CIRES

2013 ANNUAL REPORT TO NOAA

September 2012–May 2013

CIRES

COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

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CIRES: SCIENCE IN SERVICE TO SOCIETY

DAVID OONK/CIRES

Executive Summary and Research Highlights

Since its inception 45 years ago as NOAA's first cooperative institute, 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.

CIRES researchers use time-honored and cutting-edge approaches to study diverse aspects of Earth system science, with a focus on research that NOAA's Research Council terms "use-inspired." That is, CIRES science seeks to improve fundamental understanding of the changing world and also to produce applications that are useful and used by decision makers, educators, the private sector, and others.

Dr. William M. Lewis Jr. served as CIRES' Interim Director for the last year, including the nine months of this reporting period (September 1, 2012 to May 31, 2013). Under his leadership, CIRES continued its tradition of excellence in research and training, helping to ensure NOAA advanced its mission and met strategic goals.

This summary highlights a few of the past year's activities and research successes. In the Project Reports section of this report, accomplishments are reported in full, organized by CIRES' nine themes (page 13). Here, highlights are presented in alignment with NOAA's priorities: the overarching goals outlined in NOAA's Next Generation Strategic Plan (NGSP) and two enterprise objectives.

Climate Adaptation and Mitigation (NGSP)

- With NOAA partners, CIRES researchers continue to track global abundances of all major long-lived greenhouse gases. This year, CO_2 levels exceeded 400 ppm (daily average) at Mauna Loa Observatory in Hawaii for the first time.
- CIRES scientists worked closely with colleagues around the world on parts of the Intergovernmental Panel on Climate Change reports expected in late 2013 and 2014.
- CIRES researchers provided enhanced forecasts for wind energy production, and continue to conduct research on the impact of those forecasts on grid integration of renewable energy.

Weather-Ready Nation (NGSP)

- CIRES researchers and colleagues published papers evaluating the roles of climate change and variability on extreme weather events such as the Texas heat wave of 2011 and the warm spring of 2012 in the Central United States.
- CIRES solar physicists worked with NOAA colleagues in the Space Weather Prediction Center to improve understanding and prediction of solar disturbances in the geospace environment. Such disturbances can affect Earth's atmosphere and technological systems.
- CIRES scientists played critical roles in several intensive field studies of air quality–climate connections, in Utah and California, and in planning for a third field study, in the Southeastern United States.

Engagement Enterprise

- CIRES researchers and collaborators improved the weather prediction systems used at all Weather Forecast Offices (AWIPSII), adding functions to help forecasters visualize and annotate maps and other data.
- During the nine months of this reporting period, 11 new Science On a Sphere exhibits were installed in five countries, bringing NOAA and CIRES science to global audiences.
- CIRES researchers at the National Snow and Ice Data Center (NSIDC) added daily sea ice data to archives, to meet user needs and interest, and published "All About Arctic Climatology and Meteorology," a website for educators and high school students.

Science and Technology Enterprise

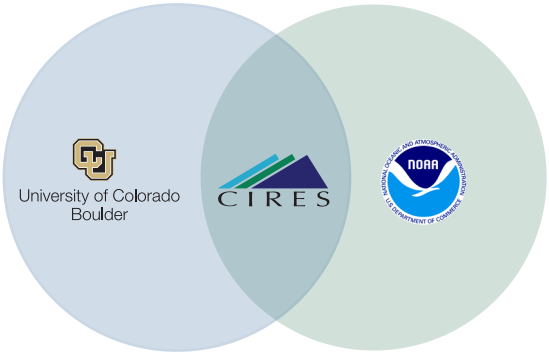
- CIRES researchers at the National Geophysical Data Center developed new Digital Elevation Models (DEMs) in support of NOAA's Tsunami programs.
- CIRES staff continue to work closely with colleagues on tools to improve the reliability, resilience, and usability of NOAA's high performance computing systems.
- CIRES staff working on satellite imagery of Earth at night began working with much higher resolution data from a new instrument on a new satellite. The work, collaborative with NOAA, NASA, and others, is revealing more detailed information about power use, biomass burning, fishing, gas flaring, and other human activities around the world.

In Institution news, CIRES continued to grow during the University's FY13 (July 2012 to 2013), with expenditures just exceeding $68 million. The Institution's financial health is supported by a diversity of funding sources beyond NOAA and the University of Colorado Boulder: NASA, the National Science Foundation, the Department of Defense, Department of Energy, U.S. Agency for International Development and more.

In FY13, CIRES included nearly 200 research scientists, 250 associate scientists, 38 visiting scientists, 29 postdoctoral researchers and 131 graduate students—many of them supported by NOAA (page 72). Those researchers and graduate students published more than 500 peer-reviewed papers, earned numerous honors and awards and were profiled in in local, national and international news outlets. All three measures of success speak to the eminence of CIRES researchers in their fields. This document includes publications; awards, honors, and news will be included in the full Annual Report to be published later this summer.

The CIRES Council of Fellows welcomed one new Fellow this year, Dr. F. Martin (Marty) Ralph. Dr. Ralph is a meteorologist at NOAA's Earth System Research Laboratory Physical Sciences Division. He is chief of the Water Cycle branch, and his research focuses on understanding, monitoring, and predicting key elements of the global water cycle.

In April 2013, the Fellows nominated Dr. Waleed Abdalati—CIRES Fellow and former NASA Chief Scientist—to be the new CIRES director. His appointment was approved by the University after the current reporting period and will be reported on in the next annual report.



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' original and continuing purpose is to support NOAA goals by facilitating interdisciplinary studies that crosscut traditional scientific fields. CIRES fosters interdisciplinary science through four centers and two key programs: the National Snow and Ice Data Center, the Center for Limnology, the Center for Science and Technology Policy Research, the Earth Science and Observation Center, the Western Water Assessment, and the Education and Outreach program. 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 NOAA alone.

University of Colorado Boulder Departments

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

Center for Limnology

Center for Science and Technology Policy Research

Earth Science and Observation Center

National Snow and Ice Data Center

Programs

Education and Outreach

Western Water Assessment

NOAA Earth System Research Laboratory (ESRL)

Chemical Sciences Division

Global Monitoring Division

Global Systems Division

Physical Sciences Division

NOAA Centers

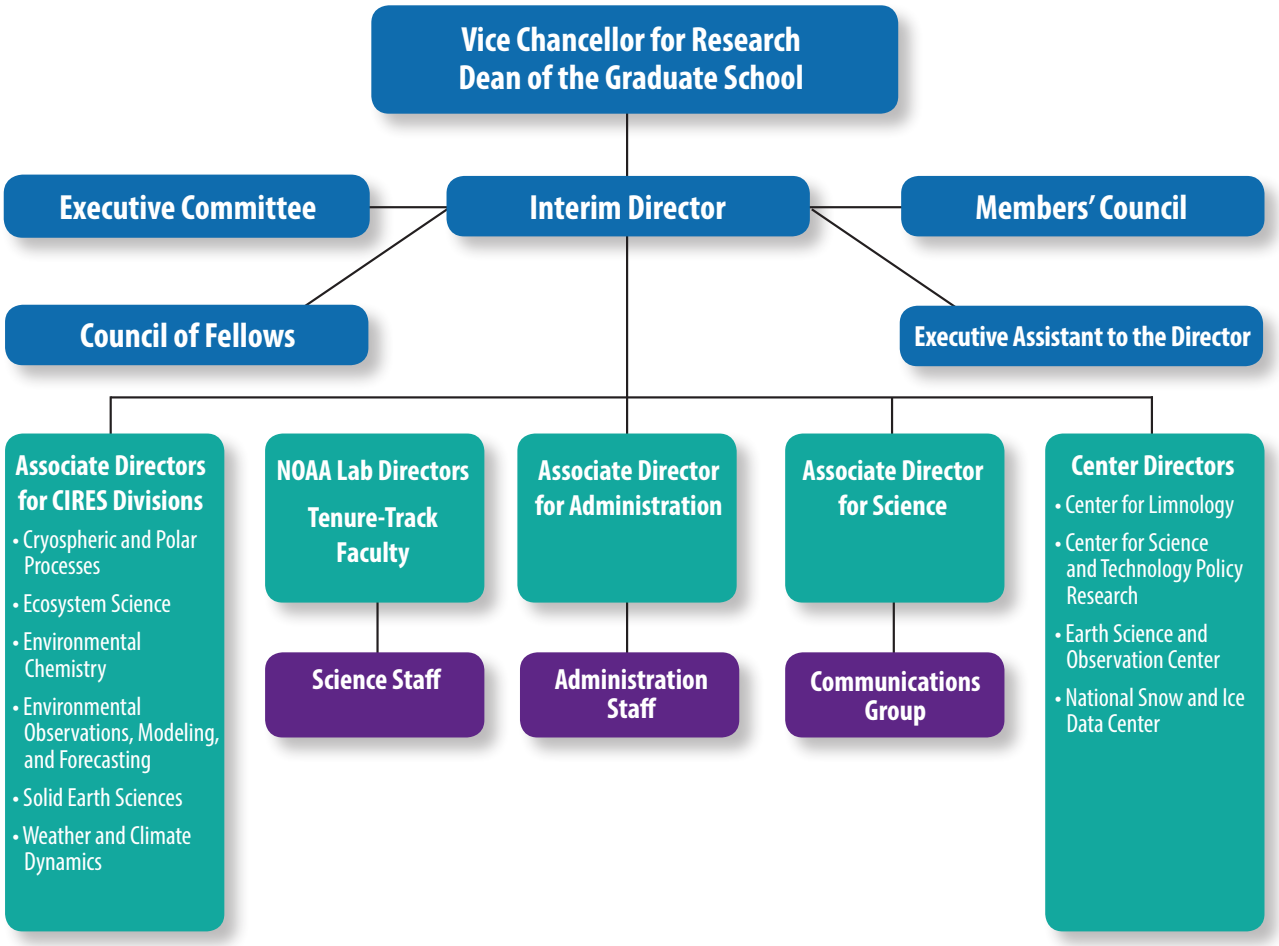
National Geophysical Data Center

Space Weather Prediction Center

GOVERNANCE, MANAGEMENT, AND ORGANIZATION

CIRES is governed and managed through its Council of Fellows, an advisory Executive Committee, and the CIRES Members' Council. The CIRES Centers (Center for Limnology, Center for Science and Technology Policy Research, National Snow and Ice Data Center, and the Earth Science and Observation Center) link NOAA to 11 different university departments. Coordination among all these entities is facilitated through the Communications Group. In FY13, Dr. William M. Lewis, Jr. led CIRES as Interim Director.

