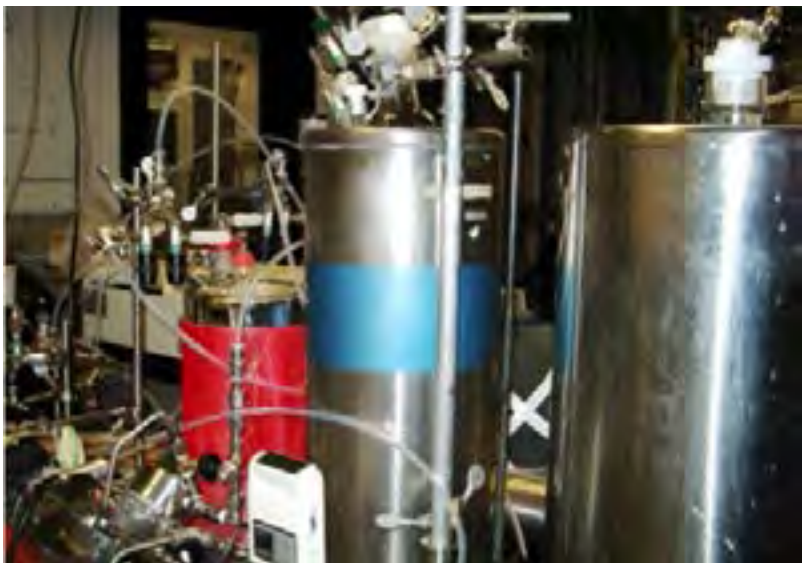
Halogen chemistry plays an important role in polar stratospheric ozone loss. The ClO dimer (ClOOCl) catalytic ozone destruction cycle accounts for the vast majority of winter/spring polar stratospheric ozone loss. A key step in the dimer catalytic cycle is the pressure- and temperature-dependent self-reaction of the ClO radical to generate ClO dimer (ClOOCl) at low temperatures and pressures under stratospheric conditions. The rate coefficient for the ClO self-reaction has been measured in previous laboratory studies but uncertainties persist, particularly at atmospherically relevant temperatures and pressures.

In this laboratory study, rate coefficients for the ClO self-reaction were measured over a range of temperatures (200–296 Kelvin) and pressures (50–600 Torr, He and N_2 bath gases). ClO radicals were produced by pulsed laser photolysis of Cl_2O at 248 nanometers. The ClO radical temporal profile was measured using dual wavelength cavity ring-down spectroscopy (CRDS) near 280 nanometers. The absolute ClO radical concentration was determined using the ClO ultraviolet absorption cross sections, and their temperature dependence was measured as part of this work.

The results from this work are in conflict with several previous studies that form the basis of current kinetic recommendations for use in atmospheric models. Analysis and interpretation of these experimental results are in progress. The impact of these differences on polar stratospheric chemistry and ozone loss will be evaluated in future work. A manuscript is in draft stage.

Milestone 2. Measure ultraviolet (UV) absorption cross sections of the long-lived ozone-depleting greenhouse gases nitrous oxide (N_2O) and carbon tetrachloride (CCl_4) as a function of temperature. Impact: UV photolysis is the key atmospheric loss process for these compounds. The laboratory data will be used as input for atmospheric models to better define the impact of these trace gases on stratospheric ozone and climate change.

The long-lived atmospheric species nitrous oxide (N_2O) and carbon tetrachloride (CCl_4) are ozone-depleting substances (ODSs) and potent radiative forcing agents. The abundance and atmospheric lifetimes of N_2O and CCl_4 are, therefore, important to understanding stratospheric ozone recovery and climate change as well as the linkage between these issues. In this study, absorption cross sections of nitrous oxide (N_2O) and carbon tetrachloride (CCl_4) are reported at five atomic UV lines (184.95, 202.548, 206.200, 213.857, and 228.8 nanometers) at temperatures in the range of 210–350 Kelvin. In addition, UV absorption spectra of CCl_4 are reported between 200–235 nanometers as a function of temperature (225–350 Kelvin).



Laboratory apparatus used to study solubility and hydrolysis

For N_2O, the present results are in good agreement with the current recommendation and reduced the estimated uncertainty in the N_2O atmospheric photolysis rate. However, for CCl_4, the present UV cross-section values are systematically greater than the current recommendation most relevant to stratospheric photolysis. Model calculations show that the new cross sections result in a 5 percent to 7 percent increase in the photolysis loss of CCl_4 throughout the lower stratosphere. The resulting stratospheric lifetime of CCl_4 decreases slightly, from 51 to 50 years (2 percent), for present day conditions. The corresponding changes in modeled inorganic chlorine and ozone in the stratosphere are quite small.

The reduced uncertainties in the N_2O and CCl_4 absorption cross section data, and in photolysis lifetimes, will provide for improved model calculations of ozone recovery. A manuscript describing these results has been published in *Atmospheric Chemistry and Physics* (Rontu Carlon, et al., 2010).

Milestone 3. Develop and use a new laboratory apparatus to measure the Henry's Law solubility of key atmospheric trace species in aqueous solutions; and measure hydrolysis rate constants and product yields for reactive species. Impact: This research will evaluate the partitioning of trace species between the gas- and aqueous-phase and the possible significance of aqueous chemistry as an atmospheric loss process. This research has implications for both stratospheric ozone and climate-chemistry coupling.

Solubility coefficients of gases in liquids (Henry's law constant, H) and rate coefficients for the hydrolysis of molecules in the liquid phase (k) of atmospheric trace gases are needed to model and quantify their aqueous-phase processing. We built an experimental apparatus to measure Henry's law solubility coefficients of weakly soluble atmospherically relevant compounds and, in applicable cases, their hydrolysis rate coefficients.

The apparatus consists of a closed-cycle bubble reactor combined with a Fourier transform infrared (FTIR) spectrometer that was used to measure the gas phase concentration of the dissolving gas and products of hydrolysis reaction. We have measured H and k of perfluoro-2-methyl-3-pentanone ($C_2F_5C(O)F(CF_3)_2$, PFMP) and perfluoro-2-methyl-3-butanone ($CF_3C(O)CF(CF_3)_2$, PFMB) as a function of pH (2–10)

and temperature (273–293 Kelvin).

PFMP is currently being used as a fire suppressant in place of Halons, which have high ozone-depletion potentials (ODP); PFMP and PFMB have essentially zero ODPs. The tropospheric photolysis lifetime of PFMP is relatively short, on the order of several weeks; thus, this molecule has a small Global Warming Potential (GWP). However, the hydrolysis of PFMP is known to produce HFC-227ea (CF_3CHFCF_3), a molecule that has low solubility, an atmospheric lifetime of 38.9 years, and a GWP of 3580 (100-year time horizon).

Therefore, the atmospheric aqueous-phase processing of PFMP to produce HFC-227ea, even if only a minor loss pathway, can lead to a very large GWP attributable to its emission. To validate our methodology, the Henry's law solubility constants for SF6, CF_3CHF_2 (HFC 134a), and $C_2F_5CF(CF_3)_2$ (HFC 227ea)—molecules that have well-established H values and extremely low hydrolysis rate coefficients—were also measured. Manuscript is in preparation.

CSV-03 Stratospheric Ozone Depletion

- CSD-04 Photochemical and Dynamical Processes that Influence Upper Troposphere/Lower Stratosphere Ozone
- GMD-05 Ozone Depletion

CSD-04 Photochemical and Dynamical Processes that Influence Upper Troposphere/Lower Stratosphere Ozone

FEDERAL LEAD: KAREN ROSENLOF
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Improve theoretical capabilities to predict the natural and human influences on the stratospheric ozone layer. Characterize the photochemical reactions relating to the anthropogenic loss of ozone in the stratosphere. Carry out *in situ* studies of the photochemical and dynamical processes that influence the stratospheric ozone layer.

Milestone 1. Use ozone data from fights of the National Center for Atmospheric Research HIAPER Gulfstream-V aircraft and the Global Hawk unmanned aircraft system to examine transport and photochemical processes in the upper troposphere and lower stratosphere (UTLS). Impact: The data and intercomparisons with high-resolution models will offer new insights into how ozone can be used to constrain transport and photochemical processes in global models.

Ozone data from additional HIAPER Pole-to-Pole Observations (HIPPO) missions were presented at the HIPPO science team meeting, and plans are being developed to compare with a number of global models to assess model dynamics and chemistry in the UTLS region.

Ozone data from the Global Hawk-Pacific (GloPac) and Airborne Tropical TRopopause EXperiment (ATTREX) missions were presented at the ATTREX science team meeting. These data, along with coincident measurements of the conserved tracer N_2O, will be used to assess possible changes in lower stratospheric ozone due to recovery of the ozone layer and climate change. Satellite data will be used to extend spatial and temporal coverage for the analysis.

Milestone 2. Using diagnosed proxies for tropical in-mixing based on meteorological analyses and satellite measured chemical species, examine changes in the width and isolation of the tropical pipe on seasonal, interannual, and decadal time scales. Impact: Changes in the characteristics of mixing between the tropics and mid-latitudes in the lowermost stratosphere can affect residence time and possibly species distribution throughout the stratosphere.

Carlye Calvin, UCAR

CIRES scientist Anne Perring readies an instrument for the HIPPO field mission.

The amount of time air resides in the stratosphere affects the distribution of trace gasses that affect the ozone layer and play a role in climate change. An important quantity in this regard is the so-called mean age of stratospheric air. This quantity is determined in part by how fast air rises in the tropics, and how vigorously air mixes between the tropics and higher latitudes. The goals of this project are to evaluate long-term changes in mixing between the tropics and extra tropics, and study the implications of these changes for stratospheric age of air.

To accomplish this, we calculated effective diffusivity using wind fields from multiple reanalyses. This data was fit to a regression model to remove year-to-year variability and evaluate long-term trends. We found that the reanalyses exhibit a long-term trend toward greater mixing between the tropics and extratropics in the lower stratosphere. These trends were combined with trace gas observations in a simple model to investigate long-term changes in the stratospheric age-of-air.

It was found that the long-term changes in stratospheric mixing have a potentially strong impact on age-of-air. These results may help explain why global climate models, which predict age-of-air decreases, and observations, which don't show age-of-air decreases, appear to be at odds regarding their long-term trends. This work was presented at multiple meetings in 2010 and 2011, and as a result this effective diffusivity data will likely be included as part of the upcoming SPARC (Stratosphere-troposphere Processes And their Role in Climate) Reanalysis Intercomparison Project (S-RIP).

Milestone 3. Examine stratospheric mean meridional circulation and mixing changes during recent decades with observations, reanalysis data, chemistry-climate model output, and a simple stratospheric model. Impact: Understanding how the stratospheric circulation has recently changed will likely help us better understand how changes in the troposphere affect the stratosphere.

To first order, variability in the mean meridional circulation and mixing in the upper troposphere and lower stratosphere control ozone variability in this region. In our previous work on mean circulation and mixing changes in the stratosphere over the past three decades, we used a simple model, tracer observations including ozone, and reanalysis output to estimate the changes in mean circulation and mixing that were consistent with observations (Ray et al., 2010).

In the last year, we have extended this work by using Lagrangian trajec-

tories in the simple model in order to obtain age of air spectra. With the age spectra, we are better able to estimate mean age from tracer observations without being affected by tropospheric growth rate changes in the tracers. In this analysis we also now include seasonal and longer time scale variability in the input to the model, which allows variability in the mean age to be clearly resolved. We find significant seasonal, quasi-biennial oscillation (QBO), volcanic, and other long time scale variability in the age spectra and the mean ages. This variability is clearly seen in the observations as well. Resolving this variability helps to understand the variability in the observations and in the mean circulation and mixing. Ideally, understanding this variability will allow a better comparison between observations and chemistry climate model output.

GMD-05 Ozone Depletion

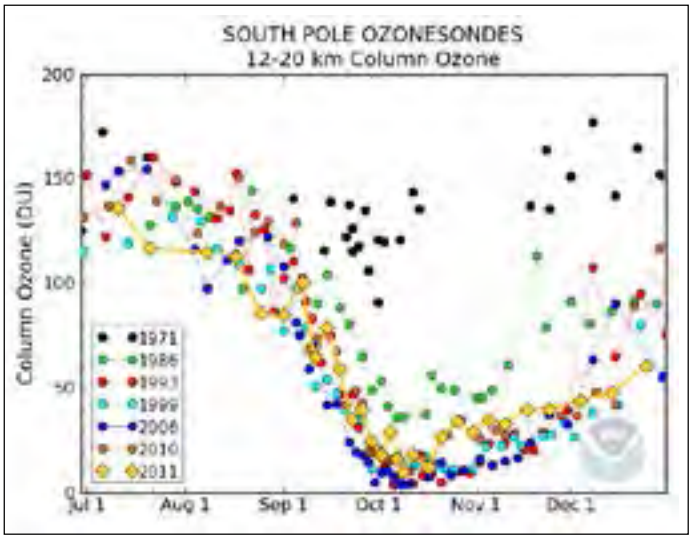
FEDERAL LEADS: JAMES ELKINS, STEPHEN MONTZKA, AND SAMUEL OLTMANS
CIRES LEAD: FRED MOORE

NOAA Goal 2: Climate

Project Goal: Understanding the production and fate of ozone and the compounds that deplete it is a focal point of collaborative CIRES research with ESRL's Global Monitoring and Chemical Sciences divisions. Stratospheric Ozone Measurements: Measure ozone declines during the past two decades at northern hemispheric midlatitudes and the tropics, and characterize dramatic ozone depletions over Antarctica. Ozone-Depleting Gases: Conduct research in the troposphere, stratosphere, oceans, polar snowpack, and terrestrial ecosystems in an effort to characterize, understand and predict the atmospheric behavior of gases that cause ozone depletion. Stratospheric Aerosols: Conduct experiments and measurements on aerosols to determine their impacts on solar insolation. Stratospheric Water Vapor: Conduct measurements to determine the change in water vapor and its coupling with aerosols.

Milestone 1. From flask and *in situ* measurements of ozone-depleting substances around the globe, update the Ozone Depleting Gas Index (ODGI) for 2009 and 2010.

Measurements of long-lived substances that cause stratospheric ozone depletion were continued at remote sites during July 2011 through June 2012. These measurement data are used to update the Ozone Depleting Gas Index. This year there are significant changes to the way the index is calculated, and it is not yet complete for the 2012 update. The old and new methodologies will be posted on the ODGI web page for comparison (http://www.esrl.noaa.gov/gmd/odgi/).



GMD-05, Milestone 3

Milestone 2. Report on the vertical profiles of ozone-depleting substances from the first three campaigns of the HIAPER Pole-to-Pole Observations of Greenhouse Gases mission (HIPPO) in 2010. Submit data to the HIPPO archive, and report on the results at a scientific meeting.

HIAPER (High-performance Instrumented Airborne Platform for Environmental Research) Pole-to-Pole Observations (HIPPO) involves the study of carbon dioxide, other greenhouse gases, and aerosols in the troposphere using the National Science Foundation (NSF)/National Center for Atmospheric Research (NCAR) Gulfstream-V research aircraft. The flight paths travel as far north as possible to the Pole from Anchorage, up and down the Pacific, and as far south as possible toward the Pole from Christchurch, New Zealand.

We flew 12 research flights (HIPPO-4) in July, followed with the final 12 research flights (HIPPO-5) in August. In HIPPO-4, we added flights in and out of Darwin, Australia; Hobart, Australia; Saipan; and Midway Island. These additional flights were flown to obtain data over Australia and data with influence from both the warm pool and from Asian outflow. In FY2012 we also supported the related NASA-sponsored ATTREX (Airborne Tropical Tropopause Experiment) mission and started the Strat-Core program. In March of this fiscal year, we held the HIPPO Science Team Meeting. Our team gave four presentations describing the data collected and the science being worked up. Presentations highlighting our work were also given at the AGU fall meeting, NDACC (Network for the Detection of Atmospheric Composition Change) Reunion Island meeting, International Year of Chemistry O3 Symposium in Washington D.C., WRCP (World Climate Research Programme) Denver meeting, GMAC (Global Monitoring Annual Conference) 2012–AGAGE45(Advanced Global Atmospheric Gases Experiment) combined meeting, and the CIRES Rendezvous. This HIPPO data is being archived for internal use on the UCAR ftp site. From here data is being made available to the public through the Carbon Dioxide Information Analysis Center (CDIAC). All data should become publicly available some time in FY2013.

Milestone 3. Analyze ground-based and balloon ozone measurements for long-term trends in the upper troposphere and stratosphere.

Ground-based Dobson Umkehr instruments operated under the NOAA Dobson network (Boulder, Colo.; OHP, France; MLO, Hawaii, Barrow, Alaska; Lauder, New Zealand; and Perth, Australia) continued to take ozone column and profile data. Weekly profiles are also collected by the balloon-born ozonesonde instruments launched at Boulder, Colo.; Trinidad Head, Calif.; Hilo, Hawaii; Samoa, American Samoa; South Pole, Antarctica; and Summit, Greenland. Data are used to identify long-term changes in stratospheric ozone over Northern Middle latitudes (Nair et al., 2011).

Ozone Dobson records at the Syowa, Antarctica, station show significant decrease in ozone above 4 hectopascals (hPa) during the 1980s and 1990s. Atmospheric chlorine levels have begun to decline, and ozone is expected to recover. However, ozone values over Syowa remain low since 2001. Weekly vertical profiles of ozone have been measured by the NOAA/ESRL Global Monitoring Division for 26 years at Amundsen

Scott South Pole Station using balloon-borne electrochemical concentration cell (ECC) ozonesondes. These measurements increased to two to three per week to monitor the development of the springtime ozone hole over Antarctica.

From early September to mid-October, ozone declines rapidly, especially within the main ozone layer (14–21 kilometers). The 2011 Antarctic ozone-hole-year was the 10th lowest. Column ozone dropped to 102 Dobson Units (DU) on Oct. 9, 2011, a 60 percent loss of the pre-ozone-hole 256 DU. Ozone changes over Antarctica depend on active chlorine concentrations in the stratosphere, wintertime stratospheric temperatures, the stability of the polar vortex, variability in greenhouse gases, meridional BD circulation, and the Solar cycle (Hassler et al, 2011).

CSV-04 Climate Dynamics

- PSD-06 Climate Dynamics
- PSD-03 Empirical and Process Studies
- PSD-15 Surface Processes

PSD-06 Climate Dynamics

FEDERAL LEAD: CHRIS FAIRALL
CIRES LEAD: LESLIE HARTTEN

NOAA Goal 2: Climate

Project Goal: Conduct research to improve understanding of tropical Pacific Ocean dynamical processes related to the sub-seasonal atmospheric variability, and atmospheric circulation, convection, and moisture and heat budgets associated with the El Niño phenomenon and the North American Monsoon (NAM).

Milestone 1. Explore the relationship between sea breezes along the West Coast of Mexico during the NAM and precipitation along the western Sierra Madres Occidental. Submit publication on results.

No progress was made on this milestone due to funding and health issues. However, the project is on hold, not defunct.

Milestone 2. Submit papers documenting the daily cycle of winds during the NAM and their longitudinal and year-to-year variability.

No progress was made on this specific milestone due to funding and health issues. The project is on hold, not defunct. Instead, there was a focus on revising a manuscript submitted by Matsui, Compo, and Hartten (CIRES) in 2010. The research explores various methods of obtaining surface pressures suitable for global reanalysis projects from the various historical tropical cyclone data archives, most of which contain only wind speed information. Two empirical TC wind speed/pressure relationships, one based on the gradient wind equation and the other based on the cyclostrophic balance equation, were evaluated.

Both methods are similar in their effectiveness, but their error characteristics are different. The additional pressure values obtained through a wind speed/pressure relationship and information about their associated errors may be useful for further improving the assimilation of tropical cyclones in historical reanalyses of global fields. Despite a slightly larger expected error, we recommend the use of more physically based gradient wind equation relationships for such historical reanalyses rather than the widely used relationships derived from cyclostrophic balance. The paper was resubmitted to *Monthly Weather Review* in October 2011, after we made very substantial revisions to clarify the language and conducted new analyses to address reviewer concerns. It was rejected in January 2012, and after discussion, we decided to rework the manuscript and submit it to a more appropriate journal, *Meteorology and Atmospheric Physics*. Work on this was halted in early February by health issues and will resume later in 2012.

PSD-03 Empirical and Process Studies

FEDERAL LEAD: RANDALL DOLE
CIRES LEAD: PRASHANT SARDESHMUKH

NOAA Goal 2: Climate

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

Milestone 1. Conduct a local and non-local feedback analysis of tropical sea surface temperature (SST) variations in observations and the Intergovernmental Panel on Climate Change (IPCC) climate models through Linear Inverse Modeling.

The SST interactions among eight broadly defined regions of coherent SST variability in the tropical Pacific, Indian, and Atlantic oceans were estimated using three observational and 76 climate model simulation data sets of the 20th century. The eight-dimensional SST feedback matrix was estimated separately using each data set by constructing a Linear Inverse Model based on the lag-covariance statistics of the 100-year monthly SST time series.

The simulated feedback matrices were found to differ in several key respects from the observed matrices and also from one another. In particular, the influence of the eastern Pacific El Niño–Southern Oscillation (ENSO) region on other regions and of the other regions on the ENSO region was found to vary considerably from model to model. The representation of remote interactions with the Indo-Pacific Warm Pool region was also found to be highly variable. This work is suggestive not only of substantial inter-model disagreement but also model errors in the representation of tropical SST feedbacks. An extension of this study suggests that these model errors are in the sense of spuriously magnifying the sensitivity of tropical SSTs to external radiative forcing.

PSD-15 Surface Processes

FEDERAL LEADS: JAMES WILCZAK AND CHRIS FAIRALL
CIRES LEAD: OLA PERSSON

NOAA Goal 2: Climate

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

Milestone 1. Analyze data from the Surface Heat Budget of the Arctic, SHEBA; Arctic Summer Cloud Ocean Study, ASCOS; Arctic Mechanisms of Interaction between Surface and Atmosphere, AMISA; and other field programs to understand the links between the clouds, at-

mospheric boundary layer, and surface processes over sea ice. Evaluate their respective contributions to the net surface energy fluxes

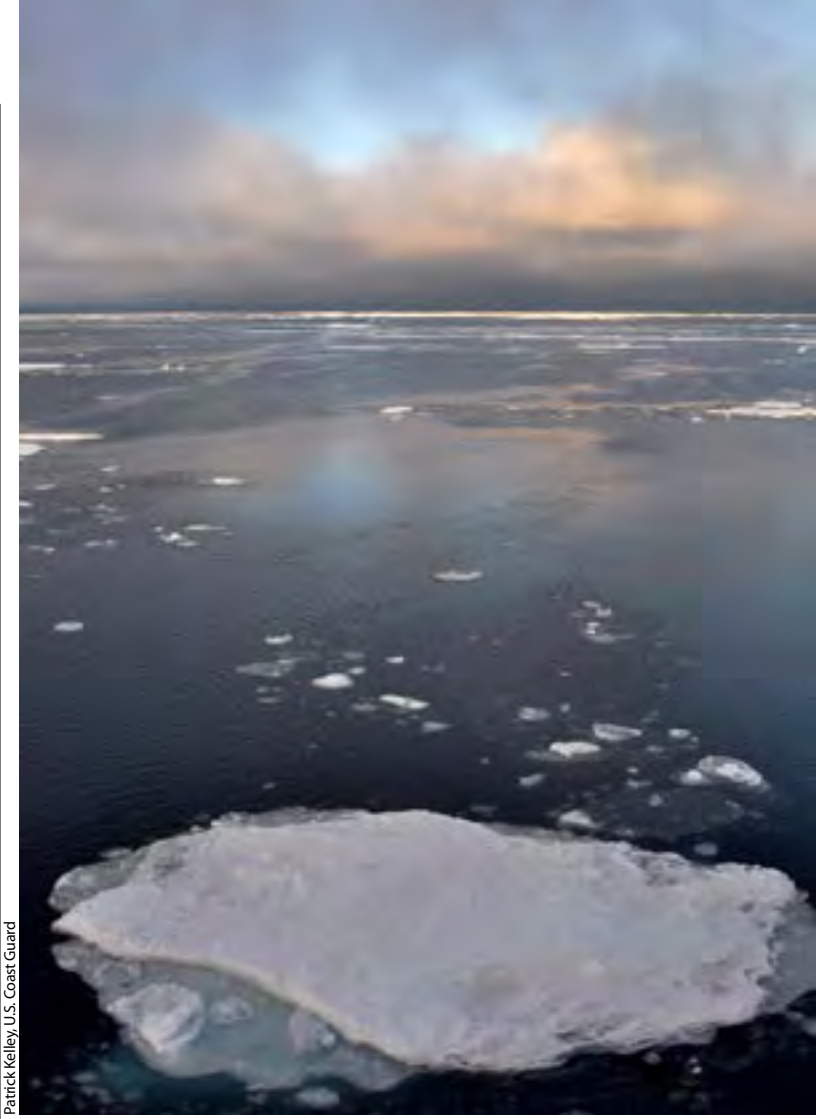
Good progress was made analyzing cloud and boundary layer data from ASCOS, which included creating a 12-day time-height series of the Richardson number. The following findings and interpretations were made. A plausible transport pathway from the free troposphere through the atmospheric boundary layer to the surface has been identified. During periods of Arctic stratocumulus clouds, small-scale turbulence occurs at the top of the clouds, providing entrainment into the cloud top of, for example, moisture and aerosols. Once into the cloud, the constituents are readily transported throughout the radiatively driven mixed layer that extends throughout the cloud and a few hundred meters below the cloud base. At times, the base of this mixed layer is dynamically coupled to the turbulent surface boundary layer, as suggested in both Figures 1 and 2, though at other times this coupling does not occur.

At least two key unknowns exist for estimating the transport rate and frequency from the free troposphere to the surface. These are (a) estimating the magnitude of the cloud-top entrainment and (b) understanding the modulation of the coupling between the cloud-driven mixed layer and the surface boundary layer. Currently, it appears as if the transport pathway operates off and on, and depends on a saturated (or near-saturated) atmosphere and some other mechanisms not yet understood. Our current hypothesis is that transport can occur downwards from above (or upwards from below) to an intermediate level where the constituent resides (accumulates?) for a while before being transported onwards when the stability decreases. A collaborative paper to be joint with colleagues in the UK and Sweden is being planned.

Additional analyses are being done on SHEBA and Russian drifting station data. One result from these analyses shows the importance of long-range moisture transport for the formation of wintertime Arctic clouds and small amounts of supercooled liquid water (approximately 10 grams per square-meter liquid water path) for large increases in downwelling longwave radiation. Another paper is in preparation on this wintertime case study.

Milestone 2. Using a Weather Research and Forecasting (WRF) or 1-D model, simulate select cases from SHEBA, ASCOS, AMISA, and other field programs to (a) evaluate the model representation of the observed physical processes and (b) suggest improvements to related parameterizations when possible. Improvements to the parameterization of turbulent fluxes and surface albedo will be tried.

The modeling papers for both the ISDAC (Indirect and SemiDirect Aerosol Campaign) springtime WRF large eddy simulation (LES) study and the internationally collaborative study on simulations of Antarctic surface fluxes were both accepted during this past year. Further modeling work was done to simulate and understand the wintertime enhanced downwelling longwave fluxes from the SHEBA case discussed above. These simulations had difficulty reproducing the observed mixed-phase clouds and in providing the indicated long-range transport from open water through the Fram Strait. Some success was obtained using a double-moment microphysics scheme, in that it was able to produce supercooled liquid water. However, there appeared to be dynamical feedbacks from this microphysics scheme that produced smaller-scale cloud bands than what was observed, and in the wrong locations. In addition, the simulation seemed to have produced a cyclogenetic effect from Greenland that was not evident in the satellite images. This set of simulations clearly showed the impact of processes on a variety of scales.



Patrick Kelley, U.S. Coast Guard

The Arctic Ocean has lost more than 30 percent of its summer ice cover in the last 30 years.

Milestone 3. In collaboration with E. Andreas, use the Surface Flux Analysis (SURFA) global Numerical Weather Prediction (NWP) surface flux archive to examine the Arctic surface energy budget and its sensitivity to surface flux parameterizations

The SURFA data set was not used, and hence the sensitivity of the modeled surface energy budgets to surface flux parameterizations was not studied.

CSV-05 Climate Research Database Development

■ NSIDC-01 Digitizing Analog Cryospheric Data under the Climate Database Modernization Program
■ NSIDC-03 World Data Center for Glaciology, Boulder, Colo.—Current Programs

NSIDC-01 Digitizing Analog Cryospheric Data under the Climate Database Modernization Program

FEDERAL LEAD: CARL GROENEVELD
CIRES LEAD: JANE BEITLER

NOAA Goal 2: Climate

Project Goal: Scan and make available online data from NSIDC's analog collections so that it is more easily located, browsed, and obtained by users.

Milestone 1. Add additional glacier photograph or other analog material to the collections to the Analog Collection in collaboration with the NOAA National Geophysical Data Center (NGDC), and the NOAA Climate Database Modernization Program (CDMP).

NOAA@NSIDC and the Roger G. Barry Resource Office for Cryospheric Studies (ROCS) launched the ROCS Archives Catalog (http://nsidc.org/rocs/archives-catalog/index.php), and with this, the completion of the International Polar Year Historical Data and Literature project—formerly known as DAHLI. More than 800 digital items (photographs, data charts, publications/literature, audio files, and even a video) relating to the first two International Polar Years (IPY) 1882–83 and 1932–33 and the International Geophysical Year (IGY) 1957–58 reside in this public, searchable catalog, most of which are available for download. To search and access the collection, see the International Polar Year Historical Data and Literature web page (http://nsidc.org/data/g02201.html).

NSIDC-03 World Data Center for Glaciology, Boulder, Colo.—Current Programs

FEDERAL LEAD: CARL GROENEVELD
CIRES LEAD: JANE BEITLER

NOAA Goal 2: Climate

Project 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, reduced sea ice cover, thawing permafrost, and changes in precipitation patterns.

Milestone 1. Maintain and update existing research data sets (e.g., the Sea Ice Index). Publish new data sets and improve data visualization tools, including Google Earth. Make research information available, acquire and catalog cryospheric materials in the NSIDC library, and maintain NSIDC's analog data sets.

World Glacier Inventory (WGI): In cooperation with the World Glacier Monitoring Service (WGMS), NOAA@NSIDC released an update to the World Glacier Inventory (WGI, http://nsidc.org/data/glacier_inventory/). The WGI was revised and updated based on additional sources from the literature. The database stores geographical coordinates of glacier label points and tabular information about glacier classification, area, length, orientation, and altitude range.

The WGI was initiated during the International Hydrological Decade (IHD), 1965–74 and is mainly based on aerial photographs and maps of the second half of the 20th century. Since 1999, NOAA@NSIDC has worked with the WGMS to make its inventory available online; with this recent update, it now provides more than 130,000 entries. The WGI is a reference data resource for the world's glaciologists and one of NSIDC's most popular data sets.

New NOAA Climate Data Record of Sea Ice Concentration: In cooperation with NOAA's National Climatic Data Center (NCDC) Climate Data Record (CDR) program, NSIDC has released a CDR of sea ice concentration that has full data transparency. Transparency, in this sense, means that the input data, code, and processing steps of the data are known, well-documented, and openly available.

The NOAA/NSIDC CDR sea ice concentrations (http://nsidc.org/data/g02202.html) are derived from passive microwave instruments, using a combination of two algorithms developed at the NASA Goddard Space Flight Center (GSFC). Fields of data quality assessment information are also included in the CDR product. The files are provided in netCDF4 format (including Climate and Forecasting [CF] metadata), which is a self-describing and sustainable file format.

CSV-07 Climate Services

- PSD-05 Experimental Regional Climate Services
- PSD-07 Experimental Climate Data and Web Services

PSD-05 Experimental Regional Climate Services

FEDERAL LEADS: ROBERT WEBB AND ROGER PULWARTY
CIRES LEADS: XIAOWEI QUAN, KLAUS WOLTER, AND JOSEPH BARSUGLI

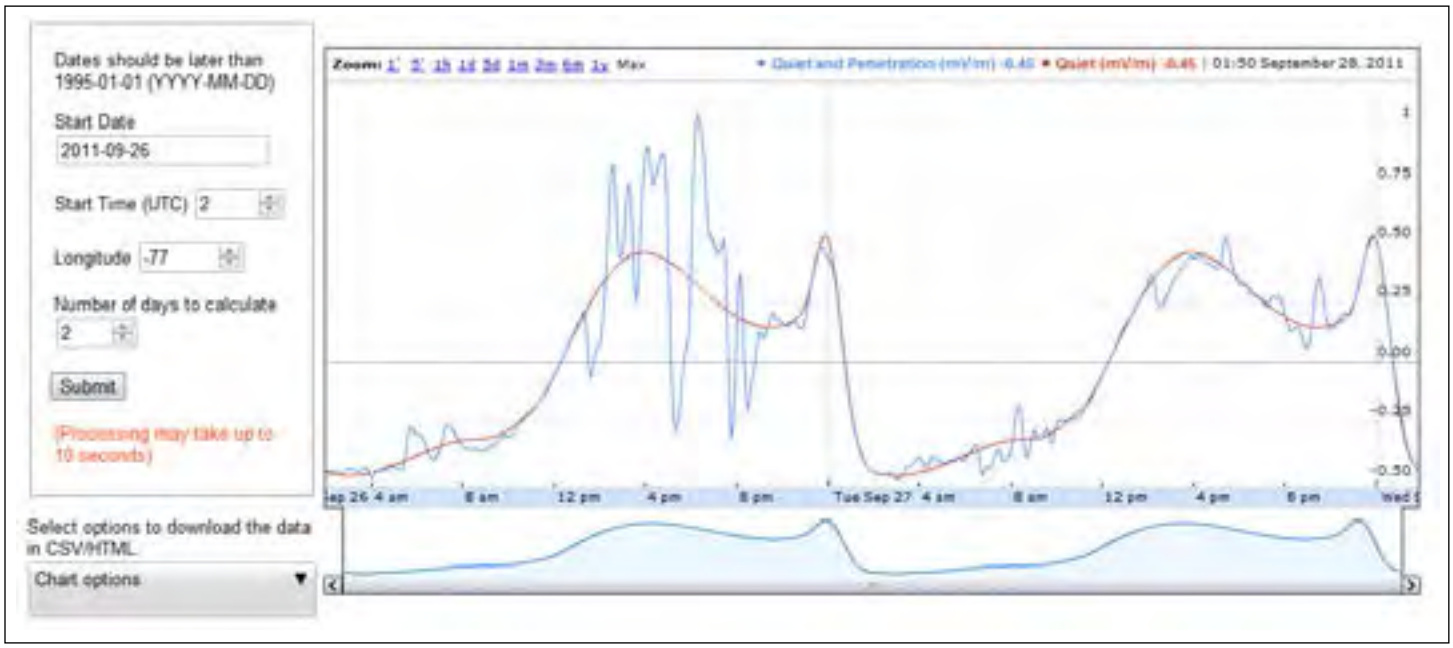
NOAA Goal 3: Weather and Water

Project 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 1. Examine the transitional probability of drought/pluvial conditions over the United States at different phases of sea surface temperature (SST) evolution in the tropical Pacific Ocean based on observational data and multi-model ensemble simulations.

The analyses on the predictability of change of an existing meteorological drought condition is completed, in collaboration with scientists at the International Research Institute for Climate and Society (IRI) and the Climate Prediction Center (CPC). We found that the persistence of the drought indicator yields considerable seasonal skill, with a region's annual cycle of precipitation driving a strong seasonality in baseline skill. The unconditioned forecast skill for drought is greatest during a region's climatological dry season, and least during a wet season.

Dynamical models forced by observed global SSTs yield increased skill relative to this baseline, with improvements realized during the cold season over regions where precipitation is sensitive to the El Niño Southern Oscillation. Fully coupled initialized model hindcasts yield little additional skill compared to the uninitialized SST-forced simulations. In particular, neither of these dynamical seasonal forecasts materially increases summer skill for the drought indicator over the Great Plains, a consequence of small SST sensitivity of that region's summer rainfall and the small impact of anomalous antecedent soil moisture conditions on the summer rainfall. However, the fully initialized predictions for monthly forecasts appreciably improve on the seasonal skill, especially during winter and spring over the northern Great Plains.



NGDC-05, Milestone 1

Milestone 2. Evaluation of statistical and dynamical down-scaled climate projections for the Colorado River Basin, including data from the North American Regional Climate Change Assessment Program (NARCCAP), particularly as it relates to hydroclimatic processes and variability. Work with stakeholders through Western Water Assessment (WWA) in evaluating needs and approaches for applying regional climate change information to water and land resource management.

A project with The Nature Conservancy and University of Washington was accomplished to calibrate the Variable Infiltration Capacity (VIC) hydrologic model for the purposes of better modeling flows relevant to ecological applications. The results were written up in a final report for the granting foundation, and a paper is in preparation for publication. A publication was accepted on analyzing the NARCCAP regional climate model projections for the San Juan River basin. The conclusion was that soil moisture feedbacks were important at high elevations in amplifying warming in summer, and a novel mechanism was proposed for enhanced wintertime warming that involves soil moisture, atmospheric humidity, and snow. The Gunnison Basin Climate Vulnerability Group completed its species and habitat vulnerability assessment with the participation of the Western Water Assessment, and a final report was published.

Milestone 3. Continue programmatic development and impact assessments of climate, weather, and water services in conjunction with the National Integrated Drought Information Service (NIDIS) and other programs.

The Colorado Water Availability Task Force, as well as the Colorado Water Conservation Board (CWCB), Colorado Basin River Forecast Center (Salt Lake City), and Upper Colorado Assessments (NIDIS Pilot), were briefed on seasonal to two-year expectations regarding precipitation and runoff prospects in Colorado. This was partially funded through CWCB.

Participation continued with water managers in the southeastern U.S. (Apalachicola-Chattahoochee-Flint Basin: ACF NIDIS pilot), who were briefed on the developing drought situation and linkages to La Niña. Seasonal rainfall forecasts were tailored for the region. This work was extended to the south-central U.S. in another NIDIS activity with a focus on Texas.

Work continues on a project with the Department of Water Resources in California to predict seasonal climate in that state, with a particular focus on the Sacramento and San Joaquin river basins. Additionally, a project with the Bureau of Reclamation to help with its seasonal-prediction efforts was continued.

Participation in a workshop on extreme events with the California Department of Water Resources: Participation with the NOAA Regional Climate Service director in support of a series of briefings on the Missouri Basin response to La Niña conditions in winter–spring 2012 for NOAA's National Climate Predictions and Projections platform, particularly regarding the prospect for flood and drought.

PSD-07 Experimental Climate Data and Web Services

FEDERAL LEADS: RANDALL DOLE AND NICK WILDE
CIRES LEADS: CATHERINE SMITH AND PRASHANT SARDESHMUKH

NOAA Goal 2: Climate

Project 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 1. Improve PSD's visualization and analysis of climate data to support experimental monitoring and explanation of current and evolving climate conditions, and to advance understanding of the climate system through imaging and animation.

PSD actively maintains a set of webpages and tools that monitor climate. This year, we have added to our collection several new tools. The first is a set of web pages that allows users to plot maps, time series and vertical cross sections of different re-analyses data sets (MERRA, ERA-Interim, 20CR, NCEP R1, and NCEP R2) and allows users to compare different reanalyses and perform some analyses (http://www.esrl.noaa.gov/psd/data/writ/). Reanalysis takes observations over a period of time and uses one unchanging model to produce a full set of physically consistent variables, thus ensuring observed changes are 'real' and not model-induced. The tool allows users to plot and compare the

different reanalyses and thus sheds light on both atmospheric processes as well as the different models.

The 2nd webpage is a web-based browser of Summit, Greenland, cloud and atmospheric observations (http://www.esrl.noaa.gov/psd/arctic/observatories/summit/). The Arctic is an important part of Earth's climate, and monitoring both the atmosphere and the ice in the region is critical to understanding global climate variability.

Third, the Wind Forecast Improvement Project (WFIP) project was designed to observe atmospheric conditions and to use those measurements to better understand and predict winds, thereby increasing the energy output of wind turbines (http://www.esrl.noaa.gov/psd/psd3/wfip/).

Finally, we have implemented a RAMADDA server (http://www.esrl.noaa.gov/psd/repository/). This server facilitates the grouping together of climate data and products such as maps, satellite photos, time series, pdfs, and other information about a particular topic. The server will be highlighting the 2011 Texas drought and what climate conditions were associated with it.

GEODYNAMICS

GEO-07 Geophysical Data Systems

■ NGDC-05 Improved Integration and Modeling of Geomagnetic Data

NGDC-05 Improved Integration and Modeling of Geomagnetic Data

FEDERAL LEAD: SUSAN MCLEAN
CIRES LEAD: HEINRICH MAUS

NOAA Goal 4. Transportation

Project Goal: Produce reference models of the geomagnetic field for land, sea, air, and spaceborne magnetic navigation and attitude/heading systems. Develop real-time models of the magnetic field for advanced magnetic accuracy requirements and space weather applications. Derive ionospheric parameters from magnetic field observations to monitor and predict ionospheric disturbances affecting global positioning systems and radio communication.

Milestone 1. Satellite-derived crustal magnetic field model: Using the latest measurements from the CHAMP satellite (CHAllenging Minisatellite Payload), develop a global crustal magnetic field model to spherical harmonic degree and order 150 and integrate it into National Geophysical Data Center (NGDC)/CIRES magnetic reference products for navigation and heading.