CIRES Organizational Structure



Council of Fellows

The Council of Fellows constitutes the "Board of Directors" and chief governing body of CIRES. It is comprised of individuals with an outstanding record of achievement and ability in diverse areas of environmental sciences. They are university faculty, senior research scientists, and government scientists who form the core leadership of the Institute. The Council of Fellows 1) provides leadership at all levels in environmental science, 2) maintains an active scientific research and education program, 3) supports the CIRES infrastructure through indirect cost recovery and in-kind contributions, 4) participates in CIRES management, and 5) contributes interdisciplinary expertise and participates in collaborative work. Fellows 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 nine times during this reporting period: September 20, October 18, November 15, and December 13 of 2012; and January 24, February 28, March 21, April 18, and May 16 of 2013.

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 for CIRES' six divisions, two Fellows elected at large for two-year terms (renewable for one term), and two Members' Council representatives. The Associate Director for Administration, Associate Director for Science, and the Director's Executive Assistant are ex-officio members.

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. Project 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. CIRES has made it a priority to extend its knowledge and community. The Diversity Committee, created in 2010, is working to achieve this goal. The Committee works with the CIRES Education and Outreach program, the Communications Group, and scientists and staff to identify opportunities for CIRES to improve diversity, enrich our science, and enhance our mission.

Members' Council

The CIRES Members' Council, created in 1997, serves 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 elected delegates serve as the liaison between the Members' Council and the CIRES Council of Fellows and Executive Committee. The Members' Council, which meets monthly, then serves as a direct line of communication to the Member population at large. At meetings, the Council hears members' inquiries and concerns, discusses and develops potential solutions to 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 CIRES Science Rendezvous, 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. These 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 (SEPTEMBER 1, 2012 –MAY 31, 2013)

Waleed Abdalati 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 for the Cryospheric and Polar Processes Division

Benjamin Balsley Research Professor Emeritus, Electrical, Computer, and Energy Engineering; CIRES Senior Research Scientist

Stan Benjamin Chief of Assimilation and Modeling Branch, NOAA 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 CIRES Senior Research Scientist

Xinzhao Chu Associate Professor of Aerospace Engineering

Shelley Copley Professor of Molecular, Cellular, and Developmental Biology

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

Lisa Dilling Assistant Professor of Environmental Studies

Randall Dole Deputy Director for Research, NOAA ESRL Physical Sciences Division (PSD); Associate Director for the Weather and Climate Dynamics Division

David Fahey Research Physicist and Program Lead, Atmospheric Composition and Chemical Processes; Senior Scientist, NOAA ESRL CSD

Christopher Fairall Chief of the Weather and Climate Physics Branch, NOAA ESRL PSD

Lang Farmer Professor and Department Chair of Geological Sciences

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

Graham Feingold Research Scientist, NOAA 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

Michael Hardesty Associate Director for the Environmental Observations, Modeling, and Forecasting Division; NOAA ESRL CSD

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, NOAA ESRL Global Monitoring Division

William Neff Senior Scientist and Director or NOAA ESRL PSD

Steven Nerem Professor of Aerospace Engineering

David Noone Associate Professor of Atmospheric and Oceanic Sciences

Judith Perlwitz CIRES Research Scientist; NOAA ESRL PSD

Roger Pielke Jr. Professor of Environmental Studies

Balaji Rajagopalan Professor of Civil, Environmental, and Architectural Engineering

F. Martin Ralph Research meteorologist and chief of the Water Cycle Branch, NOAA ESRL PSD

Prashant Sardeshmukh CIRES Senior Research Scientist; NOAA ESRL PSD

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

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

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

Margaret Tolbert Distinguished Professor of Chemistry and Biochemistry; Co-Associate Director for 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 for the Ecosystem Science Division

Tingjun Zhang CIRES Senior Research Scientist, NSIDC

CIRES CENTERS

The Centers within the CIRES enterprise link NOAA and 11 different departments at the University of Colorado Boulder. CIRES Centers provide an environment conducive to collaboration, facilitating partnerships between federal and academic entities.

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. CSTPR focuses on the intersection of the environment and society and 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.

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, 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.

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 at 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.

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.

INTERDISCIPLINARY PROGRAMS

CIRES fosters a vibrant research environment through programs and initiatives designed to stimulate interdisciplinary collaborations among CIRES, NOAA, and CU-Boulder scientists.

Western Water Assessment

The Western Water Assessment (WWA) is CIRES' 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. Through relationships with networks of decision makers, WWA develops 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 crosscutting 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

Visiting Fellows

CIRES hosts a competitive Visiting Fellows program that promotes collaborative research at the forefront of scientific knowledge. Selected annually, 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 of CIRES Fellows reviews 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 100 Visiting Fellowships. Past recipients have included previous CIRES directors Susan Avery and Konrad Steffen.

cires.colorado.edu/collaboration/fellowships

2012-2013 Visiting Fellows

Fellow	Sponsor/s
Jeffrey Amato	Lang Farmer
Franco Biondi	Thomas Chase
Joanna Boehnert	Maxwell Boykoff
Lindsay Chapman	William Lewis Jr. James McCutchan
Brian Ebel	Greg Tucker
Steven Hansen	Anne Sheehan
Mark Hemer	Baylor Fox-Kemper
Shao-Meng Li	Joost de Gouw
Bjorn-Ola Linner	Roger Pielke Jr.
Ben Livneh	Carol Wessman
Xian Lu	Xinzhao Chu
Ralph Milliff	Baylor Fox-Kemper
Kyung-Eun Min	Fred Fehsenfeld
Arnaud Temme	Greg Tucker
Dan Yakir	David Noone Steve Montzka

Innovative Research Programs

The CIRES-wide competitive Innovative Research Program (IRP) stimulates a creative research environment within CIRES and encourages synergy among disciplines and research colleagues. The program supports 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 proposals and recommends to the CIRES Director 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.
cires.colorado.edu/science/pro/irp

2013 Innovative Research Program Awards

Project	CIRES and NOAA Investigators
Formation-flying for atmospheric studies using small, autonomous aircraft	Ben Balsley and Dale Lawrence
Observations of wind turbine wakes using unmanned aircraft systems	John Cassano, Julie Lundquist, Brian Argrow, Eric Frew, and Katja Friedrich
Are microbes a significant component of free tropospheric aerosol?	Noah Fierer, Joanne Emerson, Anne Perring, Joshua Schwarz, and David Fahey
SOS: Cognition + Affect = Effect	Shilpi Gupta and Marda Kirn
Passive source imaging of Earth's ionosphere using lightning	Steven Hansen, Anne Sheehan, Paul Bedrosian, and Tim Fuller-Rowell
A new method for real-time monitoring of tsunamis with magnetic observations	Manoj Nair, Stefan Maus, Patrick Alken, Neesha Schnepf, and Arnauld Chulliat
The rise and fall of mid-Holocene Rajasthan lakes	Balaji Rajagopalan, Peter Molnar, and Emily Gill
A compact, sensitive LIF instrument for the measurement of SO_2	Andrew Rollins, Troy Thornberry, Ryan Neely, and Ru-Shan Gao

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

CIRES Graduate Student Research Fellowship Recipients (September 2012–May 2013)

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.

ESRL-CIRES Graduate Student Research Fellowship Recipients (September 2012–May 2013)

Sunil Baidar
Chemistry
Advisor: Rainer Volkamer

Katie McCaffrey
Atmospheric and Oceanic Sciences
Advisors: Baylor Fox-Kemper and Jeffrey Weiss

Ryan Reynolds Neely III
Atmospheric and Oceanic Sciences
Advisors: Brian Toon and Jeffrey Thayer

OTHER PROGRAMS

CIRES Communications

It has long been a part of CIRES' 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 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 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: Science News, The New York Times, Scientific American, CBS, Discovery, Discovery News, National Geographic, Time Nature News BBC, Business Week, MSNBC, Fox News, Science NOW, Nature News, and the Los Angeles Times.

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 have confidence that the resources provided by CIRES EO are scientifically sound and up-to-date.
cires.colorado.edu/education/outreach

FINANCE

CIRES continued to grow during the University's FY13 (July 2012–June 2013), with total expenditures just exceeding $68 million ($66.7 million in FY12). CIRES researchers continue to have great success in obtaining external research awards. As was true last year, contracts and grants expenses (48 percent of total) are greater than those in our Cooperative Agreements (46 percent). The University's monetary contribution to CIRES primarily covers faculty salaries, and it fluctuates from year to year due to changes in our rostered University faculty appointments.

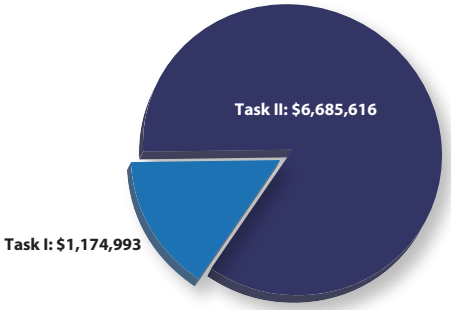
Agreement expenditures by task for FY13 are shown in the top figure at right. As of May 31, 2013, NOAA provided $7,860,609 for the first nine months of our new Cooperative Agreement (NA12OAR4320137, September 2012 to August 2017).

Task I funding is for CIRES administration and internal scientific programs, such as the Visiting Fellows and Graduate Student Fellowship programs; Task II funds CIRES' collaboration with NOAA's Earth System Research Laboratory, the National Geophysical Data Center, and the Space Weather Prediction Center, all in Boulder, Colo.

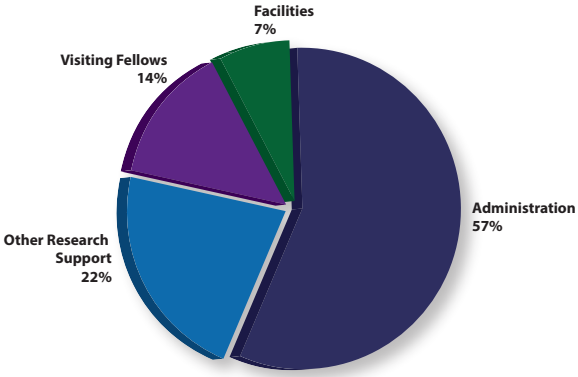
The middle chart at right breaks down Task I expenditures from FY13, including expenditures under our current and new Cooperative Agreements (NA10OAR4320142 and NA12OAR4320137). The largest share (57 percent) of Task I base funds supports CIRES administration, primarily salaries and benefits for the administrative staff. The Visiting Fellows program received 14 percent of Task I base fund support in FY13 and is subsidized by other Institute funding as well. Task I also provides partial support of CIRES' Education and Outreach program, other research support, and the physical plant facilities.

NOAA Task I base funding is augmented by CIRES' 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.

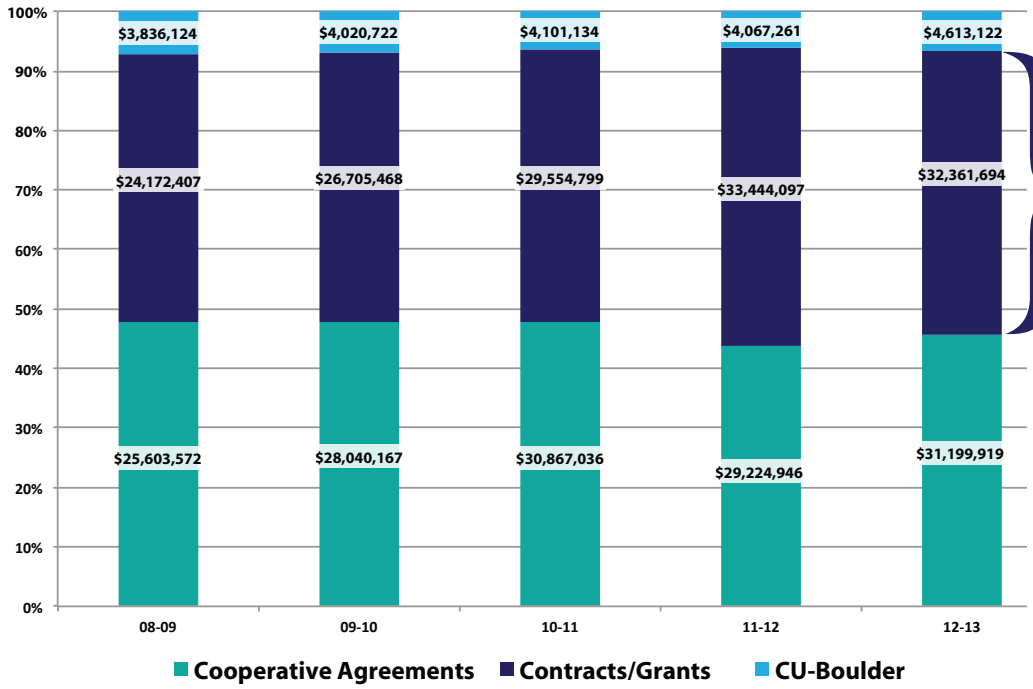
Cooperative Agreement NA120AR4320137 funding by task (September 2012–May 2013)



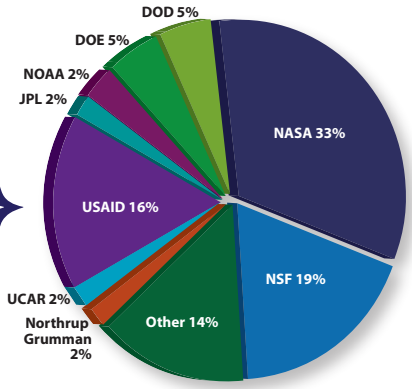
2012–2013 CIRES Task 1 base fund expenses



Expenditures by NOAA Cooperative Agreements, individual awards, and University of Colorado Boulder funds



Breakdown by funding agency



DOD: Department of Defense
DOE: Department of Energy
JPL: Jet Propulsion Laboratory
NSF: National Science Foundation
UCAR: University Corporation for Atmospheric Research
USAID: U.S. Agency for International Development

PROJECT REPORTS

Projects below are organized by CIRES theme. In the following pages, projects are listed in alphanumeric order, by NOAA organization.

Air Quality in a Changing Climate

CSD-01	14	Intensive Regional Field Studies of Climate-Air Quality Interdependencies
CSD-02	15	Chemistry, Emissions, and Transport Modeling Research
GSD-04	25	Improve Regional Air-Quality Prediction
PSD-01	35	Relationship of Air Quality to Weather

Climate Forcing, Feedbacks, and Analysis

CSD-03	15	Scientific Assessments for Decision Makers
CSD-04	15	Effects of Emissions on Atmospheric Composition
CSD-05	16	Laboratory Studies of Fundamental Chemical and Physical Processes
CSD-06	17	Aerosol Formation, Composition, Properties, and Interactions With Clouds
CSD-07	17	Atmospheric Measurements and Impacts of Aerosols, Black Carbon, and Water Vapor
CSD-08	18	Remote-Sensing Studies of the Atmosphere and Oceans
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Earth System Dynamics, Variability, and Change

PSD-03	35	Diagnosis of Natural and Anthropogenic Contributions to Climate Variability, including Changes in Extreme Weather Statistics
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PSD-10	40	Physical Processes Controlling the Arctic Surface Energy Budget
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PSD-13	42	Effects of the Tropical Ocean on Weather and Climate
PSD-15	43	An Assessment of Skill and Reliability of Regional Climate Predictions
PSD-16	44	Understanding and Explaining the Role of Extremes in Missouri Basin Flooding
PSD-17	44	Understanding How Tropical SSTs Influence Atmospheric Variability
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Management and Exploitation of Geophysical Data

NGDC -01	27	Enhancing Data Management Systems and Web-Based Data Access
NGDC-02	27	Enhancing Marine Geophysical Data Stewardship
NGDC-03	28	Improved Geomagnetic Data Integration and Earth Reference Models
NGDC-04	28	Enhanced Coastal Data Services, Integration, and Modeling
NGDC-05	29	Enhanced Stewardship of Space Weather Data
NGDC-07	30	Remote Sensing of Anthropogenic Signals
NGDC-08	31	Development of Space Environment Data Algorithms and Products

Management and Exploitation of Geophysical Data (continued)

NGDC-09	32	Enhanced Ionosonde Data Access and Stewardship
NGDC-10	32	Enhanced CORS Data Access and Stewardship
NGDC-11*	33	Enhanced Stewardship of Data on Decadal- to Millennial-Scale Climate Variability
NGDC-12*	33	Historical Surface Marine Meteorological Data Stewardship: The International Comprehensive Ocean-Atmosphere Data Set
NSIDC-03	34	Update, Improve, and Maintain Polar Region Data Sets

*These two projects were unintentionally omitted from the CIRES five-year workplan, NA12OAR4320137.