In the equatorial ionosphere of Earth, the wind driven currents coupled with Earth's primarily horizontal magnetic field produce the equatorial zonal electric field. The zonal electric field is the primary driver of two important features of the equatorial ionosphere: (1) the Equatorial Ionization Anomaly (EIA), and (2) plasma density irregularities, also known as spread-F. During propagation through the ionosphere, communication and navigation radio signals are attenuated, delayed and scattered by these ionospheric features. Prediction of the zonal electric field is, therefore, a key to the real-time specification of the ionosphere.

The zonal electric field was split into a climatological contribution plus the prompt-penetration contribution caused by the solar wind effects. A transfer-function based model, driven by the interplanetary electric field measured by the Advanced Composition Explorer (ACE) satellite, was used to predict the prompt-penetration effects in real-time. The zonal electric field is predicted about one hour in advance, covering all local times and longitudes. The real-time prediction is available as a Google application at http://www.geomag.us/models/PPEFM/RealtimeEF.html.

The benefit of this application to space weather forecasting is twofold: As the driver of the equatorial plasma fountain, the predicted zonal electric field is a leading indicator by two to three hours of the EIA and the Total Electron Content (TEC) of the equatorial ionosphere. Secondly, rapid uplift of the ionosphere by strong eastward electric fields is known to induce spread-F. Prediction of enhanced prompt penetration electric fields in the eastward direction, therefore, improves the forecast of radio communication and navigation outages in the equatorial region.

INTEGRATING ACTIVITIES

IA-01 Science and Society

■ CSD-10 Scientific Assessments for Decision Makers
■ Policy-01 Science Policy Lecture Series

CSD-10 Scientific Assessments for Decision Makers

FEDERAL LEAD: A. R. RAVISHANKARA
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

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

Milestone 1. Organize and oversee the international peer review of the United Nations Environment Programme/World Meteorological Organization 2010 scientific state-of-understanding assessment of the ozone layer for the United Nations Montreal Protocol; complete the editing and publishing of the final report; and deliver the report to the Montreal Protocol decision makers and the worldwide scientific community. Impact: This CIRES research supports the decision making of the more than 190 nations that are Parties to the United Nations Montreal Protocol on Substances that Deplete the Ozone Layer.

During the past year, work focused on the continued distribution of the 2010 assessment report to interested members of the public, as well as the scientific community and decision makers in government and industry. Communication of the key findings of the 2010 report continued. In addition, scientific summaries were presented at annual meetings of the Parties to the Montreal Protocol and the Protocol's Open-Ended Working Group. A special request from the Parties regarding the evaluation of a possible new ozone-depleting substance was addressed in the last year.

Policy-01 Science Policy Lecture Series

CIRES LEAD: ROBERTA KLEIN

NOAA Goal 2: Climate

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

Milestone 1. Organize a fall noontime seminar series focused on decision making under uncertainty, in conjunction with other units of CIRES.

Seminar Series

FALL 2011 Presentations

Normalized Tornado Losses in the United States: 1950–2011
Roger Pielke, Jr., CU Environmental Studies Program and Center for Science and Technology Policy Research

Climate Adaptation by Any Other Name: Social learning in Colorado water
Governance—Building Adaptive Capacity For Climate Uncertainty?
Shannon McNeeley, National Center for Atmospheric Research

Abrupt Climate Change: What Is It and Should I Fear It?
Jim White, CU Environmental Studies Program and INSTAAR

Collaborative Resilience: Moving Through Crisis to Opportunity
Bruce Goldstein, Department of Planning and Design, University of Colorado

Twenty Years of Water Reform in Australia: Any Lessons for the American West?
Brad Udall, Western Water Assessment, University of Colorado

Adapting to What?: Interactions of drought management, climate adaptation, and shifting vulnerability in the urban water sector
Lisa Dilling and Meaghan Daly, CU Environmental Studies Program and Center for Science and Technology Policy Research

Current Colorado Water Issues: Research and information needs
Reagan Waskom, Colorado Water Institute, Colorado State University

SPRING 2012 Presentations

Climate Change Adaptation in Alaska: Who is doing what?
Sarah Trainor, Alaska Center for Climate Assessment and Policy, University of Alaska Fairbanks

Characterizing, Creating, and Governing Florida's Hurricane Risk
Jessica Weinkle, Environmental Studies Program, University of Colorado Boulder

Panel Discussion—A Hard Look At 'Srex': The IPCC special report on extremes
Panel Convener: William Travis, Center for Science and Technology Policy Research, University of Colorado Boulder

Making Climate Change Local: High-resolution downscaling of extreme precipitation projections in the Colorado Front Range
Kelly Mahoney, Earth System Research Laboratory, NOAA

Wag the Dog: Ethics, accuracy, and impact of the science of extremes in political debates
Roger Pielke, Jr., Center for Science and Technology Policy Research, University of Colorado Boulder

Challenges in Attribution Of Weather and Climate Extremes
Randall M. Dole, Earth System Research Laboratory, NOAA

Milestone 2. Revise and update website.

Revision of the Center's website was completed in July 2010. We update our website regularly.

Milestone 3. Continue to upgrade newsletter and briefing, and expand readership.

Subscriptions to the Center's newsletter, *Ogmius*, increased from 426 to 782 over the past year. The mailing list for the Center's briefing, sent primarily to Washington, D.C. decision makers, has grown to 4,184 recipients.

IA-02 Western Water Assessment

- WWA-01 Scientific Assessments
- WWA-02 Climate Products
- WWA-03 Climate and Water Affairs
- WWA-04 Management

WWA-01 Scientific Assessments

FEDERAL LEAD: ROBIN WEBB
CIRES LEAD: ERIC GORDON

NOAA Goal 2: Climate

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

Milestone 1. The WWA education goal for coming years is to develop a suite of process-oriented frameworks for improving the climate literacy of different users with distinct informational needs.

WWA researchers Kristen Averyt and Tim Bardsley worked with the NOAA Colorado Basin River Forecast Center (CBRFC) to better understand how water managers interpret and use stream-flow forecast information through a series of interactive workshops. Workshops were held in January 2011 at the American Meteorological Society Meeting in Seattle, Wash., in conjunction with a short course on water resources,

WWA-01, Milestone 3

and in June 2011 in Salt Lake City. During these workshops, WWA introduced a gaming exercise that involved forecasted flows and reservoir schedules.

These engagements have improved managers' understanding of available products and user-driven improvements to CBRFC web based tools. In addition, scenario-based exercises indicate that most participants tend to use the median forecasts rather than worst-case scenario predicted at the tails of forecast ranges, and many use a wait-and-see approach to planning. These efforts are feeding into continued adjustment of decision support forecasts based on improved understanding of decision-making constraints and processes.

Milestone 2. WWA will continue to partner with the Center for Snow and Avalanche Studies in Silverton, Colo., to investigate the impacts of dust deposition on snow on Colorado River runoff.

Previous WWA research indicated a 5 percent reduction in annual Colorado River flow due to dust loading on snowpack in the Rocky Mountains (Painter et al., 2010). In 2011, WWA researchers began examining the impacts of unusually high dust loads (as seen in 2009 and 2010) and climate warming on flow in the Colorado River. Initial modeling results show that even under the strongest warming, timing of runoff is strongly sensitive to radiative forcing by dust. Under scenarios of extreme warming, however, volume of runoff becomes less sensitive to dust deposition. These results are expected to be published in a peer-reviewed journal in 2012.

In addition, the team working on dust-on-snow research began examining potential snowmelt 'perturbations' that may have driven unusual runoff patterns in the Upper Colorado River Basin over the past decade and resulted in anomalously high errors in peak and daily stream-flow forecasts. Water managers and hydrologic forecasters suspect that bark beetle infestations and/or increased dust deposition on snowpack might be causing these runoff anomalies, but to date there has been no concerted effort to understand the contributions of various snowmelt perturbations (see Figure 2 for conceptual model of possible snowmelt drivers).

WWA's dust-on-snow team has begun collaborating with other researchers who have expertise in climatology, meteorology, snow hydrology, and landscape ecology to bring a novel combination of methodologies to bear on this question. These researchers have assembled stream-flow data, vegetation change maps, and snow-water equivalent reconstructions in preparation for running a comprehensive land-and-snow-hydrology model. The ultimate goal of this multi-year effort is to provide usable information to improve stream-flow forecasting at CBRFC.

Milestone 3. WWA proposes to increase availability and use of paleohydrologic data in Utah during the next three to five years by coordinating methods proven successful elsewhere, beginning with scoping of Utah stakeholder needs for new paleohydrologies (gauge reconstructions) with one or two workshops in 2010, followed by an assessment of existing tree-ring data network for reconstructing those gauges, and development of new gauge reconstructions.

With the emergence in 2010 of the Wasatch Dendroclimatology Research (WADR) group at Utah State University and Brigham Young University, WWA's role in user-oriented paleohydrology in Utah shifted to an advisory one, helping the WADR group establish an effective stakeholder-oriented research program modeled similar to the paleohydrology work conducted by WWA in Colorado. In the past year, WWA team member Jeff Lukas provided the WADR group with guidance on methods and analyses and was invited to present on tree-ring paleohydrology in a special session at the USU Spring Runoff Conference in April 2012. WWA Utah Liaison Tim Bardsley participated in several meetings between the WADR group and Utah water managers. The WADR group has now developed several preliminary gauge reconstructions for northern Utah, and the results have been communicated to multiple stakeholders through meetings and the Spring Runoff Conference. WWA is preparing an ongoing evaluation to assess how these water managers perceive and use the new reconstructions. The attached image shows core samples from Douglas-fir trees whose growth rings were used to help reconstruct streamflow in the Wasatch Front.

WWA has also continued with two related paleohydrology efforts during the past year. First, a WWA-led project has produced new flow reconstructions for the lower Colorado River Basin, including a portion of southwestern Utah within the Virgin River and Kanab Creek basins. Second, WWA has maintained and updated the TreeFlow web resource for tree-ring paleohydrology (http://treeflow.info). This coming year, the Utah data produced by the WADR group and by the Lower Colorado River Basin paleohydrology project will be archived on TreeFlow.

WWA-02 Climate Products

FEDERAL LEAD: ROBIN WEBB
CIRES LEAD: ERIC GORDON

NOAA Goal 2: Climate

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

WWA-03, Milestone 2

Milestone 1. WWA will continue to publish the *Intermountain West Climate Summary* (*IWCS*), a compact Web-based package that includes the latest climate observations and forecasts for Colorado, Wyoming, and Utah. This package will be produced seven to eight times each year.

In the past year, WWA continued on its schedule of producing six web-based issues of the *IWCS* climate digest, whose release is announced to a list of 400 stakeholders. The *IWCS* feature articles over the past year covered topics such as WWA research on water use in electricity generation, analyses of regional climate model (RCM) projections for the Four Corners area, impacts of atmospheric rivers on the interior West, and the National Climate Assessment. The release of each issue of the *IWCS* continues to be announced on the homepages of NOAA National Weather Service forecast offices throughout the region and other partner organizations.

WWA-03 Climate and Water Affairs

FEDERAL LEAD: ROBIN WEBB
CIRES LEAD: ERIC GORDON

NOAA Goal 2: Climate

Project Goal: Increase decision makers' level of knowledge about climate science so they can become better consumers and demanders of climate products and assessments, which will assist Western Water Assessment (WWA) in setting its research agenda.

Milestone 1. WWA research is positioned to inform decision-making. WWA will continue facilitating conversations, discussions, and interactions within the WWA stakeholder network of 100 organizations and 250 individuals, while assessing the impacts of such outreach activities.

WWA continued to bolster its longstanding reputation with stakeholders and decision makers as a trusted source of climate information by participating in numerous stakeholder meetings and workshops. Collectively, WWA researchers gave more than 65 talks at stakeholder and academic conferences since July 1, 2011, and were cited, quoted, or interviewed by the media numerous times. The WWA research team also produced 16 articles, reports, and book chapters. WWA staff served as members of many committees and organizations, including planning for the Colorado Governor's Drought Conference scheduled for September 2012.

In addition, WWA uses its listserv of approximately 400 interested regional stakeholders to communicate climate information and research findings through the Intermountain West Climate Summary and other communication materials. These activities help fill gaps in science translation and provide us with additional information on the utility of WWA interactions and the need for future regionally based climate services and access to information.

Milestone 2. WWA researchers will, over the next two years, identify, engage, and support research, scientists, and stakeholders affected by decisions made at the interface of the water-energy nexus. In collaboration with energy-focused university and governmental researchers (including those from the National Renewable Energy Laboratory and the National Energy Technology Laboratory) and WWA's existing network of water professionals, WWA plans to identify salient issues and researchers approaching the energy-water nexus from either sector.

WWA made significant headway in 2011 on efforts related to energy and water. WWA researcher Doug Kenney published an edited collection of papers in a book titled *The Water-Energy Nexus in the American West*. This book features contributions from 24 authors including WWA scientist Kristen Averyt and multiple WWA collaborators.

In November 2011, WWA scientists collaborated with multiple nongovernmental organizations and federal and academic institutions to release the report "Freshwater Use by U.S. Power Plants." Led by WWA researcher Kristen Averyt, in collaboration with the Union of Concerned Scientists, the report outlined the results of a two-year project geared toward assessing the current state of water use by the U.S. electricity sector. Water for thermoelectric power production was analyzed in multiple ways, and the role of power plants in water stress across the U.S. was assessed. The report is continuing to receive significant media coverage, including by the The New York Times, several NPR affiliates, and other major news outlets. The results have been presented at multiple academic, public, and industry meetings. Five manuscripts are in preparation for submission to peer-reviewed journals.

WWA-04 Management

FEDERAL LEAD: ROBIN WEBB
CIRES LEAD: ERIC GORDON

NOAA Goal 3: Weather and Water

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

Milestone 1. WWA will co-locate a research liaison with respective state climatologists in Colorado, Utah, and Wyoming to build stakeholder relationships, identify climate science critical to the state, and integrate locally needed and locally occurring research with other WWA activities. These partnerships will also strengthen the relationship between WWA and National Integrated Drought Information System (NIDIS) as the state climatologists are involved in the NIDIS Upper Colorado River Basin Pilot study. Partners will meet on at least a quarterly basis at the WWA core office.

Since December 2010, WWA's Utah liaison, Tim Bardsley, has been working for WWA out of the NOAA Colorado Basin River Forecast Center in Salt Lake City. He has developed a Utah-based network of stakeholders and scientists and sent background information to authors of the "Southwest Region Technical Input Report" for the National Climate Assessment. He has also spent significant time assisting the Salt Lake City Department of Public Utilities with technical analysis to help understand the vulnerability of city water supplies to future warming. Efforts to hire a Wyoming liaison over more than one year were unsuccessful, and WWA core staff have begun their own efforts to work with stakeholders in that state, including through multiple presentations to the State Game and Fish Department and the State Engineer's Office.

Milestone 2. WWA will begin a structured review process for all activities, which will require WWA to listen to its local stakeholders and regularly reconsider its role within NOAA and NOAA-administered programs (e.g., NIDIS), including the emerging National Climate Service. This will be implemented over the next five years.

Last year, WWA hired Elizabeth McNie, an assistant professor at

Purdue University, to conduct an evaluation of WWA's work by interviewing stakeholders and researchers and putting the program in an intellectual framework capable of measuring success. McNie provided a brief overview of her initial findings at a WWA strategic review meeting in December 2011 and used feedback from program staff to finalize her report, which is expected to be delivered in mid-summer 2012. Based on McNie's findings and the program's stated commitment to adaptive learning, WWA began an internal transformation process in early 2012 aimed at making the program more efficient and clarifying its vision, goals, and processes.

The two most significant changes resulting from this transformation were (1) creation of an Executive Board comprised of University of Colorado research and teaching faculty who are empowered to craft WWA's research agenda and oversee operations and 2) replacing the RFP (Request for Proposal)–style process for developing research projects with an integrated, internalized process of soliciting initial ideas and shaping the research agenda to best meet stakeholder needs and future strategic directions of the program. To further craft and define WWA's future, the Executive Board held a two-day retreat in May 2012. A full transformation report is being developed.

IA-03 Education and Outreach

■ GSD-08 Science Education and Outreach

GSD-08 Science Education and Outreach

FEDERAL LEAD: WILLIAM BENDEL
CIRES LEAD: ELIZABETH RUSSELL

NOAA Goal 3: Weather and Water

Project Goal: Enhance scientific environmental literacy and improve understanding, value, and use of weather and water information and services to the public, including the K-12 education community.

Milestone 1. Communicate and coordinate NOAA educational activities with respect to Science On a Sphere (SOS) with the SOS user community and the public. Specific activities include the creation of thematic narratives for the user community, the annual SOS Users Group meeting, numerous traveling exhibits, and field trips from local schools and universities.

In the July 2011 through June 2012 period, 12 new Science On a Sphere (SOS) exhibits were permanently installed in science museums, visitors centers, and schools. One of those installations was in a high school, which marks the first SOS in a K-12 facility. SOS was also highlighted at the SuperComputing 2011 Conference in Seattle, Wash., in November 2011. As the number of installations and exhibits increases, so does the number of participants in the SOS Users Collaborative Network. The network continues to thrive and actively produce new content and educational activities for the SOS program. Thirty new data sets were added to the SOS data catalog in the past year, including several that came with accompanying scripts, narration tracks, and hands-on supplemental activities. A new creation this year is the EarthNow blog, which provides annotated, near-real-time data sets for SOS sites. The blog is updated bimonthly for SOS users and provides descriptions of recent events with supporting data sets to use with SOS.

The SOS team produced for the network two documents, "Docent Best Practices" and "Content Submission Guidelines," to help sites continue to develop their own educational programming. To further support the network, the SOS team has expanded in size to include a person dedicated solely to educational support for SOS. This person also coordinates the school visits to NOAA, which includes a stop at SOS. Over the past year, more than 6,000 visitors to NOAA have seen SOS through field trips, public tour, and special group visits.

Milestone 2. Develop new and enhance existing features of the SOS system through software improvements.

The Science On a Sphere (SOS) development team has been busy over the last year. Summer of 2011 saw the release of the first iOS application for iPads, iPhones, and iPod Touches, which serves as a remote control for SOS. After an early release to beta testers, the app was officially released to the SOS Network, with extremely positive reception. Continued development of the iOS app has further improved the app through the year, and a new version was made available to the SOS Network in spring 2012.

A major release for SOS is planned for summer 2012, so much of 2011 was spent preparing for the new release. In June 2012, a request for beta testers for this new version of the software was sent to the SOS Network. This new release includes many enhancements such as zooming, layering, and annotating. All of these are features that the SOS Network has specifically requested. The zooming feature utilizes a magnifying glass concept that provides a zoomed-in view of any area that the virtual magnifying glass is positioned over. The layering feature allows users to dynamically layer data sets and adjust the transparency of them to blend them together. The annotating feature gives users the ability to draw on the sphere in several different colors and to place icons in real time on the data sets. To support further development work, a new employee has been added part-time to the project, and there are plans

GSD-08, Milestone 1

for another full-time employee.

Milestone 3. Explore the expanding frontiers of virtual worlds, simulation, and visualization tools to aid NOAA education and outreach, science, and support to the public, in line with NOAA's mission.

This year has seen major new initiatives in interactive data visualization and outreach. Additionally, the team has added two collaborators: Jebb Stewart of the Technology Outreach Branch and Jeff Smith of the Advanced Computing and Evaluation Branch at NOAA's Oceanic and Atmospheric Research.

The virtual worlds group, with direction from NOAA Boulder's director Sandy MacDonald and in cooperation with groups throughout NOAA including the Climate Program Office and the NOAA Office of the Chief Information Officer (OCIO), has embarked on the creation of a visualization tool called TerraViz. The goal is "all NOAA data, anytime, anywhere."

TerraViz uses the latest generation Unity rendering engine and is able to view gigabytes of scientific data fluidly in time and space. It has been recognized by the Army's Federal Virtual Worlds Challenge; has been featured in releases from Unity Technologies; and is slated to be included on Climate.gov in 2013. Parallel work has been undertaken on a back-end metadata search tool, and TerraViz is now able to access and display more than 1,000 data sets from multiple NOAA line offices. Work is ongoing to interface with unique data sets and data types including 4-D ocean glider sensor data and large-volume weather models.

The virtual worlds group is also actively engaged in a follow-up to the successful ReGenesis project in partnership with the Interdisciplinary Scientific Environmental Technology (ISET) Cooperative Science Center (CSC). Part educational game, part interactive simulation, the project will teach students about climate change and the role of satellite observations in its prediction and management. The project is slated for a 2013 release.

IA-04 Resource Development for Educators and Decision Makers

- Policy-02 Agricultural Adjustments to Drought
- Policy-03 Impacts of Earlier Snowmelt on Water Rights Holders in the Intermountain West

Policy-02 Agricultural Adjustments to Drought

CIRES LEAD: ROBERTA KLEIN

NOAA Goal 2: Climate

Project Goal: Explain the mixture of findings of an earlier WWA-funded project (Drought Impact Indicators); and determine how farmers, ranchers, and the federal grazing system respond to climate variability and what role climate information plays in decision-making.

Milestone 1. Design field project, conduct interviews, and write up findings for peer review.

The ranching and drought project yielded a detailed roster of decisions that ranchers can make in the face of drought, including alternative grazing and land-use strategies and a host of financial and marketing choices. We have rolled the project results into the modeling of decision-making under climate uncertainty, which started with a farm model and is being elaborated with a flood control infrastructure model and a ranching model. The infrastructure model simulates the performance of an urban drainage system under changing intensity and duration of precipitation events, and the ranching model simulates grazing and marketing choices during a multiyear drought in which ranchers must judge both the prospects for grazing success during drought conditions and the timing and amount of herd reduction in the face of reduced range carrying capacity.

Policy-03 Impacts of Earlier Snowmelt on Water Rights Holders in the Intermountain West

CIRES LEAD: ROBERTA KLEIN

NOAA Goal 2: Climate

Project Goal: This project will determine whether agricultural water rights holders in the U.S. West have experienced impacts from, and made adaptations to, earlier snowmelt.

Milestone 1. Design field project, conduct interviews, and write up and present findings.

Instead of this project, Lisa Dilling (with Krister Andersson) led the Drivers of Adaptation project, which is investigating the conditions under which local decision makers in Colorado, Utah, and Wyoming decide to adapt to increased climate-related risk and hazards. They administered a survey to more than 140 individuals in 60 cities and interviewed three individuals for each city, both elected and appointed. They asked about top-priority areas; which natural hazards were seen as important; how municipalities have allocated resources to a given hazard; which types of plans exist and how they relate to implementation; impressions of memorable extreme events; where communities obtain information; how collaborations occur; how citizen groups are involved; and beliefs about climate change.

Findings include:

(1) Perceptions of risk differ between states. For example, earthquakes are a strong concern in Utah but not in Colorado, and tornados are a strong concern in Colorado but not Utah.

(2) Belief in climate change is variable among respondents and does not obviously appear to influence adaptation.

(3) There is evidence of strong adaptive capacity in Utah from coordination with the Church of Jesus Christ of Latter-Day Saints. This may confer increased capacity for disaster planning and response.

(4) Virtually all communities have experienced disasters, but there is still variation in how they respond.

(5) Municipal responses to hazards are nested within county, state, and federal policy with respect to opportunities provided by FEMA funding for example.

Products include several papers, an exploration of network analysis, and a database with perceptions of hazards, responses, and planning.

The NOAA P3 research aircraft takes off during the 2010 CalNex field study.

PLANETARY METABOLISM

PM-02 Biosphere-Atmosphere Interactions

- CSD-07 Biosphere-Atmosphere Exchange
- CSD-14 Tropical Ocean Productivity

CSD-07 Biosphere-Atmosphere Exchange

FEDERAL LEADS: JIM ROBERTS AND JIM BURKHOLDER
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 3: Weather and Water

Project Goal: Improved understanding of how the exchange of gases between the surface and the atmosphere shapes regional climate and air quality.

Milestone 1. Continue studies to measure reaction rate coefficients and evaluate the atmospheric degradation mechanisms of key biogenic species. Impact: This research will provide information needed to quantitatively evaluate the role of biogenic compounds in regional ozone production and secondary organic aerosol formation. This research has implications for regional air quality.

Biogenic volatile organic compounds (BVOCs) are emitted into the atmosphere in quantities that exceed the emission of VOCs from anthropogenic sources. BVOCs are chemically active compounds, and their gas-phase chemistry has a direct impact on air quality on local to regional scales through their impact on the abundance of HO_x (HO_x =OH+HO_2), ozone production, and contributions to secondary organic aerosol (SOA). The formation of organic nitrates locally also leads to the transport of NO_x (NO_x =NO+NO_2) and subsequent ozone production on the regional and continental scale. It is, therefore, important to know not only the atmospheric abundance of BVOCs, but also their reaction rates and degradation pathways to enable accurate model calculations used for air-quality forecasts as well as regulatory purposes.

A number of unsaturated BVOCs (molecules containing carbon-carbon double bonds) are emitted by a variety of plant species in response to wounding due to their antibacterial properties. The unsaturated compounds primarily include C5 and C6 aldehydes, ketones, and alcohols and are collectively referred to as 'green leaf volatiles.' Here, rate coefficients, k, for the gas-phase reaction of the OH radical with (Z)-3-hexen-1-ol ((Z)-CH_3CH_2CH=$CHCH_2CH_2OH$) (k1), 1-penten-3-ol ($CH_3CH_2CH(OH)CH$ =CH_2) (k2), (E)-2-penten-1-ol ((E)-CH_3CH_2CH=$CHCH_2OH$) (k3), and (E)-2-hexen-1-ol ((E)-$CH_3CH_2CH_2CH$=$CHCH_2OH$) (k4), unsaturated alcohols that are emitted into the atmosphere following vegetation wounding, are reported. Rate coefficients were measured over the temperature range 243 to 404 Kelvin at pressures between 20 to 100 Torr (He) using pulsed laser photolysis (PLP). A manuscript has been published in *Atmospheric Chemistry and Physics* (2011).

A second set of studies was conducted on methylglyoxal (CH_3CO-CHO). Methylglyoxal and glyoxal, $(HCO)_2$, are dicarbonyls that play an important role in atmospheric chemistry as tracers of atmospheric biogenic and anthropogenic organic chemistry. They also play a role in tropospheric ozone production and secondary organic aerosol (SOA) formation on local to regional scales. Methylglyoxal is formed in the degradation of volatile organic compounds including isoprene and the

aromatic hydrocarbons toluene, xylene, and trimethylbenzene. Methylglyoxal is also emitted directly into the atmosphere via the incomplete combustion of fossil fuels and biomass and to a lesser extent in automobile emissions as a result of biofuel usage. Methylglyoxal and glyoxal are short-lived species that are removed from the atmosphere primarily by UV/visible photolysis, gas-phase reaction, and heterogeneous processes.

Studies of the OH radical reaction with glyoxal and its UV/visible photolysis quantum yields have been reported in previous work from this laboratory. In this work, rate coefficients for the OH radical reaction with methylglyoxal and the NO_3 radical reaction with glyoxal and methylglyoxal are presented. In addition, we reported the infrared cross sections of methylglyoxal for the first time to be available for use by the scientific community. A manuscript describing the above research has been published in *Atmospheric Chemistry and Physics*.

Milestone 2. Initiate laboratory investigation of switch grass emissions to quantify volatile organic compounds emitted by different switch grass species, and to prepare for a summer 2011 field study of agricultural switch grass emissions. Impact: This CIRES research will provide information needed to assess the environmental impact of a large-scale production and use of alternative fuels produced from biofuel crops. Emissions of volatile organic compounds from vegetation can play a significant role in the formation of ozone and aerosol in polluted atmospheres.

In Summer 2011, a detailed field study of the surface-atmosphere exchange of trace gases over a cornfield was conducted near Fort Collins, Colo. During the study the vertical fluxes of different hydrocarbons, oxygenated VOCs, NO_x, and ozone were successfully determined from eddy covariance and leaf cuvette measurements. In addition, soil emissions and uptake were investigated using soil enclosures. It was found that dimethyl sulfide (DMS), a compound that is normally regarded as an oceanic emission, is also emitted from corn in significant quantities. This may be important for nighttime chemistry as DMS reacts efficiently with nitrate radicals (NO_3). A paper on the measurements and implications is currently in preparation. During the study, the first eddy covariance measurements of organic acids were made using a chemical ionization mass spectrometer. Fluxes of organic acids were found to be bi-directional. The atmospheric budgets of organic acids are poorly understood, and better constraints on the dry deposition are needed to improve modeling of these compounds.

Milestone 3. Develop and test the Acid chemical ionization mass spectrometry (CIMS) system for measuring organic and inorganic acids in the atmosphere. Impact: The Acid CIMS will enable measurement of a large number of organic and inorganic acids, rapidly and with high sensitivity. This capability can be applied to research as diverse as ecosystem fluxes, emissions from combustion sources, and the participation of organic acids in secondary organic aerosol formation.

The CIMS instrument based on acetate-ion chemistry was used in two field studies during the project period. In summer 2011, the surface-atmosphere exchange of organic acids over a cornfield near Fort Collins, Colo., was quantified by combining CIMS with eddy covariance. The measurements were successful and provided the first eddy covariance measurements of organic acids to date. The results showed that the fluxes could be bidirectional and provide important constraints on the treatment of atmospheric deposition in atmospheric models. This study was part of the CIRES Energy and Environment Initiative: A significant part of U.S. farmland is now used to grow corn for fuel ethanol production, and this research provides information on how the production of fuel ethanol affects the atmosphere.

In winter 2012, acidic trace gases in the Uintah Basin in Utah were measured by CIMS as part of a larger study that focused on the atmospheric emissions associated with natural gas production and the role these emissions play in atmospheric chemistry. Among the trace gases quantified by CIMS, measurements of nitrous acid (HONO) were particularly important as HONO can provide a source of free radicals that can potentially initiate ozone chemistry.

CSD-14 Tropical Ocean Productivity

FEDERAL LEAD: JAMES CHURNSIDE
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Understand the effects of changes in temperature, vertical mixing, and aerosol fertilization on primary productivity in the tropical ocean.

Milestone 1. Identify the temporal and spatial scales of the processes that link chlorophyll concentration in tropical ocean waters to aerosols and temperature. Impact: This research will help identify the processes leading to the recently observed expansion of the tropical ocean. These processes are important to predicting the rate of CO_2 uptake by the ocean of the future.

Investigating the relationship between aerosol optical depth (AOD) and chlorophyll a (chl-a) concentration has revealed declining trends that are latitudinally coincident, especially in the northern hemisphere. Using multivariate regression analysis, we found that poleward of 10 degrees north latitude, the variability in chl-a concentration was most closely related to AOD, when compared to climatic or decadal oscillations like El Niño–Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO).

One possible explanation, called the iron hypothesis, has been proposed in literature. The iron hypothesis suggests that decreasing dust leads to a decline in iron deposition, in turn, reducing productivity and aerosol production. Our analysis indicated statistically significant declines in the mid-Pacific Ocean in both chl-a concentration and AOD over northern subtropics and mid-latitudes where iron deposited through desert dust regulates photosynthesis (primary production).

PM-03 Response of Natural Systems to Perturbations

■ NGDC-07 Anthropogenic Remote Sensing

NGDC-07 Anthropogenic Remote Sensing

FEDERAL LEAD: CHRIS ELVIDGE
CIRES LEAD: MIKHAIL ZHIZHIN

NOAA Goal 4. Transportation

Project 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 1. Complete a radiance calibrated Defense Meteorological Satellite Program Operational Linescan System (DMSP OLS) nighttime lights product for the year 2010 using satellite F16.

No progress was reported for this Milestone.

Milestone 2. Develop a methodology for determining gain settings on DMSP OLS operational data for satellites F16 and F18.

No progress was reported for this Milestone.

Milestone 3. Development of a robust and effective calibration method for the DMSP OLS time series based on reflected moonlight from desert surfaces for satellites F16 and F18.

No progress was reported for this Milestone.

REGIONAL PROCESSES

RP-02 Surface/Atmosphere Exchange

■ PSD-12 Air-Sea Interaction

PSD-12 Air-Sea Interaction

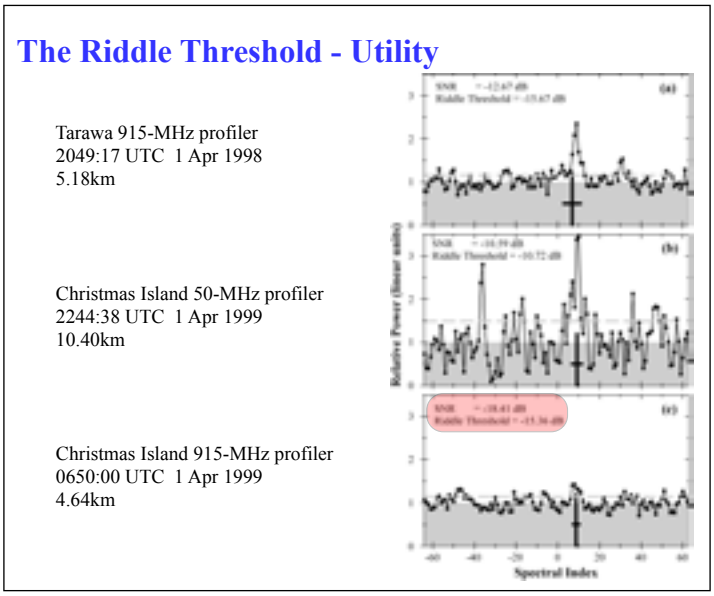
FEDERAL LEAD: CHRIS FAIRALL
CIRES LEAD: ANDREY GRACHEV

NOAA Goal 2: Climate

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

Milestone 1. Complete construction of synthesis data set for VOCALS-REx (Variability of the American Monsoon Systems' [VAMOS] Ocean-Cloud-Atmosphere-Land Study Regional Experiment) data.

The East Pacific Synthesis Data set includes data collected during several cruises as part of the Pan American Climate Study (PACS). In 2010–2011, 915-MHz profiler data collected during the fall 2000 cruise was employed, together with a modified version of an algorithm designed to identify the convective boundary layer from profiler data, in an attempt to identify the top of the stratocumulus-topped mixed layer. This work formed the bulk of the summer research project for SOARS protégé Aaron Piña, then entering his senior year at Texas A&M University. Leslie Hartten (CIRES) served as Piña's research mentor during summer 2010.



PSD-12, Milestone 1

In 2011–2012, Piña's work was extended by SOARS protégé Javier Lujan, a junior at University of Texas-El Paso. Lujan used profiler, ceilometer, and radiosonde data from the fall 2004 cruise and found clear relationships between reflectivity features, cloud bases, and the inversion atop the boundary layer. Lujan's research mentors during summer 2011 were Leslie Hartten and Paul Johnston (CIRES).

Technical issues that arose during this work resulted in a refereed journal article (Riddle et al., 2012) and a conference presentation (Hartten et al., 2012c). The combined work of Piña and Lujan resulted in two conference presentations (Hartten et al., 2012a,b). Each SOARS protégé also produced a manuscript for the annual SOARS collection (Piña, 2010; Lujan, 2011).

Milestone 2. Submit papers on parameterization of sea spray as part of the NOAA hurricane studies.

Investigation of boundary layer processes in hurricanes. This is a study of the effects that sea-spray droplets have in controlling the maximum intensity that hurricanes reach. Hurricanes are essentially heat engines that are driven by the transfer of heat energy from the warm ocean to the cooler atmosphere, and the aim of this work is to demonstrate the importance of sea-spray droplets in transferring this energy. Although current hurricane forecast models have considerable skill at forecasting hurricane track or location, they have little skill at forecasting hurricane intensity. Present operational hurricane forecast models ignore the effects of sea spray, and this work aims to demonstrate how these models can be improved by including sea spray.

Milestone 3. Analyze flux and gas transfer observations from NOAA's Southern Ocean Gas Exchange Experiment (GasEx III) field program. Submit publication on results.

The work over the last year has been dominated by consolidating results of this project and submission/revision of manuscripts based on those results. Several publications relevant to the GasEx III field program were published in the *Journal of Geophysical Research*.

RP-03 Regional Air Quality

- GSD-02 Regional Air Quality Prediction
- GMD-06 Baseline Air Quality
- PSD-13 Air Quality
- CSD-08 Regional Air Quality

GSD-02 Regional Air Quality Prediction

FEDERAL LEAD: GEORG GRELL
CIRES LEAD: STEVEN PECKHAM

NOAA Goal 3: Weather and Water

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

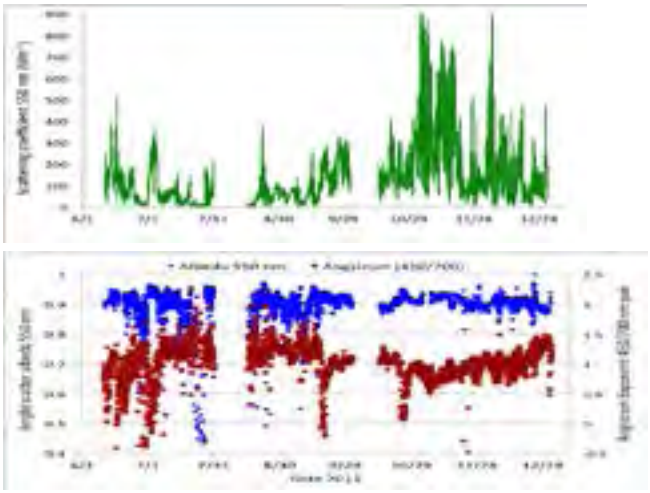
Milestone 1. Test and evaluate the global FIM-Chem (Flow-following finite-volume Icosahedral Model) currently under development in the Earth System Research Laboratory (ESRL) and containing chemistry modules from the GOCART (Goddard Chemistry Aerosol Radiation and Transport) model, together with global wildfire definition and global anthropogenic emissions data. Run FIM-Chem in real time at the highest affordable resolution to predict multiday global transport of aerosol and impact on weather forecasts.

Evaluation studies continue to be performed on GOCART aerosol modules in FIM. The studies use a modified emissions processor, based upon the one used for the Weather Research and Forecast–Chemistry model (WRF–Chem), which provides global wildfire, anthropogenic, and volcanic ash emissions.

Milestone 2. Continue to coordinate worldwide development of the Weather Research and Forecast–Chemistry model (WRF–Chem) as an air-quality prediction tool and support the growing user community.

CIRES's leadership role in the development of this modeling system continues. WRF-Chem version 3.4 was released in April 2012 with many new additions, including additional coupling between chemistry and physics modules, new additions to chemical mechanisms (provided by the National Center for Atmospheric Research, the Pacific Northwest National Laboratory, and the Earth System Research Laboratory's Chemical Sciences Division), and the inclusion of volcanic ash emissions. In addition, significant improvements have continued to be made to the data input/output (I/O) streams, which has enhanced the overall performance of the WRF-Chem model.

Real time forecasts using the WRF/Chem model were reported as a NOAA/ESRL hot item when wildfire smoke from the Whitewater-Baldy fires in New Mexico were transported northward to Colorado over the Memorial Day weekend. The work to include wildfire smoke into real-time forecasts, as well as its interaction with the weather, relates to NOAA's Climate and Weather goals by enhancing the understanding of radiatively important fine-particle aerosols as well as improving air-quality forecast models.



Aerosol scattering coefficient at 550nm (top frame) and aerosol single scatter albedo and Angstrom exponent (bottom frame) from 6/2011 to 12/2011 from Nainital, India.

GMD-06, Milestone 1

GMD-06 Baseline Air Quality

FEDERAL LEAD: SAMUEL OLTMANS
CIRES LEAD: ANNE JEFFERSON

NOAA Goal 2: Climate

Project Goal: Study intercontinental transport events to better understand their effects on overall air quality and its impacts on public health.

Milestone 1. An aerosol measurement system will be deployed to India's Ganges Valley to study the effect of aerosol on radiation, convection, and cloud formation. The study will span the pre- to post-monsoon seasons.

Aerosol optical properties from surface in-situ measurements show a large increase in the aerosol scattering coefficient between the summer monsoon season and post-monsoon, dry season. Despite this large increase in the aerosol loading between the wet and dry seasons, there was little variability in the aerosol intensive properties. There are short episodes when either large or dark aerosols are present. In general the aerosol has a relative high single scatter albedo and low angstrom exponent, indicating relatively large particles with low absorption. Hygroscopic growth factors (ratio of scattering at 85/40 percent relative humidity) are moderate to low and indicate that the aerosol isn't highly oxidized.

During the post-monsoon season a diurnal trend in the aerosol loading was frequently observed with daytime highs in the scattering coefficient around 1,200–1,900 LT. The aerosol during upslope conditions generally had a smaller angstrom exponent and higher single scatter albedo, indicating larger and less absorbing aerosol than during the nighttime and morning hours. A potential source of the daytime aerosol is secondary organics with low BC levels from the local vegetation. The smaller and darker nighttime and morning aerosol could originate from long-range transport.

PSD-13 Air Quality

FEDERAL LEAD: ALLEN WHITE
CIRES LEAD: SARA MICHELSON

NOAA Goal 2: Climate

Project 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 1. PSD engineers will deploy three wind-profiling radars with radio acoustic sounding systems and surface meteorology towers at three key locations in southern California for the CalNex field campaign in the upcoming spring and summer (2010). Meteorological observations collected at these sites will be accessed, displayed, archived, and quality-controlled.