Regional Sciences and Applications

PSD-05	37	Prediction of Extreme Regional Precipitation and Flooding

Scientific Outreach and Education

GSD-02	23	Science Education and Outreach
NSIDC-01	34	Maintain and Enhance the Sea Ice Index as an Outreach Tool
NSIDC-02	34	Update and Maintain Educational Resources for the Cryosphere
PSD-04	36	An Experimental Approach to Climate Data and Web Services

Space Weather Understanding and Prediction

NGDC-06	30	Satellite Anomaly Information Support
SWPC-01	45	Space Weather Information Technology and Data Systems
SWPC-02	45	Enhancement of Prediction Capacity for Solar Disturbances in the Geospace Environment
SWPC-03	45	Analysis of the Role of the Upper Atmosphere in Space Weather Phenomena

Stratospheric Processes and Trends

CSD-09	19	Stratospheric Radiative and Chemical Processes That Affect Climate
GMD-02	20	Analysis of the Causes of Ozone Depletion
GMD-05	22	Provide Data and Information Necessary to Understand Behavior of Ozone-Depleting Substances

Systems and Prediction Models Development

GIP-01	19	Environmental Software Infrastructure and Interoperability Program
GMD-01	20	Collect, Archive, and Analyze Global Surface Radiation Network Data
GSD-01	23	Improve Weather Information Systems
GSD-03	24	Improving Numerical Weather Prediction
GSD-05	25	Development of High-Performance Computing Systems
GSD-06	26	Verification Techniques for Evaluation of Aviation Weather Forecasts
GSD-07	26	Testbed Center for Numerical Prediction Development
PSD-12	41	Analysis of the Causes of Extreme Weather Events
PSD-14	42	Forecasts for Wind Energy

CHEMICAL SCIENCES DIVISION

CSD-01 Intensive Regional Field Studies of Climate–Air Quality Interdependencies

CIRES LEAD: ANDY NEUMAN
NOAA LEAD: DAVID PARRISH
CIRES THEME: AIR QUALITY IN A CHANGING CLIMATE
NOAA THEME: WEATHER-READY NATION

GOALS & OBJECTIVES

This project will characterize the emissions, transport processes, chemical transformations, and loss processes that contribute to regional and local air quality issues and to climate change on regional and global scales.

ACCOMPLISHMENTS

During the past year, our group's accomplishments include publishing findings from the Research at the Nexus of Air Quality and Climate Change field study (CalNex); performing extensive atmospheric sampling during the Energy and Environment–Uintah Basin Winter Ozone Study (UBWOS); and preparing for the Southeast Nexus Experiment (SENEX).

Research vans loaded with instruments to study wintertime ozone formation in the Uintah Basin, Utah.
Photo: Scott Sandberg

These three intensive regional field studies—CalNex, UBWOS, and SENEX—serve to characterize atmospheric chemistry and emissions that affect air quality and climate. Quantification of emissions improves the ability of models to estimate future climate and air quality. Atmospheric chemical and meteorological processes often dictate the abundance of constituents that control air quality and climate. These field studies provide the scientific understanding of emissions, atmospheric chemistry, and transport to support development of effective mitigation strategies.

The CalNex study enhanced scientific knowledge of issues that affect regional air quality and climate change, and we detailed these results in many peer-reviewed manuscripts published between September 2012 and May 2013. We determined emissions of climate-relevant greenhouse gases from agricultural sources in California (Peischl et al. 2013; Xiang et al. 2013) and anthropogenic sources in the Los Angeles Basin (Brioude et al. 2012; Newman et al. 2013). Additionally, we quantified emissions from the Los Angeles Basin that affect air quality (Borbon et al. 2013; Ryerson et al. 2013). We examined aerosol formation to better constrain radiative forcing from aerosols (LeBlanc et al. 2012; Liu et al. 2012; Zhang et al. 2012; Ensberg et al. 2013). We examined the effects of meteorology and transport upon ozone concentrations in California to better understand the contributions of local and regional emissions to ozone levels (Wagner et al. 2012; Lin et al. 2012; Angevine et al. 2012). We also assessed the consequences and promise of emission controls through studies of long-term trends in trace gas concentrations in the Los Angeles Basin (Warneke et al. 2012; Pollack et al. 2012).

Our team conducted an intensive field campaign in winter 2013 that studied the causes of high wintertime ozone in the Uintah Basin, Utah. Scientists have observed high wintertime ozone levels, which are damaging to human health, in several regions where geologic basins trap emissions associated with oil and gas extraction. The scientific community does not understand the chemistry and meteorology that cause these large ozone values, making effective and efficient mitigation strategies challenging and uncertain. To understand the factors that influence ozone abundance in this region, we used comprehensive measurements of trace gases, aerosols, and meteorological parameters to examine the emission sources, ozone-formation chemistry, unique radical sources, and air-mass transport in the Uintah Basin.

Planning and preparing for the SENEX study included experiment design and instrument development and calibration. Scientists involved with the SENEX study designed it in collaboration with the Southeast Atmosphere Study to facilitate extensive collaborations with other studies in the same region. The Southeast U.S. is a region with significant anthropogenic and biogenic emissions that result in large atmospheric abundances of many climate-forcing agents and air pollutants. But the sources and effects of some of the constituents are poorly known. For example, organic aerosols constitute approximately half the aerosol loading in this region, but researchers don't fully understand their sources and climate effects. Our team developed instruments to measure the gas-phase precursors to organic aerosols, and we installed these instruments on the NOAA WP-3D aircraft in preparation for the study in summer 2013.

Borbon, A, JB Gilman, WC Kuster, N Grand, S Chevaillier, A Colomb, C Dolgorouky, V Gros, M Lopez, R Sarda-Esteve, et al. 2013. Emission ratios of anthropogenic volatile organic compounds in northern mid-latitude megacities: observations versus emission inventories in Los Angeles and Paris. *J. Geophys. Res.* Forthcoming.

Ensberg, JJ, JS Craven, AR Metcalf, JD Allan, WM Angevine, R Bahreini, J Brioude, C Cai, H Coe, JA de Gouw, et al. 2013. Inorganic and black carbon aerosols in the Los Angeles Basin during CalNex. *J. Geophys. Res.* Forthcoming.

Newman, S, S Jeong, ML Fischer, X Xu, CL Haman, B Lefer, S Alvarez, B Rappenglueck, EA Kort, AE Andrews, et al. 2013. Diurnal tracking of anthropogenic CO_2 emissions in the Los Angeles basin megacity during spring 2010. *Atmos. Chem. Phys.* 13.

Peischl, J, TB Ryerson, J Brioude, KC Aikin, AE Andrews, E Atlas, D Blake, BC Daube, JA de Gouw, E Dlugokencky, et al. 2013. Quantifying sources of methane using light alkanes in the Los Angeles basin, California. *J. Geophys. Res Atmos.* 118.

Ryerson, TB, AE Andrews, WM Angevine, TS Bates, CA Brock, B Cairns, RC Cohen, OR Cooper, JA de Gouw, FC Fehsenfeld, et al. 2013. The 2010 California Research at the Nexus of Air Quality and Climate Change (CalNex) field study. *J. Geophys. Res. Atmos.* 118.

Xiang, B, Miller SM, EA Kort, GW Santoni, BC Daube, R Commane, WM Angevine, TB Ryerson, MK Trainer, AE Andrews, et al. 2013. Nitrous oxide (N_2O) emissions from California based on 2010 CalNex airborne measurements. *J. Geophys. Res. Atmos.* 118:2809–2820.

CSD-02 Chemistry, Emissions, and Transport Modeling Research

CIRES LEAD: STU MCKEEN
NOAA LEAD: MICHAEL TRAINER
CIRES THEME: AIR QUALITY IN A CHANGING CLIMATE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will use field observations and laboratory studies to provide better representation of atmospheric chemical, physical, and dynamical processes in numerical models, which will improve predictions and projections of climate and air quality.

ACCOMPLISHMENTS

An international team led by CIRES scientist Owen Cooper recently compiled an assessment of long-term (1990–2010) rural ozone trends throughout the United States and also updated free-tropospheric ozone trends above western North America. Ozone observations in the free troposphere show that ozone has increased above western North America at a rate similar to that observed at the surface of East Asia. Ozone at rural surface sites in the United States shows contrasting trends in the western and eastern portions of the country. In the eastern United States, ozone is decreasing in spring and summer for high-ozone episodes, in good agreement with declining emissions.

In the U.S. West, ozone precursor emissions have not decreased as rapidly as in the U.S. East, but emission reductions have been sufficient to greatly reduce ozone values in heavily urbanized areas of California. In contrast, ozone at most rural sites in the West has not responded to decreasing emissions. In fact, during spring, half of the rural western sites show increasing ozone. Model simulations indicate that ozone in the West should have decreased in response to reduced precursor emissions. The lack of a response suggests that rising ozone precursor emissions in East Asia are leading to greater levels of ozone imported into the West, offsetting the potential benefits from domestic reductions of ozone-precursor emissions.

CSD-03 Scientific Assessments for Decision Makers

CIRES LEAD: CHRISTINE ENNIS
NOAA LEAD: A. R. RAVISHANKARA
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project addresses adaptation and mitigation.

ACCOMPLISHMENTS

During this past year, our team's work on this project laid the foundation for the next *Scientific Assessment of Ozone Depletion* (due out in 2014) for the Montreal Protocol on Substances that Deplete the Ozone Layer. Four team members are serving on the international Scientific Steering Committee for the 2014 report. The cochairs, steering committee, and assessment coordinator worked to determine the overall approach of the report and the chapter structure. They sought the advice of the international scientific community and received it in March and April 2013. Based on the advice and further deliberations, the chairs and steering committee developed the team of chapter lead authors and review editors for the report. The team planned a first meeting to take place in June 2013.

CSD-04 Effects of Emissions on Atmospheric Composition

CIRES LEAD: JOOST DE GOUW
NOAA LEAD: TOM RYERSON
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will advance scientific understanding of the effects on air quality, climate, and stratospheric ozone of emissions from both anthropogenic and biogenic sources.

ACCOMPLISHMENTS

During this project period, our team characterized the emissions of hydrocarbons from oil and gas production in the Colorado Front Range. We found that these emissions constitute more than half of the hydrocarbon reactivity in the area, suggesting that they may be important for the formation of photochemical ozone.