No progress was made on this milestone.

Milestone 2. Execute the surface flux, boundary layer, and cloud observations for the CalNex cruise. Process and analyze the CalNex data set from the NOAA Ship Ronald H. Brown cruise, including turbulent fluxes of momentum, sensible heat and latent heat, down-welling radiative fluxes, cloud radar statistics, ceilometer observations, radio-soundings for boundary layer structure, microwave radiometer observations of cloud liquid water and column integrated water vapor, etc.

Data have been processed, and a publication has been submitted: McBride et al. (2012), A CalNex climatology of cloud optical properties retrieved from a ship-based spectrometer and comparisons with satellite and aircraft retrieved cloud properties, *J. Geophys. Res.*, submitted.

Milestone 3. Deploy systems on the Gulf of Mexico oil platform for the Minerals Management Service observational program. Data include fluxes of sensible heat, latent heat, momentum, and sea surface temperature.

Preliminary data analysis comparing the Coupled Ocean-Atmosphere Response Experiment flux (COARE) algorithm to the eddy-correlation flux measurements has been done for year 2011 and 2012. The unique data set generated will be used for further study and publications. Instruments on the oil platform are to be removed in 2012.

Milestone 4. Develop, operate, and maintain a wind profiler trajectory tool for the CalNex field campaign. The tool is used by scientists to document transport pathways for air pollution and to help plan aircraft missions. Starting this year, the trajectory tool will be maintained by the PSD Water Cycle Branch, the same group responsible for operating and maintaining the wind profilers.

The trajectory tool was updated during 2011 as per request of the Federal Energy Regulatory Commission (FERC).

CSD-08 Regional Air Quality

FEDERAL LEADS: DAVID PARRISH, JIM BURKHOLDER, AND MICHAEL HARDESTY
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

Project Goal: Conduct 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 enhances air-quality prediction and forecasting.

Milestone 1. Measure the reactivity and optical properties of compounds that are replacements for ozone-depleting substances, and evaluate their global warming potentials. Impact: The determination of the atmospheric loss processes and atmospheric lifetimes of replacement compounds is critical decision-support information. This research has implications for regional air quality, stratospheric ozone, and climate change.

During the past year, the work on the atmospheric chemistry of (Z) $CF_3CH{=}CHCF_3$ (cis-1,1,1,4,4,4-hexafluoro-2-butene) was published. This compound is a hydrofluoro-olefin that is being considered as a replacement for ozone-depleting substances. Prior to its use in commercial applications and possible release into the atmosphere, its atmospheric chemistry and potential impact on the environment need to be understood. In this research, the rate coefficient for its reaction with the hydroxyl radical (OH) was measured as a function of temperature (212–374 Kelvin) and pressure (20–200 Torr) using a pulsed laser photolysis–laser induced fluorescence (PLP–LIF) technique. We also measured the infrared absorption cross sections and used them to determine the global warming potential (GWP) of this compound. From our work, the atmospheric lifetime of (Z)-$CF_3CH{=}CHCF_3$ due to loss by OH reaction was estimated to be approximately 20 days. Infrared absorption spectra of (Z)-$CF_3CH{=}CHCF_3$ measured in this work were used to determine a GWP of approximately 9 for the 100-year time horizon.

Milestone 2. In the CalNex 2010 field campaign, use surface and airplane-, ship-, and satellite-borne sensors to survey a wide

Cora Young

The NOAA Research Vessel Atlantis at the dock in California during the 2010 CalNex field mission

variety of sources of directly emitted gas and aerosol species that impact atmospheric air quality via ozone and secondary organic aerosol formation. Impact: This CIRES research will investigate the distribution and source strengths of precursors to pollution, leading to an improved understanding of anthropogenic, agricultural, biogenic, and geologic sources of pollutant species. The study will also investigate the daytime and nighttime chemical transformations and pollutant transport in the atmosphere. These data and analyses will provide the State of California with the scientific foundation for their efforts to develop plans to bring several areas of the state into compliance with federally mandated National Ambient Air Quality Standards for ozone and particulate matter.

The principal focus of CIRES scientists involved in the CalNex 2010 study over this period was continued data analysis and write-up of findings. The references shown below have been published or are submitted or in preparation. All areas related to air quality in the Southern California region are being addressed. Emissions of priority pollutants, volatile organic compounds (VOCs), and particulate material (PM) are being characterized from measurements onboard the mobile platforms (WP-3D aircraft; Research Vessel Atlantis) and at the Pasadena, Calif., ground site (de Gouw et al., Nowak et al., and Pollack et al.).

The importance of different radical sources to photochemistry and nighttime chemistry in this region is also under investigation (Riedel et al., Veres et al., Wagner et al., Washenfelder et al., and Young et al.). Of equal importance is the characterization of pollutant transport and the dynamics of the planetary boundary layer (PBL), especially in the complex terrain of the South Coast Air Quality Basin (Cooper et al., Langford et al., and Neuman et al.). The CalNex 2010 data and analyses are further being used to evaluate the performance of chemistry-transport computer models (Lin et al.). These results will be further summarized in a scientific synthesis document that will provide information for the California Air Resources Board (CARB) to use in its efforts to reduce air-quality degradation across the state.

Milestone 3. Co-deploy airborne ozone and Doppler wind lidars during the 2010 CalNex air quality study to investigate transport processes of air pollutants. Impact: The combination of airborne ozone and Doppler lidars will allow us to measure simultaneously ozone concentration and wind speed and direction at high resolution and, thus, enable us to characterize and quantify transport processes of air pollutants in California on local and regional scales. The information will be scientific input for air-quality decision makers in California.

The measurement portion of this milestone as well as some preliminary data analysis was completed last year. During the CalNex 2010 experiment, we co-deployed NOAA's airborne Tunable Optical Profiler for Aerosol and Ozone (TOPAZ) lidar and the University of Leeds scanning Doppler wind lidar on a Twin Otter aircraft. We flew 46 missions over the State of California, totaling approximately 200 flight hours, with a focus on the Los Angeles Basin and Sacramento areas. The downward-looking lidars provided highly resolved measurements of ozone concentration, aerosol backscatter, and wind speed and direction in the boundary layer and lower free troposphere. We have used this unique data set to characterize transport of pollutants in California on local and regional scales.

This year we continued the analysis of the CalNex data with a focus on studying the effect of transport and mixing processes on ozone distribution in the Los Angeles Basin area. Using the collocated ozone and wind lidar data, we identified export pathways of high ozone concentrations from the Los Angeles Basin to the surrounding areas, and we estimated the amount of ozone exiting the eastern Basin through Banning Pass by computing the horizontal ozone flux. The results from this work were presented at the 26th International Laser Radar Conference.

In addition, we used the CalNex lidar data (in conjunction with other data sets) to investigate the potential impact of deep stratospheric intrusions on ground-level ozone in southern California. We found that on several occasions in spring 2010, high levels of ozone associated with stratospheric intrusions were mixed down to the surface in the Los Angeles Basin area. This caused an increase in background ozone levels and, when combined with locally produced ozone, led to exceedences of the National Ambient Air Quality Standard. These findings were published in the *Journal of Geophysical Research*.

RP-04 Intercontinental Transport and Chemical Transformation

■ CSD-05 Tropospheric and Stratospheric Transport and Chemical Transformation

CSD-05 Tropospheric and Stratospheric Transport and Chemical Transformation

FEDERAL LEADS: THOMAS B. RYERSON AND STEVEN BROWN
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 3: Weather and Water

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

Milestone 1. Analyze the long-range transport of aerosols in the Arctic by using data from aircraft flights and other sources to provide chemical characterization of the aerosols. Impact: Aerosol particles, especially black carbon, have large climate effects in the Arctic. This CIRES research will analyze aerosols in the Arctic free troposphere, polluted Arctic regions, biomass burning plumes in the Arctic, and the air just above the pack ice, all of which are potentially subject to long-range transport.

Analysis and presentation of Arctic chemical transformation studies from the 2008 ARCPAC (Aerosol, Radiation, and Cloud Processes affecting Arctic Climate) campaign were completed in early 2011 with a number of previously reported publications.

Analysis of optical property measurements of biomass burning aerosol sampled during the Four-Mile Fire near Boulder, Colo., has been completed, and a paper has been accepted for publication in the *Proceedings of the National Academy of Sciences*. The analysis was able to deconstruct the contribution of absorption by black carbon, brown carbon, and internal mixing, which was the first to achieve such detailed attribution of the particle optical properties. This data set advances our understanding of the climate impacts of biomass burning emissions.

CSD-05, Milestone 1

RP-05 Aerosol Chemistry and Climate Implications

■ CSD-09 Aerosol Formation, Chemical Composition, and Radiative Properties

CSD-09 Aerosol Formation, Chemical Composition, and Radiative Properties

FEDERAL LEADS: RU-SHAN GAO, DAVID FAHEY, DAN MURPHY, AND GRAHAM FEINGOLD
CIRES LEAD: CHRISTINE ENNIS

NOAA Goal 2: Climate

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

Milestone 1. Use data from the HIAPER (High-Altitude Instrumented Airborne Platform for Environmental Research) Pole-to-Pole Observations (HIPPO) mission deployments to examine the mixing state and optical size of individual black-carbon particles as well as black carbon mass loadings in remote regions. Impact: Black carbon is an important component of anthropogenic climate forcing in the Arctic region. These measurements will provide a basis to evaluate the treatment of black carbon in global aerosol models and to characterize the contribution of black carbon to global radiative forcing.

Complete analysis of the entire five-campaign flight series of HIPPO has been completed and presented at the HIPPO Science Meeting in 2011. The data from the mission have been distributed to collaborators to allow for model/measurement comparisons and analysis in support of modeling goals. For example, the typical length scales of black carbon (BC) plumes crossing the Pacific have been determined (Weigum et al, 2012). Fan et al. (2012) have used the HIPPO data to tune modeled BC IN activity and the impact of the Bergeron process on BC lifetime. We have worked with Mann et al. (2012) to help evaluate the impacts of different model schemes on modal accuracy.

The manuscript presenting these analyses and results found last year has been delayed in order to allow inclusion of the final two data missions.

Milestone 2. Examine organosulfate molecules in atmospheric aerosols. Impact: Organosulfate molecules can be formed when reaction products of isoprene and other biogenic organic products encounter acidic sulfate particles. Laboratory calibrations and a review of more than 10 years of field data will allow an assessment of the importance of these compounds in many atmospheric situations, including the Amazon boundary layer and the free troposphere over the United States.

The initial phase of this milestone was completed in 2011. The isoprene-derived organosulfate IEPOX sulfate ester was identified and quantified in free tropospheric aerosol. Results were published in the *Proceedings of the National Academy of Science* and presented at American Association for Aerosol Research and American Geophysical Union (AGU) meetings. A second phase of this milestone was initiated in 2012.

During May and June, PALMS (Particle Analysis by Laser Mass Spectrometry) aerosol composition measurements were obtained

CSD-09, Milestone 2

The Past Reveals the Future

Climate variability and change may impact more than just the water supply—it may also impact water quality. CIRES Fellow Balaji Rajagopalan, in collaboration with former student and current NCAR research scientist Erin Towler, is working to forecast water quality, in part, by looking at the distant past. By studying how extreme events, such as drought and flooding, thousands of years ago influenced water quality, researchers can get a glimpse of future scenarios.

How can climate variability affect water quality?

Climate variability affects water quality in two ways: streamflow variability and temperature variability. Reduced streamflow, for example, can lead to higher salinity concentrations that can increase the treatment cost to water utilities and reduce the lifespan of water-using appliances for customers. On the other hand, peak streamflows from high-intensity precipitation events can bring increased sediment loads, or turbidity, which can cause water-quality violations and require changes in plant operations. Temperature variability impacts stream temperature, which is related to the amount of dissolved oxygen available in the stream. As such, it has a direct bearing on aquatic health and is related to events such as algal blooms, which affect treatment decisions.

How could this impact people in the future?

Climate change may exacerbate water-quality issues in areas where climate variability is already stressing the system. As such, to ensure efficient management, it's important to consider current and future climate risk to not just water quantity, but water quality as well. As supplies become more limited and water-quality regulations are heightened, the extension of forecasting efforts to water quality is critical.

Are people more receptive to information on past extreme events than forecasts of future ones?

Especially in the context of paleo-reconstructed streamflow, it is easier to make a case for better preparedness using past variability than with the same information under climate change. In this regard, policy makers are more receptive.

What's one of the most surprising findings you've made?

How modest changes in the probabilities of extreme climate and water-quality events have a disproportionately larger impact on the water-supply system, both for the utilities and the public.

aboard the NASA DC8 as part of the DC3 campaign. During this campaign the aircraft was outfitted with important complementary chemical instrumentation that was not available previously. This suite of measurements allows for a more detailed analysis of sources and chemistry for organosulfates detected by PALMS other than IEPOX sulfate ester. Flights over the southeastern U.S. in particular, where summertime biogenic emissions are high, provide excellent cases for organosulfate formation in contrast to western U.S. flights. PALMS aerosol composition measurements from the DC3 campaign will also be used to investigate aerosol processing, transport, and secondary production by convective storms. Data analysis and organization of initial scientific results will be performed during the proceeding year.

The MACPEX (Mid-latitude Airborne Cirrus Properties Experiment) 2011 aircraft measurement campaign investigated mid-latitude aerosol properties and cirrus formation over the central U.S. *in situ* measurements of aerosol composition by the PALMS instrument were complemented by filter collection and offline compositional analysis by electron microscopy. Ice nuclei and background aerosol were analyzed for general composition, emissions source, chemical aging, and cloud processing. The data showed that certain terrestrial aerosol, such as mineral dust and industrial metallic particles, preferentially nucleated ice to form upper tropospheric cirrus clouds, whereas elemental carbon, biomass burning, and biological particles did not. The work demonstrates a relationship between terrestrial aerosol sources and cirrus cloud properties. Initial results were presented at the 2011 AGU conference.

Milestone 3. Use data from the 2010 CalNex air-quality study to investigate secondary organic aerosol (SOA) formation in the urban Los Angeles area. Impact: This CIRES research will enable us to quantify the anthropogenic source of SOA to the atmosphere, which is currently not well understood. By combining the results from multiple measurements, we will investigate how the budget of organic carbon in the gas and aerosol phases changes as a function of the degree of photochemical processing. The results will be used to estimate the global source of SOA derived from anthropogenic volatile organic compounds and other urban precursors.

The effects of different emissions between weekdays and weekends, when diesel traffic is significantly reduced, on the formation of SOA formation was investigated using data obtained during CalNex. In contrast to expectations, SOA was found to be higher on weekends as opposed to be lower because of the reduction in diesel emissions. The more efficient formation of SOA was attributed to the reduced emissions of NOx and is analogous to the more efficient and well-documented formation of ozone on weekends. It was found that in air masses that were similarly aged on weekends and weekdays, the SOA formation was equally efficient. From these findings, it could be concluded that emissions of hydrocarbons associated with gasoline use are responsible for the dominant fraction of SOA formation.

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Measures of Achievement

CIRES scientists and faculty published 572 peer-reviewed papers in 2011, commanding attention from the scientific community and the news media. International awards and a strong record of service reflect institutional excellence.

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Publications by the Numbers

CIRES scientists and faculty published 572 peer-reviewed papers during calendar year 2011. The table below tabulates publications by affiliation of first author. CIRES scientists and faculty published an additional 162 non-refereed publications in 2011. These publication counts are only one measure of CIRES's impact. Additional information on how CIRES research is pushing the boundaries of scientific knowledge is summarized in the Executive Summary and detailed throughout this report.

Refereed Publications

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CIRES Lead Author	112	177	165	188	141	130	110	158	137	238
NOAA Lead Author	60	31	56	20	81	73	99	79	63	41
Other Lead Author	110	183	134	145	289	264	385	342	312	293
Total	**282**	**391**	**355**	**353**	**511**	**467**	**594**	**579**	**512**	**572**

Publications

Journal Articles

Ahmed, M, M Sultan, J Wahr, E Yan, A Milewski, W Sauck, R Becker, and B Welton' (2011), Integration of GRACE (Gravity Recovery and Climate Experiment) data with traditional data sets for a better understanding of the time-dependent water partitioning in African watersheds, *Geology*, 39(5), 10.1130/G31812.1.

Alken, P, S Maus, AD Richmond, and A Maute (2011), The ionospheric gravity and diamagnetic current systems, *J. Geophys. Res.-Space*, 116, 10.1029/2011JA017126.

Alvarez, RJ, CJ Senff, AO Langford, AM Weickmann, DC Law, JL Machol, DA Merritt, RD Marchbanks, SP Sandberg, WA Brewer, RM Hardesty, and RM Banta (2011), Development and application of a compact, tunable, solid-state airborne ozone LiDAR system for boundary layer profiling, *J. Atmos. Ocean. Tech.*, 28(10), 1258-1272,10.1175/JTECH-D-10-05044.1.

Anderson, DM, BA Bauer, CR Buckner, E Gille, WS Gross, M Hartman, C Morrill, AM Shah, and ER Wahl (2011), Web 2.0 collaborations address uncertainty in climate reconstructions of the past millennium, *Earth Sci.*, 4(4), 161-167,10.1007/s12145-011-0086-3.

Andrew, E, JA Ogren, P Bonasoni, A Marinoni, E Cuevas, S Rodriguez, JY Sun, DA Jaffe, EV Fischer, U Baltensperger, E Weingartner, MC Coen, S Sharma, AM Macdonald, WR Leaitch, NH Lin, P Laj, T Arsov, I Kalapov, A Jefferson, and P Sheridan (2011), Climatology of aerosol radiative properties in the free troposphere, *Atmos. Res.*, 102(4), 365-393, 10.1016/j.atmosres.2011.08.017.

Andrews, E, PJ Sheridan, and JA Ogren (2011), Seasonal differences in the vertical profiles of aerosol optical properties over rural Oklahoma, *Atmos. Chem. Phys.*, 11(20), 10661-10676,10.5194/acp-11-10661-2011.

Aquila, V, J Hendricks, A Lauer, N Riemer, H Vogel, D Baumgardner, A Minikin, A Petzold, JP Schwarz, JR Spackman, B Weinzierl, M Righi, and M Dall'Amico (2011), MADE-in: A new aerosol microphysics submodel for global simulation of insoluble particles and their mixing state, *Geosci. Model Dev.*, 4(2), 325-355,10.5194/gmd-4-325-2011.

Araujo-Pradere, EA, DN Anderson, M Fedrizzi, and R Stoneback (2011), Communications/navigation outage forecasting system observational support for the equatorial E x B drift velocities associated with the four-cell tidal structures, *Radio Sci.*, 46, 10.1029/2010RS004557.

Araujo-Pradere, EA, R Redmon, M Fedrizzi, R Viereck, and TJ Fuller-Rowell (2011), Some characteristics of the ionospheric behavior during the solar cycle 23-24 minimum, *Sol. Phys.*, 274(2-Jan), 439-456,10.1007/s11207-011-9728-3.

Asa-Awuku, A, RH Moore, A Nenes, R Bahreini, JS Holloway, CA Brock, AM Middlebrook, TB Ryerson, JL Jimenez, PF DeCarlo, A Hecobian, RJ Weber, R Stickel, DJ Tanner, and LG Huey (2011), Airborne cloud condensation nuclei measurements during the 2006 Texas Air Quality Study, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014874.

Attal, M, PA Cowie, AC Whittaker, D Hobley, GE Tucker, and GP Roberts (2011), Testing fluvial erosion models using the transient response of bedrock rivers to tectonic forcing in the Apennines, Italy, *J. Geophys. Res.-Earth Surf.*, 116, 10.1029/2010JF001875.

Ault, AP, CR Williams, AB White, PJ Neiman, JM Creamean, CJ Gaston, FM Ralph, and KA Prather (2011), Detection of Asian dust in California orographic precipitation, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015351.

Axson, JL, RA Washenfelder, TF Kahan, CJ Young, V Vaida, and SS Brown (2011), Absolute ozone absorption cross section in the Huggins Chappuis minimum (350-470 nm) at 296 K, *Atmos. Chem. Phys.*, 11(22), 11581-11590,10.5194/acp-11-11581-2011.

Baasandorj, M, AR Ravishankara, and JB Burkholder (2011), Atmospheric chemistry of (Z)-CF3CH=CHCF3: OH radical reaction rate coefficient and global warming potential, *J. Phys. Chem. A*, 115(38), 10539-10549,10.1021/jp206195g.

Baasandorj, M, KJ Feierabend, and JB Burkholder (2011), Rate coefficients and ClO radical yields in the reaction of O(D-1) with CClF2CCl2F, CCl3CF3, CClF2CClF2, and CCl2FCF3, *Int. J. Chem. Kinet.*, 43(8), 393-401,10.1002/kin.20561.

Bailey, A, TN Chase, JJ Cassano, and D Noone (2011), Changing temperature inversion characteristics in the US southwest and relationships to large-scale atmospheric circulation, *J. Appl. Meteorol. Clim.*, 50(6), 1307-1323,10.1175/2011JAMC2584.1.

Baker, DN, D Odstrcil, BJ Anderson, CN Arge, M Benna, G Gloeckler, H Korth, LR Mayer, JM Raines, D Schriver, JA Slavin, SC Solomon, PM Travnicek, and TH Zurbuchen (2011), The space environment of Mercury at the times of the second and third MESSENGER flybys, *Planet Space Sci.*, 59(15), 2066-2074,10.1016/j.pss.2011.01.018.

Ballagh, LM, BH Raup, RE Duerr, SJS Khalsa, C Helm, D Fowler, and A Gupte (2011), Representing scientific data sets in KML: Methods and challenges, *Computat. Geosci.*, 37(1), 57-64,10.1016/j.cageo.2010.05.004.

Ballantyne, AP, JB Miller, IT Baker, PP Tans, and JWC White (2011), Novel applications of carbon isotopes in atmospheric CO2: what can atmospheric measurements teach us about processes in the biosphere?, *Biogeosciences*, 8(10), 3093-3106,10.5194/bg-8-3093-2011.

Balsley, B, D Lawrence, R Woodman, D Fritts (2011), Fine-scale characteristics of temperature, wind, and turbulence in the lower atmosphere (0-1300 m) over the south Peruvian coast, *Bound.-Lay. Meteorol.*

Bamberger, I, L Hvrtnagl, TM Ruuskanen, R Schnitzhofer, M M|ller, M Graus, T Karl, G Wohlfahrt, and A Hansel (2011), Deposition fluxes of terpenes over grassland, *J. Geophys. Res. - Atmos.*, 116, 10.1029/2010jd015457.

Banta, RM, CJ Senff, RJ Alvarez, AO Langford, DD Parrish, MK Trainer, LS Darby, RM Hardesty, B Lambeth, JA Neuman, WM Angevine, J Nielsen-Gammon, SP Sandberg, and AB White (2011), Dependence of daily peak O-3 concentrations near Houston, Texas on environmental factors: Wind speed, temperature, and boundary-layer depth, *Atmos. Environ.*, 45(1), 162-173,10.1016/j.atmosenv.2010.09.030.

Bao, JW, CW Fairall, SA Michelson, and L Bianco (2011), Parameterizations of sea-spray impact on the air-sea momentum and heat fluxes, *Mon. Weather Rev.*, 139(12), 3781-3797,10.1175/MWR-D-11-00007.1.

Bao, J-W, SG Gopalakrishnan, SA Michelson, FD Marks, and MT Montgomery (2011), Impact of horizontal and vertical diffusion on idealized intensification in the HWRF model, *Mon. Weather Rev.*, .

Barsugli, JJ, JM Vogel, L Kaatz, JB Smith, M Waage, and C Anderson (2011), Two faces of uncertainty: Climate science and water utility planning methods, J. *Water Resour. Plann.-Manage.*, .

Basu, S, S Houweling, W Peters, C Sweeney, T Machida, S Maksyutov, PK Patra, R Saito, F Chevallier, Y Niwa, H Matsueda, and Y Sawa (2011), The seasonal cycle amplitude of total column CO2: Factors behind the model-observation mismatch, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016124.

Bates, ST, D Berg-Lyons, JG Caporaso, WA Walters, R Knight, and N Fierer (2011), Examining the global distribution of dominant archaeal populations in soil, *ISME J.*, 5(5), 908-917,10.1038/ismej.2010.171.

Bates, ST, GWG Cropsey, JG Caporaso, R Knight, and N Fierer (2011), Bacterial communities associated with the lichen symbiosis, *Appl. Environ. Microbiol.*, 77(4), 1309-1314,10.1128/AEM.02257-10.

Befus, KM, AF Sheehan, M Leopold, SP Anderson, and RS Anderson (2011), Seismic constraints on critical zone architecture, Boulder Creek Watershed, Front Range, Colorado, *Vadose Zone J.*, 10(3), 915-927,10.2136/vzj2010.0108.

Bergmann, GT, ST Bates, KG Eilers, CL Lauber, JG Caporaso, WA Walters, R Knight, and N Fierer (2011), The under-recognized dominance of Verrucomicrobia in soil bacterial communities, *Soil Biol. Biochem.*, 43(7), 1450-1455,10.1016/j.soilbio.2011.03.012.

Berkelhammer, M, D Noone, A Bailey, C Still, M Hu, Gochis, Barnard, and Rahn (2011), The nocturnal water cycle of an open canopy forest, *Geophys. Res. Lett.*, .

Berkowitz, CM, LK Berg, XY Yu, ML Alexander, A Laskin, RA Zaveri, BT Jobson, E Andrews, and JA Ogren (2011), The influence of fog and airmass history on aerosol optical, physical and chemical properties at Pt. Reyes National Seashore, *Atmos. Environ.*, 45(15), 2559-2568,10.1016/j.atmosenv.2011.02.016.

Bertram, TH, JR Kimmel, TA Crisp, OS Ryder, RLN Yatavelli, JA Thornton, MJ Cubison, M Gonin, and DR Worsnop (2011), A field-deployable, chemical ionization time-of-flight mass spectrometer, *Atmos. Meas. Tech.*, 4(7), 1471-1479,10.5194/amt-4-1471-2011.

Bianco, L, IV Djalalova, CW King, and JM Wilczak (2011), Diurnal evolution and annual vari-

ability of boundary-layer height and its correlation to other meteorological variables in California's Central Valley, *Bound.-Lay. Meteorol.*, 140(3), 491-511,10.1007/s10546-011-9622-4.

Bianco, L, JW Bao, CW Fairall, and SA Michelson (2011), Impact of sea-spray on the atmospheric surface layer, *Bound.-Lay. Meteorol.*, 140(3), 361-381,10.1007/s10546-011-9617-1.

Bilitza, D, LA McKinnell, B Reinisch, and T Fuller-Rowell (2011), The international reference ionosphere today and in the future, *J. Geodesy*, 85(12), 909-920,10.1007/s00190-010-0427-x.

Bindoff, N, P Stott, KM AchutaRao, M Allen, N Gillett, D Gutzler, K Hansingo, G Hegerl, Y Hu, S Jain, I Mokhov, J Overland, J Perlwitz, R Sebbari, and X Zhang (2011), ZOD and FOD, chapter 10: Detection and attribution of climate change: From global to regional, *IPCC AR5 WG1*, .

Bindschadler, R, H Choi, A Wichlacz, R Bingham, J Bohlander, K Brunt, H Corr, R Drews, H Fricker, M Hall, R Hindmarsh, J Kohler, L Padman, W Rack, G Rotschky, S Urbini, P Vornberger, and N Young (2011), Getting around Antarctica: New high-resolution mappings of the grounded and freely-floating boundaries of the Antarctic ice sheet created for the International Polar Year, *Cryosphere*, 5(3), 569-588,10.5194/tc-5-569-2011.

Bladi, I, B Liebmann, D Fortuny, and GJ van Oldenborgh (2011), Observed and simulated impacts of the summer NAO in Europe: Implications for projected drying in the Medeterranean region, *Clim. Dynam.*, , 10.1007/s00382-011-1195-x.

Blonquist, JM, SA Montzka, JW Munger, D Yakir, AR Desai, D Dragoni, TJ Griffis, RK Monson, RL Scott, and DR Bowling (2011), The potential of carbonyl sulfide as a proxy for gross primary production at flux tower sites, *J. Geophys. Res.-Biogeosci.*, 116, 10.1029/2011JG001723.

Bocquet, F, B Balsley, M Tjernstrom, and G Svensson (2011), Comparing Estimates of Turbulence Based on Near-Surface Measurements in the Nocturnal Stable Boundary Layer, *Bound.-Lay. Meteorol.*, 138(1), 43-60,10.1007/s10546-010-9542-8.

Bodas-Salcedo, A, MJ Webb, S Bony, H Chepfer, JL Dufresne, SA Klein, Y Zhang, R Marchand, JM Haynes, R Pincus, and VO John (2011), COSP satellite simulation software for model assessment, *Bull. Amer. Meteorol. Soc.*, 92(8), 1023-1043,10.1175/2011BAMS2856.1.

Bon, DM, IM Ulbrich, JA de Gouw, C Warneke, WC Kuster, ML Alexander, A Baker, AJ Beyersdorf, D Blake, R Fall, JL Jimenez, SC Herndon, LG Huey, WB Knighton, J Ortega, S Springston, and O Vargas (2011), Measurements of volatile organic compounds at a suburban ground site (T1) in Mexico City during the MILAGRO 2006 campaign: measurement comparison, emission ratios, and source attribution, *Atmos. Chem. Phys.*, 11(6), 2399-2421,10.5194/acp-11-2399-2011.

Bond, TC, SJ Doherty, DW Fahey, PM Forster, TK Berntsen, O Boucher, BJ DeAngelo, MG Flanner, SJ Ghan, B Kdrcher, D Koch, S Kinn2e, Y Kondo, U Lohmann, PK Quinn, MC Sarofim, M Schultz, M Schulz, C Venkataraman, H Zhang, S Zhang, N Bellouin, S Guttikunda, P (2011), Bounding the role of black carbon in the climate system: A scientific assessment, *Journal of Geophysical Research*.

Bonisch, H, A Engel, T Birner, P Hoor, DW Tarasick, and EA Ray (2011), On the structural changes in the Brewer-Dobson circulation after 2000, *Atmos. Chem. Phys.*, 11(8), 3937-3948,10.5194/acp-11-3937-2011.

Bowers, RM, AP Sullivan, EK Costello, JL Collett, R Knight, and N Fierer (2011), Sources of bacteria in outdoor air across cities in the midwestern United States, *Appl. Environ. Microbiol.*, 77(18), 6350-6356,10.1128/AEM.05498-11.

Bowers, RM, S McLetchie, R Knight, and N Fierer (2011), Spatial variability in airborne bacterial communities across land-use types and their relationship to the bacterial communities of potential source environments, *ISME J.*, 5(4), 601-612,10.1038/ismej.2010.167.

Brioude, J, SW Kim, WM Angevine, GJ Frost, SH Lee, SA McKeen, M Trainer, FC Fehsenfeld, JS Holloway, TB Ryerson, EJ Williams, G Petron, and JD Fast (2011), Top-down estimate of anthropogenic emission inventories and their interannual variability in Houston using a mesoscale inverse modeling technique, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016215.

Britter, R, J Weil, J Leung, and S Hanna (2011), Toxic industrial chemical (TIC) source emissions improvements for pressurized liquefied gases, *Atmos. Environ.*, 45, 1-25.

Brock, CA, DM Murphy, R Bahreini, and AM Middlebrook (2011), Formation and growth of organic aerosols downwind of the Deepwater Horizon oil spill, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048541.

Brock, CA, J Cozic, R Bahreini, KD Froyd, AM Middlebrook, A McComiskey, J Brioude, OR Cooper, A Stohl, KC Aikin, JA de Gouw, DW Fahey, RA Ferrare, RS Gao, W Gore, JS Holloway, G Hubler, A Jefferson, DA Lack, S Lance, RH Moore, DM Murphy, A Nenes, PC Novel (2011), Characteristics, sources, and transport of aerosols measured in spring 2008 during the aerosol, radiation, and cloud processes affecting Arctic Climate (ARCPAC) Project, *Atmos. Chem. Phys.*, 11(6), 2423-2453,10.5194/acp-11-2423-2011.

Brodin, M, D Helmig, B Johnson, and S Oltmans (2011), Comparison of ozone concentrations on a surface elevation gradient with balloon-borne ozonesonde measurements, *Atmos. Environ.*, 45(31), 5431-5439,10.1016/j.atmosenv.2011.07.002.

Bronnimann, S, AN Grant, GP Compo, T Ewen, T Griesser, AM Fischer, M Schraner, and A Stickler (2011), A multi-data set comparison of the vertical structure of temperature variability and change over the Arctic during the past 100 years, *Clim. Dynam.*, , 10.1007/s00382-012-1291-6.

Bronnimann, S, GP Compo, R Spadin, R Allan, and W Adam (2011), Early ship-based upper-air data and comparison with the Twentieth Century Reanalysis, *Clim. Past.*, 7(1), 265-276,10.5194/cp-7-265-2011.

Brooks, IM, G Canut, C Birch, T Mauritsen, O Persson, J Sedlar, M Shupe, and M Tjernstrvm (2011), The vertical turbulent structure of the Arctic summer boundary layer during ASCOS, *Atmos. Chem. Phys*.

Brown, SS, WP Dube, J Peischl, TB Ryerson, E Atlas, C Warneke, JA de Gouw, ST Hekkert, CA Brock, F Flocke, M Trainer, DD Parrish, FC Feshenfeld, and AR Ravishankara (2011), Budgets for nocturnal VOC oxidation by nitrate radicals aloft during the 2006 Texas Air Quality Study, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016544.

Browne, EC, AE Perring, PJ Wooldridge, E Apel, SR Hall, LG Huey, J Mao, KM Spencer, JM St Clair, AJ Weinheimer, A Wisthaler, and RC Cohen (2011), Global and regional effects of the photochemistry of CH3O2NO2: evidence from ARCTAS, *Atmos. Chem. Phys.*, 11(9), 4209-4219.

Buenning, NH, DC Noone, WJ Riley, CJ Still, and JWC White (2011), Influences of the hydrological cycle on observed interannual variations in atmospheric (COO)-O-18, *J. Geophys. Res.-Biogeosci.*, 116, 10.1029/2010JG001576.

Buhr, SM, SE Lynds, and TS Ledley (2011), Navigating climate science in the classroom: Teacher preparation, perceptions and practices, *JGE*.

Buma, B and CA Wessman (2011), Disturbance interactions can impact resilience mechanisms of forests, *Ecosphere*, 2(5), 10.1890/ES11-00038.1.

Bustamante, MC, S Andelman, M Lahsen, T Schor, R Swap, JP Ometto, and H Tiessen (2011), Regional knowledge networks on environmental changes in Latin America and Africa, *Ecol. Soc.*

Butchart, N, AJ Charlton-Perez, I Cionni, SC Hardiman, PH Haynes, K Kruger, PJ Kushner, PA Newman, SM Osprey, J Perlwitz, M Sigmond, L Wang, H Akiyoshi, J Austin, S Bekki, A Baumgaertner, P Braesicke, C Bruhl, M Chipperfield, M Dameris, S Dhomse, V Eyring (2011), Multimodel climate and variability of the stratosphere, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014995.

Caldwell, RJ, L Taylor, B Eakins, K Carignan, and S Collins (2011), Digital elevation model of southeast Alaska: Procedures, data sources, and analysis, *NOAA Technical Memorandum*, .

Callaghan, TV, M Johansson, RD Brown, PY Groisman, N Labba, V Radionov, RS Bradley, S Blangy, ON Bulygina, TR Christensen, JE Colman, RLH Essery, BC Forbes, MC Forchhammer, VN Golubev, RE Honrath, GP Juday, AV Meshcherskaya, GK Phoenix, J Pomeroy, A Rauti (2011), Multiple effects of changes in arctic snow cover, *Ambio*, 40, 32-45,10.1007/s13280-011-0213-x.

Caporaso, JG, CL Lauber, EK Costello, D Berg-Lyons, A Gonzalez, J Stombaugh, D Knights, P Gajer, J Ravel, N Fierer, JI Gordon, and R Knight (2011), Moving pictures of the human microbiome, *Genome Biol.*, 12(5), 10.1186/gb-2011-12-5-r50.

Caporaso, JG, CL Lauber, WA Walters, D Berg-Lyons, CA Lozupone, PJ Turnbaugh, N Fierer, and R Knight (2011), Global patterns of 16S rRNA diversity at a depth of millions of sequences per sample, *Proc. Natl. Acad. Sci. U. S. A.*, 108, 4516-4522,10.1073/pnas.1000080107.

Carn, SA, KD Froyd, BE Anderson, P Wennberg, J Crounse, K Spencer, JE Dibb, NA Krotkov, EV Browell, JW Hair, G Diskin, G Sachse, and SA Vay (2011), In situ measurements of tropospheric volcanic plumes in Ecuador and Colombia during TC4, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014718.

Carvalho, LMV, AE Silva, C Jones, B Liebmann, PLS Dias, and HR Rocha (2011), Moisture transport and intraseasonal variability in the South America monsoon system, *Clim.*

Dyn., 36(10-Sep), 1865-1880,10.1007/s00382-010-0806-2.

Carvalho, LMV, C Jones, AE Silva, B Liebmann, and PLS Dias (2011), The South American Monsoon System and the 1970s climate transition, *Int. J. Climatol.*, 31(8), 1248-1256,10.1002/joc.2147.

Cassano, EN, JJ Cassano, and M Nolan (2011), Synoptic weather pattern controls on temperature in Alaska, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015341.

Cassano, EN, JJ Cassano, ME Higgins, and M Serreze (2011), Atmospheric impacts of an Arctic sea ice minimum as seen in the *Community Atmospheric Model, Int. J. Climatol.*

Cassano, JJ, ME Higgins, and MW Seefeldt (2011), Performance of the weather research and forecasting model for month-long pan-Arctic simulations, *Mon. Weather Rev.*, 139(11), 3469-3488,10.1175/MWR-D-10-05065.1.

Cerully, KM, T Raatikainen, S Lance, D Tkacik, P Tiitta, T Petaja, M Ehn, M Kulmala, DR Worsnop, A Laaksonen, JN Smith, and A Nenes (2011), Aerosol hygroscopicity and CCN activation kinetics in a boreal forest environment during the 2007 EUCAARI campaign, *Atmos. Chem. Phys.*, 11(23), 12369-12386,10.5194/acp-11-12369-2011.

Chang, RYW, C Leck, M Graus, M M||ller, J Paatero, JF Burkhart, A Stohl, LH Orr, K Hayden, SM Li, A Hansel, M Tjernstrvm, WR Leaitch, and JPD Abbatt (2011), Aerosol composition and sources in the central Arctic Ocean during ASCOS, *Atmos. Chem. Phys*, 11, 10619-10636,10.5194/acp-11-10619-2011.

Chaturvedi M, T Ghosh, and L Bhandari (2011), Assessing income distribution at the district level for India using nighttime satellite imagery, *Proceedings of the 32nd Asia-Pacific Advanced Network Meeting*, , 196-223.

Cherney, DN (2011), Securing the free movement of wildlife: Lessons from the American West's longest land mammal migration, *Environ. Law*, 41(2), 599-617.

Chu, XZ, WT Huang, WC Fong, ZB Yu, ZJ Wang, JA Smith, and CS Gardner (2011), First LiDAR observations of polar mesospheric clouds and Fe temperatures at McMurdo (77.8 degrees S, 166.7 degrees E), Antarctica, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048373.

Chu, XZ, ZB Yu, CS Gardner, C Chen, and WC Fong (2011), LiDAR observations of neutral Fe layers and fast gravity waves in the thermosphere (110-155 km) at McMurdo (77.8 degrees S, 166.7 degrees E), Antarctica, *Geophys. Res. Lett.*, 38, 10.1029/2011GL050016.

Chumachenko, N, Y Novikov, RK Shoemaker, and SD Copley (2011), A dimethyl ketal-protected benzoin-based linker suitable for photolytic release of unprotected peptides, *J. Org. Chem.*, 76(22), 9409-9416,10.1021/jo2017263.

Church, JA, NJ White, LF Konikow, CM Domingues, JG Cogley, E Rignot, JM Gregory, MR van den Broeke, AJ Monaghan, and I Velicogna (2011), Revisiting the Earth's sea-level and energy budgets from 1961 to 2008, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048794.

Cimini, D, E Campos, R Ware, S Albers, G Giuliani, J Oreamuno, P Joe, SE Koch, S Cober, and E Westwater (2011), Thermodynamic atmospheric profiling during the 2010 Winter Olympics using ground-based microwave radiometry, *IEEE Trans. Geosci. Remote Sensing*, 49(12), 4959-4969,10.1109/TGRS.2011.2154337.

Clark, MP, J Hendrikx, AG Slater, D Kavetski, B Anderson, NJ Cullen, T Kerr, EO Hreinsson, and RA Woods (2011), Representing spatial variability of snow water equivalent in hydrologic and land-surface models: A review, *Water Resour. Res.*, 47, 10.1029/2011WR010745.

Clark, SG, MB Rutherford, MR Auer, DN Cherney, RL Wallace, DJ Mattson, DA Clark, L Foote, N Krogman, P Wilshusen, and T Steelman (2011), College and university environmental programs as a policy problem (Part 1): Integrating knowledge, education, and action for a better world?, *Environ. Manage.*, 47(5), 701-715,10.1007/s00267-011-9619-2.

Clark, SG, MB Rutherford, MR Auer, DN Cherney, RL Wallace, DJ Mattson, DA Clark, L Foote, N Krogman, P Wilshusen, and T Steelman (2011), College and university environmental programs as a policy problem (Part 2): Strategies for improvement, *Environ. Manage.*, 47(5), 716-726,10.1007/s00267-011-9635-2.

Clow, DW, C Rhoades, J Briggs, M Caldwell, and WM Lewis (2011), Responses of soil and water chemistry to mountain pine beetle induced tree mortality in Grand County, Colorado, USA, *Appl. Geochem.*, 26(S), S174-S178,10.1016/j.apgeochem.2011.03.096.

Coburn, S, B Dix, R Sinreich, and R Volkamer (2011), The CU ground MAX-DOAS instrument: characterization of RMS noise limitations and first measurements near Pensacola, FL of BrO, IO, and CHOCHO, *Atmos. Meas. Tech.*, 4(11), 2421-2439,10.5194/amt-4-2421-2011.

Cole, KL, K Ironside, J Eischeid, G Garfin, PB Duffy, and C Toney (2011), Past and ongoing shifts in Joshua tree distribution support future modeled range contraction, *Ecol. Appl.*, 21(1), 137-149,10.1890/09-1800.1.

Colette, A, C Granier, O Hodnebrog, H Jakobs, A Maurizi, A Nyiri, B Bessagnet, A D'Angiola, M D'Isidoro, M Gauss, F Meleux, M Memmesheimer, A Mieville, L Rouil, F Russo, S Solberg, F Stordal, and F Tampieri (2011), Air quality trends in Europe over the past decade: a first multi- model assessment, *Atmos. Chem. Phys.*, 11(22), 11657-11678,10.5194/acp-11-11657-2011.

Colgan, W, H Rajaram, R Anderson, K Steffen, T Phillips, I Joughin, HJ Zwally, and W Abdalati (2011), The annual glaciohydrology cycle in the ablation zone of the Greenland ice sheet: Part 1. Hydrology model, *J. Glaciol.*, 57(204), 697-709.

Colgan, W, K Steffen, WS McLamb, W Abdalati, H Rajaram, R Motyka, T Phillips, and R Anderson (2011), An increase in crevasse extent, West Greenland: Hydrologic implications, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048491.

Collins, JA, P Molnar, and AF Sheehan (2011), Multibeam bathymetric surveys of submarine volcanoes and mega-pockmarks on the Chatham Rise, New Zealand, *N. Z. J. Geol. Geophys.*, 54(3), 329-339,10.1080/00288306.2011.589860.

Compo, GP, JS Whitaker, PD Sardeshmukh, N Matsui, RJ Allan, X Yin, BE Gleason, RS Vose, G Rutledge, P Bessemoulin, S Bronnimann, M Brunet, RI Crouthamel, AN Grant, PY Groisman, PD Jones, MC Kruk, AC Kruger, GJ Marshall, M Maugeri, HY Mok, O Nordli, TF Ros (2011), The Twentieth Century Reanalysis Project, *Q. J. R. Meteorol. Soc.*, 137(654), 1-28,10.1002/qj.776.

Conley, SA, IC Faloona, DH Lenschow, T Campos, C Heizer, A Weinheimer, CA Cantrell, RL Mauldin, RS Hornbrook, I Pollack, and A Bandy (2011), A complete dynamical ozone budget measured in the tropical marine boundary layer during PASE, *J. Atmos. Chem.*, 68(1), 55-70,10.1007/s10874-011-9195-0.

Cooper, OR, SJ Oltmans, BJ Johnson, J Brioude, W Angevine, M Trainer, DD Parrish, TR Ryerson, I Pollack, PD Cullis, MA Ives, DW Tarasick, J Al-Saadi, and I Stajner (2011), Measurement of western US baseline ozone from the surface to the tropopause and assessment of downwind impact regions, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016095.

Corazza, M, P Bergamaschi, AT Vermeulen, T Aalto, L Haszpra, F Meinhardt, S O'Doherty, R Thompson, J Moncrieff, E Popa, M Steinbacher, A Jordan, E Dlugokencky, C Bruhl, M Krol, and F Dentener (2011), Inverse modelling of European N2O emissions: assimilating observations from different networks, *Atmos. Chem. Phys.*, 11(5), 2381-2398,10.5194/acp-11-2381-2011.

Crompton, RP, KJ McAneney, KP Chen, RA Pielke, and K Haynes (2011), Comments on "Influence of location, population, and climate on building damage and fatalities due to Australian bushfire: 1925-2009" Reply, *Weather Clim. Soc.*, 3(1), 63-66,10.1175/WCAS-D-11-00002.1.

Crompton, RP, RA Pielke, and KJ McAneney (2011), Emergence timescales for detection of anthropogenic climate change in US tropical cyclone loss data, *Environ. Res. Lett.*, 6(1), 10.1088/1748-9326/6/1/014003.

Cubison, MJ, AM Ortega, PL Hayes, DK Farmer, D Day, MJ Lechner, WH Brune, E Apel, GS Diskin, JA Fisher, HE Fuelberg, A Hecobian, DJ Knapp, T Mikoviny, D Riemer, GW Sachse, W Sessions, RJ Weber, AJ Weinheimer, A Wisthaler, and JL Jimenez (2011), Effects of aging on organic aerosol from open biomass burning smoke in aircraft and laboratory studies, *Atmos. Chem. Phys.*, 11(23), 12049-12064,10.5194/acp-11-12049-2011.

Davis, CJ, CA de Koning, JA Davies, D Biesecker, G Millward, M Dryer, C Deehr, DF Webb, K Schenk, SL Freeland, C Mostl, CJ Farrugia, and D Odstrcil (2011), A comparison of space weather analysis techniques used to predict the arrival of the Earth-directed CME and its shockwave launched on 8 April 2010, *Space Weather*, 9, 10.1029/2010SW000620.

de Boer, G, H Morrison, MD Shupe, and R Hildner (2011), Evidence of liquid dependent ice nucleation in high-latitude stratiform clouds from surface remote sensors, *Geophys. Res. Lett.*, 38, 10.1029/2010GL046016.

de Boer, G, WD Collins, S Menon, and CN Long (2011), Using surface remote sensors to derive radiative characteristics of Mixed-Phase Clouds: an example from M-PACE, *Atmos. Chem. Phys.*, 11(23), 11937-11949,10.5194/acp-11-11937-2011.

de Boer, G, WD Collins, S Menon, and CN Long (2011), Using surface remote sensors to derive mixed-phase cloud radiative forcing: An example from M-PACE, *Atmos. Chem. Phys. Discuss.*, 11, 1-32,10.5194/acpd-11-1-2011.

de Gouw, JA, AM Middlebrook, C Warneke, R Ahmadov, EL Atlas, R Bahreini, DR Blake, CA

Brock, J Brioude, DW Fahey, FC Fehsenfeld, JS Holloway, M Le Henaff, RA Lueb, SA McKeen, JF Meagher, DM Murphy, C Paris, DD Parrish, AE Perring, IB Pollack, AR Ravishank (2011), Organic aerosol formation downwind from the Deepwater Horizon oil spill, *Science*, 331(6022), 1295-1299,10.1126/science.1200320.

De Haan, DO, LN Hawkins, JA Kononenko, JJ Turley, AL Corrigan, MA Tolbert, and JL Jimenez (2011), Formation of nitrogen-containing oligomers by methylglyoxal and amines in simulated evaporating cloud droplets, *Environ. Sci. Technol.*, 45(3), 984-991,10.1021/es102933x.

de Koning, CA and VJ Pizzo (2011), Polarimetric localization: A new tool for calculating the CME speed and direction of propagation in near-real time, *Space Weather*, 9, 10.1029/2010SW000595.

de Koning, CA, JT Gosling, RM Skoug, JT Steinberg, RP Lin, and LH Wang (2011), Electron distributions during the solar electron burst of 22 March 2002, *J. Geophys. Res-Space Phys.*, 116, 10.1029/2010JA015863.

Dee, D, P Berrisford, MG Bosilovich, M Chelliah , G Compo, A Ebita, PD Jones, S Kobayashi, A Kumar, G Rutledge, S Saha , H Sato, A Simmons, C Smith, and R Vose (2011), [Global Climate] The use of reanalysis data for monitoring the state of the climate [in "State of the climate in 2010"], *Bull. Am. Meteorol. Soc.*, 92(6), S34-S35,10.1175/1520-0477-92.6.S1.

Degu, AM, F Hossain, D Niyogi, R Pielke, JM Shepherd, N Voisin, and T Chronis (2011), The influence of large dams on surrounding climate and precipitation patterns, *Geophys. Res. Lett.*, 38, 10.1029/2010GL046482.

Deng, Y, TJ Fuller-Rowell, RA Akmaev, and AJ Ridley (2011), Impact of the altitudinal Joule heating distribution on the thermosphere, *J. Geophys. Res-Space Phys.*, 116, 10.1029/2010JA016019.

Diaz, HF, R Trigo, MK Hughes, ME Mann, E Xoplaki, and D Barriopedro (2011), Spatial and temporal characteristics of climate in medieval times revisited, *Bull. Am. Meteorol. Soc.*, 92(11), 10.1175/2011BAMS-D-10-05003.1.

Diaz, HF, TW Giambelluca, and JK Eischeid (2011), Changes in the vertical profiles of mean temperature and humidity in the Hawaiian Islands, Global Planet. *Change*, 77(2-Jan), 21-25,10.1016/j.gloplacha.2011.02.007.

Dietze, MC, R Vargas, AD Richardson, PC Stoy, AG Barr, RS Anderson, MA Arain, IT Baker, TA Black, JM Chen, P Ciais, LB Flanagan, CM Gough, RF Grant, D Hollinger, RC Izaurralde, CJ Kucharik, P Lafleur, SG Liu, E Lokupitiya, YQ Luo, JW Munger, CH Peng, B Po (2011), Characterizing the performance of ecosystem models across time scales: A spectral analysis of the North American Carbon Program site-level synthesis, *J. Geophys. Res.-Biogeosci.*, 116, 10.1029/2011JG001661.

Dilling, L, and MC Lemos (2011), Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy, *Glob. Environ. Change-Human Policy Dimens.*, 21(2), 680-689,10.1016/j.gloenvcha.2010.11.006.

Dixon, D, PA Mayewski, E Kokorish, SB Sneed, MJ Handley, DJ Krone, and TA Scambos (2011), A spatial framework for assessing current conditions and monitoring future change in teh chemistry of the Antarctic atmosphere, *The Cryosphere Discuss.*, 5, 885-,10.5194/tcd-5-885-2011.

Docherty, KS, AC Aiken, JA Huffman, IM Ulbrich, PF DeCarlo, D Sueper, DR Worsnop, DC Snyder, RE Peltier, RJ Weber, BD Grover, DJ Eatough, BJ Williams, AH Goldstein, PJ Ziemann, and JL Jimenez (2011), The 2005 study of organic aerosols at riverside (SOAR-1): Instrumental intercomparisons and fine particle composition, *Atmos. Chem. Phys.*, 11(23), 12387-12420,10.5194/acp-11-12387-2011.

Dole, R, M Hoerling, J Perlwitz, J Eischeid, P Pegion, T Zhang, XW Quan, TY Xu, and D Murray (2011), Was there a basis for anticipating the 2010 Russian heat wave?, *Geophys. Res. Lett.*, 38, 10.1029/2010GL046582.

Dong, CM, JC McWilliams, A Hall, and M Hughes (2011), Numerical simulation of a synoptic event in the Southern California Bight, *J. Geophys. Res.-Oceans*, 116, 10.1029/2010JC006578.

Donner, LJ, BL Wyman, RS Hemler, LW Horowitz, Y Ming, M Zhao, JC Golaz, P Ginoux, SJ Lin, MD Schwarzkopf, J Austin, G Alaka, WF Cooke, TL Delworth, SM Freidenreich, CT Gordon, SM Griffies, IM Held, WJ Hurlin, SA Klein, TR Knutson, AR Langenhorst, HC Lee, (2011), The dynamical core, physical parameterizations, and basic simulation characteristics of the atmospheric component AM3 of the GFDL Global Coupled Model CM3, *J. Clim.*, 24(13), 3484-3519,10.1175/2011JCLI3955.1.

Doyle, JD, S Gabersek, QF Jiang, L Bernardet, JM Brown, A Dornback, E Filaus, V Grubisic, DJ Kirshbaum, O Knoth, S Koch, J Schmidli, I Stiperski, S Vosper, and SY Zhong (2011), An intercomparison of T-REX mountain-wave simulations and implications for mesoscale predictability, *Mon. Weather Rev.*, 139(9), 2811-2831,10.1175/MWR-D-10-05042.1.

Druckenmiller, ML, H Eicken, JC George, and L Brower (2011), Trails to the whale: Reflections of change and choice on an Iqupiat icescape, *Polar Geography*.

Du, P, E Girard, AK Bertram, and MD Shupe (2011), Modeling of the cloud and radiation processes observed during SHEBA, *Atmos. Res.*, 101(4), 911-927,10.1016/j.atmosres.2011.05.018.

Duerr, RE, RR Downs, C Tilmes, B Barkstrom, WC Lenhardt, J Glassy, LE Bermudez, and P Slaughter (2011), On the utility of identification schemes for digital earth science data: an assessment and recommendations, *Earth Sci. Inform.*, 4(3), 139-160,10.1007/s12145-011-0083-6.

Dunbar, P, H McCullough, G Mungov, J Varner, and K Stroker (2011), Tohoku earthquake and tsunami data available from NOAA/NGDC, *Geomatics, Natural Hazards & Risk*, 2(4), 305-323,10.1080/19475705.2011.632443.

Dunn, WC, BT Milne, R Mantilla, and VK Gupta (2011), Scaling relations between riparian vegetation and stream order in the Whitewater River network, Kansas, USA, *Landscape Ecol.*, 26(7), 983-997,10.1007/s10980-011-9622-2.

Duplissy, J, PF DeCarlo, J Dommen, MR Alfarra, A Metzger, I Barmpadimos, ASH Prevot, E Weingartner, T Tritscher, M Gysel, AC Aiken, JL Jimenez, MR Canagaratna, DR Worsnop, DR Collins, J Tomlinson, and U Baltensperger (2011), Relating hygroscopicity and composition of organic aerosol particulate matter, *Atmos. Chem. Phys.*, 11(3), 1155-1165,10.5194/acp-11-1155-2011.

Dzepina, K, CD Cappa, RM Volkamer, S Madronich, PF DeCarlo, RA Zaveri, and JL Jimenez (2011), Modeling the multiday evolution and aging of secondary organic aerosol during MILAGRO 2006, *Environ. Sci. Technol.*, 45(8), 3496-3503,10.1021/es103186f.

Eakins, BW, LA Taylor, KS Carignan, and MR Kenny (2011), Advances in coastal digital elevation models, Eos, 92(3 May 2011), 149-150.

Eccles, V, DD Rice, JJ Sojka, CE Valladares, T Bullett, and JL Chau (2011), Lunar atmospheric tidal effects in the plasma drifts observed by the Low-Latitude Ionospheric Sensor Network, *J. Geophys. Res-Space Phys.*, 116, 10.1029/2010JA016282.

Edson, JB, CW Fairall, L Bariteau, CJ Zappa, A Cifuentes-Lorenzen, WR McGillis, S Pezoa, JE Hare, and D Helmig (2011), Direct covariance measurement of CO2 gas transfer velocity during the 2008 Southern Ocean Gas Exchange Experiment: Wind speed dependency, *J. Geophys. Res.-Oceans*, 116, 10.1029/2011JC007022.

Edwards, P, MJ Evans, R Commane, T Ingham, D Stone, AS Mahajan, H Oetjen, JR Dorsey, JR Hopkins, JD Lee, SJ Moller, R Leigh, JMC Plane, LJ Carpenter, and DE Heard (2011), Hydrogen oxide photochemistry in the northern Canadian spring time boundary layer, *J. Geophys. Res.*, 116, 10.1029/2011JD016390.

Eicken, H, J Jones, MV Rohith, C Kambhamettu, F Meyer, A Mahoney, and ML Druckenmiller (2011), Environmental security in Arctic ice-covered seas: From strategy to tactics of hazard identification and emergency response, *Mar. Technol. Soc. J.*, 45(3), 37-48.

Eller, ASD, K Sekimoto, JB Gilman, WC Kuster, JA de Gouw, RK Monson, M Graus, E Crespo, C Warneke, and R Fall (2011), Volatile organic compound emissions from switchgrass cultivars used as biofuel crops, *Atmos. Environ.*, 45(19), 3333-3337,10.1016/j.atmosenv.2011.03.042.

Eller, ASD, KL McGuire, and JP Sparks (2011), Responses of sugar maple and hemlock seedlings to elevated carbon dioxide under altered above- and belowground nitrogen sources, *Tree Physiol.*, 31(4), 391-401,10.1093/treephys/tpr014.

Elvidge, CD, PC Sutton, S Anderson, K Baugh, and DC Ziskin (2011), Satellite observation of urban metabolism, *Earthzine*.

Emery, BA, IG Richardson, DS Evans, FJ Rich, and GR Wilson (2011), Solar rotational periodicities and the semiannual variation in the solar wind, radiation belt, and aurora, *Sol. Phys.*, 274(2-Jan), 399-425,10.1007/s11207-011-9758-x.

Ervens, B, BJ Turpin, and RJ Weber (2011), Secondary organic aerosol formation in cloud droplets and aqueous particles (aqSOA): a review of laboratory, field and model studies, *Atmos. Chem. Phys.*, 11(21), 11069-11102,10.5194/acp-11-11069-2011.

Ervens, B, G Feingold, K Sulia, and J Harrington (2011), The impact of microphysical parameters, ice nucleation mode, and habit growth on the ice/liquid partitioning in mixed-phase Arctic clouds, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD015729.

Fairall, CW, MX Yang, L Bariteau, JB Edson, D Helmig, W McGillis, S Pezoa, JE Hare, B Huebert, and B Blomquist (2011), Implementation of the coupled ocean-atmosphere response experiment flux algorithm with CO2, dimethyl sulfide, and O-3, *J. Geophys. Res.-Oceans*, 116, 10.1029/2010JC006884.

Falkner, KK, H Melling, AM M|nchow, JE Box, T Wohlleben, HL Johnson, P Gudmandsen, R Samelson, L Copland, K Steffen, E Rignot, and AK Higgins (2011), Context for the recent massive Petermann Glacier calving event, *Eos. Trans. AGU*, 92(14), 117-,10.1029/2011EO140001.

Fall, S, A Watts, J Nielsen-Gammon, E Jones, D Niyogi, JR Christy, and RA Pielke (2011), Analysis of the impacts of station exposure on the US Historical Climatology Network temperatures and temperature trends, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015146.

Fan, ZS, JC Neff, JW Harden, TJ Zhang, H Veldhuis, CI Czimczik, GC Winston, and JA O'Donnell (2011), Water and heat transport in boreal soils: Implications for soil response to climate change, *Sci. Total Environ.*, 409(10), 1836-1842,10.1016/j.scitotenv.2011.02.009.

Farmer, DK, JR Kimmel, G Phillips, KS Docherty, DR Worsnop, D Sueper, E Nemitz, and JL Jimenez (2011), Eddy covariance measurements with high-resolution time-of-flight aerosol mass spectrometry: A new approach to chemically-resolved aerosol fluxes, *Atmos. Meas. Tech.*, 4(6), 1275-1289,10.5194/amt-4-1275-2011.

Fast, JD, WI Gustafson, EG Chapman, RC Easter, JP Rishel, RA Zaveri, GA Grell, and MC Barth (2011), The aerosol modeling testbed: A community tool to objectively evaluate aerosol process modules, *Bull. Amer. Meteorol. Soc.*, 92(3), 343-360,10.1175/2010BAMS2868.1.

Fausto, RS, AP Ahlstrom, D Van As, and K Steffen (2011), Present-day temperature standard deviation parameterization for Greenland, *J. Glaciol.*, 57(206), 1181-1183.

Ferguson, IM, PB Duffy, TJ Phillips, X Liang, JA Dracup, and S Schubert (2011), Non-stationarity of the signal and noise characteristics of seasonal precipitation anomalies, *Clim. Dyn.*, 36(4-Mar), 739-752,10.1007/s00382-010-0850-y.

Fierer, N and JT Lennon (2011), The generation and maintenance of diversity in moicrobial communities, *Am. J. Bot.*, 98(3), 439-448,10.3732/ajb.1000498.

Fierer, N, CM McCain, P Meir, M Zimmermann, JM Rapp, MR Silman, and R Knight (2011), Microbes do not follow the elevational diversity patterns of plants and animals, *Ecology*, 92(4), 797-804,10.1890/10-1170.1.

Fischer, EV, DA Jaffe, and EC Weatherhead (2011), Free tropospheric peroxyacetyl nitrate (PAN) and ozone at Mount Bachelor: Potential causes of variability and timescale for trend detection, *Atmos. Chem. Phys.*, 11(12), 5641-5654,10.5194/acp-11-5641-2011.

Fisel, BJ, WJ Gutowski, JM Hobbs, and JJ Cassano (2011), Multiregime states of Arctic atmospheric circulation, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD015790.

Fisher, JA, DJ Jacob, QQ Wang, R Bahreini, CC Carouge, MJ Cubison, JE Dibb, T Diehl, JL Jimenez, EM Leibensperger, ZF Lu, MBJ Meinders, HOT Pye, PK Quinn, S Sharma, DG Streets, A van Donkelaar, and RM Yantosca (2011), Sources, distribution, and acidity of sulfate-ammonium aerosol in the Arctic in winter-spring, *Atmos. Environ.*, 45(39), 7301-7318,10.1016/j.atmosenv.2011.08.030.

Flores, GE, ST Bates, D Knights, CL Lauber, J Stombaugh, R Knight, and N Fierer (2011), Microbial biogeography of public restroom surfaces, *PLoS One*, 6(11), 10.1371/journal.pone.0028132.

Fox-Kemper, B, G Danabasoglu, R Ferrari, SM Griffies, RW Hallberg, MM Holland, ME Maltrud, S Peacock, and BL Samuels (2011), Parameterization of mixed layer eddies. III: Implementation and impact in global ocean climate simulations, *Ocean Model.*, 39(2-Jan), 61-78,10.1016/j.ocemod.2010.09.002.

Frassetto, AM, G Zandt, H Gilbert, TJ Owens, and CH Jones (2011), Structure of the Sierra Nevada from receiver functions and implications for lithospheric foundering, *Geosphere*, 7(4), 898-921,10.1130/GES00570.1.

Frauenfeld, OW, and TJ Zhang (2011), An observational 71-year history of seasonally frozen ground changes in the Eurasian high latitudes, *Environ. Res. Lett.*, 6(4), 10.1088/1748-9326/6/4/044024.

Frehlich, R (2011), The definition of 'truth' for Numerical Weather Prediction error statistics, *Q. J. Roy. Meteorol. Soc.*, 137(654), 84-98,10.1002/qj.738.

Fried, A, C Cantrell, J Olson, JH Crawford, P Weibring, J Walega, D Richter, W Junkermann, R Volkamer, R Sinreich, BG Heikes, D O'Sullivan, DR Blake, N Blake, S Meinardi, E Apel, A Weinheimer, D Knapp, A Perring, RC Cohen, H Fuelberg, RE Shetter, SR Hall, (2011), Detailed comparisons of airborne formaldehyde measurements with box models during the 2006 INTEX-B and MILAGRO campaigns: Potential evidence for significant impacts of unmeasured and multi-generation volatile organic carbon compounds, *Atmos. Chem. Phys.*, 11(22), 11867-11894,10.5194/acp-11-11867-2011.

Frost, GJ, L Tarrason, C Granier, and P Middleton (2011), GEIA: The Global Emissions InitiAtive, *IGAC News*, 46, 16-17.

Frost, GJ, S Falke, A Keane, P Middleton, and C Granier (2011), CIERA: The Community Initiative for Emissions Research and Applications, IGAC News, 46, 21-23.

Fry, JL, A Kiendler-Scharr, AW Rollins, T Brauers, SS Brown, HP Dorn, WP Dube, H Fuchs, A Mensah, F Rohrer, R Tillmann, A Wahner, PJ Wooldridge, and RC Cohen (2011), SOA from limonene: Role of NO3 in its generation and degradation, *Atmos. Chem. Phys.*, 11(8), 3879-3894,10.5194/acp-11-3879-2011.

Fuller-Rowell, T, HJ Wang, R Akmaev, F Wu, TW Fang, M Iredell, and A Richmond (2011), Forecasting the dynamic and electrodynamic response to the January 2009 sudden stratospheric warming, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047732.

Fuller-Rowell, T, R Akmaev, F Wu, M Fedrizzi, RA Viereck, and HJ Wang (2011), Did the January 2009 sudden stratospheric warming cool or warm the thermosphere?, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048985.

Gardner, CS, XZ Chu, PJ Espy, JMC Plane, DR Marsh, and D Janches (2011), Seasonal variations of the mesospheric Fe layer at Rothera, Antarctica (67.5 degrees S, 68.0 degrees W), *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014655.

Gearheard, S, C Aporta, G Aipellee, and K O'Keefe (2011), The Igliniit project: Inuit hunters document life on the trail to map and monitor arctic change, *Can. Geogr.-Geogr. Can.*, 55(1), 42-55,10.1111/j.1541-0064.2010.00344.x.

German, DP, MN Weintraub, AS Grandy, CL Lauber, ZL Rinkes, and SD Allison (2011), Optimization of hydrolytic and oxidative enzyme methods for ecosystem studies, *Soil Biol. Biochem.*, 43(7), 1387-1397,10.1016/j.soilbio.2011.03.017.

Glasser, NF, TA Scambos, J Bohlander, M Truffer, E Pettit, and BJ Davies (2011), From ice-shelf tributary to tidewater glacier: Continued rapid recession, acceleration and thinning of Rohss Glacier following the 1995 collapse of the Prince Gustav Ice Shelf, Antarctic Peninsula, *J. Glaciol.*, 57(203), 397-406,10.3189/002214311796905578.

Goddard, L, A Kumar, A Solomon, D Smith, G Boer, P Gonzalez, C Deser, S Mason, B Kirtman, R Msadek, R Sutton, E Hawkins, T Fricker, S Kharin, W Merryfield, G Hegerl, C Ferro, D Stephenson, GA Meehl, T Stockdale, R Burgman, A Greene, Y Kushnir, M Newman, J (2011), A verification framework for interannual-to-decadal predictions experiments, *Clim. Dyn.*

Godin, OA (2011), Acoustic-gravity waves in atmospheric and oceanic waveguides, *J. Acoust. Soc. Am*.

Godin, OA (2011), Scattering of a spherical wave by a small sphere: An elementary solution, *J. Acoust. Soc. Am.*, 130(4), EL135-EL141,10.1121/1.3629140.

Godin, OA (2011), Low-frequency sound transmission through a gas-solid interface, J. Acoust. Soc. Am., 129(2), EL45-EL51,10.1121/1.3535578.

Gough, RV, JJ Turley, GR Ferrell, KE Cordova, SE Wood, DO DeHaan, CP Mckay, OB Toon, and MA Tolbert (2011), Can rapid loss and high variability of Martian methane be explained by surface H2O2?, *Planet. Space Sci.*, 59(3-Feb), 238-246,10.1016/j.pss.2010.09.018.

Gough, RV, VF Chevrier, KJ Baustian, ME Wise, and MA Tolbert (2011), Laboratory studies of perchlorate phase transitions: Support for metastable aqueous perchlorate solutions on Mars, *Earth Planet. Sci. Lett.*, 312(4-Mar), 371-377,10.1016/j.epsl.2011.10.026.

Grachev, AA, EL Andreasv, PS Guest, and OPG Persson (2011), The critical Richardson number and limits of applicability of local similarity theory in the stable boundary layer, *Bound.-Lay. Meteorol.*

Grachev, AA, L Bariteau, CW Fairall, JE Hare, D Helmig, J Hueber, and EK Lang (2011), Turbulent fluxes and transfer of trace gases from ship-based measurements during TexAQS 2006, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015502.

Grafton, RQ, J Pittock, J Williams, G Fu, M Warburton, B Udall, R Davis, R McKenzie, X Yu, N Che, D Connell, Q Jiang, T Kompas, A Lynch, R Norris, H Possingham, and J Quiggen (2011), Climate change, water consumption and river health: Lessons from the Colorado, Huang

He (Yellow), Murray-Darling and Orange, *Nature Clim. Change*.

Granier, C, B Bessagnet, T Bond, A D'Angiola, HD van der Gon, GJ Frost, A Heil, JW Kaiser, S Kinne, Z Klimont, S Kloster, JF Lamarque, C Liousse, T Masui, F Meleux, A Mieville, T Ohara, JC Raut, K Riahi, MG Schultz, SJ Smith, A Thompson, J van Aardenne, G (2011), Evolution of anthropogenic and biomass burning emissions of air pollutants at global and regional scales during the 1980-2010 period, *Clim. Change*, 109(2-Jan), 163-190,10.1007/s10584-011-0154-1.

Granier, C, S Darras, C Liousse, P Middleton, A Mieville, M Paulin, and V Pignot (2011), The EC-CAD Database: Emissions of Atmospheric Compounds and Compilation of Ancillary Data, *IGAC News*, 46, 18-20.

Graus, M, ASD Eller, R Fall, B Yuan, Y Qian, P Westra, J de Gouw, and C Warneke (2011), Biosphere-atmosphere exchange of volatile organic compounds over C4 biofuel crops., *Atmos. Environ.*

Gray, ST, JJ Lukas, and CA Woodhouse (2011), Millennial-length records of streamflow from the three major upper Colorado River tributaries, *J. Am. Water Resour. Assoc.*, 47(4), 702-712,10.1111/j.1752-1688.2011.00535.x.

Grell, G, SR Freitas, M Stuefer, and J Fast (2011), Inclusion of biomass burning in WRF-Chem: impact of wildfires on weather forecasts, *Atmos. Chem. Phys.*, 11(11), 5289-5303,10.5194/acp-11-5289-2011.

Grooms, I, K Julien, and B Fox-Kemper (2011), On the interactions between planetary geostrophy and mesoscale eddies, *Dyn. Atmos. Oceans*, 51(3), 109-136,10.1016/j.dynatmoce.2011.02.002.

Hackett, E, M Lahsen, S Zehr, and W Shrum (2011), Science under Pressure: Intellectual, Organizational, and Ethical Challenges of Science for Sustainability, *BioScience*.

Hale, B and L Dilling (2011), Geoengineering, ocean fertilization, and the problem of permissible pollution, *Sci. Technol. Hum. Val.*, 36(2), 190-212,10.1177/0162243910366150.

Hall, BD, GS Dutton, DJ Mondeel, JD Nance, M Rigby, JH Butler, FL Moore, DF Hurst, and JW Elkins (2011), Improving measurements of SF6 for the study of atmospheric transport and emissions, *Atmos. Meas. Tech.*, 4(11), 2441-2451,10.5194/amt-4-2441-2011.

Hamlington, BD, RR Leben, OA Godin, JF Legeais, E Gica, and VV Titov (2011), Detection of the 2010 Chilean tsunami using satellite altimetry, *Nat. Hazards Earth Syst. Sci.*, 11(9), 2391-2406,10.5194/nhess-11-2391-2011.

Hanna, E, P Huybrechts, J Cappelen, K Steffen, RC Bales, E Burgess, JR McConnell, JP Steffensen, M Van den Broeke, L Wake, G Bigg, M Griffiths, and D Savas (2011), Greenland ice sheet surface mass balance 1870 to 2010 based on Twentieth century reanalysis, and links with global climate forcing, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016387.

Hao, X, T Nguyen, DB Kearns, CC Arpin, R Fall, and T Sammakia (2011), New inhibitors of colony spreading in Bacillus subtilis and Bacillus anthracis, *Bioorg. Med. Chem. Lett.*, 21(18), 5583-5588,10.1016/j.bmcl.2011.06.082.

Hardin, N, S Yuter, K Friedrich, and D Kingsmill (2011), Characteristics of orographic snowfall in a high altitude environment, *Weather and Forecasting*.

Hare, JA, J Manderson, J Nye, M Alexander, P Auster, D Borggard, A Capotondi, K Damon-Randall, E Heupel, I Mateo, L O'Brien, D Richardson, C Stock, and S Biegel (2011), Cusk (Brosme brosme) and climate change: assessing the threat to a candidate marine fish species under the Endangered Species Act, *ICES J. of Mar. Sci.*

Hare, R, B Eakins, and C Amante (2011), Modelling bathymetric uncertainty, *Int. Hydrogr. Rev.*, 6, 31-42.

Harnik, N, J Perlwitz, and TA Shaw (2011), Observed decadal changes in downward wave coupling between the stratosphere and troposphere in the southern hemisphere, *J. Clim.*, 24(17), 4558-4569,10.1175/2011JCLI4118.1.

Hasenkopf, CA, MA Freedman, MR Beaver, OB Toon, and MA Tolbert (2011), Potential climatic impact of organic haze on early Earth, *Astrobiology*, 11(2), 135-149,10.1089/ast.2010.0541.

Hassler, B, GE Bodeker, S Solomon, and PJ Young (2011), Changes in the polar vortex: Effects on Antarctic total ozone observations at various stations, *Geophys. Res. Lett.*, 38, 10.1029/2010GL045542.

Hassler, B, JS Daniel, BJ Johnson, S Solomon, and SJ Oltmans (2011), An assessment of changing ozone loss rates at South Pole: Twenty-five years of ozonesonde measurements, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016353.

Heald, CL, H Coe, JL Jimenez, RJ Weber, R Bahreini, AM Middlebrook, LM Russell, M Jolleys, TM Fu, JD Allan, KN Bower, G Capes, J Crosier, WT Morgan, NH Robinson, PI Williams, MJ Cubison, PF DeCarlo, and EJ Dunlea (2011), Exploring the vertical profile of atmospheric organic aerosol: Comparing 17 aircraft field campaigns with a global model, *Atmos. Chem. Phys.*, 11(24), 12673-12696,10.5194/acp-11-12673-2011.

Heckel, A, , A Richter, M Trainer, and JP Burrows (2011), Influence of low spatial resolution a priori data on tropospheric NO2 satellite retrievals, *Atmos. Meas. Tech.*, 4(9), 1805-1820,10.5194/amt-4-1805-2011.

Hecobian, A, Z Liu, CJ Hennigan, LG Huey, JL Jimenez, MJ Cubison, S Vay, GS Diskin, GW Sachse, A Wisthaler, T Mikoviny, AJ Weinheimer, J Liao, DJ Knapp, PO Wennberg, A Kurten, JD Crounse, J St Clair, Y Wang, and RJ Weber (2011), Comparison of chemical characteristics of 495 biomass burning plumes intercepted by the NASA DC-8 aircraft during the ARCTAS/CARB-2008 field campaign, *Atmos. Chem. Phys.*, 11(24), 13325-13337,10.5194/acp-11-13325-2011.

Hennigan, CJ, MA Miracolo, GJ Engelhart, AA May, AA Presto, T Lee, AP Sullivan, GR McMeeking, H Coe, CE Wold, WM Hao, JB Gilman, WC Kuster, J de Gouw, BA Schichtel, JL Collett, SM Kreidenweis, and AL Robinson (2011), Chemical and physical transformations of organic aerosol from the photo-oxidation of open biomass burning emissions in an environmental chamber, *Atmos. Chem. Phys.*, 11(15), 7669-7686,10.5194/acp-11-7669-2011.

Herzfeld, UC, BF Wallin, CJ Leuschen, and J Plummer (2011), An algorithm for generalizing topography to grids while preserving subscale morphologic characteristics-creating a glacier bed DEM for Jakobshavn trough as low-resolution input for dynamic ice-sheet models, *Comput. Geosci.*, 37(11), 1793-1801,10.1016/j.cageo.2011.02.021.

Higgins, ME, JJ Cassano, A Craig, W Gutowski, J He, J Jakacki, D Lettenmaier, W Maslowski, A Roberts, and C Zhu (2011), The Regional Arctic Climate Model (RACM): Atmospheric implementation and validation, J. Climate.

Hines, KM, DH Bromwich, LS Bai, M Barlage, and AG Slater (2011), Development and Testing of Polar WRF. Part III: Arctic Land, *J. Clim.*, 24(1), 26-48,10.1175/2010JCLI3460.1.

Hodzic, A and JL Jimenez (2011), Modeling anthropogenically controlled secondary organic aerosols in a megacity: a simplified framework for global and climate models, *Geosci. Model Dev.*, 4(4), 901-917,10.5194/gmd-4-901-2011.

Hoerling, M, E Easterling, J Perlwitz, J Eischeid, P Pegion, and D Murray (2011), An Assessment of 2010 North America Temperatures, *Bull. Amer. Meteor. Soc.*, , S178-S179,10.1175/1520-0477-92.6.S1.

Hoerling, M, J Hurrell, A Kumar, L Terray, J Eischeid, P Pegion, T Zhang, XW Quan, and TY Xu (2011), On North American decadal climate for 2011-20, *J. Clim.*, 24(16), 4519-4528,10.1175/2011JCLI4137.1.

Hoke, MRT, BM Hynek, and GE Tucker (2011), Formation timescales of large Martian valley networks, *Earth Planet. Sci. Lett.*, 312(2-Jan), 1-12,10.1016/j.epsl.2011.09.053.

Holland, MM and J Stroeve (2011), Changing seasonal sea ice predictor relationships in a changing Arctic climate, *Geophys. Res. Lett.*, 38, 10.1029/2011GL049303.

Hortnagl, L, I Bamberger, M Graus, TM Ruuskanen, R Schnitzhofer, M Muller, A Hansel, and G Wohlfahrt (2011), Biotic, abiotic, and management controls on methanol exchange above a temperate mountain grassland, *J. Geophys. Res.-Biogeosci.*, 116, 10.1029/2011JG001641.

Hossain, F, D Niyogi, J Adekoke, G Kallos, and RA Pielke Sr. (2011), Making sense of the water resources that will be available for future use., *Eos*, 90, 144-145,doi:10.1029/2011EO170005.

Hsu, C and B Muller (2011), Evaluating route formation and disturbance of off-highway travel using logistic regression method, *Comput. Environ. Urban*.

Hsu, C, RJ Zamora, LE Johnson, and TL Schneider (2011), Downscaling of Advanced Microwave Scanning Radiometer (AMSR-E) soil moisture using a thermal sensor and the physically-based models, *J. Hydrometeorol*.

Huang, M, GR Carmichael, SN Spak, B Adhikary, S Kulkarni, Y Cheng, C Wei, Y Tang, A D'Allura, PO Wennberg, GL Huey, JE Dibb, JL Jimenez, MJ Cubison, AJ Weinheimer, A Kaduwela, C Cai, M Wong, RB Pierce, JA Al-Saadi, DG Streets, and Q Zhang (2011), Multi-scale modeling study of the source contributions to near-surface ozone and sulfur oxides levels over California during the ARCTAS-CARB period, *Atmos. Chem. Phys.*, 11(7), 3173-3194,10.5194/acp-11-3173-2011.

Huang, XF, RS Gao, JP Schwarz, LY He, DW Fahey, LA Watts, A McComiskey, OR Cooper, TL Sun,

LW Zeng, M Hu, and YH Zhang (2011), Black carbon measurements in the Pearl River Delta region of China, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014933.

Hughes, M, A Hall, and J Kim (2011), Human-induced changes in wind, temperature and relative humidity during Santa Ana events, *Clim. Change*, 109, 119-132,10.1007/s10584-011-0300-9.

Hughes, M, PJ Neiman, E Sukovich, and FM Ralph (2011), Representation of the Sierra Barrier Jet in 11 years of a high-resolution dynamical reanalysis downscaling compared with long-term wind profiler observations, *JGR-Atmos*.

Huisman, AJ, JR Hottle, MM Galloway, JP DiGangi, KL Coens, W Choi, IC Faloona, JB Gilman, WC Kuster, J de Gouw, NC Bouvier-Brown, AH Goldstein, BW LaFranchi, RC Cohen, GM Wolfe, JA Thornton, KS Docherty, DK Farmer, MJ Cubison, JL Jimenez, J Mao, WH Brune, (2011), Photochemical modeling of glyoxal at a rural site: observations and analysis from BEARPEX 2007, *Atmos. Chem. Phys.*, 11(17), 8883-8897,10.5194/acp-11-8883-2011.

Hulme, M, M Mahony, S Beck, C Gorg, B Hansjurgens, J Hauck, C Nesshover, A Paulsch, M Vandewalle, H Wittmer, S Boschen, P Bridgewater, MC Diaw, P Fabre, A Figueroa, KL Heong, H Korn, R Leemans, E Lovbrand, MN Hamid, C Monfreda, R Pielke, J Settele, M Wint (2011), Science-policy interface: Beyond assessments, *Science*, 333(6043), 697-698.

Huneeus, N, M Schulz, Y Balkanski, J Griesfeller, J Prospero, S Kinne, S Bauer, O Boucher, M Chin, F Dentener, T Diehl, R Easter, D Fillmore, S Ghan, P Ginoux, A Grini, L Horowitz, D Koch, MC Krol, W Landing, X Liu, N Mahowald, R Miller, JJ Morcrette, G M (2011), Global dust model intercomparison in AeroCom phase I, *Atmos. Chem. Phys.*, 11(15), 7781-7816,10.5194/acp-11-7781-2011.

Huntington, HP, S Gearheard, AR Mahoney, and AK Salomon (2011), Integrating traditional and scientific knowledge through collaborative natural science field research: Identifying elements for success, *Arctic*, 64(4), 437-445.