From the 2010 CalNex (Research at the Nexus of Air Quality and Climate Change field study) data, we determined the emissions of methane and other small alkanes from the Los Angeles Basin. The analysis showed that the two largest methane sources in the city are emissions of gas from pipelines and/or geologic seeps (47 percent) and emissions from landfills (40 percent).

Using measurements made at the Fire Sciences Laboratory in Missoula, Mont., in 2009, our team determined the emissions of trace gases and fine particles from controlled laboratory burns. The data set amounted to one of the most comprehensive measurements of biomass-burning emissions to date.

Using field measurements made in Fort Collins, Colo., in 2011, we determined emissions of volatile organic compounds (VOCs) associated with the growing of biofuel crops. We found that the VOC emissions from the growing of biofuel crops are of the same order of magnitude as those associated with the use of the biofuel that is produced as a transportation fuel. In a separate study, we found that urban emissions of ethanol have strongly increased over the last decade due to an increased use of E10 fuel, a blend of 10 percent ethanol and gasoline.

We determined emissions of hydrocarbons and nitrogen oxides in the Los Angeles Basin, and long-term trends therein, by using the CalNex data set and comparison with earlier measurements in the area. Our team found that urban emissions of hydrocarbons and nitrogen oxides have strongly decreased during the last several decades.

CSD-05 Laboratory Studies of Fundamental Chemical and Physical Processes

CIRES LEAD: RANAJIT TALUKDAR
NOAA LEAD: JIM BURKHOLDER
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This research will produce fundamental information on photochemical processes, chemical reactions of atmospheric relevance, and chemical and physical processes that contribute to aerosol formation and growth. The information is used to improve climate and air-quality predictions and projections made by numerical models.

ACCOMPLISHMENTS

Our team elucidated lifetimes, ozone-depletion potentials (ODP), and global-warming potentials (GWP) of long-lived greenhouse gases (GHG). The contribution of long-lived GHGs—including NF_3, SF_5CF_3, CHF_3 (known as HFC-23), C_2F_6, c-C_4F_8, n-C_5F_{12}, and n-C6F_{14}—to the radiative forcing of Earth has increased during the past several decades. Their long atmospheric lifetimes and GWPs result primarily from stratospheric loss processes via reaction with the electronically excited oxygen O(^{1}D) and their strong absorption in the infrared "window" region. The improved O(^{1}D) rate coefficients that we measured will result in longer atmospheric lifetime of GHGs compared to the present evaluation (Baasandorj et al. 2012).

We also calculated atmospheric photolysis rates and global annually averaged lifetimes of NF_3 (a persistent GHG) by using our measured UV absorption cross sections, photolysis quantum yields, and O(^{1}D) reaction with the Goddard Space Flight Center 2-D model (Papadimitriou et al. 2013). Our new data increased NF_3's calculated global lifetime from 484 years to 585 years and GWP by 6.5 percent for a new value of 19,700 on a 500-year time horizon (Papadimitriou et al. 2013).

Additionally, our team researched society's ongoing switch from halons. Perfluoroketones (PFK)—such as PFMP (perfluoro-2-methyl-3-pentatnone, $C_2F_5C(O)F(CF_3)_2$), a clean fire-extinguishing agent with a GWP of approximately 1 and a photolysis lifetime of approximately two weeks—are replacing hydrofluorocarbons (HFC) and halons. Aqueous-phase processing of PFMP produces the halocarbon HFC 227ea which is long-lived (39 years) and has a high GWP (3,580 on a 100-year time horizon). This consequently increases the effective GWP of PFMP. We determined the Henry's law solubility coefficients and hydrolysis rate coefficients of PFK and other persistent long-lived molecules of atmospheric interest by using a newly developed methodology and apparatus in our laboratory. We will use these values to understand the atmospheric impact of PFMP and other long-lived molecules.

We also made advances in our understanding of halons. We re-evaluated the ozone-depleting substances CF_2Br_2 (known as Halon-1202), CF_2ClBr (Halon-1211), and CF_2BrCF_2Br (Halon-2402) by measuring their UV absorption cross section with a highly sensitive cavity ring down technique. The new, improved values reduced the uncertainties of calculated ODP and GWP (Papanastasiou et al. 2013).

We made progress in the realm of halogen chemistry as well. Nitryl chloride is produced in the atmosphere via the heterogeneous interaction of gas-phase N_2O_5 with chloride-containing salt (in the aerosols). We studied the photochemistry of this molecule relevant to atmospheric conditions by measuring its UV absorption cross sections and quantum yields for the formation of the chloride atom and oxygen atom to evaluate its oxidative capacity (Ghosh et al. 2012).

Other topics we investigated include: heterogeneous processing of N_2O_5 on HCl-doped H_2SO_4 under stratospheric conditions to produce $ClNO_2$ (Talukdar et al. 2012); UV photolysis of oxalyl chloride, $(COCl)_2$; determination of photodissociation of quantum yield (Ghosh et al. 2012); and degradation of volatile organic compounds (VOC). With the latter, we studied OH-initiated atmospheric degradation of isomers of butanols as a function of temperature, which included the determination of OH rate coefficients and the products of the reaction. The manuscript on the OH reaction is forthcoming in the *Journal of Physical Chemistry A*.

Finally, we initiated three new projects:

1) The medical field uses 1,2-dichlorohexafluoro-butane (1,2-c-$C_4F_6Cl_2$, or R-316c) as a nonimmobilizer amnesiac. Manufacturers have recently been considering this compound as a potential replacement in industrial applications. And the United States is considering using hydrofluoro ether mixtures, such as with methyl-perfluoroheptene-ether ($C_7F_{13}OCH_3$, or MPHE), as a potential replacement for perfluorinated alkane (PFC) and perfluorinated polyether mixtures used as heat transfer fluids. Using our measured rate coefficients for these compounds' reactions with O(1D), and OH, O_3, UV cross sections, photolysis products, and infrared cross sections, we calculated their lifetimes, ODP, and GWP.

2) We set up experiments to study the NO_3 reactions with VOCs by using cavity ring down technique to understand their nighttime processing.

3) To study heterogeneous chemistry of atmospheric interest with an electrospray ion source mass spectrometer (ESI-MS), we designed and modified the front end of a chemical ionization mass spectrometer (CIMS) to adapt an ESI and detect the ions with a quadruple mass filter.

Baasandorj, M, EL Fleming, CH Jackman, and JB Burkholder. 2013. O(^{1}D) kinetic study of key ozone depleting substances and greenhouse gases. *J. Phys. Chem. A.* 117(12):2434-2445.

Papadimitriou, VC, MR McGillen, EL Fleming, CH Jackman, and JB Burkholder. 2013. NF^3: UV absorption spectrum temperature dependence and the atmospheric and climate forcing implications. *Geophys. Res. Lett.* 40(2):440-445.

Papanastasiou, DK, NR Carlon, JA Neuman, EL Fleming, CH Jackman, and JB Burkholder. 2013. Revised UV absorption spectra, ozone depletion potentials, and global warming potentials for the ozone-depleting substances CF_2Br_2, CF_2C_lBr, and CF_2BrCF_2Br. *Geophys. Res. Lett*. 40(2):464-469.

CSD-06 Aerosol Formation, Composition, Properties, and Interactions With Clouds

CIRES LEAD: DAN LACK
NOAA LEAD: DAN MURPHY
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will investigate the origins, transformations, and fate of aerosols in the atmosphere, including both direct and indirect (interactions with clouds) radiative effects.

ACCOMPLISHMENTS

During the reporting period, our team made advancements in the following areas.

Shipping emissions: In collaboration with Norwegian researchers, we published modeling studies on the impact of current and future shipping emissions on the rapidly changing Arctic environment. This work, in addition to prior studies from our group, provided to the International Maritime Organization's (IMO) policy discussions scientific expertise on the impacts of ship black carbon in the Arctic and global environment.

Forest fires: We also continued to publish work on the chemical and optical relationships of particles emitted from forest fires. The emitted particles can have significant effect on climate, and our measurements have provided initial insights to the contributions of black carbon and brown oils to the climate impacts of forest-fire smoke.

Development of secondary organic aerosol (SOA) models: In collaboration with colleagues from CU-Boulder and by using laboratory-derived reaction parameters, we showed that chemical processes in the aqueous phase can explain a large fraction of SOA formation in Mexico City.

Development of ice microphysics models: Cloud models poorly represent ice nucleation due to unknown key parameters and the complexity of ice nuclei. Analysis of different descriptions of heterogeneous freezing has revealed that researchers need more accurate descriptions since simplification can lead to great biases in predicted ice-particle concentrations.

Cirrus cloud ice nuclei: In collaboration with colleagues from the Massachusetts Institute of Technology and other universities, we have shown through measurements of upper tropospheric ice nuclei that mineral dust and industrial metallic particles exert a disproportionally large influence on cirrus cloud formation in a variety of geographic regions. These observations will help simplify theoretical treatments of global cirrus formation and also suggest a new route whereby human activities may modify the upper tropospheric radiation balance.

Aerosol nucleation and Earth's radiative forcing: We have published a climate model study of aerosol nucleation in the atmosphere. For this purpose, we developed a representation of aerosol nucleation for use in climate models. The results of this study quantify the effect of aerosol nucleation on Earth's radiative forcing and show that aerosol nucleation has a far greater effect on clouds and radiative forcing over oceans than over continents.