Hurst, DF, EG Hall, AF Jordan, LM Miloshevich, DN Whiteman, T Leblanc, D Walsh, H Vomel, and SJ Oltmans (2011), Comparisons of temperature, pressure and humidity measurements by balloon-borne radiosondes and frost point hygrometers during MOHAVE-2009, *Atmos. Meas. Tech.*, 4(12), 2777-2793,10.5194/amt-4-2777-2011.

Hurst, DF, SJ Oltmans, H Vomel, KH Rosenlof, SM Davis, EA Ray, EG Hall, and AF Jordan (2011), Stratospheric water vapor trends over Boulder, Colorado: Analysis of the 30 year Boulder record, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015065.

Hwang, Y, MP Clark, and B Rajagopalan (2011), Use of daily precipitation uncertainties in streamflow simulation and forecast, *Stoch. Environ. Res. Risk Assess.*, 25(7), 957-972,10.1007/s00477-011-0460-1.

Jamiyansharav, K, D Ojima, RA Pielke, W Parton, J Morgan, A Beltran-Przekurat, D LeCain, and D Smith (2011), Seasonal and interannual variability in surface energy partitioning and vegetation cover with grazing at shortgrass steppe, *J. Arid. Environ.*, 75(4), 360-370,10.1016/j.jaridenv.2010.11.008.

Jimenez, JL, I Campos, and MA Lopez-Marino (2011), A new perspective of the Abraham-Minkowski controversy, *Eur. Phys. J. Plus*, 126(5), 10.1140/epjp/i2011-11050-8.

Johnson, LR, ZD Sharp, J Galewsky, M Strong, AD Van Pelt, and F Dong (2011), Hydrogen isotope correction for laser instrument measurement bias at low water vapor concentration using conventional isotope analyses: application to measurements from Mauna Loa Observatory, Hawaii, *Rapid Commun. Mass Spectrom.*, 25(5), 608-616,10.1002/rcm.4894.

Jonassen, R and R Pielke (2011), Improving conveyance of uncertainties in the findings of the IPCC, Clim. Change, 108(4), 745-753,10.1007/s10584-011-0185-7.

Jones, CH, GL Farmer, B Sageman, and SJ Zhong (2011), Hydrodynamic mechanism for the Laramide orogeny, *Geosphere*, 7(1), 183-201,10.1130/GES00575.1.

Jones, RM, and AJ Bedard, Jr. (2011), Gravity-wave ray tracing, *JGR*.

Jones, RM, and AJ Bedard, Jr. (2011), Mesoscale atmospheric effects on sound propagation, Planned for *J. of Geophys. Res.*

Jones, RT, A Bressan, AM Greenwell, and N Fierer (2011), Bacterial communities of two parthenogenetic aphid species cocolonizing two host plants across the Hawaiian islands, *Appl. Environ. Microbiol.*, 77(23), 8345-8349,10.1128/AEM.05974-11.

Karmalkar, AV, RS Bradley, and HF Diaz (2011), Climate change in Central America and Mexico: Regional climate model validation and climate change projections, *Clim. Dyn.*, 37(4-Mar), 605-629,10.1007/s00382-011-1099-9.

Kazil, J, H Wang, G Feingold, AD Clarke, JR Snider, and AR Bandy (2011), Modeling chemical and aerosol processes in the transition from closed to open cells during VOCALS-REx, *Atmos. Chem. Phys.*, 11(15), 7491-7514,10.5194/acp-11-7491-2011.

Keiser, AD, MS Strickland, N Fierer, and MA Bradford (2011), The effect of resource history on the functioning of soil microbial communities is maintained across time, *Biogeosciences*, 8(6), 1477-1486,10.5194/bg-8-1477-2011.

Kennedy, OJ, B Ouyang, JM Langridge, MJS Daniels, S Bauguitte, R Freshwater, MW McLeod, C Ironmonger, J Sendall, O Norris, R Nightingale, SM Ball, and RL Jones (2011), An aircraft based three channel broadband cavity enhanced absorption spectrometer for simultaneous measurements of NO3, N2O5 and NO2, *Atmos. Meas. Tech.*, 4(9), 1759-1776,10.5194/amt-4-1759-2011.

Killett, B, J Wahr, S Desai, D Yuan, and M Watkins (2011), Arctic Ocean tides from GRACE satellite accelerations, *J. Geophys. Res.-Oceans*, 116, 10.1029/2011JC007111.

Kim, SW, SA McKeen, GJ Frost, SH Lee, M Trainer, A Richter, WM Angevine, E Atlas, L Bianco, KF Boersma, J Brioude, JP Burrows, J de Gouw, A Fried, J Gleason, A Hilboll, J Mellqvist, J Peischl, D Richter, C Rivera, T Ryerson, STL Hekkert, J Walega, C Warne (2011), Evaluations of NOx and highly reactive VOC emission inventories in Texas and their implications for ozone plume simulations during the Texas Air Quality Study 2006, *Atmos. Chem. Phys.*, 11(22), 11361-11386,10.5194/acp-11-11361-2011.

Kimmel, JR, DK Farmer, MJ Cubison, D Sueper, C Tanner, E Nemitz, DR Worsnop, M Gonin, and JL Jimenez (2011), Real-time aerosol mass spectrometry with millisecond resolution, Int. *J. Mass Spectrom.*, 303(1), 15-26,10.1016/j.ijms.2010.12.004.

Kineman, JJ (2011), Relational science: A synthesis, Axiomathes, 21(3), 393-437,10.1007/s10516-011-9154-z.

Kingsmill, D, P Neiman, B Moore, M Hughes, S Yuter, and M Ralph (2011), Kinematc and thermodynamic structure of the Sierra Barrier Jet during a landfalling winter storm in northern California, *Mon. Weather Rev.*

Kisich, KO, MP Higgins, I Park, SP Cape, L Lindsay, DJ Bennett, S Winston, J Searles, and RE Sievers (2011), Dry powder measles vaccine: Particle deposition, virus replication, and immune response in cotton rats following inhalation, *Vaccine*, 29(5), 905-912,10.1016/j.vaccine.2010.10.020.

Klocke, D, R Pincus, and J Quaas (2011), On constraining estimates of climate sensitivity with present-day observations through model weighting, *J. Clim.*, 24(23), 6092-6099,10.1175/2011JCLI4193.1.

Knote, C, D Brunner, H Vogel, J Allan, A Asmi, M Aijala, S Carbone, HD van der Gon, JL Jimenez, A Kiendler-Scharr, C Mohr, L Poulain, ASH Prevot, E Swietlicki, and B Vogel (2011), Towards an online-coupled chemistry-climate model: Evaluation of trace gases and aerosols in COSMO-ART, *Geosci. Model Dev.*, 4(4), 1077-1102,10.5194/gmd-4-1077-2011.

Knuth, SL and JJ Cassano (2011), An analysis of near-surface winds, air temperature, and cyclone activity in Terra Nova Bay, Antarctica, from 1993 to 2009, *J. Appl. Meteorol. Climatol.*, 50(3), 662-680,10.1175/2010JAMC2507.1.

Kondo, Y, H Matsui, N Moteki, L Sahu, N Takegawa, M Kajino, Y Zhao, MJ Cubison, JL Jimenez, S Vay, GS Diskin, B Anderson, A Wisthaler, T Mikoviny, HE Fuelberg, DR Blake, G Huey, AJ Weinheimer, DJ Knapp, and WH Brune (2011), Emissions of black carbon, organic, and inorganic aerosols from biomass burning in North America and Asia in 2008, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015152.

Kort, EA, PK Patra, K Ishijima, BC Daube, R Jimenez, J Elkins, D Hurst, FL Moore, C Sweeney and, SC Wofsy (2011), *Tropospheric distribution and variability of N2O: Evidence for strong tropical emissions, Geophys. Res. Lett.*, 38, 10.1029/2011GL047612.

Kristina, HY, SJ Anderson, RL Powell, DG Sullivan, and PC Sutton (2011), Identifying similar biophysical characteristics among nesting beaches of green turtles of Turkey using remote sensing techniques, *IJRSA*, , 22-29.

Kroll, JH, NM Donahue, JL Jimenez, SH Kessler, MR Canagaratna, KR Wilson, KE Altieri, LR Mazzoleni, AS Wozniak, H Bluhm, ER Mysak, JD Smith, CE Kolb, and DR Worsnop (2011), Carbon oxidation state as a metric for describing the chemistry of atmospheric organic aerosol, *Nat. Chem.*, 3(2), 133-139,10.1038/NCHEM.948.

Kumar, KK, K Kamala, B Rajagopalan, MP Hoerling, JK Eischeid, SK Patwardhan, G Srinivasan, BN Goswami, and R Nemani (2011), The once and future pulse of Indian monsoonal climate, *Clim. Dyn.*, 36(12-Nov), 2159-2170,10.1007/s00382-010-0974-0.

Kunkel, KE, TR Karl, H Brooks, J Kossin, JH Lawrimore, D Arndt, L Bosart, D Changnon, SL Cut-

ter, N Doesken, K Emanuel, PY Groisman, RW Katz, T Knutson, J OBrien, CJ Paciorek, TC Peterson, K Redmond, D Robinson, J Trapp, R Vose, S Weaver, M Wehner, K Wolte (2011), Monitoring and understanding changes in extreme storm trends: State of knowledge, *Bull. Amer. Meteor. Soc.*, 49, .

Kurita, N, D Noone, C Risi, GA Schmidt, H Yamada, and K Yoneyama (2011), Intraseasonal isotopic variation associated with the Madden-Julian Oscillation, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015209.

Lack, DA, CD Cappa, J Langridge, R Bahreini, G Buffaloe, C Brock, K Cerully, D Coffman, K Hayden, J Holloway, B Lerner, P Massoli, SM Li, R McLaren, AM Middlebrook, R Moore, A Nenes, I Nuaaman, TB Onasch, J Peischl, A Perring, PK Quinn, T Ryerson, JP Schw (2011), Impact of fuel quality regulation and speed reductions on shipping emissions: Implications for climate and air quality, *Environ. Sci. Technol.*, 45(20), 9052-9060,10.1021/es2013424.

Lahsen, M (2011), Anatomy of dissent: A cultural analysis of climate skepticism, *Am. Behav. Sci.*, Forthcoming, .

Lahsen, M (2011), A space for skepticism: An argument for a cultural and dialogic approach, *Weather, Climate, and Society.*

Lahsen, M (2011), Climategate: The role of the social sciences, *Clim. Change*.

Lahsen, M (2011), A vision of a visioning process: Set-points restraining change in the global environmental change research community, .

Lance, S, MD Shupe, G Feingold, CA Brock, J Cozic, JS Holloway, RH Moore, A Nenes, JP Schwarz, JR Spackman, KD Froyd, DM Murphy, J Brioude, OR Cooper, A Stohl, and JF Burkhart (2011), Cloud condensation nuclei as a modulator of ice processes in Arctic mixed-phase clouds, *Atmos. Chem. Phys.*, 11(15), 8003-8015,10.5194/acp-11-8003-2011.

Landais, A, HC Steen-Larsen, M Guillevic, V Masson-Delmotte, B Vinther, and R Winkler (2011), Triple Isotopic composition of oxygen in surface snow and water vapor at NEEM (Greenland)., *Geochimica et Cosmochimica Acta*, 77, 304-.

Langford, AO, CJ Senff, RJ Alvarez, RM Banta, RM Hardesty, DD Parrish, and TB Ryerson (2011), Comparison between the TOPAZ Airborne Ozone LiDAR and In Situ Measurements during TexAQS 2006, *J. Atmos. Ocean. Technol.*, 28(10), 1243-1257,10.1175/JTECH-D-10-05043.1.

Langley, K, J Kohler, K Matsuoka, A Sinisalo, T Scambos, T Neumann, A Muto, JG Winther, and M Albert (2011), Recovery Lakes, East Antarctica: Radar assessment of sub-glacial water extent, *Geophys. Res. Lett.*, 38, 10.1029/2010GL046094.

Langridge, JM, MS Richardson, D Lack, D Law, and DM Murphy (2011), Aircraft instrument for comprehensive characterization of aerosol optical properties, part I: Wavelength-dependent optical extinction and its relative humidity dependence measured using cavity ringdown spectroscopy, *Aerosol Sci. Technol.*, 45(11), 1305-1318,10.1080/02786826.2011.592745.

Langston, AL, GE Tucker, RS Anderson, and SP Anderson (2011), Exploring links between vadose zone hydrology and chemical weathering in the Boulder Creek critical zone observatory, *Appl. Geochem.*, 26(S), S70-S71,10.1016/j.apgeochem.2011.03.033.

Lauvset, SK, WR McGillis, L Bariteau, CW Fairall, T Johannessen, A Olsen, and CJ Zappa (2011), Direct measurements of CO2 flux in the Greenland Sea, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047722.

Lawrence, CR, JC Neff, and GL Farmer (2011), The accretion of aeolian dust in soils of the San Juan Mountains, Colorado, USA, *J. Geophys. Res.-Earth Surf.*, 116, 10.1029/2010JF001899.

Lawrence, D and B Balsley (2011), High-resolution atmospheric sensing using a low-cost miniature autonomous arial vehicle, J. Atmos. Ocean Technol.

Lawrence, DM, KW Oleson, MG Flanner, PE Thornton, SC Swenson, PJ Lawrence, XB Zeng, ZL Yang, S Levis, K Sakaguchi, GB Bonan, and AG Slater (2011), Parameterization improvements and functional and structural advances in version 4 of the community land model, *J. Adv. Model. Earth Syst.*, 3, 10.1029/2011MS000045.

Le, G, WJ Burke, RF Pfaff, H Freudenreich, S Maus, and H Luhr (2011), C/NOFS measurements of magnetic perturbations in the low-latitude ionosphere during magnetic storms, J. *Geophys. Res-Space Phys.*, 116, 10.1029/2011JA017026.

Leblanc, T, TD Walsh, IS McDermid, GC Toon, JF Blavier, B Haines, WG Read, B Herman, E Fetzer, S Sander, T Pongetti, DN Whiteman, TG McGee, L Twigg, G Sumnicht, D Venable, M Calhoun, A Dirisu, D Hurst, A Jordan, E Hall, L Miloshevich, H Vomel, C Straub, N (2011), Measurements Of Humidity in the Atmosphere and Validation Experiments (MOHAVE)-2009: Overview of campaign operations and results, *Atmos. Meas. Tech.*, 4(12), 2579-2605,10.5194/amt-4-2579-2011.

Ledley, T, M Taber, S Lynds, B Domenico, and L Dahlman (2011), A model for enabling an effective outcome-oriented communication between the scientific and educational communities, *J. Geosci. Educ.*

Lee, CM, JB Lee, and JC Turnbull (2011), Refining the chronology of the Agate Basin Complex: Radiocarbon dating the frazier site, northeastern Colorado, *Plains Anthropol.*, 56(219), 243-258.

Lee, E, WJ Sacks, TN Chase, and JA Foley (2011), Simulated impacts of irrigation on the atmospheric circulation over Asia, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014740.

Lee, IT, T Matsuo, AD Richmond, JY Liu, W Wang, CH Lin, JL Anderson, and MQ Chen (2011), Assimilation of FORMOSAT-3/COSMIC electron density profiles into thermosphere/Ionosphere coupling model by using ensemble Kalman filter, J. Geophys. *Res. - Space Phys.*

Lee, J, J Worden, D Noone, K Bowman, A Eldering, A LeGrande, JLF Li, G Schmidt, and H Sodemann (2011), Relating tropical ocean clouds to moist processes using water vapor isotope measurements, *Atmos. Chem. Phys.*, 11(2), 741-752,10.5194/acp-11-741-2011.

Lee, SH (2011), Further development of the vegetated urban canopy model including a grass-covered surface parametrization and photosynthesis effects, *Bound.-Lay. Meteorol.*, 140(2), 315-342,10.1007/s10546-011-9603-7.

Lee, SH, SW Kim, M Trainer, GJ Frost, SA McKeen, OR Cooper, F Flocke, JS Holloway, JA Neuman, T Ryerson, CJ Senff, AL Swanson, and AM Thompson (2011), Modeling ozone plumes observed downwind of New York City over the North Atlantic Ocean during the ICARTT field campaign, *Atmos. Chem. Phys.*, 11(14), 7375-7397,10.5194/acp-11-7375-2011.

Lee, SH, SW Kim, WM Angevine, L Bianco, SA McKeen, CJ Senff, M Trainer, SC Tucker, and RJ Zamora (2011), Evaluation of urban surface parameterizations in the WRF model using measurements during the Texas Air Quality Study 2006 field campaign, *Atmos. Chem. Phys.*, 11(5), 2127-2143,10.5194/acp-11-2127-2011.

Lee, SS and JE Penner (2011), Dependence of aerosol-cloud interactions in stratocumulus clouds on liquid-water path, *J. Atmos. Sci.*, 45, 6337-.

Lee, SS and LJ Donner (2011), Effects of cloud parameterization on radiation and precipitation: A comparison between single-moment microphysics and double-moment microphysics, *Terr. Atmos. Ocean. Sci.*, 22(4), 403-420,10.3319/TAO.2011.03.03.01(A).

Lefohn, AS, H Wernli, D Shadwick, S Limbach, SJ Oltmans, and M Shapiro (2011), The importance of stratospheric-tropospheric transport in affecting surface ozone concentrations in the western and northern tier of the United States, *Atmos. Environ.*, 45(28), 4845-4857,10.1016/j.atmosenv.2011.06.014.

Lewis, WM, Jr. (2011), Global primary production of lakes: 19th Baldi Memorial Lecture, *Inland Waters*, 1(1), 1-28.

Lewis, WM, WA Wurtsbaugh, and HW Paerl (2011), Rationale for control of anthropogenic nitrogen and phosphorus to reduce eutrophication of inland waters, *Environ. Sci. Technol.*, 45(24), 10300-10305,10.1021/es202401p.

Liang, J, XQ Yang, and DZ Sun (2011), The effect of ENSO events on the Tropical Pacific Mean Climate: Insights from an analytical model, *J. Clim.*

Liao, J, H Sihler, LG Huey, JA Neuman, DJ Tanner, U Friess, U Platt, FM Flocke, JJ Orlando, PB Shepson, HJ Beine, AJ Weinheimer, SJ Sjostedt, JB Nowak, DJ Knapp, RM Staebler, W Zheng, R Sander, SR Hall, and K Ullmann (2011), A comparison of Arctic BrO measurements by chemical ionization mass spectrometry and long path-differential optical absorption spectroscopy, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014788.

Liebmann, B, GN Kiladis, D Allured, CS Vera, C Jones, LMV Carvalho, I Blade, and PLM Gonzales (2011), Mechanisms associated with large daily rainfall events in northeast Brazil, *J. Clim.*, 24(2), 376-396,10.1175/2010JCLI3457.1.

Lin, WH, DE Griffin, PA Rota, M Papania, SP Cape, D Bennett, B Quinn, RE Sievers, C Shermer, K Powell, RJ Adams, S Godin, and S Winston (2011), Successful respiratory immunization with dry powder live-attenuated measles virus vaccine in rhesus macaques, *Proc. Natl. Acad. Sci. U. S. A.*, 108(7), 2987-2992,10.1073/pnas.1017334108.

Liu, D, J Allan, B Corris, M Flynn, E Andrews, J Ogren, K Beswick, K Bower, R Burgess, T Choularton, J Dorsey, W Morgan, PI Williams and H Coe (2011), Carbonaceous aerosols contributed by traffic and solid fuel burning at a polluted rural site in Northwestern England, *Atmos. Chem. Phys.*, 11(4), 1603-1619,10.5194/acp-11-1603-2011.

Liu, S, DA Day, JE Shields, and LM Russell (2011), Ozone-driven photochemical formation of

carboxylic acid groups from alkane groups, *Atmos. Chem. Phys.*, 11, 8321-8341.

Lovbrand, E, R Pielke, and S Beck (2011), A democracy paradox in studies of science and technology, *Sci. Technol. Hum. Values*, 36(4), 474-496,10.1177/0162243910366154.

Lundquist, JD, N Cristea, J Deems, SP Loheide II, CS Lowry, and CE Moore (2011), Differential subcatchment hydrologic response to climate change scenarios in a snowmelt-dominated watershed, *Water Resour. Res.*

Lundquist, JD, N Cristea, JS Deems, SP Loheide, CS Lowry, CE Moore, and MS Raleigh (2011), The relative importance of distributing spatially-varying parameters in a snowmelt-dominated watershed in complex terrain, *Water Resour. Res*.

Lynch, BJ, AA Reinard, T Mulligan, KK Reeves, CE Rakowski, JC Allred, Y Li, JM Laming, PJ MacNeice, and JA Linker (2011), Ionic compsition structure of coronal mass ejections in axisymmetric magnetohydrodynamic models, *Astrophys. J.*, 740(2), 10.1088/0004-637X/740/2/112.

Lynds, S, T Ledley, M Taber, S Buhr, B Domenico, and L Dahlman (2011), Iterative evaluation for recurring workshops-A model for refining a program and its evaluation to maximize success, *Am. J. Eval*.

Lyon, B, MA Bell, MK Tippett, A Kumar, MP Hoerling, XW Quan, and H Wang (2011), Baseline probabilities for the seasonal prediction of meteorological drought, *J. of Appl. Meteorol. Climatol*.

Mahoney, KM and GM Lackmann (2011), The sensitivity of momentum transport and severe surface winds to environmental moisture in idealized simulations of a mesoscale convective system, *Mon. Weather Rev.*, 139(5), 1352-1369,10.1175/2010MWR3468.1.

Mair, JL, GL Farmer, DI Groves, CJR Hart, and RJ Goldfarb (2011), Petrogenesis of Postcollisional Magmatism at Scheelite Dome, Yukon, Canada: Evidence for a Lithospheric Mantle Source for Magmas Associated with Intrusion-Related Gold Systems, *Econ. Geol.*, 106(3), 451-480.

Mann, GW, KS Carslaw, DA Ridley, DV Spracklen, KJ Pringle, J Merikanto, H Korhonen, JP Schwarz, LA Lee, PT Manktelow, MT Woodhouse, A Schmidt, TJ Breider, KM Emmerson, MP Chipperfield, and SJ Pickering (2011), Evaluation of a modal aerosol microphysics model against a sectional scheme and benchmark observations in a 3D global model, *Atmos. Chem. Phys. Discuss.*

Manney, GL, MI Hegglin, WH Daffer, ML Santee, EA Ray, S Pawson, MJ Schwartz, CD Boone, L Froidevaux, NJ Livesey, WG Read, and KA Walker (2011), Jet characterization in the upper troposphere/lower stratosphere (UTLS): Applications to climatology and transport studies, *Atmos. Chem. Phys.*, 11(12), 6115-6137,10.5194/acp-11-6115-2011.

Manoj, C and S Maus (2011), A real-time model of the ionospheric prompt penetration electric fields, *Space*.

Manoj, C, S Maus, and A Chulliat (2011), Observation of magnetic fields generated by tsunamis, *Eos Trans. AGU*, 92(2), 10.1029/2011EO020002.

Manoj, C, S Maus, and P Alken (2011), Equatorial zonal electric field spectra and prompt penetration effects derived from the CHAMP measurements, *J. Geophys. Res.*

Mantilla, R, VK Gupta, and BM Troutman (2011), Scaling of peak flows with constant flow velocity in random self-similar networks, *Nonlinear Proc. Geophys*., 18(4), 489-502,10.5194/npg-18-489-2011.

Maron, MK, K Takahashi, RK Shoemaker, and V Vaida (2011), Hydration of pyruvic acid to its geminal-diol, 2,2-dihydroxypropanoic acid, in a water-restricted environment, *Chem. Phys. Lett.*, 513(6-Apr), 184-190,10.1016/j.cplett.2011.07.090.

Marquis, M, S Albers, and EC Weatherhead (2011), For better integration, improve the forecast, *Solar Today*, 25, 52-.

Maruyama, N, PG Richards, TW Fang, C Negrea, L Mayer, TJ Fuller-Rowell, AD Richmond, and A Maute (2011), The Ionosphere-Plasmasphere-Electrodynamics (IPE) model: An impact of the realistic geomagnetic field model on the ionospheric dynamics, *J. Geophys. Res.*

Maruyama, N, TJ Fuller-Rowell, MV Codrescu, and M Fedrizzi (2011), The CTIPe model, *Geoph. Monog. Series.*

Maruyama, N, TJ Fuller-Rowell, MV Codrescu, D Anderson, AD Richmond, A Maute, S Sazykin, RW Spiro, RA Wolf, FR Toffoletto, and GH Millward (2011), Modeling SAPS and SEDs from the coupled RCM-CTIPe model, *J. Geophys. Res.*

Masarie, KA, G Petron, A Andrews, L Bruhwiler, TJ Conway, AR Jacobson, JB Miller, PP Tans, DE Worthy, and W Peters (2011), Impact of CO2 measurement bias on CarbonTracker surface flux estimates, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016270.

Maslanik, J, J Stroeve, C Fowler, and W Emery (2011), Distribution and trends in Arctic sea ice age through spring 2011, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047735.

Masson-Delmotte, V, P Braconnot, G Hoffmann, J Jouzel, M Kageyama, A Landais, Q Lejeune, C Risi, L Sime, J Sjolte, D Swingedouw, and B Vinther (2011), Sensitivity of interglacial Greenland temperature and delta O-18: ice core data, orbital and increased CO2 climate simulations, *Clim. Past.*, 7(3), 1041-1059,10.5194/cp-7-1041-2011.

Matrosov, SY (2011), CloudSat measurements of landfalling hurricanes Gustav and Ike (2008), *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014506.

Matrosov, SY (2011), Feasibility of using radar differential Doppler velocity and dual-frequency ratio for sizing particles in thick ice clouds, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD015857.

Matrosov, SY (2011), Polarimetric radar-based estimates of spatial variability in characteristic sizes of raindrops in stratiform rainfall, *J. Appl. Meteorol. Clim.*, 50(12), 2514-2525,10.1175/JAMC-D-11-053.1.

Matsui, H, Y Kondo, N Moteki, N Takegawa, LK Sahu, M Koike, Y Zhao, HE Fuelberg, WR Sessions, G Diskin, BE Anderson, DR Blake, A Wisthaler, MJ Cubison, and JL Jimenez (2011), Accumulation-mode aerosol number concentrations in the Arctic during the ARCTAS aircraft campaign: Long-range transport of polluted and clean air from the Asian continent, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016189.

Matsuo, T and EA Araujo-Pradere (2011), Role of thermosphere-ionosphere coupling in a global ionospheric specification, *Radio Sci.*, 46, 10.1029/2010RS004576.

Matsuo, T, DW Nychka, and D Paul (2011), Nonstationary covariance modeling for incomplete data: Monte Carlo EM approach, *Comput. Stat. Data An.*, 55(6), 2059-2073,10.1016/j.csda.2010.12.002.

Mauritsen, T, J Sedlar, M Tjernstrom, C Leck, M Martin, M Shupe, S Sjogren, B Sierau, POG Persson, IM Brooks, and E Swietlicki (2011), An Arctic CCN-limited cloud-aerosol regime, *Atmos. Chem. Phys.*, 11(1), 165-173,10.5194/acp-11-165-2011.

May-Ostendorp, P, GP Henze, CD Corbin, B Rajagopalan, and C Felsmann (2011), Model-predictive control of mixed-mode buildings with rule extraction, *Build. Environ.*, 46(2), 428-437,10.1016/j.buildenv.2010.08.004.

McDonald, SE, C Coker, KF Dymond, DN Anderson, and EA Araujo-Pradere (2011), A study of the strong linear relationship between the equatorial ionization anomaly and the prereversal E x B drift velocity at solar minimum, *Radio Sci.*, 46, 10.1029/2011RS004702.

McFarquhar, GM, S Ghan, J Verlinde, A Korolev, JW Strapp, B Schmid, JM Tomlinson, M Wolde, SD Brooks, D Cziczo, MK Dubey, JW Fan, C Flynn, I Gultepe, J Hubbe, MK Gilles, A Laskin, P Lawson, WR Leaitch, P Liu, XH Liu, D Lubin, C Mazzoleni, AM Macdonald, RC (2011), indirect and semi-direct aersol campaign: The impact of Arctic aerosols on clouds, *B. Am. Meteorol. Soc.*, 92(2), 183-+,10.1175/2010BAMS2935.1.

McGillen, MR, AT Archibald, T Carey, KE Leather, DE Shallcross, JC Wenger, and CJ Percival (2011), Structure-activity relationship (SAR) for the prediction of gas-phase ozonolysis rate coefficients: an extension towards heteroatomic unsaturated species, *Phys. Chem. Chem. Phys.*, 13(7), 2842-2849,10.1039/c0cp01732a.

McGillen, MR, M Ghalaieny, and CJ Percival (2011), Determination of gas-phase ozonolysis rate coefficients of C8-14 terminal alkenes at elevated temperatures using the relative rate method, *Phys. Chem. Chem. Phys.*, 13(23), 10965-10969,10.1039/c0cp02643c.

McGrath, D, W Colgan, K Steffen, P Lauffenburger, and J Balog (2011), Assessing the summer water budget of a moulin basin in the Sermeq Avannarleq ablation region, Greenland ice sheet, *J. Glaciol.*, 57(205), 954-964.

McNaughton, CS, AD Clarke, S Freitag, VN Kapustin, Y Kondo, N Moteki, L Sahu, N Takegawa, JP Schwarz, JR Spackman, L Watts, G Diskin, J Podolske, JS Holloway, A Wisthaler, T Mikoviny, J de Gouw, C Warneke, J Jimenez, M Cubison, SG Howell, A Middlebrook, R (2011), Absorbing aerosol in the troposphere of the Western Arctic during the 2008 ARCTAS/ARCPAC airborne field campaigns, *Atmos. Chem. Phys.*, 11(15), 7561-7582,10.5194/acp-11-7561-2011.

McNeil, BI, C Sweeney, and JAE Gibson (2011), Short note natural seasonal variability of aragonite saturation state within two Antarctic coastal ocean sites, Antarct. Sci., 23(4), 411-412,10.1017/S0954102011000204.

Meier, WN (2011), A new climate data record of sea ice concentration, *IEEE T. Geosci. Remote*, .

Meier, WN, and G Heygster (2011), Was the 2011 Arctic sea ice extent a new record minimum?, *Eos, Transactions of the American Geophysical Union*.

Meier, WN, and others (2011), A review of Arctic sea ice and implications for climate, ecosystems, and society, Rev Geophys.

Meslin, PY, R Gough, F Lefevre, and F Forget (2011), Little variability of methane on Mars induced by adsorption in the regolith, *Planet Space Sci.*, 59(3-Feb), 247-258,10.1016/j.pss.2010.09.022.

Michalsky, J, EG Dutton, D Nelson, J Wendell, S Wilcox, A Andreas, P Gotseff, D Myers, I Reda, T Stoffel, K Behrens, T Carlund, W Finsterle, and D Halliwell (2011), An extensive comparison of commercial pyrheliometers under a wide range of routine observing conditions, *J. Atmos. Ocean. Technol.*, 28(6), 752-766,10.1175/2010JTECHA1518.1.

Middlebrook, AM, DM Murphy, R Ahmadov, EL Atlas, R Bahreini, DR Blake, J Brioude, JA de Gouw, FC Fehsenfeld, GJ Frost, JS Holloway, DA Lack, JM Langridge, RA Lueb, SA McKeen, JF Meagher, S Meinardi, JA Neuman, JB Nowak, DD Parrish, J Peischl, AE Perring, (2011), Air quality implications of the Deepwater Horizon oil spill, *P. Natl. Acad. Sci. USA*, , 10.1073/pnas.1110052108.

Miller, BR and LJM Kuijpers (2011), Projecting future HFC-23 emissions, *Atmos. Chem. Phys.*, 11(24), 13259-13267,10.5194/acp-11-13259-2011.

Minder, J and D Kingsmill (2011), Mesoscale variations of the atmospheric snowline over the northern Sierra Nevada: climatology, case study, and mechanisms, *Mon. Weather Rev.*

Minguillon, MC, N Perron, X Querol, S Szidat, SM Fahrni, A Alastuey, JL Jimenez, C Mohr, AM Ortega, DA Day, VA Lanz, L Wacker, C Reche, M Cusack, F Amato, G Kiss, A Hoffer, S Decesari, F Moretti, R Hillamo, K Teinila, R Seco, J Penuelas, A Metzger, S Scha (2011), Fossil versus contemporary sources of fine elemental and organic carbonaceous particulate matter during the DAURE campaign in Northeast Spain, *Atmos. Chem. Phys.*, 11(23), 12067-12084,10.5194/acp-11-12067-2011.

Mitcham, C (2011), Petroski's Policy Henry Petroski, The Essential Engineer, *Technol. Cult.*, 52(2), 380-384.

Mizukami, N, V Koren, M Smith, D Kingsmill, Z Zhang, B Cosgrove, and Z Cui (2011), Hydrologic simulation using rain-snow partitioning derived from HMT-West radar-detected bright-band height, *J. Hydrometeorol.*

Molnar, P (2011), Jack Oliver (1923-2011), Nature, 470(7333), 176-176,10.1038/470176a.

Molnar, P and T Rautian (2011), Harry Fielding Reid Medal Citation for Tatyana Glebovna Rautian, *Seismol. Res. Lett.*, 82(5), 700-702.

Montandon, LM, S Fall, RA Pielke, and D Niyogi (2011), Distribution of landscape types in the global historical climatology network, *Earth Interact.*, 15, 10.1175/2010EI371.1.

Montzka, SA, M Krol, E Dlugokencky, B Hall, P Jockel, and J Lelieveld (2011), Small interannual variability of global atmospheric hydroxyl, *Science*, 331(6013), 67-69,10.1126/science.1197640.

Moore, RH, R Bahreini, CA Brock, KD Froyd, J Cozic, JS Holloway, AM Middlebrook, DM Murphy, and A Nenes (2011), Hygroscopicity and composition of Alaskan Arctic CCN during April 2008, *Atmos. Chem. Phys.*, 11(22), 11807-11825,10.5194/acp-11-11807-2011.

Morrill, C, AJ Wagner, BL Otto-Bliesner, and N Rosenbloom (2011), Evidence for significant climate impacts in monsoonal Asia at 8.2 ka from multiple proxies and model simulations, *Journal of Earth Environment*, 2(3), 426-441.

Morrison, H, P Zuidema, A Ackerman, A Avramov, G de Boer, J Fan, A Fridlind, T Hashino, J Harrington, Y Luo, M Ovchinnikov, and B Shipway (2011), Intercomparison of cloud model simulations of arctic mixed-phase boundary layer clouds observed during SHEBA, *Journal of Advances in the Modeling of Earth Systems*, 3, 10.1029/2011MS000066.

Morss, RE, OV Wilhelmi, GA Meehl, and L Dilling (2011), Improving societal outcomes of extreme weather in a changing climate: An integrated perspective, *Annu. Rev. Env. Resour.*, 36, 1-25,10.1146/annurev-environ-060809-100145.

Muto, A, TA Scambos, K Steffen, AG Slater, and GD Clow (2011), Recent surface temperature trends in the interior of East Antarctica from borehole firn temperature measurements and geophysical inverse methods, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048086.Nair, PJ, S Godin-Beekmann, A Pazmino, A Hauchecorne, G Ancellet, I Petropavlovskikh, LE Flynn, and L Froidevaux (2011), Coherence of long-term stratospheric ozone vertical distribution time series used for the study of ozone recovery at a northern mid-latitude station, *Atmos. Chem. Phys.*, 11(10), 4957-4975,10.5194/acp-11-4957-2011.

Nair, US, Y Wu, J Kala, TJ Lyons, RA Pielke, and JM Hacker (2011), The role of land use change on the development and evolution of the west coast trough, convective clouds, and precipitation in southwest Australia, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014950.

Nalli, NR, E Joseph, VR Morris, CD Barnet, WW Wolf, D Wolfe, PJ Minnett, M Szczodrak, MA Izaguirre, R Lumpkin, H Xie, A Smirnov, TS King, and J Wei (2011), Multiyear observations of the tropical atlantic atmosphere: Multidisciplinary applications of the NOAA aerosols and ocean science expeditions, *B. Am. Meteorol. Soc.*, 92(6), 765-789,10.1175/2011BAMS2997.1.

Naugol'nykh, K (2011), Sound amplification in a supersaturated vapor, *Acoust. Phys.*, 57(4), 460-464,10.1134/S1063771011030158.

Neely, RR, JM English, OB Toon, S Solomon, M Mills, and JP Thayer (2011), Implications of extinction due to meteoritic smoke in the upper stratosphere, *Geophys. Res. Lett.*, 38, 10.1029/2011GL049865.

Neiman, PJ, LJ Schick, FM Ralph, M Hughes, and GA Wick (2011), Flooding in western Washington: The connection to atmospheric rivers, *J. Hydrometeorol.*, 12(6), 1337-1358,10.1175/2011JHM1358.1.

Nemergut, DR, EK Costello, M Hamady, C Lozupone, L Jiang, SK Schmidt, N Fierer, AR Townsend, CC Cleveland, L Stanish, and R Knight (2011), Global patterns in the biogeography of bacterial taxa, *Environ. Microbiol.*, 13(1), 135-144,10.1111/j.1462-2920.2010.02315.x.

Nerem, RS and DP Chambers (2011), Orbit determination and sea level rise: How astrodynamics informs us about the climate, *J. Astronaut. Sci.*, 57(4), 767-776.

Nerem, RS, and J Wahr (2011), Recent changes in the Earth's oblateness driven by Greenland and Antarctic ice mass loss, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047879.

Nevison, CD, E Dlugokencky, G Dutton, JW Elkins, P Fraser, B Hall, PB Krummel, RL Langenfelds, S O'Doherty, RG Prinn, LP Steele, and RF Weiss (2011), Exploring causes of interannual variability in the seasonal cycles of tropospheric nitrous oxide, *Atmos. Chem. Phys.*, 11(8), 3713-3730,10.5194/acp-11-3713-2011.

Newman, M, GN Kiladis, KM Weickmann, FM Ralph, and PD Sardeshmukh (2011), Relative contributions of synoptic and low-frequency eddies to time-mean atmospheric moisture transport, including the role of atmospheric rivers, *J. Climate*.

Newman, M, MA Alexander, and JD Scott (2011), An empirical model of tropical ocean dynamics, *Clim. Dynam.*, 37(10-Sep), 1823-1841,10.1007/s00382-011-1034-0.

Newman, M, SI Shin, and MA Alexander (2011), Natural variation in ENSO flavors, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047658.

Ng, NL, MR Canagaratna, JL Jimenez, PS Chhabra, JH Seinfeld, and DR Worsnop (2011), Changes in organic aerosol composition with aging inferred from aerosol mass spectra, *Atmos. Chem. Phys.*, 11(13), 6465-6474,10.5194/acp-11-6465-2011.

Ng, NL, MR Canagaratna, JL Jimenez, Q Zhang, IM Ulbrich, and DR Worsnop (2011), Real-time methods for estimating organic component mass concentrations from aerosol mass spectrometer data, *Environ. Sci. Technol.*, 45(3), 910-916,10.1021/es102951k.

Ng, NL, SC Herndon, A Trimborn, MR Canagaratna, PL Croteau, TB Onasch, D Sueper, DR Worsnop, Q Zhang, YL Sun, and JT Jayne (2011), An Aerosol Chemical Speciation Monitor (ACSM) for routine monitoring of the composition and mass concentrations of ambient aerosol, *Aerosol Sci. Tech.*, 45(7), 780-794,10.1080/02786826.2011.560211.

Nicholls, ME, and DA Schecter (2011), Numerical simulation of infrasound generated by thermally driven tornado-like vortices, .

Nicholls, ME, and MT Montgomery (2011), An examination of two pathways to tropical cyclogenesis occurring in idealized simulations with a cloud-resolving numerial model, .

Nigro, MA, JJ Cassano, and MW Seefeldt (2011), A weather-pattern-based approach to evaluate the Antarctic Mesoscale Prediction System (AMPS) forecasts: Comparison to automatic weather station observations, *Weather Forecast.*, 26(2), 184-198,10.1175/2010WAF2222444.1.

Noone, D, J Galewsky, ZD Sharp, J Worden, J Barnes, D Baer, A Bailey, DP Brown, L Christensen, E Crosson, F Dong, JV Hurley, LR Johnson, M Strong, D Toohey, A Van Pelt, and JS Wright (2011), Properties of air mass mixing and humidity in the subtropics from measurements of the D/H isotope ratio of water vapor at the Mauna Loa Observatory, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD015773.

Novikov, Y, SD Copley, and BE Eaton (2011), A simple route for synthesis of 4-phospho-D-

erythronate, *Tetrahedron Lett.*, 52(16), 1913-1915,10.1016/j.tetlet.2011.02.045.

Nowak, KC, B Rajagopalan, and E Zagona (2011), Wavelet Auto-Regressive Method (WARM) for multi-site streamflow simulation of data with non-stationary spectra, *J. Hydrol.*, 410(2-Jan), 1-12,10.1016/j.jhydrol.2011.08.051.

Olsen, MS, TV Callaghan, JD Reist, LO Reiersen, D Dahl-Jensen, MA Granskog, B Goodison, GK Hovelsrud, M Johansson, R Kallenborn, J Key, A Klepikov, W Meier, JE Overland, TD Prowse, M Sharp, WF Vincent, and J Walsh (2011), The changing Arctic cryosphere and likely consequences: An overview, *Ambio*, 40, 111-118,10.1007/s13280-011-0220-y.