Effects of solar activity on climate: We published a climate model study of the effect of the decadal solar cycle on Earth's cloud cover and on Earth's radiative forcing. The effect arises from charged nucleation of aerosol in the atmosphere, which is initiated by the ionization of air molecules by galactic cosmic rays. The Sun's magnetic field modulates the flux of galactic cosmic rays in the course of its decadal activity cycle, and a resulting signal could propagate to cloud properties via the various effects of aerosol particles on clouds. The results show that the decadal solar cycle has a small effect on Earth's cloud cover and radiative forcing. This outcome challenges the arguments of anthropogenic-climate-change critics who invoke a large influence of solar variability as an explanation for the 20th-century warming of the planet.

Aerosol nucleation in open cells: We have published a large-eddy-simulation study that explains the mechanisms leading to aerosol nucleation in marine boundary layer open cells.

CSD-07 Atmospheric Measurements and Impacts of Aerosols, Black Carbon, and Water Vapor

CIRES LEAD: JOSHUA SCHWARZ
NOAA LEAD: DAVID FAHEY
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will provide improved measurement capability and data for atmospheric aerosols (including black carbon) and water vapor. Analyses and modeling results will lead to more accurate representation of these critical species in numerical models, which will advance the scientific understanding of their climate impacts.

ACCOMPLISHMENTS

During the past nine months, work on this project has resulted in expanded capabilities to measure aerosols and water vapor in the atmosphere, as well as continued analysis of recently obtained data sets. In March, our team acquired a Wide-Incidence Bioaerosol Sensor (WIBS4) from Droplet Measurement Technology Inc. in Boulder, Colo., and we are evaluating it in the laboratory in preparation for measurements at the Boulder Atmospheric Observatory (BAO). The BAO work stems from a funded CIRES Innovative Research Program proposal that links the WIBS4 measurement with flow-cytometry measurements made by CIRES Fellow Noah Fierer's research group of airborne bacteria.

Work continued on analysis of the Deep Convective Clouds and Chemistry (DC3) data set obtained in summer 2012 with our new humidified-dual single particle soot photometer (HD-SP2). We finalized the data and are preparing a manuscript describing the black carbon aerosol measurements made during DC3. Also in conjunction with this data, the group hosted a collaborator, Sho Ohata, from the University of Tokyo, in preparation for the upcoming Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) mission in summer 2014. He stayed for one month and contributed to improving the quality assessment of the HD-SP2 measurements by improving the design of the humidification system and improving our analysis of the data. We also presented black carbon data from the 2011 Mid-latitude Airborne Cirrus Proper-

ties Experiment (MACPEX) campaign in a manuscript describing a technical improvement to the sampling system; this technical improvement allows measurement of interstitial aerosols in cirrus clouds. We submitted the manuscript to *Aerosol Science and Technology*, and it is currently in revision.

We deployed the NOAA unmanned aircraft system (UAS) ozone instrument on the NASA Global Hawk UAS during the second stage of the Airborne Tropical Tropopause Experiment (ATTREX) in January–March 2013. We measured ozone values in the Pacific tropical tropopause layer (TTL) to provide an indication of the tropospheric or stratospheric nature of the air being sampled.

Our efforts on measurement of water vapor and condensed-phase water in the upper troposphere and lower stratosphere (UT/LS) during the last nine months involved completing construction of a new two-channel, tunable, diode-laser-based instrument and integration and deployment of the instrument on the NASA Global Hawk unmanned aircraft for the second stage of the ATTREX campaign. The instrument performed well during its initial deployment and yielded measurements of both low TTL water-vapor mixing ratios and the ice-water content of high-altitude tropical cirrus clouds. This information is important for understanding the mechanisms leading to dehydration of air transported into the stratosphere.

In April 2013, the water instrument participated in the Aqua-VIT2 (Aqua Validation and Instrument Tests) water-vapor measurement intercomparison campaign at the AIDA (Aerosol Interaction and Dynamics in the Atmosphere) chamber of the Karlsruhe Institute of Technology in Germany. This intercomparison seeks to address outstanding questions about the ability to make accurate measurements in the driest regions of the UT/LS.

A manuscript describing the measurement of water vapor in the UT/LS through the use of chemical ionization mass spectrometry during the MACPEX campaign is forthcoming. We are also preparing a manuscript analyzing the agreement and potential sources of disagreement between a number of UT/LS hygrometers operating in the MACPEX campaign.

CSD-08 Remote-Sensing Studies of the Atmosphere and Oceans

CIRES LEAD: CHRISTOPH SENFF
NOAA LEAD: ALAN BREWER
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: WEATHER-READY NATION

GOALS & OBJECTIVES

This project will investigate atmospheric dynamics, including transport of atmospheric constituents over complex terrain, in coastal and open ocean regions, and from high altitudes to the surface. These studies have particular relevance to air quality, climate, ocean ecosystems, and renewable energy.

ACCOMPLISHMENTS

During the past year, work under this project included studies to investigate the distribution and transport of ozone, quantify greenhouse gas emissions, characterize the wind field at potential offshore-wind-farm sites, and investigate ocean properties.

Our team used lidar backscatter data from the Spaceborne Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations satellite (CALIPSO) to develop a method for identification of plankton layers just beneath the ocean surface. Changes in biological activity near the ocean surface may be coupled to changes in atmospheric aerosol concentrations and, thus, impact climate. Other ocean-ecosystem-related work included a laboratory study to determine if aircraft-based lidar can measure certain ocean properties by using laser light scattered by underwater air bubbles. To characterize the wind field over the ocean at wind-turbine-rotor heights, we used data collected with the High Resolution Doppler Lidar (HRDL) over the Gulf of Maine during the 2004 New England Air Quality Study. This data set will provide crucial information for siting and design of future offshore wind farms.

This spring, our team used the HRDL to quantify greenhouse gas emissions associated with oil and gas exploration. HRDL provided wind profiles throughout the boundary layer as well as a record of boundary-layer height. These data, combined with airborne in situ measurements of greenhouse gas concentrations, allowed the retrieval of greenhouse gas fluxes downwind of a large oil and gas field. We deployed the TOPAZ (Tunable Optical Profiler for Aerosol and oZone) ozone and aerosol lidar at two different field campaigns: the Uintah Basin Wintertime Ozone Study (UBWOS) and the Las Vegas Ozone Study (LVOS). At UBWOS, the TOPAZ lidar provided unique information about the vertical distribution of ozone, including the height of the polluted layer, during high-ozone events. During the LVOS study, which concludes at the end of June 2013, we are using TOPAZ to assess the influence of stratosphere-to-troposphere transport—as well as transport of ozone from southern California and Asia—on surface ozone concentrations in the Las Vegas area.

CSD-09 Stratospheric Radiative and Chemical Processes That Affect Climate

CIRES LEAD: SEAN DAVIS
NOAA LEAD: KAREN ROSENLOF
CIRES THEME: STRATOSPHERIC PROCESSES AND TRENDS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project seeks to understand the processes in the stratosphere and upper troposphere that affect the radiative balance, transport (horizontal and vertical), and chemistry, especially the in stratospheric ozone layer, in that region of the atmosphere.

ACCOMPLISHMENTS

During the past year, this project advanced understanding of past changes in stratospheric composition and their radiative impacts, as well as understanding of processes that govern variability in stratospheric composition.

Radiative forcing is an important metric for quantifying surface climate impacts because it allows for the direct comparison of impacts due to different climate-forcing agents. Estimates of radiative forcing due to ozone depletion during the past 30 years stem from databases of ozone-concentration measurements. Through a new and improved historical record of ozone concentrations, our study identified stronger ozone depletion. In the study, we calculate a stronger radiative forcing due to past stratospheric ozone depletion than previous studies (Hassler et al. 2012). This study pointed to an increased role for ozone depletion in recent climate change.

Our team also performed preliminary work for understanding the sensitivity of the climate response to stratospheric ozone depletion. We used the aforementioned ozone-concentration database as input for climate model experiments with the National Center for Atmospheric Research Community Earth System Model. Analysis is ongoing, but the initial results indicate that the use of the new database enhances the model-predicted climate change. This initial analysis suggests that previous studies that used climate models forced with ozone data sets containing too little ozone depletion have underestimated climate change due to stratospheric ozone depletion.

In addition to our work improving understanding of past stratospheric composition and radiative changes, several studies increased understanding of processes that govern variability in stratospheric composition. Previous studies have shown that the concentration of stratospheric aerosols has increased during the past decade and that this increase caused a significant radiative forcing and contributed to a slowdown in surface climate warming. The cause of these changes is important for future climate projections, but researchers did not know whether the aerosol changes were due to increased sulfate emissions from Asia or natural variability. Using a state-of-the-art climate model coupled to an aerosol microphysical model, we showed definitively that the increases in aerosols were due to moderate volcanic eruptions, not Asian emissions (Neely et al. 2013).

Several recent studies have also highlighted the radiative importance of changes in stratospheric humidity, which is largely determined by coupled radiative, microphysical, and dynamical processes operating in the 14- to 19-km region of the tropical atmosphere, called the Tropical Tropopause Layer (TTL). We showed the importance of cirrus clouds for accurately simulating TTL temperatures, which largely determine stratospheric humidity (Evan et al. 2013). Another study showed that TTL cirrus cloud occurrence is modulated both "from above" by stratospheric dynamical variability and "from below" due to the El Niño Southern Oscillation (Davis et al. forthcoming). Together, these studies highlight the need for improved model representation of coupled TTL processes in order to predict future changes in stratospheric humidity.