Ostashev, VE, DK Wilson, and SN Vecherin (2011), Effect of randomly varying impedance on the interference of the direct and ground-reflected waves, *J. Acoust. Soc. Am.*, 130(4), 1844-1850,10.1121/1.3624817.

Papadimitriou, VC, YG Lazarou, RK Talukdar, and JB Burkholder (2011), Atmospheric Chemistry of CF3CF=CH2 and (Z)-CF3CF=CHF: Cl and NO3 rate coefficients, Cl reaction product yields, and thermochemical calculations, *J. Phys. Chem. A*, 115(2), 167-181,10.1021/jp110021u.

Papanastasiou, DK, KJ Feierabend, and JB Burkholder (2011), Cl2O Photochemistry: UV/vis Absorption Spectrum Temperature Dependence and O(3P) Quantum Yield at 193 and 248 nm, *J. Chem. Phys.*

Parsons, MA (2011), Making data useful for modelers to understand complex Earth systems, *Earth Sci. Inform.*, 4(4), 197-223,10.1007/s12145-011-0089-0.

Parsons, MA and P Fox (2011), Is data publication the right metaphor?, *Data Sci. J.*

Parsons, MA, O Godoy, E LeDrew, TF de Bruin, B Danis, S Tomlinson, and D Carlson (2011), A conceptual framework for managing very diverse data for complex, interdisciplinary science, *J. Inf. Sci.*, 37(6), 555-569,10.1177/0165551511412705.

Paulot, F, D Wunch, JD Crounse, GC Toon, DB Millet, PF DeCarlo, C Vigouroux, NM Deutscher, GG Abad, J Notholt, T Warneke, JW Hannigan, C Warneke, JA de Gouw, EJ Dunlea, M De Maziere, DWT Griffith, P Bernath, JL Jimenez, and PO Wennberg (2011), Importance of secondary sources in the atmospheric budgets of formic and acetic acids, *Atmos. Chem. Phys.*, 11(5), 1989-2013,10.5194/acp-11-1989-2011.

Pedatella, NM, JM Forbes, A Maute, AD Richmond, TW Fang, KM Larson, and G Millward (2011), Longitudinal variations in the F region ionosphere and the topside ionosphere-plasmasphere: Observations and model simulations, *J. Geophys. Res-Space Phys.*, 116, 10.1029/2011JA016600.

Pegion, K and PD Sardeshmukh (2011), Prospects for improving subseasonal predictions, *Mon. Weather Rev.*, 139(11), 3648-3666,10.1175/MWR-D-11-00004.1.

Pegion, K, P Pegion, M Alexander, R Dole, and J Eischeid (2011), Long-term changes in extreme warm and cold months, *J. Climate*.

Pegion, P and M Hoerling (2011), Diagnosing a daily index of tornado variability with global reanalysis, *J. Climate*.

Perez, OJ, R Bilham, M Sequera, L Molina, P Gavotti, H Codallo, C Moncayo, C Rodriguez, R Velandia, M Guzman, and P Molnar (2011), GPS derived velocity field in western Venezuela: Dextral shear component associated to the Bocono fault and convergent component normal to the Andes, *Interciencia*, 36(1), 39-44.

Perlwitz, J, T Xu, M Hoerling, X Quan, and R Dole (2011), Extreme heat wave probability conditioned by blocking, *J. Climate*.

Perovich, D, H Eicken, and W Meier (2011), International coordination to improve observing, understanding, and predicting changes in the Arctic sea ice cover, *Eos*, Transactions of the American Geophysical Union.

Perovich, DK, KF Jones, B Light, H Eicken, T Markus, J Stroeve, and R Lindsay (2011), Solar partitioning in a changing Arctic sea-ice cover, *Ann. Glaciol.*, 52(57), 192-196.

Perring, AE, JP Schwarz, JR Spackman, R Bahreini, JA de Gouw, RS Gao, JS Holloway, DA Lack, JM Langridge, J Peischl, AM Middlebrook, TB Ryerson, C Warneke, LA Watts, and DW Fahey (2011), Characteristics of black carbon aerosol from a surface oil burn during the Deepwater Horizon oil spill, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048356.

Persson, POG (2011), Onset and end of the summer melt season over sea ice: Thermal structure and surface energy perspective from SHEBA, *Clim. Dynam.*, , 10.1007/s00382-011-1196-9.

Persson, POG, A Solomon, and M Shupe (2011), Melt season transition scenarios over sea ice from non-SHEBA in-situ data, *J. Geophys. Res.-Atmos*.

Persson, POG, C Wheeler, and J Cassano (2011), Performance of reanalyses over Arctic pack ice during SHEBA, *J. Climate*.

Persson, POG, EL Andreas, J-W Bao, CW Fairall, AA Grachev, PS Guest, and J Maslanik (2011), Determining wintertime heterogeneous pack ice characteristics and their impact on the aggregate atmospheric surface flux, *J. Geophys. Res.-Atmos.*

Peterson, MD, PL Hayes, IS Martinez, LC Cass, JL Achtyl, EA Weiss, and FM Geiger (2011), Second harmonic generation imaging with a kHz amplifier, *Opt. Mater. Express*, 1(1), 57-66.

Peterson, TC, RR Heim,Jr., R Hirsch, DP Kaiser, H Brooks, NS Diffenbaugh, RM Dole, JP Giovannettone, K Guirguis, TR Karl, RW Katz, KE Kunkel, D Lettenmaier, GJ McCabe, CJ Paciorek, KR Ryberg, S Schubert, VBS Silva, BC Stewart, AV Vecchia, G Villarini, RS (2011), Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States: State of knowledge, *Bull. Amer. Meteor. Soc.*, 49, .

Petropavlovskikh, I, R Evans, G McConville, S Oltmans, D Quincy, K Lantz, P Disterhoft, M Stanek, and L Flynn (2011), Sensitivity of Dobson and Brewer Umkehr ozone profile retrievals to ozone cross-sections and stray light effects, *Atmos. Meas. Tech.*, 4(9), 1841-1853,10.5194/amt-4-1841-2011.

Pfister, GG, DD Parrish, H Worden, LK Emmons, DP Edwards, C Wiedinmyer, GS Diskin, G Huey, SJ Oltmans, V Thouret, A Weinheimer, and A Wisthaler (2011), Characterizing summertime chemical boundary conditions for airmasses entering the US West Coast, *Atmos. Chem. Phys.*, 11(4), 1769-1790,10.5194/acp-11-1769-2011.

Phillips, T, S Leyk, H Rajaram, W Colgan, W Abdalati, D McGrath, and K Steffen (2011), Modeling moulin distribution on Sermeq Avannarleq glacier using ASTER and WorldView imagery and fuzzy set theory, *Remote Sens. Environ.*, 115(9), 2292-2301,10.1016/j.rse.2011.04.029.

Pickett-Heaps, CA, PJ Rayner, RM Law, P Ciais, PK Patra, P Bousquet, P Peylin, S Maksyutov, J Marshall, C Rodenbeck, RL Langenfelds, LP Steele, RJ Francey, P Tans, and C Sweeney (2011), Atmospheric CO2 inversion validation using vertical profile measurements: Analysis of four independent inversion models, J. *Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014887.

Pielke, Jr., RA (2011), Democracy's open secret, *Bridges*, 29, .

Pielke, Jr., RA (2011), Innovation policy lessons of the Vasa, *Bridges*, 32, .

Pielke, Jr., RA (2011), The policy advisor's dilemma, *Bridges*, 30, .

Pielke, Jr., RA (2011), Lessons of the L'Aquila lawsuit,*Bridges*, 31, .

Pielke, R (2011), John Marburger (1941-2011) OBITUARY, *Nature*, 476(7360), 284-284.

Pielke, R (2011), CORRESPONDENCE: Challenging convention, *Nat. Clim. Chang.*, 1(2), 70-70.

Pielke, R (2011), Science, policy and the value-free ideal, *Issues Sci. Technol.*, 27(2), 94-95.

Pielke, R and R Byerly (2011), Shuttle programme lifetime cost, *Nature*, 472(7341), 38-38.

Pielke, RA (2011), An evaluation of the targets and timetables of proposed Australian emissions reduction policies, *Environ. Sci. Policy*, 14(1), 20-27,10.1016/j.envsci.2010.10.008.

Pillai, D, C Gerbig, R Ahmadov, C Rodenbeck, R Kretschmer, T Koch, R Thompson, B Neininger, and JV Lavric (2011), High-resolution simulations of atmospheric CO2 over complex terrain - representing the Ochsenkopf mountain tall tower, *Atmos. Chem. Phys.*, 11(15), 7445-7464,10.5194/acp-11-7445-2011.

Pincus, R, RJP Hofmann, JL Anderson, K Raeder, N Collins, and JS Whitaker (2011), Can fully accounting for clouds in data assimilation improve short-term forecasts by global models?, *Mon. Weather Rev.*, 139(3), 946-957,10.1175/2010MWR3412.1.

Pizzo, V, G Millward, A Parsons, D Biesecker, S Hill, and D Odstrcil (2011), Wang-Sheeley-Arge-Enlil cone model transitions to operations, *Adv. Space Res.*, 9, 10.1029/2011SW000663.

Polley, WH, DD Briske, JA Morgan, K Wolter, DW Bailey, and JR Brown (2011), Climate change and North American rangelands: Evidence, trends, and implications, *Rangeland Ecol. Manag.*, 65, .

Porter, DF, JJ Cassano, and MC Serreze (2011), Analysis of the Arctic atmospheric energy budget in WRF: A comparison with reanalyses and satellite observations, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016622.

Prabha, TV, G Hoogenboom, and TG Smirnova (2011), Role of land surface parameterizations on modeling cold-pooling events and low-level jets, *Atmos. Res.*, 99(1), 147-161,10.1016/j.atmosres.2010.09.017.

Pratt, KA, SM Murphy, R Subramanian, PJ DeMott, GL Kok, T Campos, DC Rogers, AJ Prenni, AJ Heymsfield, JH Seinfeld, and KA Prather (2011), Flight-based chemical characterization of

biomass burning aerosols within two prescribed burn smoke plumes, *Atmos. Chem. Phys*., 11(24), 12549-12565,10.5194/acp-11-12549-2011.

Protat, A and CR Williams (2011), The accuracy of radar estimates of ice terminal fall speed from vertically pointing Doppler radar measurements, *J. Appl. Meteorol. Clim*., 50(10), 2120-2138,10.1175/JAMC-D-10-05031.1.

Pulkkinen, A, M Kuznetsova, A Ridley, J Raeder, A Vapirev, D Weimer, RS Weigel, M Wiltberger, G Millward, L Rastatter, M Hesse, HJ Singer and A Chulaki (2011), Geospace environment modeling 2008-2009 challenge: Ground magnetic field perturbations, *Adv. Space Res*., 9, 10.1029/2010SW000600.

Pulsifer, P, S Gearheard, H Huntington, MA Parsons, C McNeave, and H McCann (2011), The role of data management in engaging communities in Arctic research: Overview of the Exchange for Local Observations and Knowledge of the Arctic (ELOKA), *Polar Geogr*.

Pulsifer, PL (2011), Encoding Inuit knowledge: Rearticulating the formal ontology narrative, *Cult. Geogr.*

Pulsifer, PL, GJ Laidler, DRF Taylor, and A Hayes (2011), Towards an Indigenist data management program: reflections on experiences developing an atlas of sea ice knowledge and use, *Can. Geogr.*, 55(1), 108-124,10.1111/j.1541-0064.2010.00348.x.

Quan, XW, MP Hoerling, B Lyon, A Kumar, MA Bell, MK Tippett, and H Wang (2011), Prospects for dynamical prediction of meteorological drought, *J. Appl. Meteorol. Clim*.

Ralph, FM, PJ Neiman, GN Kiladis, K Weickmann, and DW Reynolds (2011), A multiscale observational case study of a Pacific atmospheric river exhibiting tropical-extratropical connections and a mesoscale frontal wave, *Mon. Weather Rev.*, 139(4), 1169-1189,10.1175/2010MWR3596.1.

Ray, EA, FL Moore, and KH Rosenlof (2011), Transport pathways in the stratosphere from long-lived trace gas measurements, .

Regonda, S, E Zagona, and B Rajagopalan (2011), Prototype decision support system for operations on the Gunnison basin with improved forecasts, *J. Water Resour. Plan*. Manage.-ASCE, 137(5), 428-438,10.1061/(ASCE)WR.1943-5452.0000133.

Rick, UK, MT Boykoff, and RA Pielke (2011), Effective media reporting of sea level rise projections: 1989-2009, *Environ. Res. Lett.*, 6(1), 10.1088/1748-9326/6/1/014004.

Riedel, TP, TH Betram, TA Crisp, EJ Williams, BM Lerner, A Vlasenko, S-M Li, JB Gilman, J de Gouw, DM Bon, NL Wagner, SS Brown, and JA Thornton (2011), Nitryl chloride and molecular chlorine in the coastal marine boundary layer, *Environ. Sci. Technol.*

Riemer, M, MT Montgomery, and ME Nicholls (2011), Further examination of the thermodynamic modification of the inflow layer of tropical cyclones by vertical shear, *Atmos. Chem. Phys.*

Rienecker, M, M Suarez, R Gelaro, R Todling, J Bacmeister, E Liu, M Bosilovich, S Schubert, L Takacs, G-K Kim, S Bloom, J Chen, D Collins, A Conaty, A da Silva, W Gu, J Joiner, R Koster, R Lucchesi, A Molod, T Owens, S Pawson, P Pegion, C Redder, R Reichl (2011), MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications, *J. Climate*, 24(14), 3624-3648,10.1175/JCLI-D-11-00015.1.

Riley, EM, BE Mapes, and SN Tulich (2011), Clouds associated with the Madden-Julian oscillation: A new perspective from CloudSat, *J. Atmos. Sci.*, 68(12), 3032-3051,10.1175/JAS-D-11-030.1.

Rinaldi, M, S Decesari, C Carbone, E Finessi, S Fuzzi, D Ceburnis, CD O'Dowd, J Sciare, JP Burrows, M Vrekoussis, B Ervens, K Tsigaridis, and MC Facchini (2011), Evidence of a natural marine source of oxalic acid and a possible link to glyoxal, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD015659.

Roberts, JM, PR Veres, AK Cochran, C Warneke, IR Burling, RJ Yokelson, B Lerner, JB Gilman, WC Kuster, R Fall, and J de Gouw (2011), Isocyanic acid in the atmosphere and its possible link to smoke-related health effects, *Proc. Natl. Acad. Sci. U. S. A.*, 108(22), 8966-8971,10.1073/pnas.1103352108.

Robinson, CB, JR Kimmel, DE David, JT Jayne, A Trimborn, DR Worsnop, and JL Jimenez (2011), Thermal desorption metastable atom bombardment ionization aerosol mass spectrometer, *Int. J. Mass Spectrom.*, 303(3-Feb), 164-172,10.1016/j.ijms.2011.01.027.

Robinson, NH, JF Hamilton, JD Allan, B Langford, DE Oram, Q Chen, K Docherty, DK Farmer, JL Jimenez, MW Ward, CN Hewitt, MH Barley, ME Jenkin, AR Rickard, ST Martin, G McFiggans, and H Coe (2011), Evidence for a significant proportion of Secondary Organic Aerosol from isoprene above a maritime tropical forest, *Atmos. Chem. Phys.*, 11(3), 1039-1050,10.5194/acp-11-1039-2011.

Roiger, A, H Schlager, A Schafler, H Huntrieser, M Scheibe, H Aufmhoff, OR Cooper, H Sodemann, A Stohl, J Burkhart, M Lazzara, C Schiller, KS Law, and F Arnold (2011), In-situ observation of Asian pollution transported into the Arctic lowermost stratosphere, *Atmos. Chem. Phys*., 11(21), 10975-10994,10.5194/acp-11-10975-2011.

Rollins, AW, TD Thornberry, RS Gao, BD Hall, and DW Fahey (2011), Catalytic oxidation of H-2 on platinum: a robust method for generating low mixing ratio H2O standards, *Atmos. Meas. Tech.*, 4(10), 2059-2064,10.5194/amt-4-2059-2011.

Rosenlof, KH and DF Hurst (2011), Stratospheric Water Vapor, *Bull. Amer. Meteor. Soc.*, 92, S70-S71.

Russell, AR, AE Perring, LC Valin, EJ Bucsela, EC Browne, KE Min, PJ Wooldridge, and RC Cohen (2011), A high spatial resolution retrieval of NO2 column densities from OMI: method and evaluation, *Atmospheric Chemistry and Physics*, 11(16), 8543-8554.

Ruuskanen, TM, M Miller, R Schnitzhofer, T Karl, M Graus, I Bamberger, L Hvrtnagl, F Brilli, G Wohlfahrt, and A Hansel (2011), Eddy covariance VOC emission and deposition fluxes above grassland using PTR-TOF, *Atmos. Chem. Phys*., 11(2), 611-625,10.5194/acp-11-611-2011.

Ryerson, T, R Camilli, J Kessler, E Kujawinski, C Reddy, D Valentine, E Atlas, D Blake, J de Gouw, S Meinardi, D Parrish, J Peischl, J Seewald, and C Warneke (2011), Chemical data quantify Deepwater Horizon hydrocarbon flow rate and environmental distribution, *Proc. Natl. Acad. Sci.*, , 10.1073/pnas.1110564109.

Ryerson, TB, KC Aikin, WM Angevine, EL Atlas, DR Blake, CA Brock, FC Fehsenfeld, RS Gao, JA de Gouw, DW Fahey, JS Holloway, DA Lack, RA Lueb, S Meinardi, AM Middlebrook, DM Murphy, JA Neuman, JB Nowak, DD Parrish, J Peischl, AE Perring, IB Pollack, AR Rav (2011), Atmospheric emissions from the Deepwater Horizon spill constrain air-water partitioning, hydrocarbon fate, and leak rate, *Geophys. Res. Lett.*, 38, 10.1029/2011GL046726.

Saito, K, T Zhang, D Yang, S Marhenko, RG Barry, V Romanovsky, and L Hinzman (2011), Influence of the physical terrestrial Arctic in the eco-climate system, *Ecology*.

Salas, JD, CJ Fu, and B Rajagopalan (2011), Long-Range forecasting of Colorado streamflows based on hydrologic, atmospheric, and oceanic data, *J. Hydrol. Eng.*, 16(6), 508-520,10.1061/(ASCE)HE.1943-5584.0000343.

Scambos, T (2011), Earth's ice: Sea level, climate, and our future commitment, *Bull. Atom. Scient.*, 67(1), 28-40,10.1177/0096340210392965.

Scambos, TA, E Berthier, and CA Shuman (2011), The triggering of subglacial lake drainage during rapid glacier drawdown: Crane Glacier, Antarctic Peninsula, *Ann. Glaciol.*, 52(59), 74-82.

Scambos, TA, M Frezzotti, T Haran, J Bohlander, JTM Lenaerts, MR van den Broeke, K Jezek, D Long, S Urbini, K Farness, T Neumann, M Albert, and J Gunnar-Winther (2011), Extent of zero-accumulation 'wind glaze' areas on the East Antarctic plateau: implications for continental ice mass balance, *J. Glaciol.*

Schaefer, K, TJ Zhang, L Bruhwiler, and AP Barrett (2011), Amount and timing of permafrost carbon release in response to climate warming, *Tellus B*, 63(2), 165-180,10.1111/j.1600-0889.2011.00527.x.

Schneider, J, F Freutel, SR Zorn, Q Chen, DK Farmer, JL Jimenez, ST Martin, P Artaxo, A Wiedensohler, and S Borrmann (2011), Mass- spectrometric identification of primary biological particle markers and application to pristine submicron aerosol measurements in Amazonia, *Atmos. Chem. Phys*., 11(22), 11415-11429,10.5194/acp-11-11415-2011.

Schulte-Pelkum, V, G Biasi, A Sheehan, and C Jones (2011), Differential motion between upper crust and lithospheric mantle in the central Basin and Range, *Nat. Geosci.*, 4(9), 619-623,10.1038/ngeo1229.

Schuur, EAG, Abbot, B, et al. (2011), High Risk of permafrost thaw, *Science*, 480, .

Schwalm, CR, CA Williams and, K Schaefer (2011), Carbon consequences of global hydrologic change, 1948-2009, *J. Geophys. Res.-Biogeosci.*, 116, 10.1029/2011JG001674.

Schwalm, CR, CA Williams, K Schaefer, I Baker, GJ Collatz, and C Rodenbeck (2011), Does terrestrial drought explain global CO2 flux anomalies induced by El Nino?, *Biogeosciences*, 8(9), 2493-2506,10.5194/bg-8-2493-2011.

Sedlar, J, M Tjernstrom, T Mauritsen, MD Shupe, IM Brooks, POG Persson, CE Birch, C Leck, A Sirevaag, and M Nicolaus (2011), A transitioning Arctic surface energy budget: the impacts of solar zenith angle, surface albedo and cloud radiative forcing, *Clim. Dyn*., 37(8-Jul),

1643-1660,10.1007/s00382-010-0937-5.

Seefeldt, M, T Hopson, and T Warner (2011), A characterization of the variation in relative humidity across West Africa during the dry season., *J. Appl. Meteorol. Clim.*

Seethala, C, G Pandithurai, JD Fast, SD Polade, MS Reddy, and SE Peckham (2011), Evaluating WRF-chem multi-scalen model in simulating aerosol radiative properties over the tropics - A case study over India, *MAPAN-J. Metrol. Soc. India*, 26(4), 269-284.

Segura, C, JH McCutchan, WM Lewis, and J Pitlick (2011), The influence of channel bed disturbance on algal biomass in a Colorado mountain stream, *Ecohydrology*, 4(3), 411-421,10.1002/eco.142.

Serreze, MC and AP Barrett (2011), Characteristics of the Beaufort sea high, *J. Clim.*, 24(1), 159-182,10.1175/2010JCLI3636.1.

Serreze, MC and RG Barry (2011), Processes and impacts of Arctic amplification: A research synthesis, *Glob. Planet. Change*, 77(2-Jan), 85-96,10.1016/j.gloplacha.2011.03.004.

Serreze, MC, AP Barrett, and JJ Cassano (2011), Circulation and surface controls on the lower tropospheric air temperature field of the Arctic, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015127.

Shaw, TA, and J Perlwitz (2011), The lifecycle of Northern Hemisphere downward wave coupling, *J. Clim.*

Shaw, TA, J Perlwitz, N Harnik, PA Newman, and S Pawson (2011), The impact of stratospheric ozone changes on downward wave coupling in the southern hemisphere, *J. Clim.*, 24(16), 4210-4229,10.1175/2011JCLI4170.1.

Shi, CM, V Masson-Delmotte, C Risi, T Eglin, M Stievenard, M Pierre, XC Wang, J Gao, FM Breon, QB Zhang, and V Daux (2011), Sampling strategy and climatic implications of tree-ring stable isotopes on the southeast Tibetan Plateau, *Earth Planet. Sci. Lett.*, 301(2-Jan), 307-316,10.1016/j.epsl.2010.11.014.

Shim, JS, M Kuznetsova, L Rastatter, M Hesse, D Bilitza, M Butala, M Codrescu, B Emery, B Foster, T Fuller-Rowell, J Huba, AJ Mannucci, X Pi, A Ridley, L Scherliess, RW Schunk, P Stephens, DC Thompson, L Zhu, D Anderson, JL Chau, JJ Sojka, and B Rideout (2011), CEDAR Electrodynamics Thermosphere Ionosphere (ETI) challenge for systematic assessment of ionosphere/thermosphere models: NmF2, hmF2, and vertical drift using ground-based observations, *Space Weather*, 9, 10.1029/2011SW000727.

Shin, SI and PD Sardeshmukh (2011), Critical influence of the pattern of Tropical Ocean warming on remote climate trends, *Clim. Dyn.*, 36(8-Jul), 1577-1591,10.1007/s00382-009-0732-3.

Shin, SI, PD Sardeshmukh, and SW Yeh (2011), Sensitivity of the northeast Asian summer monsoon to tropical sea surface temperatures, *Geophys. Res. Lett.*, 38, 10.1029/2011GL049391.

Shrivastava, M, J Fast, R Easter, WI Gustafson, RA Zaveri, JL Jimenez, P Saide, and A Hodzic (2011), Modeling organic aerosols in a megacity: comparison of simple and complex representations of the volatility basis set approach, *Atmos. Chem. Phys.*, 11(13), 6639-6662,10.5194/acp-11-6639-2011.

Shuman, CA, E Berthier, and TA Scambos (2011), 2001-2009 elevation and mass losses in the Larsen A and B embayments, Antarctic Peninsula, *J. Glaciol.*, 57(204), 737-754.

Shupe, MD (2011), Clouds at Arctic atmospheric observatories. Part II: Thermodynamic phase characteristics, *J. Appl. Meteorol. Climatol.*, 50(3), 645-661,10.1175/2010JAMC2468.1.

Shupe, MD, VP Walden, E Eloranta, T Uttal, JR Campbell, SM Starkweather, and M Shiobara (2011), Clouds at Arctic atmospheric observatories. Part I: Occurrence and macrophysical properties, *J. Appl. Meteorol. Climatol.*, 50(3), 626-644,10.1175/2010JAMC2467.1.

Simonsen, SB, SJ Johnsen, TJ Popp, BM Vinther, V Gkinis, and HC Steen-Larsen (2011), Past surface temperatures at the NorthGRIP drill site from the difference in firn diffusion of water isotopes, *Clim. Past Discuss.*, 7, 921-.

Sinha, A, M Berkelhammer, L Stott, M Mudelsee, H Cheng, and J Biswas (2011), The leading mode of Indian Summer Monsoon precipitation variability during the last millennium, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047713.

Sivy, TL, R Fall, and TN Rosenstiel (2011), Evidence of isoprenoid precursor toxicity in Bacillus subtilis, *Biosci. Biotechnol. Bioch.*, 75(12), 2376-2383,10.1271/bbb.110572.

Smirnov, D and DJ Vimont (2011), Variability of the Atlantic meridional mode during the atlantic hurricane season, *J. Clim.*, 24, 1409-1424.

Solomon, A and M Newman (2011), Decadal predictability of tropical Indo-Pacific Ocean temperature trends due to anthropogenic forcing in a coupled climate model, *Geophys. Res. Lett.*, 38, 10.1029/2010GL045978.

Solomon, A and M Newman (2011), Reconciling disparate 20th century Indo-Pacific ocean temperature trends in the instrumental record., *Nature Clim. Change*.

Solomon, A, L Goddard, A Kumar, J Carton, C Deser, I Fukumori, AM Greene, G Hegerl, B Kirtman, Y Kushnir, M Newman, D Smith, D Vimont, T Delworth, GA Meehl, and T Stockdale (2011), Distinguishing the roles of natural and anthropogenically forced decadal climate variability: Implications for Prediction, *Bull. Amer. Meteorol. Soc.*, 92(2), 141-+,10.1175/2010BAMS2962.1.

Solomon, A, MD Shupe, POG Persson, and H Morrison (2011), Moisture and dynamical interactions maintaining decoupled Arctic mixed-phase stratocumulus in the presence of a humidity inversion, *Atmos. Chem. Phys.*, 11(19), 10127-10148,10.5194/acp-11-10127-2011.

Solomon, S, JS Daniel, RR Neely, JP Vernier, EG Dutton, and LW Thomason (2011), The persistently variable 'background' stratospheric aerosol layer and global climate change, *Science*, 333(6044), 866-870,10.1126/science.1206027.

Sommariva, R, JA de Gouw, M Trainer, E Atlas, PD Goldan, WC Kuster, C Warneke, and FC Fehsenfeld (2011), Emissions and photochemistry of oxygenated VOCs in urban plumes in the Northeastern United States, *Atmos. Chem. Phys.*, 11(14), 7081-7096,10.5194/acp-11-7081-2011.

Sommariva, R, SS Brown, JM Roberts, DM Brookes, AE Parker, PS Monks, TS Bates, D Bon, JA de Gouw, GJ Frost, JB Gilman, PD Goldan, SC Herndon, WC Kuster, BM Lerner, HD Osthoff, SC Tucker, C Warneke, EJ Williams, and MS Zahniser (2011), Ozone production in remote oceanic and industrial areas derived from ship based measurements of peroxy radicals during TexAQS 2006, *Atmos. Chem. Phys.*, 11(6), 2471-2485,10.5194/acp-11-2471-2011.

Sommariva, R, TS Bates, D Bon, DM Brookes, JA de Gouw, JB Gilman, SC Herndon, WC Kuster, BM Lerner, PS Monks, HD Osthoff, AE Parker, JM Roberts, SC Tucker, C Warneke, EJ Williams, MS Zahniser, and SS Brown (2011), Modelled and measured concentrations of peroxy radicals and nitrate radical in the US Gulf Coast region during TexAQS 2006, *J. Atmos. Chem.*, 68(4), 331-362,10.1007/s10874-012-9224-7.

Spackman, JR, RS Gao, JP Schwarz, LA Watts, DW Fahey, L Pfister, and TP Bui (2011), Seasonal variability of black carbon mass in the tropical tropopause layer, *Geophys. Res. Lett.*, 38, 10.1029/2010GL046343.

Spracklen, DV, JL Jimenez, KS Carslaw, DR Worsnop, MJ Evans, GW Mann, Q Zhang, MR Canagaratna, J Allan, H Coe, G McFiggans, A Rap, and P Forster (2011), Aerosol mass spectrometer constraint on the global secondary organic aerosol budget, *Atmos. Chem. Phys.*, 11(23), 12109-12136,10.5194/acp-11-12109-2011.

Stark, H, SS Brown, KW Wong, J Stutz, CD Elvidge, IB Pollack, TB Ryerson, WP Dube, NL Wagner, and DD Parrish (2011), City lights and urban air, *Nat. Geosci.*, 4(11), 730-731.

Steeneveld, GJ, AAM Holtslag, RT McNider, and RA Pielke (2011), Screen level temperature increase due to higher atmospheric carbon dioxide in calm and windy nights revisited, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014612.

Steen-Larsen, HC, V Masson-Delmotte, J Sjolte, SJ Johnsen, BM Vinther, FM Breon, HB Clausen, D Dahl-Jensen, S Falourd, X Fettweis, H Gallee, J Jouzel, M Kageyama, H Lerche, B Minster, G Picard, HJ Punge, C Risi, D Salas, J Schwander, K Steffen, AE Sveinbj (2011), Understanding the climatic signal in the water stable isotope records from the NEEM shallow firn/ice cores in northwest Greenland, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014311.

Stone, RS, JA Augustine, EG Dutton, NT O'Neill, and A Saha (2011), Empirical determinations of the longwave and shortwave radiative forcing efficiencies of wildfire smoke, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015471.

Stott, PA, M Allen, N Christidis, R Dole, M Hoerling, C Huntingford, P Pall, J Perlwitz, and D Stone (2011), Attribution of weather and climate-related extreme events, *WCRP Conference 2011*.

Stroeve, JC, J Maslanik, MC Serreze, I Rigor, W Meier, and C Fowler (2011), Sea ice response to an extreme negative phase of the Arctic Oscillation during winter 2009/2010, *Geophys. Res. Lett.*, 38, 10.1029/2010GL045662.

Stroeve, JC, MC Serreze, A Barrett, and DN Kindig (2011), Attribution of recent changes in autumn cyclone associated precipitation in the Arctic, *Tellus A*, 63(4), 653-663,10.1111/j.1600-0870.2011.00515.x.

Suarez, A, R Mahmood, AI Quintanar, and A Beltran-Przekurat (2011), Sensitivity of planetary boundary layer to varying soil moisture: a comparison of the MM5 and the RAMS simula-

tions, *J. Appl. Meteorol. Clim.*

Sun, Y, DZ Sun and L Wu (2011), Evidence from climate models for a role of ENSO events in shaping the climatological size and temperature of the warm-pool, *J. Clim*.

Sutton, P, S Anderson, B Tuttle, and L Morse (2011), The real wealth of nations: Mapping and monetizing the human ecological footprint, *Ecol. Indic.*, , 10.1016/j.ecolind.2011.03.008.

Svensson, G, AAM Holtslag, V Kumar, T Mauritsen, GJ Steeneveld, WM Angevine, E Bazile, A Beljaars, EIF de Bruijn, A Cheng, L Conangla, J Cuxart, M Ek, MJ Falk, F Freedman, H Kitagawa, VE Larson, A Lock, J Mailhot, V Masson, S Park, J Pleim, S Soderberg, W (2011), Evaluation of the diurnal cycle in the atmospheric boundary layer over land as represented by a variety of single-column models: The second GABLS experiment, *Bound.-Layer Meteor.*, 140(2), 177-206,10.1007/s10546-011-9611-7.

Swenson, SC and JM Wahr (2011), Estimating signal loss in regularized GRACE gravity field solutions, Geophys. J. Int., 185(2), 693-702,10.1111/j.1365-246X.2011.04977.x.

Taber, M, T Ledley, S Lynds, B Domenico, and L Dahlman (2011), Geoscience data for educational use: Recommendations from scientific/technical and educational communities, *J. Geophys. Educ.*

Talukdar, RK, L Zhu, KJ Feierabend, and JB Burkholder (2011), Rate coefficients for the reaction of methylglyoxal (CH3COCHO) with OH and NO3 and glyoxal (HCO)(2) with NO3, *Atmos. Chem. Phys.*, 11(21), 10837-10851,10.5194/acp-11-10837-2011.

Tandon, NF, LM Polvani, and SM Davis (2011), The response of the tropospheric circulation to water vapor-like forcings in the stratosphere, J. Clim., 24(21), 5713-5720,10.1175/JCLI-D-11-00069.1.

Tedesco, M, X Fettweis, MR van den Broeke, RSW van de Wal, CJPP Smeets, WJ van de Berg, MC Serreze, and JE Box (2011), The role of albedo and accumulation in the 2010 melting record in Greenland, *Environ. Res. Lett.*, 6(1), 10.1088/1748-9326/6/1/014005.

Temmer, M, T Rollett, C Mostl, AM Veronig, B Vrsnak, and D Odstrcil (2011), Influence of the ambient solar wind flow on the propagation behavior of interplanetary coronal mass ejections, *Astrophys. J.*, 743(2), 10.1088/0004-637X/743/2/101.

Thornberry, T, T Gierczak, RS Gao, H Vomel, LA Watts, JB Burkholder, and DW Fahey (2011), Laboratory evaluation of the effect of nitric acid uptake on frost point hygrometer performance, *Atmos. Meas. Tech.*, 4(2), 289-296,10.5194/amt-4-289-2011.

Timm, OE, HF Diaz, TW Giambelluca, and M Takahashi (2011), Projection of changes in the frequency of heavy rain events over Hawaii based on leading Pacific climate modes, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014923.

Tiwari, VM and J Wahr (2011), Grace estimates of water mass loss from northern Indian region, *J. Geol. Soc. India*, 78(3), 279-280,10.1007/s12594-011-0081-9.

Tiwari, VM, JM Wahr, S Swenson and B Singh (2011), Land water storage variation over Southern India from space gravimetry, *Curr. Sci.*, 101(4), 536-540.

Tjernstrvm, M, C Birch, I Brooks, C Leck, T Mauritsen, J Paatero, O Persson, J Sedlar, M Shupe, M Szczodrak, and C Wheeler (2011), Central Arctic atmospheric conditions during the Arctic Summer Cloud Ocean Study (ASCOS) field phase: Contrasting to previous expeditions, *Atmos. Chem. Phys*.

Tjernstrvm, M, C Leck, C Birch, B Brooks, I Brooks, L Bdcklin, R Chang, E Granath, M Graus, J Heintzenberg, A Held, A Hind, S de la Rosa Hxhn, P Johnston, J Knulst, M Westberg, G de Leeuw, L Di Liberto, M Martin, P Matrai, T Mauritsen, M M|ller, S Norris, (2011), The Arctic Summer Cloud-Ocean Study (ASCOS): Overview and experimental design, *Atmos. Chem. Phys.*

Trenberth, K, A Watson, RA Pielke, Jr, K Emanuel, J Curry, L Bouwer, GC Hegerl, and W Hooke (2011), Forum: Is extreme weather linked to global warming?, *Yale Environment 360*.

Tucker, GE, SW McCoy, AC Whittaker, GP Roberts, ST Lancaster, and R Phillips (2011), Geomorphic significance of postglacial bedrock scarps on normal-fault footwalls, *J. Geophys. Res.-Earth Surf.*, 116, 10.1029/2010JF001861.

Tulich, SN, GN Kiladis, and A Suzuki-Parker (2011), Convectively coupled Kelvin and easterly waves in a regional climate simulation of the tropics, *Clim. Dyn.*, 36(2-Jan), 185-203,10.1007/s00382-009-0697-2.

Turnbull, JC, A Karion, ML Fischer, I Faloona, T Guilderson, SJ Lehman, BR Miller, JB Miller, S Montzka, T Sherwood, S Saripalli, C Sweeney, and PP Tans (2011), Assessment of fossil fuel carbon dioxide and other anthropogenic trace gas emissions from airborne measurements over Sacramento, California in spring 2009, *Atmos. Chem. Phys.*, 11(2), 705-721,10.5194/acp-11-705-2011.

Turnbull, JC, PP Tans, SJ Lehman, D Baker, TJ Conway, YS Chung, J Gregg, JB Miller, JR Southon, and LX Zhou (2011), Atmospheric observations of carbon monoxide and fossil fuel CO2 emissions from East Asia, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016691.

Turuncoglu, U, N Dalfes, S Murphy, and C DeLuca (2011), Toward self-describing and workflow integrated Earth system models: A coupled atmosphere-ocean modeling system application, *Environ. Modell. Softw*.

Turuncoglu, U, S Murphy, C DeLuca, and N Dalfes (2011), A scientific workflow environment for earth system related studies, *Computat. Geosci.*, 37, 943-952.

Vaida, V (2011), Perspective: Water cluster mediated atmospheric chemistry, *J. Chem. Phys.*, 135(2), 10.1063/1.3608919.

van Wijk, K, TD Mikesell, V Schulte-Pelkum, and J Stachnik (2011), Estimating the Rayleigh-wave impulse response between seismic stations with the cross terms of the Green tensor, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047442.

Vecherin, SN, DK Wilson, and VE Ostashev (2011), Incorporating source directionality into outdoor sound propagation calculations, *J. Acoust. Soc. Am.*, 130(6), 3608-3622,10.1121/1.3655881.

Veres, PR, JM Roberts, AK Cochran, JB Gilman, WC Kuster, JS Holloway, M Graus, J Flynn, B Lefer, C Warneke, and J de Gouw (2011), Evidence of rapid production of organic acids in an urban air mass, *Geophys. Res. Lett.*, 38, 10.1029/2011GL048420.

Verhulst, NO, YT Qiu, H Beijleveld, C Maliepaard, D Knights, S Schulz, D Berg-Lyons, CL Lauber, W Verduijn, GW Haasnoot, R Mumm, HJ Bouwmeester, FHJ Claas, M Dicke, JJA van Loon, W Takken, R Knight, and RC Smallegange (2011), Composition of human skin microbiota affects attractiveness to malaria mosquitoes, *PLoS One*, 6(12), 10.1371/journal.pone.0028991.

Vimeux, F, G Tremoy, C Risi, and R Gallaire (2011), A strong control of the South American SeeSaw on the intra-seasonal variability of the isotopic composition of precipitation in the Bolivian Andes, *Earth Planet. Sci. Lett.*, 307(2-Jan), 47-58,10.1016/j.epsl.2011.04.031.

Vizcarra, N (2011), Waiting for Gojal, *Sensing Our Planet: NASA Earth Science Research Features*, , 2-5.

Vizcarra, N (2011), Once more into the storm, *Sensing Our Planet: NASA Earth Science Research Features*, 2011, 28-31.

Vizcarra, N (2011), Looking for mud, *Sensing Our Planet: NASA Earth Science Research Features*, , 40-43.

Vogel, B, LL Pan, P Konopka, G Gunther, R Muller, W Hall, T Campos, I Pollack, A Weinheimer, J Wei, EL Atlas, and KP Bowman (2011), Transport pathways and signatures of mixing in the extratropical tropopause region derived from Lagrangian model simulations, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD014876.

Voigt, C, U Schumann, P Jessberger, T Jurkat, A Petzold, JF Gayet, M Kramer, T Thornberry, and DW Fahey (2011), Extinction and optical depth of contrails, *Geophys. Res. Lett.*, 38, 10.1029/2011GL047189.

Vollmer, MK, BR Miller, M Rigby, S Reimann, J Muhle, PB Krummel, S O'Doherty, J Kim, TS Rhee, RF Weiss, PJ Fraser, PG Simmonds, PK Salameh, CM Harth, RHJ Wang, LP Steele, D Young, CR Lunder, O Hermansen, D Ivy, T Arnold, N Schmidbauer, KR Kim, BR Greally, (2011), Atmospheric histories and global emissions of the anthropogenic hydrofluorocarbons HFC-365mfc, HFC-245fa, HFC-227ea, and HFC-236fa, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2010JD015309.

Voronovich, AG, VE Ostashev, and JA Colosi (2011), Temporal coherence of acoustic signals in a fluctuating ocean, *J. Acoust. Soc. Am.*, 129(6), 3590-3597,10.1121/1.3533726.

Wagner, AJ and NC Slowey (2011), Oxygen isotopes in seawater from the Texas-Louisiana shelf, *Bull. Mar. Sci.*, 87(1), 1-12,10.5343/bms.2010.1004.

Wagner, NL, WP Dube, RA Washenfelder, CJ Young, IB Pollack, TB Ryerson, and SS Brown (2011), Diode laser-based cavity ring-down instrument for NO3, N2O5, NO, NO2 and O-3 from aircraft, *Atmos. Meas. Tech.*, 4(6), 1227-1240,10.5194/amt-4-1227-2011.

Walters, WA, JG Caporaso, CL Lauber, D Berg-Lyons, N Fierer, and R Knight (2011), Primer Prospector: De novo design and taxonomic analysis of barcoded polymerase chain reaction primers, *Bioinformatics*, 27(8), 1159-1161,10.1093/bioinformatics/btr087.

Wang, H, TJ Fuller-Rowell, RA Akmaev, M Hu, DT Kleist, and MD Iredell (2011), First simulations with a whole atmosphere data assimilation and forecast system: The January 2009 major

sudden stratospheric warming, *J. Geophys. Res-Space Phys*., 116, 10.1029/2011JA017081.

Wang, Q, DJ Jacob, JA Fisher, J Mao, EM Leibensperger, CC Carouge, P Le Sager, Y Kondo, JL Jimenez, MJ Cubison, and SJ Doherty (2011), Sources of carbonaceous aerosols and deposited black carbon in the Arctic in winter-spring: implications for radiative forcing, *Atmos. Chem. Phys.*, 11(23), 12453-12473,10.5194/acp-11-12453-2011.

Wang, XL, Y Feng, GP Compo, VR Swail, FW Zwiers, RJ Allan, and PD Sardeshmukh (2011), Trends and low frequency variability of extra-tropical cyclone activity in the ensemble of twentieth century reanalysis, *Clim. Dyn.*

Wang, XLL, H Wan, FW Zwiers, VR Swail, GP Compo, RJ Allan, RS Vose, S Jourdain, and XG Yin (2011), Trends and low-frequency variability of storminess over western Europe, 1878-2007, *Clim. Dyn.*, 37(12-Nov), 2355-2371,10.1007/s00382-011-1107-0.

Ward, D, K Mahan, and V Schulte-Pelkum (2011), Roles of quartz and mica in seismic anisotropy of mylonites, *Geophys. J. Int.*

Warneke, C, JM Roberts, P Veres, J Gilman, WC Kuster, I Burling, R Yokelson, and JA de Gouw (2011), VOC identification and inter-comparison from laboratory biomass burning using PTR-MS and PIT-MS, *Int. J. Mass Spectrom.*, 303(1), 6-14,10.1016/j.ijms.2010.12.002.

Warneke, C, P Veres, JS Holloway, J Stutz, C Tsai, S Alvarez, B Rappenglueck, FC Fehsenfeld, M Graus, JB Gilman, and JA de Gouw (2011), Airborne formaldehyde measurements using PTR-MS: calibration, humidity dependence, inter-comparison and initial results, *Atmos. Meas. Tech.*, 4(10), 2345-2358,10.5194/amt-4-2345-2011.

Washenfelder, RA, CJ Young, SS Brown, WM Angevine, EL Atlas, DR Blake, DM Bon, MJ Cubison, JA de Gouw, S Dusanter, J Flynn, JB Gilman, M Graus, S Griffith, N Grossberg, PL Hayes, JL Jimenez, WC Kuster, BL Lefer, IB Pollack, TB Ryerson, H Stark, PS Stevens (2011), The glyoxal budget and its contribution to organic aerosol for Los Angeles, California, during CalNex 2010, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016314.

Washenfelder, RA, NL Wagner, WP Dube, and SS Brown (2011), Measurement of atmospheric ozone by cavity ring-down spectroscopy, *Environ. Sci. Technol.*, 45(7), 2938-2944,10.1021/es103340u.

Weatherhead, E (2011), Solar renewable energy, *B. Am. Meteorol. Soc.*

Weatherhead, E and G Frederick (2011), Building a stronger weather and climate enterprise: Keeping the economy moving, *B. Am. Meteorol. Soc*.

Webb, A and B Fox-Kemper (2011), Wave spectral moments and Stokes drift estimation, *Ocean Model.*, 40(4-Mar), 273-288,10.1016/j.ocemod.2011.08.007.

Wei, M, D Sandwell, Y Fialko, and R Bilham (2011), Slip on faults in the Imperial Valley triggered by the 4 April 2010 Mw 7.2 El Mayor-Cucapah earthquake revealed by InSAR, *Geophys. Res. Lett.*, 38, 10.1029/2010GL045235.

Weil, JC (2011), Modeling of winds, temperature, and turbulence in the stable boundary layer: a 'similarity' K-model closure, *J. Atmos. Sci.*

Weil, JC, EG Patton, and PP Sullivan (2011), Lagrangian modeling of dispersion in the stable boundary layer using LES fields, *J. Atmos. Sci*.

Weil, JC, PP Sullivan, EG Patton, and CH Moeng (2011), Statistical variability of dispersion in the convective boundary layer: ensembles of simulations and observations, *Bound.-Lay. Meteorol*.

Weirich, SR, J Silverstein, and B Rajagopalan (2011), Effect of average flow and capacity utilization on effluent water quality from US municipal wastewater treatment facilities, *Water Res.*, 45(14), 4279-4286,10.1016/j.watres.2011.06.002.

Wen, Z, TJ Zhang, Y Sheng, W Ma, QB Wu, WJ Feng, and ZZ Sun (2011), Managing ice-rich permafrost exposed during cutting excavation along Qinghai-Tibetan railway: Experiences and implementation, *Eng. Geol.*, 122(4-Mar), 316-327,10.1016/j.enggeo.2011.07.012.

Whiteman, DN, KC Vermeesch, LD Oman, and EC Weatherhead (2011), The relative importance of random error and observation frequency in detecting trends in upper tropospheric water vapor, *J. Geophys. Res.-Atmos.*, 116, 10.1029/2011JD016610.

Wiese, DN, P Visser, and RS Nerem (2011), Estimating low resolution gravity fields at short time intervals to reduce temporal aliasing errors, *Adv. Space Res.*, 48(6), 1094-1107,10.1016/j.asr.2011.05.027.

Wiese, DN, RS Nerem and SC Han (2011), Expected improvements in determining continental hydrology, ice mass variations, ocean bottom pressure signals, and earthquakes using two pairs of dedicated satellites for temporal gravity recovery, *J. Geophys. Res.-Solid Earth*, 116, 10.1029/2011JB008375.

Wilcox, T, K Mueller, P Upton, YG Chen, ST Huang, B Yanites, and G Tucker (2011), Linking Taiwan's subcritical Hsuehshan Range topography and foreland basin architecture, *Tectonics*, 30(TC4011), 10.1029/2010TC002825.

Williams, CR (2011), Inexpensive FM-CW radar for boundary-layer precipitation studies, I*EEE Geosci. Remote S.*, 8(6), 1031-1035,10.1109/LGRS.2011.2150733.

Winterbottom, HR and EP Chassignet (2011), A vortex isolation and removal algorithm for numerical weather prediction model tropical cyclone applications, *J. Adv. Model. Earth Syst.*, 3, 10.1029/2011MS000088.

Wofsy, S, BC Daube, R Jimenez, E Kort, JV Pittman, S Park, R Commane, B Xiang, G Santoni, D Jacob, J Fisher, C Pickett-Heaps, H Wang, K Wecht, QQ Wang, BB Stephens, S Shertz, P Romashkin, T Campos, J Haggerty, WA Cooper, D Rogers, S Beaton, R Hendershot, (2011), HIAPER Pole-to-Pole Observations (HIPPO): Fine-grained, global scale measurements of climatically important atmospheric gases and aerosols, *Phil. Trans. R. Soc. A*, 369(1943), 2073-2086.

Wolfe, GM, JA Thornton, NC Bouvier-Brown, AH Goldstein, JH Park, M Mckay, DM Matross, J Mao, WH Brune, BW LaFranchi, EC Browne, KE Min, PJ Wooldridge, RC Cohen, JD Crounse, IC Faloona, JB Gilman, WC Kuster, JA de Gouw, A Huisman, and FN Keutsch (2011), The Chemistry of Atmosphere-Forest Exchange (CAFE) Model - Part 2: Application to BEARPEX-2007 observations, *Atmos. Chem. Phys.*, 11(3), 1269-1294,10.5194/acp-11-1269-2011.

Wood, R, CR Mechoso, CS Bretherton, RA Weller, B Huebert, F Straneo, BA Albrecht, H Coe, G Allen, G Vaughan, P Daum, C Fairall, D Chand, LG Klenner, R Garreaud, C Grados, DS Covert, TS Bates, R Krejci, LM Russell, S de Szoeke, A Brewer, SE Yuter, SR Sprin (2011), The VAMOS Ocean-Cloud-Atmosphere-Land Study Regional Experiment (VOCALS-REx): goals, platforms, and field operations, *Atmos. Chem. Phys*., 11(2), 627-654,10.5194/acp-11-627-2011.

Worden, J, D Noone, J Galewsky, A Bailey, K Bowman, D Brown, J Hurley, S Kulawik, J Lee, and M Strong (2011), Estimate of bias in Aura TES HDO/H2O profiles from comparison of TES and in situ HDO/H2O measurements at the Mauna Loa observatory, *Atmos. Chem. Phys*., 11(9), 4491-4503,10.5194/acp-11-4491-2011.

Worton, DR, AH Goldstein, DK Farmer, KS Docherty, JL Jimenez, JB Gilman, WC Kuster, J de Gouw, BJ Williams, NM Kreisberg, SV Hering, G Bench, M McKay, K Kristensen, M Glasius, JD Surratt, and JH Seinfeld (2011), Origins and composition of fine atmospheric carbonaceous aerosol in the Sierra Nevada Mountains, California, *Atmos. Chem. Phys.*, 11(19), 10219-10241,10.5194/acp-11-10219-2011.

Wu, CQ, TJ Zhou, DZ Sun, and Q Bao (2011), Water vapor and cloud radiative forcings over the Pacific Ocean simulated by the LASG/IAP AGCM: Sensitivity to convection schemes, *Adv. Atmos. Sci.*, 28(1), 80-98,10.1007/s00376-010-9205-1.

Wunch, D, GC Toon, JFL Blavier, RA Washenfelder, J Notholt, B Connor, D Griffith, and PO Wennberg (2011), The Total Carbon Column Observing Network (TCCON), *Phil. Trans. R. Soc. A.*, 369, 2087-2112,10.1098/rsta.2010.0240.

Xie, LA, HQ Liu, B Liu, and SW Bao (2011), A numerical study of the effect of hurricane wind asymmetry on storm surge and inundation, *Ocean Model*., 36(2-Jan), 71-79,10.1016/j.ocemod.2010.10.001.

Yamaguchi, T, DA Randall, and MF Khairoutdinov (2011), Cloud modeling tests of the ULTIMATE-MACHO scalar advection scheme, *Mon. Weather Rev*., 139(10), 3248-3264,10.1175/MWR-D-10-05044.1.

Yang, XG, TJ Zhang, DH Qin, SC Kang, and XA Qin (2011), Characteristics and changes in air temperature and glacier's response on the North Slope of Mt. Qomolangma (Mt. Everest), *Arct. Antarct. Alp. Res*., 43(1), 147-160,10.1657/1938-4246-43.1.147.

Yang, YJ, MH Ritzwoller, and CH Jones (2011), Crustal structure determined from ambient noise tomography near the magmatic centers of the Coso region, southeastern California, Geochem. *Geophys. Geosyst.*, 12, 10.1029/2010GC003362.

Yang, ZH, A Sheehan, and P Shearer (2011), Stress-induced upper crustal anisotropy in southern California, *J. Geophys. Res.-Solid Earth*, 116, 10.1029/2010JB007655.

Yanites, BJ, GE Tucker, HL Hsu, CC Chen, YG Chen, and KJ Mueller (2011), The influence of sediment cover variability on long-term river incision rates: An example from the Peikang River, central Taiwan, *J. Geophys. Res.-Earth Surf.*, 116, 10.1029/2010JF001933.

Yatavelli, RLN, F Lopez-Hilfiker, JD Wargo, JR Kimmel, MJ Cubison, TH Bertram, JL Jimenez,

M Gonin, DR Worsnop, and JA Thornton (2011), A chemical ionization high-resolution time-of-flight mass spectrometer coupled to a micro orifice volatilization impactor (MOVI-HRToF-CIMS) for analysis of gas and particle-phase organic species, *Aerosol Sci. Tech*.

Yilmaz, P, R Kottmann, D Field, R Knight, JR Cole, L Amaral-Zettler, JA Gilbert, I Karsch-Mizrachi, A Johnston, G Cochrane, R Vaughan, C Hunter, J Park, N Morrison, P Rocca-Serra, P Sterk, M Arumugam, M Bailey, L Baumgartner, BW Birren, MJ Blaser, V Bonaz (2011), Minimum information about a marker gene sequence (MIMARKS) and minimum information about any (x) sequence (MIxS) specifications, *Nat. Biotechnol.*, 29(5), 415-420,10.1038/nbt.1823.

Young, PJ, DWJ Thompson, KH Rosenlof, S Solomon, and JF Lamarque (2011), The seasonal cycle and interannual variability in stratospheric temperatures and links to the Brewer-Dobson circulation: An analysis of MSU and SSU data, *J. Clim.,* 24(23), 6243-6258,10.1175/JCLI-D-10-05028.1.

Yuan, DY, JD Champagnac, WP Ge, P Molnar, PZ Zhang, WJ Zheng, HP Zhang, and XW Liu (2011), Late Quaternary right-lateral slip rates of faults adjacent to the lake Qinghai, northeastern margin of the Tibetan Plateau, *Geol. Soc. Am. Bull*., 123(10-Sep), 2016-2030,10.1130/B30315.1.

Zabotin, N and T Bullett (2011), Spatial effects of HF multiple scattering in the ionosphere: Experimental observations, *Radio Sci.*, 46, 10.1029/2011RS004645.

Zabotin, NA and OA Godin (2011), Acoustic wavefront tracing in inhomogeneous, moving media, *J. Comput. Acoust*.

Zabotin, NA and OA Godin (2011), Emergence of acoustic green's functions from time averages of ambient noise, *Acta Acust. United Ac.*, 97(1), 44-53,10.3813/AAA.918385.

Zaveri, RA et al. (incl. RD Marchbanks, CJ Senff, AM Weickmann) (2011), Overview of the 2010 Carbonaceous Aerosols and Radiative Effects Study (CARES), *Atmos. Chem. Phys. Discuss*., , 10.5194/acpd-12-1299-2012.

Zemp, M, F Paul, . B Raup, . (54 authors total) (2011), Summary of international glacier monitoring summit, *Earth Observer*, 23(4), 28-31.

Zhang, J, Y Qi, D Kingsmill, and K Howard (2011), Radar-based quantitative precipitation estimation for the cool season in complex terrain: Case studies from the NOAA hydrometeorological testbed (HMT), *J. Hydrometerol.*

Zhang, K, J Feichter, J Kazil, H Wan, W Zhuo, AD Griffiths, H Sartorius, W Zahorowski, M Ramonet, M Schmidt, C Yver, REM Neubert, and EG Brunke (2011), Radon activity in the lower troposphere and its impact on ionization rate: a global estimate using different radon emissions, *Atmos. Chem. Phys*., 11(15), 7817-7838,10.5194/acp-11-7817-2011.

Zhang, T, MP Hoerling, J Perlwitz, DZ Sun, and D Murray (2011), Physics of US surface temperature response to ENSO, *J. Clim.*, 24(18), 4874-4887,10.1175/2011JCLI3944.1.

Zhang, TJ (2011), Progress of global permafrost and climate change studies, *Quarternary Res.*

Zhao, NZ, T Ghosh, NA Currit, and CD Elvidge (2011), Relationships between satellite observed lit area and water footprints, *Water Resour. Manag.*, 25(9), 2241-2250,10.1007/s11269-011-9804-3.

Zheng, YX, T Shinoda, JL Lin, and GN Kiladis (2011), Sea surface temperature biases under the stratus cloud deck in the southeast Pacific Ocean in 19 IPCC AR4 coupled general circulation models, *J. Clim.*, 24(15), 4139-4164,10.1175/2011JCLI4172.1.

Ziskin, D, C Aubrecht, C Elvidge, B Tuttle, CM Eakin, AE Strong, and LS Guild (2011), Describing coral reef bleaching using very high spatial resolution satellite imagery: experimental methodology, *J. Appl. Remote Sens.*, 5, 10.1117/1.3595300.

Books

Alexander, CR (2011). *A Mobile Radar Based Climatology of Supercell Tornado Structures and Dynamics*. University of Oklahoma and ProQuest/UMI Dissertation Publishing.

Boykoff, M (2011). *Who Speaks for the Climate? Making Sense of Mass Media Reporting on Climate Change.* Cambridge University Press.

Hughes, MK, TW Swetnam, and HF Diaz (eds.) (2011). *Dendroclimatology, Progress and Prospects.* Springer.

Solomon, S, D Battisti, S Doney, K Hayhoe, IM Held, DP Lettenmaier, D Lobell, HD Matthews, R Pierrehubert, M Raphael, R Richels, RL Root, K Steffen, C Tebaldidi, and GW Yohe (2011). *Climate Stabilization Targets: Emissions, Concentrations, and Impacts Over Decades to Millennia.* National Academies Press.

Book Chapters

Angevine, WM, and CJ Senff (2011). Boundary Layers: Observational Techniques—Remote. In *Encyclopedia of Atmospheric Sciences* (Eds: JR Holton, J Pyle, and JA Curry) .

Averyt, K (2011). The Coal Conundrum. In *The Water-Energy Nexus in the American West* (Eds: D Kenney, R Wilkinson). Edward Elgar Publishing.

Berkelhammer, M, Sinha, Stott, Cheng, Pausata, Yoshimura (2011). An Abrupt Shift in the Indian Summer Monsoon 4,000 years ago. In *Geophysical Monograph*. (Ed: R Fla), AGU.

Boykoff, M (2011). Box 16.1: The role of the media. In *Climate Change: Global Risks, Challenges and Decisions* (Eds: K Richardson, W Steffen, and D Liverman), pp. 455-458. Cambridge University Press.

Brekke, LB, J Barsugli (2011). Uncertainties in Projections of Future Changes in Extremes. In *Exremes in a Changing Climate* (Ed: A AghaKouchak). Springer.

Eakins, B, R Hare, and M Jakobsson (2011). Data Cleaning (Eds: K Marks), pp. 85-92. International Hydrographic Bureau.

Elvidge, CD, KE Baugh, PC Sutton, B Bhaduri, BT Tuttle, T Ghosh,D Ziskin, and EH Erwin (2011). Who's in the Dark: Satellite Based Estimates of Electrification Rates. *In Urban Remote Sensing: Monitoring, Synthesis and Modeling in the Urban Environment* (Ed.: X Yang). Wiley-Blackwell.

Fuller-Rowell, TJ (2011). Storm-Time Response of the Thermosphere-Ionosphere System. In *Aeronomy of the Earth's Atmosphere and Ionosphere* (Eds: Abdu, MA, D Pancheva, A Bhattacharyya), pp.419-436. Springer.

Gearheard, S, H Huntington, M Parsons, C McNeave and P Pulsifer (2011). Exchanging and Sharing Knowledge with Local Stakeholders—ELOKA. In *Understanding Earth's Polar Challenges: International Polar Year 2007-2008* (Eds: I Krupnik, I Allison, R Bell, P Cutler, D Hik, J Lspez-Martmnez, V Rachold, E Sarukhanian, and C Summerhayes), pp. 581-584. CCI Press.

Hamlington, BD, OA Godin, VG Irisov, and R Leben (2011). Detection of tsunamis from changes in ocean surface roughness. In *The Tsunami Threat—Research and Technology* (Ed.: NA Mvrner), pp. 29-46. INTECH, Vienna.

Kargel, JS, R Furfaro, G Kaser, G Leonard, W Fink, C Huggel, A Kaab, B Raup, J Reynolds, D Wolfe, and M Zapata (2011). ASTER Imaging and Analysis of Glacier Hazards. In *Land Remote Sensing and Global Environmental Change* (Eds: Ramachandran, B, CO Justice, and MJ Abrams). Springer.

Klein, L, A Savtchenko, A Taaheri, C Praderas, and SJS Khalsa (2011). The Language of EOS Data: Hierarchical Data Format. In *Land Remote Sensing and Global Environmental Change* (Eds: Ramachandran, B, C Justice, and M Abrams), pp.203-227. Springer.

Liebmann, B, and CR Mechoso (2011). The South American Monsoon System. In *The Global Monsoon System: Research and Forecast, 2nd Edition* (Ed: CP Chang), pp.137-157. World Scientific.

Maruyama, N, TJ Fuller-Rowell, MV Codrescu, D Anderson, AD Richmond, A Maute, S Sazykin, RW Spiro, RA Wolf, FR Toffoletto, and GH Millward (2011). Modeling the Storm Time Electrodynamics. In *Aeronomy of the Earth's Atmosphere and Ionosphere* (MA Abdu, D Pancheva, A Bhattacharyya), pp.455-464. Springer.

Mitrovica, JX and J Wahr (2011). Ice Age Earth Rotation. In *Annual Review of Earth and Planetary Sciences* (Eds: Jeanloz, R, and KH Freeman), pp.577-616.

Montzka, SA, S Reimann, A Engel, K Kruger, S O'Doherty, WT Sturges, D Blake, M Dorf, P Fraser, L Froidvaux, K Jucks, K Kreher, MJ Kurylo, A Mellouki, J Miller, OJ Nielsen, VL Orkin, RG Prinn, R Rhew, ML Santee, A Stohl, and D Verdonik (2011). Ozone-Depleting Substances (ODSs) and Related Chemicals. In *Scientific Assessment of Ozone Depletion: 2010*. World Meteorological Organization.

Moser, SC, and L Dilling (2011). Communicating Climate Change: Closing the Science-Action Gap. In *The Oxford Handbook of Climate Change and Society* (Eds: JS Dryzek, RB Norgaard, and D Schlosberg), pp.161-174. Oxford University Press.

O'Neill, SJ, and M Boykoff (2011). The role of new media in engaging the public with climate change. In *Engaging the Public with Climate Change: Communication and Behaviour Change* (Eds: L Whitmarsh, SJ O'Neill, and I Lorenzoni), chapter 13. Earthscan, London.

Overland, JE, and MC Serreze (2011). Advances in Arctic Atmospheric Research. In *Arctic Climate Change: The ACSYS Decade and Beyond* (Eds: Lemke, P, and HW Jacobi),

pp.11-27. Springer Verlag, Atmospheric and Oceanographic Science Library 42.
Parsons, MA, T de Bruin, S Tomlinson, H Campbell, X Godxy, J LeClert, and IPY Data Policy and Management SubCommittee (2011). The State of Polar Data—the IPY Experience. In *Understanding Earth's Polar Challenges: International Polar Year 2007-2008* (Eds: Krupnik, I, I Allison, R Bell, P Cutler, D Hik, J Lspez-Martmnez, V Rachold, E Sarukhanian and C Summerhayes), pp.457-476. CCI Press.
Peterson, WK, DN Baker, CE Barton, P Fox, MA Parsons, and E Cobabe-Ammann (2011). The Electronic Geophysical Year. In *Encyclopedia of Solid Earth Geophysics* (Ed: Gupta, HK). Springer.
Steffen, K, et al. (2011). ACSYS: A Scientific Foundation for the Climate and Cryosphere Programme (CliC). In *Arctic Climate Change: The ACSYS Decade and Beyond* (Eds: Lemke, P, and HW Jacobi), pp.437-461. Springer Verlag, Atmospheric and Oceanographic Science Library 42.
Stroeve, JC, and WN Meier (2011). Arctic Sea Ice Decline. In *Greenhouse Gases—Emission, Measurement and Management* (Ed: Liu, G). InTech.
Weil, JC (2011). Atmospheric Dispersion. Ed: Fernando, HJ. CRC Press, Taylor and Francis Group.
Young, CJ, RA Washenfelder, and SS Brown (2011). Cavity Ring-down Spectroscopy and Cavity Enhanced Techniques. In *Encyclopedia of Analytical Chemistry: Applications, Theory, and Instrumentation* (Ed: Sigrist, MJ). John Wiley & Sons, Ltd.

Technical Reports

Amante, CJ, MR Love, LA Taylor, and BW Eakins (2011), Digital Elevation Models of Mobile, Alabama: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum.*
Amante, CJ, MR Love, LA Taylor, and BW Eakins (2011), Digital Elevation Models of Panama City, Florida: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum.*
Anderson, RF, D Bronk, KJ Davis, RS DeFries, AS Denning, L Dilling, RB Jackson, A Jacobson, S Lohrenz, G Marland, AD McGuire, GA McKinley, AM Michalak, C Miller, B Moore III, DS Ojima, B O'Neill, JT Randerson, SW Running, CL Sabine, B Sohngen, PP Tans, PE (2011), A U.S. Carbon Cycle Science Plan, *A report of the University Corporation for Atmospheric Research supported by NASA, DOE, USDA, USGS, NOAA, NSF, and NIST.*
Atkinson, RN, J Chhetri, I Freed, C Galiana, C Green, S Hayward, J Jenkins, E Malone, T Nordhaus, R Pielke Jr., G Prins, S Rayner, D Sarewitz, and M Shellenberger (2011), Climate Pragmatism: Innovation, Resilience and No Regrets, *The Hartwell Analysis in an American Context*.
Averyt, K, J Fisher, A Huber-Lee, A Lewis, J Macknick, N Madden, J Rogers, and S Tellinghuisen (2011), Freshwater Use by US power plants: Electricity's thirst for a precious resource.
Averyt, K, K Cody, E Gordon, R Klein, J Lukas, J Smith, W Travis, B Udall, and J Vogel (2011), Colorado Climate Preparedness Project Final Report, *Western Water Assessment for the State of Colorado*.
Banta, RM, A Brewer, Y Pichugina, and et al. (2011), Enhancing energy production by wind farms, SPIE Newsroom. ., *SPIE Newsroom*.
Bedard AJ and RT Nishiyama (2011), Flow Noise Reduction for Airborne Infrasonic Sensors.
Bedard, AJ (2011), Analysis of the Data Sets Developed During the ASAP Experiment During January 2011 at the Boulder Atmospheric Observatory.
Beitler, JA, Editor (2011), Sensing Our Planet: NASA Earth Science Research Features 2011.
Buhr, SM and J Wright (2011), National Association of Geoscience Teachers Position statement: High School Earth Science Teaching, *National Association of Geoscience Teachers Position statement: High School Earth Science Teaching*.
Caldwell, RJ, BW Eakins, and E Lim (2011), Digital Elevation Models of Yakutat, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Caldwell, RJ, BW Eakins, and E Lim (2011), Digital Elevation Models of Prince William Sound, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Caldwell, RJ, LA Taylor, BW Eakins, KS Carignan, PR Grothe, E Lim, and DZ Friday (2011), Digital Elevation Models of Santa Monica, California: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Carignan, KS, LA Taylor, BW Eakins, RJ Caldwell, DZ Friday, and PR Grothe (2011), Digital Elevation Models of Central California and San Francisco Bay: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*
Carignan, KS, LA Taylor, BW Eakins, DZ Friday, PR Grothe, E Lim, and MR Love (2011), Digital Elevation Model of Hanalei, Hawaii: Procedures, Data Sources and Analysis, *NOAA technical report*.
Carignan, KS, LA Taylor, BW Eakins, DZ Friday, PR Grothe, E Lim, and MR Love (2011), Digital Elevation Models of Keauhou and Kawaihae, Hawaii: Procedures, Data Sources and Analysis, *NOAA technical report*.
Cozzetto, K, I Rangwala, and J Neff (2011), Downscaled Air Temperature and Precipitation Projections for the San Juan Mountain Region, Western Water Assessment.
Friday, DZ, LA Taylor, BW Eakins, KS Carignan, PR Grothe, E Lim, and MR Love (2011), Digital Elevation Models of Bar Harbor, Maine: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Friday, DZ, LA Taylor, BW Eakins, KS Carignan, PR Grothe, E Lim, and MR Love (2011), Digital Elevation Models of Port San Luis, California: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Friday, DZ, LA Taylor, BW Eakins, KS Carignan, RJ Caldwell, PR Grothe, and E Lim (2011), Digital Elevation Model of Atka, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Grothe, P, LA Taylor, BW Eakins, KS Carignan, DZ Friday, CJ Amante, and MR Love (2011), Digital Elevation Models of Sitka, Alaska: Procedures, Data Sources and Analysis, *NOAA technical report*.
Grothe, P, LA Taylor, BW Eakins, KS Carignan, DZ Friday, E Lim, and MR Love (2011), Digital Elevation Models of Morehead City, North Carolina: Procedures, Data Sources and Analysis, *NOAA technical report*.
Grothe, P, LA Taylor, BW Eakins, KS Carignan, DZ Friday, E Lim, and MR Love (2011), Digital Elevation Models of Key West, Florida: Procedures, Data Sources and Analysis, *NOAA technical report*.
Grothe, P, LA Taylor, BW Eakins, KS Carignan, RJ Caldwell, E Lim, and DZ Friday (2011), Digital Elevation Models of Cordova, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Grothe, P, LA Taylor, BW Eakins, KS Carignan, RJ Caldwell, E Lim, and DZ Friday (2011), Digital Elevation Models of Crescent City, California: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Hoerling, M, M Dettinger, K Wolter, J Lukas, J Eischeid, R Nemani, B Liebmann, and K Kunkel (2011), Chapter 5: Evolving weather and climate conditions of the Southwest United States, *National Climate Assessment, Southwest Regional Technical Report*.
Lack, SA, GJ Layne, S Madine, MA Petty, and JL Mahoney (2011), Quality Assessment of CoSPA, *OAR/GSD Tech Memo*.
Layne, GJ, AF Loughe, JE Hart, MP Kay, MA Petty, and JL Mahoney (2011), Investigation of the Use of CALIPSO-based Icing Potential Diagnostics in the Verification of Operational Icing Products, *Report to the Federal Aviation Administration*.
Leitzell, K and WN Meier (2011), *IceLight*s.
Lim, E, LA Taylor, BW Eakins, KS Carignan, RJ Caldwell, DZ Friday, and PR Grothe (2011), Digital Elevation Models of Port Townsend, Washington: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Lim, E, BW Eakins, and R Wigley (2011), Coastal Relief Model of Southern Alaska: Procedures, Data Sources and Analysi, *NOAA Technical Memorandum*.
Lim, E, BW Eakins, and RJ Caldwell (2011), Digital Elevation Models of Akutan, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Lim, E, LA Taylor, BW Eakins, KS Carignan, RJ Caldwell, PR Grothe, and DZ Friday (2011), Digital Elevation Model of Nikolski, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.
Loughe, AF, JE Hart, GJ Layne, MA Petty, JL Mahoney (2011), Icing Algorithm Assessment: RUC-derived and WRR-derived CIP and FIP, *Report to the Federal Aviation Administration.*
Love, MR, BW Eakins, LA Taylor, KS Carignan, DZ Friday, and PR Grothe (2011), Digital Elevation Model of Port Alexander, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.

Love, MR, BW Eakins, LA Taylor, KS Carignan, DZ Friday, PR Grothe, and E Lim (2011), Digital Elevation Model of Hilo, Hawaii: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.

Love, MR, BW Eakins, LA Taylor, KS Carignan, DZ Friday, PR Grothe, and E Lim (2011), Digital Elevation Model of Haleiwa, Hawaii: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.

Love, MR, CJ Amante, LA Taylor, and BW Eakins (2011), Digital Elevation Models of New Orleans, Louisiana: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.

Love, MR, LA Taylor, BW Eakins, KS Carignan, DZ Friday, and PR Grothe (2011), Digital Elevation Model of Elfin Cove, Alaska: Procedures, Data Sources and Analysis, *NOAA Technical Memorandum*.

Lynds, S (2011), CLEAN October 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN June 2011 Quarterly Webstat Report.

Lynds, S (2011), CLEAN July 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN September 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN TERC Professional Development Webinars.

Lynds, S (2011), CLEAN SERC Professional Development Workshop.

Lynds, S (2011), CLEAN TERC Professional Development Webinar Feedback Survey Data and Observations October 19, 2011.

Lynds, S (2011), CLEAN TERC Professional Development Webinar Feedback Survey Data and Transcript November 15, 2011.

Lynds, S (2011), CLEAN November 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN September 2011 Quarterly Webstat Report.

Lynds, S (2011), CLEAN August 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN April 18 2011 Quarterly Webstat Report.

Lynds, S (2011), CLEAN June 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN SERC Professional Development Workshop 2 Post-Workshop 2 Feedback Survey Data.

Lynds, S (2011), CLEAN TERC Professional Development Webinar Feedback Survey Data and Observations September 19, 2011.

Lynds, S (2011), CLEAN (Climate Literacy & Energy Awareness Network) Review Camp August 2011 Internal Evaluation Report.

Lynds, S (2011), CLEAN Informant Survey Number 1 Descriptive Data Internal Evaluation Report (not disaggregated).

Lynds, S (2011), CLEAN Advisory Board Meeting 9/07/11 Feedback Survey Internal Evaluation Report.

Lynds, S (2011), CLEAN (Climate Literacy & Energy Awareness Network) Review MiniCamp June 2-3, 2011 Internal Evaluation Report.

Lynds, S (2011), CLEAN April 18 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN May 2011 Monthly Webstat Report.

Lynds, S (2011), CLEAN Annual Meeting Feb 2011 Feedback Survey Internal Evaluation Report.

Lynds, S (2011), EarthLabs Advisory Board Meeting May 5, 2011 Feedback Survey Data Internal Evaluation Report.

Lynds, S (2011), COSEE West Colorado Collaborative April 9, 2011 Evaluation Report.

Lynds, S (2011), Climate Change Student Summit (C2S2) Program 2010-2011 Evaluation Report.

Lynds, S (2011), CLEAN Informant Invitation Survey Results Descriptive Data Internal Evaluation Report (not disaggregated).

Lynds, S (2011), A Decision Support System for Ecosystem-Based Tropical Coral Reef Management Front-End Survey Results.

Lynds, S (2011), COSEE West Colorado Collaborative Evaluation Report July 31, 2011.

Lynds, S (2011), COSEE West Colorado Collaborative May 7, 2011 Evaluation Report.

Lynds, S (2011), COSEE West Colorado Collaborative Evaluation Results of Registration Surveys May 6, 2010.

Lynds, S (2011), GeoMapApp and the High School Classroom: Transformative Resources for the 21st Century Educator Workshop I--April 9, 2011 Evaluation Report.

Lynds, S (2011), GeoScience Research at Storm Peak Project (GRASP) External Evaluation Report 2010.

Lynds, S (2011), Curriculum Development Survey--Ecosystem Management of Regionally Abundant, Invasive Plants Evaluation Report.

Lynds, S (2011), EarthLabs Annual Meeting Feb 2011 Feedback Survey Evaluation Report.

Lynds, S (2011), Geo Science Research at Storm Peak Project (GRASP) Registration Survey Data 2011.

Lynds, S (2011), Comparative Environmental Studies - Diverse Study Solutions Year 2 Evaluation Report June 7, 2011.

Lynds, S, K Merryman, and S Eyerman (2011), CLEAN Informant Survey Number 1 Descriptive Data Internal Evaluation Report--Disaggregated by Middle/High School.

Lynds, S and S Buhr (2011), AccessData Longitudinal Survey December 2009-January 2010 Evaluation Report.

Lynds, S and S Eyerman (2011), CLEAN Informant Invitation Survey Results Descriptive Data Internal Evaluation Report Middle vs High Disaggregation.

McKeen, SA, JA de Gouw, C Warneke, T Ryerson, D Parrish, JF Meagher, and RA Ravishankara (2011), Plume Dispersion Modeling of Aromatic VOC from the Deep Water Horizon Oil Spill., *Internal CSD report*.

Meier, WN (2011), WCRP Climate and CryosphereSatellite-derived Sea Ice Products Community Workshop Report.

Meier, WN, M Granskog, S Gerland, and J Key (2011), *Sea ice, Snow, Water, Ice, and Permafrost in the Arctic Assessment Report*.

Meier, WN, M Serreze, J Stroeve, T Scambos, and K Leitzell (2011), Arctic Sea Ice News and Analysis.

Neely, B, R Rondeau, J Sanderson, C Pague, B Kuhn, J Siemers, L Grunau, J Robertson, P McCarthy, J Barsugli, T Schulz, and C Knapp (2011), Gunnison Basin: Vulnerability Assessment for the Gunnison Climate Working Group, *The Nature Conservancy, Colorado Natural Heritage Program, Western Water Assessment, University of Colorado, Boulder, and University of Alaska, Fairbanks. Project of the Southwest Climate Change Initiative*.

Parsons, MA (2011), Expert Report on Data Policy--Open Access.

Peckham, S, GA Grell, SA McKeen, M Barth, G Pfister, C Wiedinmyer, JD Fast, WI Gustafson, R Zaveri, RC Easter, J Barnard, E Chapman, M Hewson, R Schmitz, M Salzmann, and S Freitas (2011), WRF/Chem Version 3.3 User's Guide, NOAA Technical Memorandum.

Perovich, D, H Eicken, W Meier, and S Gerland (2011), Arctic CliC Sea Ice Working Group Meeting.

Perovich, D, J Richter-Menge, J Maslanik, and W Meier (2011), Arctic Sea Ice, *Arctic Report Card*.

Pritchett, J, S Reateagui, S Tellinghuisen, B Udall (2011), Energy-Water Nexus in a Drying West: A Case Study Analysis and Methodology.

Seckmeyer, G, A Bais, G Bernhard, M Blumthaler, K Lantz, RL, McKenzie, B Johnsen, (2011), Instruments to measure UV solar radiation: Multi-channel filter radiometers, *World Meteorological Organization Reports*.

Seckmeyer, G, A Bais, G Bernhard, M Blumthaler, K Lantz, RL McKenzie, P Kiedron, S Drake, S Riechelmann (2011), Instruments to measure UV Solar Radiation: Array spectroradiometers,*World Meteorological Organization Reports*.

Smith, D, D Scott, and H Conover (2011), Report from the Passive Microwave Data Set Management Workshop, *Wokshop held 17-19 May, 2011, Huntsville, AL*.

Stratus Consulting, lead author (incl. J Barsugli) (2011), Boulder County Climate Change Preparedness Plan -- Draft.

Wandishin, MS, BP Pettegrew, MA Petty, and JL Mahoney (2011), Quality Assessment Report: Graphical Turbulence Guidance, Version 2.5, *NOAA Technical Memorandum*.

Weil, JC (2011), Buoyant Cloud Rise, Dispersion, and Deposition Modeling, *Lawrence Livermore National Laboratory.*

Reviews

Pielke, RA, A Pitman, D Niyogi, R Mahmood, C McAlpine, F Hossain, KK Goldewijk, U Nair, R Betts, S Fall, M Reichstein, P Kabat, and N de Noblet (2011), Land use/land cover changes and climate: modeling analysis and observational evidence, *Wiley Interdiscip. Rev.-Clim. Chang.*, 2(6), 10.1002/wcc.144.

Walsh, JJ, DA Dieterle, FR Chen, JM Lenes, W Maslowski, JJ Cassano, TE Whitledge, D Stockwell, M Flint, IN Sukhanova, and J Christensen (2011), Trophic cascades and

future harmful algal blooms within ice-free Arctic Seas north of Bering Strait: A simulation analysis, *Prog. Oceanogr.*, 91(3), 10.1016/j.pocean.2011.02.001.
Zhang, Q, JL Jimenez, MR Canagaratna, IM Ulbrich, NL Ng, DR Worsnop, and YL Sun (2011), Understanding atmospheric organic aerosols via factor analysis of aerosol mass spectrometry: a review, *Anal. Bioanal. Chem.*, 401(10), 10.1007/s00216-011-5355-y.