Davis, SM, CK Liang, and KH Rosenlof. Interannual variability of tropical tropopause layer clouds. *Geophys. Res. Lett.* Forthcoming.

Evan, S, KH Rosenlof, J Dudhia, B Hassler, and SM Davis. 2013. The representation of the TTL in a tropical channel version of the WRF model. *J. Geophys. Res. Atmos.* 118:2835–2848.

Neely, RR III, OB Toon, S Solomon, JP Vernier, C Alvarez, and JM English, et al. 2013. Recent anthropogenic increases in SO_2 from Asia have minimal impact on stratospheric aerosol. *Geophys Res Lett.* 40.

GLOBAL INTEROPERABILITY PROGRAM

GIP-01 Environmental Software Infrastructure and Interoperability Program

CIRES LEAD: CECELIA DELUCA
NOAA LEAD: ADAM DUNBAR
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project provides infrastructure software in support of NOAA modeling and data services.

ACCOMPLISHMENTS

During the past year, our team delivered releases of the Earth System Modeling Framework (ESMF), with improvements including 3-D first-order conservative weight generation and nearest-neighbor grid remapping. The National Weather Service, the Navy, the National Center for Atmospheric Research (NCAR), NASA, and other institutions continue to use ESMF as infrastructure in their research and operational climate and weather codes.

We delivered releases of ESMP (the Python interface) to ESMF grid remapping functions. End users widely employed this software and incorporated it into multiple analysis and visualization packages including Ferret, NCL (NCAR Command Language), and UV-CDAT (Ultrascale Visualization Climate Data Analysis Tools).

In collaboration with U.S. operational weather and water prediction centers and their research partners, we prepared a set of conventions and templates, called the NUOPC (National Unified Operational Prediction Capability) Layer, for use with ESMF and for release next year.

We received a new award from NASA to develop an Integrated Development Environment, called Cupid, for ESMF/NUOPC, in collaboration with NASA teams and the Georgia Institute of Technology.

Our team developed and used the Earth System CoG (Community

Governance) collaboration environment to support the Dynamical Core Model Intercomparison Project (DCMIP), a two-week summer colloquium focused on comparison of atmospheric dynamical cores. About 150 people used the Web-based environment for collaborative analysis.

We developed and integrated into CoG a metadata collection system to support the DCMIP workshop. We also integrated into CoG for DCMIP a metadata display tool developed by the international Earth System Documentation (ES-DOC) project, which the CIRES team co-leads.

We prepared the OpenClimateGIS software—a tool for subsetting, reformatting, and performing calculations on climate data—for use during a downscaling intercomparison project that will take place summer 2013.

GLOBAL MONITORING DIVISION

GMD-01 Collect, Archive, and Analyze Global Surface Radiation Network Data

CIRES LEAD: GARY HODGES
NOAA LEAD: JOSEPH MICHALSKY
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

Initial project goals include developing a mobile SURFRAD station to complement the network of seven fixed sites.

ACCOMPLISHMENTS

A paper that came out of the described research was published 30 January 30, 2013 in the *Journal of Geophysical Research–Atmospheres*. This paper presents an initial look at four years of spectral measurements used to calculate albedo for the Colorado prairie just east of the Rocky Mountain range foothills. In the paper, project researchers discuss some issues associated with calculating broadband albedo from thermopile sensors, demonstrating that uncorrected instrument issues have led to incorrect conclusions. Normalized Difference Vegetative Index is defined for the spectral instruments in this study and used to demonstrate the dramatic changes that can be monitored with this very sensitive product. We present examples of albedo wavelength and solar-zenith angle dependence for different stages of vegetative growth and senescence. The spectral albedo of fresh snow and its spectral and solar-zenith angle dependence are discussed and contrasted with other studies of these dependencies. We conclude that fresh snow is consistent with a Lambertian reflector over the solar incidence angles measured; this is contrary to most snow albedo results. Even a slope of a degree or two in the viewed surface can explain the asymmetry in the morning and afternoon albedos for snow and vegetation. We describe plans for extending these spectral measurements for albedo to longer wavelengths and to additional sites.

Michalsky, JJ and GB Hodges. 2013. Field measured spectral albedo–four years of data from the Western U.S. prairie. *J. Geophys. Res. Atmos.*118:813–825.

GMD-02 Analysis of the Causes of Ozone Depletion

CIRES LEAD: IRINA PETROPAVLOVSKIKH
NOAA LEAD: RUSS SCHNELL
CIRES THEME: STRATOSPHERIC PROCESSES AND TRENDS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project addresses long-term changes in the chemistry and dynamics of the stratosphere that affect ozone depletion, and supports national and international adaptation and mitigation policies that are necessary to stabilize ozone in the stratosphere.

ACCOMPLISHMENTS

Since the 1960s, researchers have used Dobson ozone spectrophotometers to measure atmospheric total ozone variability across the continental United States. Almost 50 years of Dobson total ozone column climatology show a distinct seasonal cycle that varies among individual stations. Although all stations commonly detect the long-term ozone changes, the interannual variability is of interest for understanding how local dynamics and transport affect the long-term time series. The long-term changes in patterns of the transport (quasi-biannual oscillations, QBO, at 30 hPa and 50 hPa) can be related to climate changes over the United States. Therefore, continuous monitoring of column ozone is very important for assessment of climate changes on global, regional, and local environment.

In addition to standard evaluation techniques of ozone variability, we used the STL method (a seasonal-trend decomposition procedure based on Locally Weighted Scatterplot Smoothing (LOESS) to address temporal variability and trends in the Dobson data. Furthermore, we apply a statistical modeling approach to the ozone data set to attribute ozone variability to individual driving forces associated with natural causes (e.g., solar cycle) and anthropogenic causes (e.g., effective equivalent stratospheric chlorine, or EESC). All five Dobson records show a clear seasonal cycle with maxima in spring and minima in late fall/early winter (in accordance with the Brewer-Dobson circulation transporting ozone-rich air toward northern mid-latitudes during boreal winter).

In addition, the LOESS-smoothed trend component shows the decline of ozone during recent decades. In particular, the effects of the two major volcanic eruptions of El Chichón (1982) and Mt. Pinatubo (1991) are strongly visible in the trend component. However, next to the volcanic eruptions, we can also derive "fingerprints" of dynamical features, such as the North Atlantic Oscillation and El Niño Southern Oscillation, from the decomposition. The residual component shows a high degree of short- to medium-term variability, which we can attribute to synoptic-scale meteorological variability and climate variability. We also apply statistical extreme-value models for extreme low ozone (ELO) and extreme high ozone (EHO) events and autoregressive moving average models for mean values at mid-latitudes. We find that the trends derived from Dobson time series decrease by half when we remove the ELO and EHO events from analysis.

The world-standard Dobson resides in the NOAA Earth System Research Laboratory's Global Monitoring Division (GMD), and scientists use it to calibrate local network and regional standards for traceability of the World Meteorological Organization (WMO) ozone network. The maintenance and calibration of this instrument occurs at the Mauna Lao Observatory station in Hawaii. The Langley plots measurements

and analysis occur on a two-year schedule. Between calibrations against the world standard, all station instruments rely on the lamp tests. Our team wrote the software to track the parameters of the standard lamps and schedules for station verification tests. It is important to keep the record free of instrumental interferences. GMD personnel process annual total ozone data from 15 Dobson stations at the end of each calendar year and archive it locally at NOAA and at the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) in Canada.

In 2012, we converted all historical U.S. total ozone data (five stations) to a new processing system, and we verified the conversion against the original archives. We therefore detected and fixed some instrument-related issues, and we are in the process of submitting data to the WOUDC. We also updated the NOAA website for Dobson ozone, and all records are now accessible from http://www.esrl.noaa.gov/gmd/ozwv/dobson/.

Every four years, we exchange the Dobson instrument at the South Pole station with the new instrument. We run a series of intercomparisons at the South Pole station during the exchange to ensure that no instrumental artifacts are in the long-time series. Last polar spring (2012) was unusually warm, so the record low ozone measured at South Pole station was higher than in previous years. The vortex broke and shifted off the South Pole sooner in 2012 than is typical. Thus, the recovery of the spring depletion was faster than in previous years. South Pole personnel will continue to monitor ozone depletion in Antarctica.

We also worked to address the effect of ozone cross sections on ozone profile and column retrievals from the NOAA Dobson and Brewer network. A new data set recently developed by the University of Bremen became available for conducting tests on how ozone retrievals are sensitive to atmospheric-temperature variability. The data set plays an important role in reconciling historical differences among ozone products derived from various ozone-measuring systems, including satellites. The problem becomes more pronounced over the tropics (low temperatures in the vicinity of the tropopause) and at high latitudes (where low sun and large ozone amounts make comparisons very difficult). The WMO advisory group has to decide whether to recommend changes to currently used ozone cross sections.

Our team reprocessed the ozonesonde records at several long-term NOAA stations to correct the instrumental artifacts (change of the sonde types in time series and the pump pressure corrections). We developed new corrections in 2012–2013 by launching several types of ozonesonde instruments attached to the same balloon. The processing occurs in accordance with the WMO directives to homogenize time series of ozonesonde data for trend analysis in the upcoming 2014 WMO Ozone Assessment. Data are available at http://www.esrl.noaa.gov/gmd/ozwv/ozsondes/index.html.