Magazines

Beitler, JA (2011), The un-ice age, *Sensing Our Planet: NASA Earth Science Research Features*, 2011.
Beitler, JA (2011), Repatterning the world, *Sensing Our Planet: NASA Earth Science Research Features*, 2011.
Beitler, JA (2011), Sky Rivers, *National Geographic*, 2011.
Boykoff, M (2011), COP17: Global Vs Local Solutions, *Think Africa Press*, 2011.
Cherney, DN (2011), Science Student Profile: Why I Picked University of Colorado Boulder, *U.S. News and World Report*, 2011.
Cozzetto, K, I Rangwala, and J Lukas (2011), Examining Regional Climate Model (RCM) projections: What do they add to our picture of future climate in the region?, *Intermountain West Climate Summary*, 2011.
Lee, SS (2011), ATMOSPHERIC SCIENCE Aerosols, clouds and climate, *Nat. Geosci.*, DEC/2011.
LeFevre, K (2011), Growing Jamaica, *Sensing Our Planet: NASA Earth Science Research Features 2011*, 2011.
Leitzell, K (2011), Take the Data to the People Making Climate Science More Accessible and Transparent, *Science Progress*, 2011.
Leitzell, KH (2011), A black cloud over Cairo, *NASA Sensing Our Planet*, 2011.
Leitzell, KH (2011), The time of cholera, *NASA Sensing Our Planet*, 2011.
Leitzell, KH (2011), Hidden carbon, *NASA Sensing Our Planet*, 2011.
Lukas, J (2011), The spring runoff roundup another look at ENSO, dust-on-snow, beetles, and Lake Mead, *Intermountain West Climate Summary*, 2011.
Lukas, J (2011), The National Climate Assessment Available and forthcoming resources for the Intermountain West and beyond, *Intermountain West Climate Summary*, 2011.
Lukas, J, R Klein, E Gordon, and B Travis (2011), The Colorado Climate Preparedness Project Capturing the state of climate adaptation in Colorado, *Intermountain West Climate Summary*, 2011.
Naranjo, L (2011), The feather followers, Sensing Our Planet: *NASA Earth Science Research Features 2011*, 2011.
Naranjo, L (2011), Baja's fault, *NASA Earth Science Research Features 2011*, 2011.
Naranjo, L (2011), Volatile trees, *NASA Earth Science Research Features 2011*, 2011.
Pielke, Jr., RA (2011), England Shows the Way for Members to Tackle FIFA Crisis, *Financial Times*, 2011.
Pielke, Jr., RA (2011), Can World Soccer Root Out Corruption? Holding the Agency Accountable, *New York Times*, July 20/2011.
Pielke, Jr., RA (2011), Klinsmann Will Find There Are No Points for Style, *New York Times*, August 6/2011.
Pielke, Jr., RA (2011), Commentary: Pay-for-play in college athletics, *Boulder Daily Camera*, July 24/2011.
Pielke, Jr., RA (2011), The Problem With In-State Tuition, *Chronicle of Higher Education*, July 24/2011.
Pielke, Jr., RA (2011), Putting trust in science at risk, *Financial Times*, 2011.
Pielke, Jr., RA (2011), Extreme Weather and Climate Change, *National Journal*, July 5/2011.
Pielke, Jr., RA (2011), Let There Be More Efficient Light, *New York Times*, 2011.
Pielke, Jr., RA (2011), The messy business of cleaning up carbon policy (and how to sell it to the electorate), *ABC News Australia*, April 1/2011.
Russell, EL and WB Bendel (2011), NOAA's Science On a Sphere Provides Educational Technology for All Ages, *Technology for Today*, 2011.
Scott, M (2011), Why does the Earth Observatory show some floods and not others?, *NASA Earth Observatory*, 2011.
Scott, M (2011), Are you ever fooled by relief inversion?, *NASA Earth Observatory*, 2011.
Scott, M (2011), Heavy Rains and Dry Lands Don t Mix: Reflections on the 2010 Pakistan Flood, *NASA Earth Observatory*, 2011.
Travis, WR (2011), A Future of Mass Evacuations, *New York Times*, August 29/2011.
Vizcarra, N (2011), http://nsidc.org/monthlyhighlights/2011/04/spanning-the-satellite-generations/, *NSIDC Monthly Highlights*, 2011.

Discussions

Pielke, Jr., R. A. (2011), Politics is about acting alike, not thinking alike, *Bulletin of the Atomic Scientists*.
Pielke, Jr., R. A. (2011), When politicians distort science, *Bulletin of the Atomic Scientists.*

Corrections

Befus, KM, AF Sheehan, M Leopold, SP Anderson, and RS Anderson (2011), Seismic Constraints on Critical Zone Architecture, Boulder Creek Watershed, Front Range, Colorado (vol 10, pg 915, 2011), *Vadose Zone J.*, 10(4), 10.2136/vzj2010.0108er.
Bowling, DR, JB Miller, ME Rhodes, SP Burns, RK Monson, and D Baer (2011), Soil, plant, and transport influences on methane in a subalpine forest under high ultraviolet irradiance (vol 6, pg 1311, 2009), *Biogeosciences*, 8(4), 10.5194/bg-8-851-2011.
Miller, GH, J Brigham-Grette, RB Alley, L Anderson, HA Bauch, MSV Douglas, ME Edwards, SA Elias, BP Finney, JJ Fitzpatrick, SV Funder, TD Herbert, LD Hinzman, DS Kaufman, GM MacDonald, L Polyak, A Robock, MC Serreze, JP Smol, R Spielhagen, JWC White, AP Wolfe, and EW Wolff (2011), Temperature and precipitation history of the Arctic (vol 29, pg 1679, 2010), *Quat. Sci. Rev.*, 30(19-20), 10.1016/j.quascirev.2010.07.018.
Roesch, A, M Wild, A Ohmura, EG Dutton, CN Long, and T Zhang (2011), Assessment of BSRN radiation records for the computation of monthly means (vol 4, pg 339, 2011), *Atmos. Meas. Tech.*, 4(5), 10.5194/amt-4-973-2011.

Honors and Awards

CIRES Outstanding Performance Awards

The CIRES Awards Committee, comprising CIRES Members' Council representatives and members at large, annually reviews nominations and makes recommendations for outstanding professional achievement in the categories of "Science and Engineering" and "Service." This year, CIRES recognized six awards of $2,000 each.

Science and Engineering

Cecelia DeLuca for being the driving force behind the important and novel software development efforts at NOAA's Environmental Software Infrastructure and Interoperability Group (NESII). She guides the group with diverse expertise in high-performance computing, software project management, and Earth sciences, and a vision to bring their efforts to fruition.

Anna Karion, Tim Newberger, and Colm Sweeney for developing a new atmospheric sampling instrument, the AirCore, which can profile altitude gradients of greenhouse gases. The low-cost, lightweight tool also can be used to validate satellite profiles and may yield new discoveries in stratospheric composition and circulation trends.

Dan Lack for his work putting black carbon emissions inventories for shipping on a sound scientific basis, which has had a major impact on policy decisions for regulation of international shipping.

Troy Thornberry, Andrew Rollins, and Laurel Watts for designing and demonstrating an airborne chemical ionization mass spectrometer (CIMS) for ultra-low water vapor measurements in the lower stratosphere. Their effort led to unique measurements that will advance our understanding of water vapor in the climate system.

Service

Ken Aiken for his essential work mastering, maintaining, and teaching all things digital. The research of NOAA's Chemical Sciences Division requires multifaceted data collection, manipulation, and presentation, at which Aiken is an unparalleled expert.

Dave Gallaher and Ron Weaver for their leadership in data-center design and operation with the NSIDC Green Data Center Project. The innovative data-center redesign slashed energy consumption for data-center cooling by more than 90 percent, demonstrating how other data centers and the technology industry can save energy and reduce carbon emissions.

Director's Awards

Director's Award for Diversity

Edward Aruajo-Pradere, for demonstrating that a distinguished scientific career and regular diversity outreach can be combined to the benefit of both.

Director's Award

Jon Eischeid, for his essential work authoring the hydro-climate report "Understanding and Explaining Hydro-Climate Variations at Devils Lake." This key assessment of the climate conditions relevant to the recent rise of Devils Lake elevation supports the Interagency Initiative to Address Flooding Issues at Devils Lake, North Dakota.

Detecting Groundwater from Space

In 2012, geophysicist John Wahr, then a CIRES Fellow, was elected a member of the prestigious National Academy of Sciences. Wahr was honored, in part, for his groundbreaking work in the use of GRACE (Gravity Recovery And Climate Experiment)—twin satellites that measure changes in Earth's gravity and, hence, mass at any region on the planet—to monitor the planet's glaciers, sea levels, crustal deformation, and even groundwater depletion.

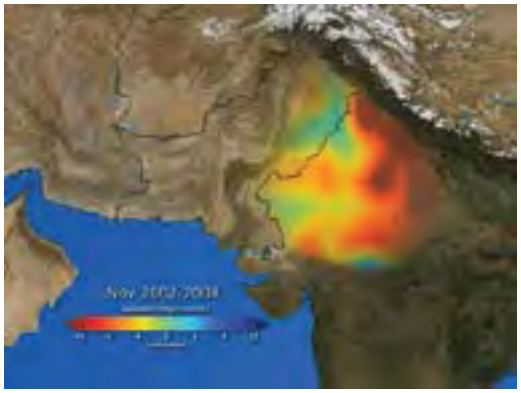

Image courtesy of NASA/Trent Schindler

Where has GRACE recorded the biggest mass changes?

Since 2002, the biggest mass changes recorded have been ice melt in Greenland, Antarctica, and Alaska. But another dramatic, long-term mass change we've seen is in northern India, Pakistan, and Bangladesh. It's a huge mass loss, and it's due to farmers pumping water from the ground for their fields. It's a serious problem. In India, the wells are drying up, and some people are having trouble getting enough to drink.

How has India responded to the data?

Our results have been discussed even on the floor of the Indian parliament, but people who try to manage groundwater sources using traditional methods are skeptical of satellite-based measurements. It is a radical idea to think you can measure changes in groundwater from space—that somehow the satellites up there can see water beneath the soil. Even though I've been involved with GRACE from the beginning, it's still staggering to think about what you can accomplish. But once you understand how GRACE works, you understand how fantastic the methodology is.

How accurately can it detect groundwater changes?

GRACE can measure changes in total water to about 1-centimeter accuracy over the scale of the Mississippi River Basin. No other method for monitoring groundwater gives such an accurate, big-picture view for a whole region.

Select Awards and Honors, 2011

CIRES researchers received numerous awards and honors during 2011. A selection of significant achievements is outlined below.

Maxwell Boykoff
Scotsman Book of the Year Selection: *Who Speaks for the Climate?*

Gilbert Compo
High Performance Computing Innovation Excellence Award, International Data Corporation

Baylor Fox-Kemper
2011 Ocean Sciences Early Career Award, American Geophysical Union

Birgit Hassler, Andrew Rollins, and Paul Young
Outstanding Poster Presentation Award, World Climate Research Programme (WCRP)

Patrick Lewis Hayes
Fellow, Dissertation Initiative for the Advancement of Climate Change Research Symposium (DISCCRS)

Patrick Lewis Hayes and Andrew Rollins
Select participant, Atmospheric Chemistry Colloquium for Emerging Senior Scientists (ACCESS)

Susan Lynds
Science Prize for Online Resources in Education (SPORE), American Association for the Advancement of Science

Peter Molnar
Jack E. Oliver Honorary Visiting Professor at Cornell University

Michale O'Neill
OAR Outstanding Scientific Paper Award, NOAA

Gopakumar Padmanabhan
Best NOAA-GSD Web Product for 2011, NOAA

Roger Pielke, Jr.
Distinguished Visiting Professor, Linkoepings Universitet, Sweden

Eric Ray, Troy Thornberry, and Laurel Watts
Group Achievement Award for outstanding accomplishments for NASA and Earth science during the successful Global Hawk Pacific Mission (GloPac) in 2010, NASA

Mark Serreze
Colorado Governor's Award for High-Impact Research

Ranajit Talukdar
Visiting Professor at the University of Orleans, France

Margaret Tolbert
Harold S. Johnston Lecturer, UC Berkeley

Veronica Vaida
E. Bright Wilson Award in Spectroscopy, American Chemical Society

Rainer Volkamer
NSF CAREER Award recipient, National Science Foundation

John Wahr
Elected a member of the National Academy of Sciences

Conferences, Workshops, Events, and Presentations

- **UCAR:** What's New with the Weather? Forecasts for Human Health, Energy, and the Car Behind You (panel, 8/11)
- **American Meteorological Society:** 2011 AMS Summer Community Meeting (8/11)
- **CIRES Staff Appreciation Summer Picnic** (8/11)
- **PSD Seminar:** Fine Scale Meteorology and Air Quality Models as Urban Forecasting, Planning, and Assessment Tools by Jason Ching, University of North Carolina at Chapel Hill (8/11)
- **Geological Sciences Colloquium:** The Root of Branching River Networks by Taylor Perron, MIT Department of Earth and Planetary Sciences (8/11)
- **Analytical Chemistry Seminar:** Chiral Receptor Compounds as Enantioselective NMR Shift Reagents and Catalysts for Curricular Reform by Thomas J. Wenzel, Department of Chemistry at Bates College (8/11)
- **Hydrology and Water Resources Seminar:** Cryo-hydrologic Warming Explains Increased Ice Velocities on a Glacier in West Greenland by Hari Rajaram, University of Colorado Boulder (8/11)
- **CIRES Graduate Student Association Kick-Off Party** (9/11)
- **GEOG Colloquium:** The Climate Change-Conflict Controversy: The Evidence from East Africa, 1990–2009 (panel, 9/11)
- **Hydrology and Water Resources Seminar:** The Threshold Between Braided and Meandering Rivers by John Pitlick and Erich Mueller, University of Colorado Boulder (9/11)
- **CU Geophysics Seminar:** Introduction to Space Weather by Thomas Bogdan, NOAA Space Weather Center (9/11)
- **Hydrology and Water Resources Seminar:** Lessons in Water Management from Australia for the Colorado River Basin by Brad Udall, Western Water Assessment (9/11)
- **GEOG Colloquium:** Environmental Geopolitics in the Twenty First Century by Simon Dalby, Geography, Environmental Studies and Political Economy, Carleton University and Department of Political Science, University of Victoria (9/11)
- **Analytical Chemistry Seminar:** Inhalable Dry Powder Aerosols of Vaccines and Antibiotics by Bob Sievers, CIRES Fellow (9/11)
- **Analytical Chemistry Seminar:** Organic Aerosol Sources and Processing in the Atmosphere by Jose L. Jimenez, CIRES Fellow (9/11)
- **Hydrology and Water Resources Seminar:** Seasonal to Inter-Annual Streamflow Simulation and Forecasting on the Upper Colorado River Basin and Implications for Water Resources Management by Cameron Bracken, CIRES Ph.D. student (9/11)
- **GEOG Colloquium:** Research on Global Environmental Change: Time for Change, by Myanna Lahsen, Earth System Science Center, Brazilian Institute for Space Research (9/11)
- **Geophysics Seminar:** National Earthquake Information Center Operations and Realtime Earthquake Response by Gavin Hayes, USGS National Earthquake Information Center (9/11)
- **Hydrology and Water Resources Seminar:** Desert Dust Impacts on Snowmelt and Hydrology in the Upper Colorado River Basin by Jeffrey S. Deems, CIRES–NOAA Western Water Assessment and University of Colorado (9/11)
- **CSD Seminar:** Toward an Improved Understanding of Tropical Widening by Sean Davis, NOAA ESRL CSD and CU–CIRES (9/11)
- **GEOG Colloquium:** The Nation *Ex-Situ*: Climate-Induced Migration, Deterritorialized Nationhood, and the Post-Climate Era by Maxine Burkett, Center for Island Climate Adaptation and Policy, School of Law, University of Hawai'i, Manoa (9/11)
- **Analytical Chemistry Seminar:** Importance of Aerosol Mixing State for Ice Nucleating Efficiency: Combined Laboratory and Field Study by Margaret A. Tolbert, CIRES Fellow (10/11)
- **Analytical Chemistry Seminar:** Oceans, Atmospheric Chemistry, and Climate: Novel Processes at the Air-Sea Interface by Rainer Volkamer, CIRES Fellow (10/11)
- **Hydrology and Water Resources Seminar:** Global Change and Water Resources in the Next 100 Years by Matthew C. Larsen (10/11)
- **Special CSD Seminar:** Climategate, Michael Mann, and Penn State's Investigation by William H. Brune, Department of Meteorology, Pennsylvania State University (10/11)
- **CSD Seminar:** Some New Ways to Look at Atmospheric Oxidation by William H. Brune, Department of Meteorology, Pennsylvania State University (10/11)
- **GEOG Colloquium:** Interrogating the Tradeoffs: Carbon Commodification and Community Forest Governance in Chiapas, Mexico, by Tracey Osborne, School of Geography and Development, University of Arizona (10/11)
- **Hydrology and Water Resources Seminar:** The Role of Turbulence and Structured Stirring on Fertilization Success in Broadcast Spawners by John Crimaldi, University of Colorado Boulder (10/11)
- **GEOG Colloquium:** Ozone Depletion and Antarctic Climate Change by Susan Solomon, NOAA (10/11)
- **Analytical Chemistry Seminar:** Isotopic Substitution in the Atmosphere and Solar Nebula: Cavity Ring-Down Spectroscopy of CO_2 and VUV Photodissociation of CO by Ryan Davis, University of Colorado Boulder graduate student (10/11)
- **Analytical Chemistry Seminar:** Temporal Dynamics and Sources of Particle Types in Milwaukee, WI, Studied with Single-Particle Mass Spectrometry by Samantha Thompson, CIRES Ph.D. student (10/11)
- **Geophysics Seminar:** Earthquake Engineering Research at the USGS in Golden, CO: Building Codes and Risk Assessment by Nicholas Luco, USGS (10/11)
- **Hydrology and Water Resources Seminar:** Incorporating Preferential Flow Structures into Hydrogeologic Models by Michael J. Ronayne, Department of Geoscience, Colorado State University (10/11)
- **CSD Seminar:** Emissions of VOC in Northern Mid-Latitude Urban Areas from Long-Term and Intensive Observations by Agnes Borbon, CNRS France and CU CIRES Visiting Fellow (10/11)
- **Geological Sciences Seminar:** Implications of Post-Seismic Surface Displacements for the Nature of the Mantle and Earthquake Triggering (Andy Freed, Purdue, 10/11)
- **Geophysics Seminar:** Overview of the Comprehensive Test Ban Treaty Verification Regime by Lynda Lastowka, USGS (10/11)
- **COSI Seminar:** Scientists in Policy and Politics by Roger Pielke, Jr., CIRES Fellow (10/11)
- **Peace Corps Extravaganza at CU Boulder:** Panel discussion including Max Boykoff, CIRES Fellow (10/11)
- **Geophysics Seminar:** Introduction to Magnetotelluric Exploration of Continental Crust and Upper Mantle by Paul Bedrosian, USGS, Denver (10/11)
- **Hydrology and Water Resources Seminar:** Using Adjoint Methodology to Quantify Stream Depletion by Scott Griebling, master's of science candidate, Department of Civil Environmental and Architectural Engineering (11/11)
- **GEOG Colloquium:** Pages from the Book of the Unknown Explorer by Judit Hersko, Visual and Performing Arts Department, California State University, San Marcos (11/11)
- **Analytical Chemistry Seminar:** Nighttime Chemistry: Field Measurements of N_2O_5 Uptake and $ClNO_2$ Production by Nick Wagner (11/11)
- **Analytical Chemistry Seminar:** Role of Organic Nitrates in Secondary Organic Aerosol (SOA) Production in Forests by Juliane L. Fry, Reed College, Portland, Ore.; currently on sabbatical at CIRES and NCAR Advanced Study Program (11/11)
- **Science Forum at Chautauqua:** The Arctic: Unique, Beautiful, Fascinating (panel, 11/11)
- **Hydrology and Water Resources Seminar:** Water Management Issues at Oil Sands Operations in Canada by Dobroslav Znidarcic (11/11)
- **CSD Seminar:** Calibrated *In Situ* Measurement of UT/LS Water Vapor Using Chemical Ionization Mass Spectrometry by Troy Thornberry, CIRES/NOAA ESRL CSD (11/11)
- **American Meteorological Society:** Denver/Boulder American Meteorological Society November Meeting (11/11)
- **Analytical Chemistry Seminar:** Gas and Particle-Phase Organic Acids Measurement at a Forest Site Using Chemical Ionization High-Resolution Time-of-Flight Mass Spectrometry During BEACHON-RoMBAS Campaign by Reddy Yatavelli and Harald Stark (11/11)

- **GEOG Colloquium:** What Does It Mean to 'Adapt'? Gender, Climate Change, Post-Conflict Transition and Forestry Governance in Nepal by Andrea Nightingale, School of Geosciences, University of Edinburgh (12/11)
- **CIRES Graduate Student Association Lunch:** A discussion on volunteer and service opportunities relating to outreach in local schools, by Tommy Detmer (12/11)
- **CIRES Holiday Party** (12/11)
- **Analytical Chemistry Seminar:** Comprehensive Studies of the Chemistry of Aerosol Formation from Alkane Oxidation by Paul Ziemann, University of California, Riverside (1/12)
- **Hydrology and Water Resources Seminar:** Application of Radar-Rainfall Estimates to Probable Maximum Precipitation in the Carolinas by Raymond Jason Caldwell, Ph.D. Candidate, Dept. of Civil, Environmental, and Architectural Engineering, University of Colorado (1/12)
- **CIRES Graduate Student Association Research Lunch Meeting** (1/12)
- **Hydrology and Water Resources Seminar:** I've Seen Fire and I've Seen Rain: Post-Wildfire Hydrology in Fourmile Canyon, Colo., by Brian Ebel, U.S. Geological Survey (2/12)
- **CIRES Graduate Student Association Research Lunch Meeting** (2/12)
- **GEOG Colloquium:** Climate Policy, Redd+, and The Road Ahead by William Boyd, University of Colorado Law School, and Krister Andersson, Department of Political Science and Environmental Studies Program, University of Colorado (2/12)
- **GEOG Colloquium:** Institutional Access, Democratic Articulation, and Self-Organized Adaptation to Climate Change by Ashwini Chhatre, Department of Geography, University of Illinois at Urbana-Champaign (2/12)
- **GEOG Colloquium:** The Science and the Politics of Disasters and Climate Change by Roger Pielke, Jr., , CIRES Fellow and Environmental Studies Program, University of Colorado (3/12)
- **National Ocean Sciences Bowl** (3/12)
- **GEOG Colloquium:** Catching Climate Fever: Diagnosing the Changing Environment of Infectious Disease by Andrew Comrie, University of Arizona (3/12)
- **ENVS Graduate Student Seminar:** Beyond 'NIMBY': Considering 'Wise-Use' Values in Place Protective Politics of Wind Energy Development in the Rural West by Shawn Olson (3/12)
- **GEOG Colloquium:** Responding to the Challenges of Global Environmental Change by Diana Liverman, Institute of the Environment, Geography and Development, University of Arizona (3/12)
- **Symposium on Chemical Ionization Mass Spectrometry (CIMS):** Panel discussion (3/12)
- **Analytical Chemistry Seminar:** Selection of DNA Aptamers that Would Improve Diagnostic Tests for Tuberculosis by Lia Rebits (4/12)
- **CSD Seminar:** Volatile Organic Compounds (VOCs) Associated with Oil and Natural Gas Operations in Colorado and Utah: Regional Characteristics and Potential Atmospheric Impacts by Jessica Gilman, CU-CIRES/NOAA ESRL CSD (4/12)
- **ENVS Graduate Student Seminar:** Illegal Crossings: United States' Hazardous Waste in India by Lucy McAllister (4/12)
- **GEOG Colloquium:** Greenland Ice Sheet and Dynamic Response to Global Warming by Konrad Steffen, CIRES Fellow and Department of Geography, University of Colorado, (4/12)
- **Analytical Chemistry Seminar:** Airborne MAX-DOAS for Measurement of Atmospheric Trace Gases by Sunil Baidar (4/12)
- **Hydrology and Water Resources Seminar:** Hillslope, River, and Mountain: Some Surprises in Landscape Evolution by Greg Tucker, CIRES Fellow (4/12)
- **PSD Seminar:** Physical Processes Associated with Heavy Flooding Rainfall in Nashville, Tennessee, and Vicinity during 1-2 May 2010: The Role of an Atmospheric River and Mesoscale Convective Systems by Benjamin Moore, CIRES/NOAA, Boulder, Colo. (4/12)
- **Analytical Chemistry Seminar:** The TORERO Project by Rainer Volkamer, CIRES Fellow (4/12)
- **ENVS Graduate Student Seminar:** Where Did the Cap and Trade Bill Go?: Views and Politics of Climate Change in the U.S. Congress by Mike Henry (4/12)
- **GEOG Colloquium:** Paleoreconstructions of Sierra Nevada Snowpack Using Diatom Inference Models by James Sickman, Department of Environmental Sciences, University of California Riverside (4/12)
- **Analytical Chemistry Seminar:** Known and Unexplored Organic Constituents in the Earth's Atmosphere: Instrument Development to Enhance Exploration by Allen Goldstein, Department of Environmental Science, Policy, and Management and Department of Civil and Environmental Engineering, University of California at Berkeley (4/12)
- **Analytical Chemistry Seminar:** The Role of Organic Species on the Ice Nucleation Capabilities of Atmospheric Aerosol by Gregory Schill (4/12)
- **Analytical Chemistry Seminar:** The Story Behind an Upcoming Field Campaign in Ulaanbaatar, Mongolia: One of the World's Most PM-Polluted Cities by Christa Hasenkopf (5/12)
- **Program for Writing and Rhetoric Summer Seminar:** Rhetoric of Climate Change Deniers by Max Boykoff, CIRES Fellow (5/12)
- **WWA Seminar:** Adapting to Climate Change on the Shoshone National Forest: A Science-Management Collaboration to Develop Planning and Management Tools by Janine Rice (5/12)

CSPTR Noontime Seminars

- **Roger Pielke, Jr.:** Normalized Tornado Losses in the United States (9/11)
- **Shannon McNeeley:** Climate Adaptation by Any Other Name—Social Learning in Colorado Water Governance (10/11)
- **Jim White:** Abrupt Climate Change—What Is It and Should I Fear It? (10/11)
- **Brad Udall:** Twenty Years of Water Reform in Australia: Any Lessons for the American West? (11/11)
- **Lisa Dilling and Meaghan Daly:** Adapting to What? Interactions of Drought Management, Climate Adaptation, and Shifting Vulnerability (12/11)
- **Reagan Waskom:** Climate Change Impacts on Agriculture in the Colorado River Basin (12/11)
- **Sarah Trainor:** Climate Change Adaptation in Alaska—Who Is Doing What? (3/12)
- **Panel:** A Hard Look at 'SREX'—The IPCC Special Report on Extremes (3/12)
- **Kelly Mahoney:** Making Climate Change Local—High-resolution Downscaling of Extreme Precipitation Projections in the Colorado Front Range (4/12)
- **Roger Pielke, Jr.:** Wag the Dog—Ethics, Accuracy, and Impact of the Science of Extremes in Political Debates (4/12)
- **Randall Dole:** Challenges in Attribution of Weather and Climate Extremes (4/12)

ENVS Colloquia

- **S. Ravi Rajan:** Environmental Human Rights (8/11)
- **Andrew Light:** Sustainable Climate Ethics—Moving from Mitigation to International Finance (9/11)
- **Sharon Collinge:** Sustainable Food Systems—Going Beyond 'The Omnivore Dilemma' (10/11)
- **Diane McKnight:** Acid Mine Drainage and Climate Change in the Rocky Mountains (11/11)
- **Paul Robbins:** Producing Wildlife—Managing a Conservation Reserve in India During the Anthropocene (2/12)
- **David Schimel:** Observing Changing Ecological Diversity in the Anthropocene—The Science of Observation (2/12)
- **Robin Chazdon:** Resurgence—Successional Dynamics of Tropical Forests (2/12)
- **Daniel Doak:** Fostering Understanding of How Ecological Systems Work—Plans for Teaching, Research, and Mentoring in Environmental Studies (2/12)
- **Arun Agarwal:** Natural Resource Governance and Outcomes (3/12)
- **J. Timmons Roberts:** Managing $30 Billion for Sustainability: Tracking, Evaluating, and Improving 'Fast Start' Climate Change Finance (4/12)

Appendices

Personnel Demographics

CIRES Personnel Breakdown 2011–2012

Category	Total CIRES Personnel	NOAA-supported CIRES Personnel	Highest Degree Earned by NOAA-supported Personnel B.S.	M.S.	Ph.D.
Faculty	20	1			1
Research Scientist	187	109			109
Visiting Scientist	32	2			2
Postdoctorate Researcher	26	7			7
Associate Scientist	237	134	62	69	3
Administrative	38	27	21	4	2
Total > 50% NOAA support		**280**	**83**	**73**	**124**
Undergraduate Students	76	47			
Graduate Students	101	19	19		
Received < 50% NOAA Support		**97**	**22**	**32**	**43**
Total CIRES personnel	**717**				
CIRES Personnel in NOAA Boulder Laboratories					
OAR/CSD		70			
ESRL-DIR		8			
GMD		49			
GSD		36			
PSD		74			
TOTAL OAR		237			
NESDIS/NGDG		45			
NWS/SWPC		22			
Total NOAA		**304**			
Obtained NOAA Employment in Last Year		0			

Acronyms

20CR	Twentieth Century Reanalysis
ACCMIP	Atmospheric Chemistry and Climate Model Intercomparison Project
ACE	Atmospheric Composition Explorer
ACF	Apalachicola-Chattahoochee-Flint Basin
ACPD	Atmospheric Chemistry and Physics
ACRF	Atmospheric Climate Research Facility
AFRL	Air Force Research Laboratory
AGAGE45	Advanced Global Atmospheric Gases Experiment
AGL	Above Ground Level
AGU	American Geophysical Union
ALT	Active Layer Thickness
AMISA	Arctic Mechanisms of Interaction between Surface and Atmosphere
AMOS	Automatic Meteorological Observing Station
AOD	Aerosol Optical Depth
AP	Antarctic Peninsula
API	Application Programming Interface
AR	Atmospheric River
ARCPAC	Aerosol, Radiation, and Cloud Processes affecting Arctic Climate
ARM	Atmospheric Radiation Measurement
ASCOS	Arctic Summer Cloud Ocean Study
ATTREX	Airborne Tropical TRopopause EXperiment
AWIPS II	Advanced Weather Interactive Processing System II
BASE	Bighorn Arch Seismic Experiment
BC	Black Carbon
BHM	Bighorn Mountains
BVOC	Biogenic Volatile Organic Compounds
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CalNex	California Nexus (Research at the Nexus of Air Quality and Climate Change field program)
CAM	Community Atmosphere Model
CAN-BD	Carbon Dioxide Assisted Nebulization with a Bubble Dryer
CARB	California Air Resources Board
CAT	CME Analysis Tool
CAVE	Common AWIPS Visualization Environment
CBRFC	Colorado Basin River Forecast Center
CC14	Carbon Tetrachloride
CDC	Centers for Disease Control and Prevention
CDC	Climate Diagnostics Center
CDIAC	Carbon Dioxide Information Analysis Center
CDMP	Climate Database Modernization Program
CDR	Climate Data Record

CEAS	Cavity Enhanced Absorption Spectroscopy
CEDAR	Coupling, Energetics and Dynamics, and Atmospheric Regions
CF	Climate and Forecasting
CHAMP	CHAllenging Minisatellite Payload
CIERA	Community Initiative for Emissions Research and Applications
CIMS	Chemical Ionization Mass Spectrometry
CIP	Current Icing Potential
CIRES	Cooperative Institute for Research in Environmental Sciences
CLASS	Comprehensive Large Array Stewardship System
CloudSat	Cloud Satellite
CME	Coronal Mass Ejection
CMIP5	Coupled Model Intercomparison Project phase 5
CMIP6	Coupled Model Intercomparison Project phase 6
CO2	Carbon Dioxide
COARE	Coupled Ocean-Atmosphere Response Experiment
COOP	Continuity of Operations
CORS	Continuously Operating Reference Stations
CoSPA	Consolidated Storm Prediction for Aviation
CPC	Climate Prediction Center
CRB	Colorado River Basin
CRDS	Cavity Ring-Down Spectroscopy
CSC	Cooperative Science Center
CSD	Chemical Sciences Division
CSTPR	Center for Science and Technology Policy Research
CSW	Catalog Service for the Web
CTIPe	Coupled Thermosphere Ionosphere Physical Model
CU	University of Colorado
CWCB	Colorado Water Conservation Board
DART	Deep-Ocean Assessment and Reporting of Tsunamis
DCGI	Drugs Controller General of India
DEM	Digital Elevation Model
DMS	Dimethyl Sulfide
DMSP	Defense Meteorological Satellite Program
DNA	Deoxyribonucleic Acid
DNS	Direct Numerical Simulation
DOE	Department of Energy
DRAP	D-Region Absorption Prediction
DTC	Developmental Testbed Center
DU	Dobson Units
DWH	Deepwater Horizon

DYNAMO2011	Dynamics of the Madden-Julian Oscillation 2011
ECC	Electrochemical Concentration Cell
ECMWF	European Center for Medium Range Weather Forecasting
ECS	Extended Continental Shelf
EDR	Eddy Dissipation Rate
EIA	Equatorial Ionization Anomaly
EMS	Enterprise Metadata System
ENSO	El Niño Southern Oscillation
EO	Education and Outreach
EPA	Environmental Protection Agency
ESIP	Earth Science Information Partners
ESOC	Earth Science and Observation Center
ESRL	Earth System Research Laboratory
ETH	Eidgenössische Technische Hochschule
EVA	Extreme Value Analysis
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FGDC	Federal Geographic Data Committee
FIM	Flow-following finite-volume Icosahedral atmospheric Model
FIP	Forecast Icing Potential
FNIH	Foundation for the National Institutes of Health
FOC	Final Operating Capability
FTIR	Fourier Transform InfraRed
FTP	File Transfer Protocol
FY	Fiscal Year
GasEx III	NOAA's Southern Ocean Gas Exchange Experiment
GBM	Greybull Monocline
GCM	General Circulation Model
GIS	Geographical Information System
GloPac	Global Hawk-Pacific
GMAC	Global Monitoring Annual Conference
GMD	Global Monitoring Division
GNSS	Global Navigation Satellite System
GOCART	Goddard Chemistry Aerosol Radiation and Transport
GOES	Geostationary Operational Environmental Satellite
GOES-NOP	Geostationary Operational Environmental Satellites N, O, and P
GOMOS	Global Ozone Monitoring by Occultation of Stars
GPS	Global Positioning System
GPU	Graphical Processor Units
GRACE	Gravity Recovery And Climate Experiment

GSD	Global Systems Division
GSFC	NASA Goddard Space Flight Center
GSI	Gridpoint Statistical Interpolator
GTG	Graphical Turbulence Guidance
GUI	Graphical User Interface
GV	Gulfstream V aircraft
GWP	Global Warming Potential
H	Henry's Law Constant
HALOE	Halogen Occultation Experiment
HIAPER	High-Performance Instrumented Airborne Platform for Environmental Research
HIPPO	HIAPER Pole-to-Pole Observations
HMT	Hydrometeorology Testbed
HMT-West	Hydrometeorology Testbed West
HPCS	High-Performance Computing Systems
HRRR	High-Resolution Rapid Refresh
HTML	HyperText Markup Language
HWRF	Hurricane-Weather Research and Forecasting
I/O	Input/Output
ICECAPS	Integrated Characterization of Energy, Clouds, Atmospheric State, and Precipitation at Summit
ICEE	Inspiring Climate Education Excellence
ICESat	Ice Cloud and land Elevation Satellite
ICE-T	Ice in Clouds Experiment—Tropical
ICR	Indirect Cost Recovery
IDW	Inverse Distance Weighting
IGAC	International Global Atmospheric Chemistry
IGY	International Geophysical Year
IHD	International Hydrological Decade
ILRC	International Laser Radar Conference
IOC	Initial Operating Capability
IOCM	Integrated Ocean and Coastal Mapping
IOP	Intense Observing Period
IPCC	Intergovernmental Panel on Climate Change
IPCCAR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IPY	International Polar Years
IRI	International Institute for Climate and Society
ISDAC	Indirect and SemiDirect Aerosol Campaign
ISET	Interdisciplinary Scientific Environmental Technology
ISO	International Standards Organization
ITG	Inside The Greenhouse
IWCS	Intermountain West Climate Summary
LCRB	Lower Colorado River Basin

LES	Large Eddy Simulation
LiDAR	Light Detection and Ranging
LIM	Linear Inverse Models
LISA	Laboratoire Interuniversitaire des Systèmes Atmosphériques
LS	Lower Stratosphere
LT	Local Time
M2M	Machine-to-Machine
MACPEX	Mid-Latitude Airborne Cirrus Properties Experiment
MADIS	Meteorological Assimilation Data Ingest System
MAGT	Mean Annual Ground Temperature
MAX-DOAS	Multi Axis Differential Optical Absorption Spectroscopy
MERRA	Modern Era Retrospective Analysis for Research and Applications
MIRRMAG	Mirror of Online Magnetic Data
MLO	Mauna Loa Observatory
MLOST	Merged Land-Ocean Surface Temperature Analysis
MLS	Microwave Limb Sounder
MMCR	Millimeter Wave Cloud Radar
MSIS	Mass Spectrometer and Incoherent Scatter
Mw	Moment Magnitude
NAAQS	National Ambient Air Quality Standard
NADH	Nicotinamide Adenine Dinucleotide
NAM	North American Monsoon
NAO	North Atlantic Oscillation
NARCCAP	North American Regional Climate Change Assessment Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climate Data Center
NCEP	National Centers for Environmental Prediction
NDACC	Network for the Detection of Atmospheric Composition Change
NEAQS	New England Air Quality Study
NEI2005	National Emission Inventory 2005
NESDIS	National Environmental Satellite, Data, and Information Service
NESII	NOAA's Environmental Software Infrastructure and Interoperability
NEUBrew	NOAA/EPA Brewer Spectrophotometer UV Monitoring Network
NEXRAD	Next Generation Weather Radar
NGDC	National Geophysical Data Center
NIDIS	National Integrated Drought Information Service
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanographic and Atmospheric Administration
NOx	Mono-Nitrogen Oxides NO and NO2
NSF	National Science Foundation

NSIDC	National Snow and Ice Data Center
NTAS	Northwest Tropical Atlantic Station
NWP	Numerical Weather Prediction
NWS	National Weather Service
OA	Organic Aerosol
OAR	Office of Oceanic and Atmospheric Research
OBF	Oregon Basin Fault
OCIO	Office of the Chief Information Officer
ODE	Ozone Depletion Events
ODGI	Ozone Depleting Gas Index
ODS	Ozone-Depleting Substance
OGC	Open Geospatial Consortium
OHP	Haute-Provence Observatory
OLR	Outgoing Long-Wave Radiation
OLS	Operational Linescan System
OOB	Out-of-Band Stray Light
PAGES	Past Global Changes project
PALMS	Particle Analysis by Laser Mass Spectrometry
PBL	Planetary Boundary Layer
PCP	Pentachlorophenol
PcpB	PCP hydroxylase
PcpD	TCBQ reductase
PDF	Probability Density Function
PDO	Pacific Decadal Oscillation
PDR	Preliminary Design Review
PFMB	Perfluoro-2-Methyl-3-Butanone
PFMP	Perfluoro-2-Methyl-3-Pentanone
PIRATA	Prediction and Research Moored Array in the Atlantic
PLP	Pulse Laser Photolysis
PM	Particulate Matter
PNE	PIRATA Northeast Extension
POM-TC	Princeton Ocean Model for Tropical Cyclones
PP	Preprocessor
PSD	Physical Sciences Division
PWC	Pacific Walker Circulation
QBO	Quasi-Biennial Oscillation
QPE	Quantitative Precipitation Estimation
R/V	Research Vessel
RAMADDA	Repository for Archiving, Managing, and Accessing Diverse Data
RAP	Rapid Refresh Potential
RCM	Regional Climate Model

RCP	Representative Concentration Pathway
REE	Rare Earth Element
RFC	Request-For-Change
ROCS	Roger G. Barry Resource Office for Cryospheric Studies
RTGM	Real-Time Ground Magnetometer
RUC	Rapid Update Cycle
SAGE	Systems Approach to Geomorphic Engineering
SBJ	Sierra Barrier Jet
SBUV	Solar Backscatter Ultraviolet Instrument
SEAESRT	Space, Environmental Expert System Real Time
SEARCH	Study of Arctic Environmental Change
SHEBA	Surface Heat Budget of the Arctic
SOA	Secondary Organic Aerosol
SOARS	Significant Opportunities in Atmospheric Research and Science
SOM	Slab Ocean Component
SOS	Science on a Sphere
SPARC	Stratosphere-Troposphere Processes and their Role in Climate
SPIDR	Space Physics Interactive Data Resource
S-RIP	SPARC Reanalysis Intercomparison Project
SST	Sea Surface Temperature
SSW	Sudden Stratospheric Warming
SUMO	Small Unmanned Meteorological Observer
SURFA	Surface Flux Analysis
SURFRAD	Surface Radiation
SUVI	Solar Ultraviolet Imager
SWPC	Space Weather Prediction Center
SXI	Solar X-Ray Imager
TCBQ	Tetrachlorobenzoquinone
TDL	Tunable Diode Laser
TEC	Total Electron Content
TIN	Triangular Irregular Networks
TOPAZ	Tunable Optical Profiler for Aerosol and Ozone
TORERO	Tropical Ocean tRoposphere Exchange of Reactive halogens and Oxygenated voc
TVR	Teleseismic Virtual Source Reflection
TWP	Tropical Western Pacific
UARS	Upper Atmosphere Research Satellite
UAV	Unmanned Aerial Vehicle
UCAR	University Corporation for Atmospheric Research
UCRB	Upper Colorado River Basin
UNOLS	University-National Oceanographic Laboratory System
UPEC	Université Paris-Est Créteil

USGS	United States Geological Survey
UT	Upper Troposphere
UTLS	Upper Troposphere and Lower Stratosphere
UV	Ultraviolet
VBS	Volatility Basis Set
VHF	Very High Frequency
VIC	Variable Infiltration Capacity
WADR	Wasatch Dendroclimatology Research
WAF	Web Accessible Folders
WAM	Whole Atmosphere Model
WCN	Western China profile
WFIP	Wind Forecast Improvement Project
WGI	World Glacier Inventory
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organisation
WOUDC	World Ozone and Ultraviolet Radiation Data Centre
WRCP	World Climate Research Programme
WRF	Weather Research and Forecasting
WSA	Wang-Sheeley-Arge
WWA	Western Water Assessment
XMPP	Extensible Messaging and Presence Protocol

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