Finally, NOAA and CIRES personnel closely monitored long-term changes in upper troposphere/lower stratosphere water vapor through monthly flights of the balloon-born NOAA frost point hygrometer at three sites: Boulder, Colo.; Hilo, Hawaii; and Lauder, New Zealand. The 33-year Boulder record shows a net increase in stratospheric water vapor of 1 ppmv (27 percent) with implications for both ozone recovery and climate forcing. These high-resolution vertical profiles also provide critical calibration and validation data for satellite-based water vapor sensors. See more information about data at http://www.esrl.noaa.gov/gmd/ozwv/wvap/.

GMD-03 Monitor and Understand the Influences of Aerosol Properties on Climate

CIRES LEAD: ANNE JEFFERSON
NOAA LEAD: JOHN OGREN
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project makes use of aerosol measurements from long-term monitoring sites and shorter-term deployments to analyze trends in aerosol properties, transport, and aerosol radiative forcing.

ACCOMPLISHMENTS

Our team deployed the Aerosol Observing System (AOS) to the Cape Cod National Seashore as part of the Department of Energy's Two-Column Aerosol Project to study aerosol- and cloud-formation behavior and test a regional-scale model. The region's seasonal variation of air masses—including polluted air during the summer and clean, marine air during the winter—offers the opportunity to study and test closure among measurements and model algorithms of varying aerosol and cloud type. During the deployment, the site was in the path of Superstorm Sandy, which necessitated instrument and site infrastructure repairs. Downtime was minimal, and surface instruments were ready for an intensive operation period in January and February 2012, with aircraft measurements over the site.

We devoted a great deal of work to analyzing long-term and seasonal trends across the NOAA and global network of aerosol-monitoring sites. This resulted in five publications, one paper submitted, and another in preparation. The two papers published in *Atmospheric Chemistry and Physics* examine decadal trends in aerosol optical properties and particle concentrations across Europe and North America. The submitted paper looks at seasonal trends in the aerosol properties at a Himalayan site in India. We are working with one of our Appalachian State University colleagues to examine long-term and seasonal trends in aerosol optical properties and radiative forcing at four sites in the United States.

Laboratory and modeling work is in progress to develop and test a radiative transfer model for two common absorption photometers used to measure aerosol absorption at visible wavelengths. Researchers often use these instruments to estimate atmospheric concentrations of black carbon, which is predicted to be the second-largest forcing agent after CO_2. So accurate calibrations and measurements of these instruments are essential to predicting climate change from absorbing aerosol.

GMD-04 Studies of Greenhouse Gas Trends and Distributions

CIRES LEAD: JOHN B. MILLER
NOAA LEAD: PIETER P. TANS
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project focuses on the global distribution of the anthropogenically influenced greenhouse gases: both the major ones (CO_2, CH_4, and N_2O) and the large suite of minor ones (CFCs, HFCs, and HCFCs). In addition to providing an accurate and well-documented record of their distributions and trends, the project aims to use these distributions to determine the time-space distributions of sources and sinks of these gases.

ACCOMPLISHMENTS

As summarized in NOAA's Annual Greenhouse Gas Index, our team determined changes in global abundances for all major long-lived greenhouse gases for 2012 and calculated their influence on radiative forcing. We will soon post this information to http://www.esrl.noaa.gov/gmd/aggi/.

Additionally, we are currently calculating CarbonTracker CO_2 and CH_4 updates. We will post them for public review in summer 2013. We also recently published GlobalView 2012 data products in a new format called "ObsPack." It is available for public download.

GMD-05 Provide Data and Information Necessary to Understand Behavior of Ozone-Depleting Substances

CIRES LEAD: FRED MOORE
NOAA LEAD: JAMES W. ELKINS
CIRES THEME: STRATOSPHERIC PROCESSES AND TRENDS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project provides both long-term global surface data sets and correlated vertical data sets that are used to quantify emissions, chemistry, and transport of ozone-depleting gases. This information is used to monitor national and international emission policies, and is combined with models to improve our understanding of ozone, climate, and the feedback mechanisms that connect and drive both.

ACCOMPLISHMENTS

The contributions of our group center around two surface networks: a weekly flask program and an hourly in situ program. Long-term surface trend data from these programs feed into the calculations of NOAA's Annual Greenhouse Gas Index (AGGI) and the Ozone-Depleting Gas Index (ODGI). This year, we made improvements in the ODGI to more accurately reflect the stratospheric distribution of ozone-depleting halocarbons and their partitioning into reactive halogens.

Regular low-altitude airborne flask measurements and periodic higher-altitude, mission-oriented data sets complement this surface data set. The three active high-altitude data sets come from the recent High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) Pole-to-Pole Observations (HIPPO) mission, which is funded by the National Science Foundation; the recent NASA-funded Global Hawk Pacific (GloPac) mission; and the continuing NASA Airborne Tropical Tropopause Experiment (ATTREX) mission.

These airborne programs help define the process that connects the surface network measurements to the atmosphere as a whole. By itself each data set addresses specific aspects of atmospheric chemistry, etc. But because these data sets conform to a common in-house standards program, they represent a much more powerful tool when combined and are especially well-suited to 3-D models analysis. Many global and process-oriented studies used this combined data set during the past year. We list some of these studies (many not yet final) below; they investigate trace-gas lifetime and loss estimates; trace-gas source and emissions estimates; and satellite-validation measurements.

Kellmann, S, T von Clarmann, GP Stiller, E Eckert, N Glatthor, M Höpfner, M Kiefer, J Orphal, B Funke, U Grabowski, A Linden, GS Dutton, and JW Elkins. 2012. Global CFC-11 ($CFCl_3$) and CFC-12 (CF_2Cl_2) measurements with the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS): retrieval, climatologies and trends. *Atmos. Chem. Phys. Discuss.* 12:18325-18377.

Rigby, M, RG Prinn, S O'Doherty, SA Montzka, A McCulloch, CM Harth, J Mühle, PK Salameh, RF Weiss, D Young, PG Simmonds, BD Hall, GS Dutton, D Nance, DJ Mondeel, JW Elkins, PB Krummel, LP Steele, and PJ Fraser. 2012. Re-evaluation of the lifetimes of the major CFCs and CH_3CCl_3 using atmospheric trends. *Atmos. Chem. Phys. Discuss.* 12:24469-24499.

Saikawa, E, M Rigby, RG Prinn, SA Montzka, BR Miller, LJM Kuijpers, PJB Fraser, MK Vollmer, T Saito, Y Yokouchi, CM Harth, J Mühle, RF Weiss, PK Salameh, J Kim, S Li, S Park, K-R Kim, D Young, S O'Doherty, PG Simmonds, A McCulloch, PB Krummel, LP Steele, C Lunder, O Hermansen, M Maione, J Arduini, B Yao, LX Zhou, HJ Wang, JW Elkins, and B Hall. 2012. Global and regional emission estimates for HCFC-22. *Atmos. Chem. Phys.* 12:10033-10050.

Thompson, RL, F Chevallier, AM Crotwell, G Dutton, RL Langenfelds, RG Prinn, RF Weiss, Y Tohjima, T Nakazawa, PB Krummel, LP Steele, P Fraser, K Ishijima, and S Aoki. 2013. Nitrous oxide emissions 1999–2009 from a global atmospheric inversion. *Atmos. Chem. Phys. Discuss.* 13:15697-15747.

Yver, C, H Graven, DD Lucas, P Cameron-Smith, J Muhle, JE Shields, PK Salameh, CM Harth, SA Montzka, ML Fisher, R Weiss, and R Keeling. 2013. Observation-based estimates of HFC-134a emissions from California. *J. Geophys. Res. Atmos.* Submitted.

GLOBAL SYSTEMS DIVISION

GSD-01 Improve Weather Information Systems

CIRES LEAD: LEON BENJAMIN
NOAA LEAD: GREGORY PRATT
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: NOAA ENGAGEMENT ENTERPRISE

GOALS & OBJECTIVES

This project maintains and improves the advanced weather forecasting system and assures its accessibility for broad national use.

ACCOMPLISHMENTS

During this reporting period, our team worked toward achieving final operating capability (FOC) of the Meteorological Assimilation Data Ingest System (MADIS) at the National Weather Service (NWS). MADIS is a conduit for providing non-NWS meteorological data and quality-control algorithms to NWS operations and for use by the greater meteorological community.

MADIS FOC at NWS should occur fiscal year 2015. MADIS ported its primary processing system from the Central Computing System supercomputer at the National Centers for Environmental Prediction to the new Weather and Climate Operational Supercomputer Systems (WCOSS). MADIS added 2,000 new fixed-surface sites plus mobile sites; added five data providers; increased sites processed per hour by 30,000; added 200 data users; and serviced more than one million data requests a day. MADIS ported its backup processing system to a new architect that uses RAM (random-access memory) disk technology to improve throughput. MADIS upgraded its graphical data displays to leverage relational databases and Google Maps technology to deliver a state-of-the-art user interface that allows users to interactively view, query, plot, filter, and spatially subset MADIS real-time data.

We also worked on the port of FX-Collaborate software to the Advanced Weather Interactive Processing System (AWIPS II). FX-Collaborate is a drawing tool that gives weather forecasters the ability to produce annotated products, such as a cold front line, text explaining various features, and shaded shapes representing warning areas. It is now a Common AWIPS Visualization Environment (CAVE) plug-in that augments the core AWIPS II software. Recent improvements include the addition of the ability to vary the shadow size, color, opacity, and features to allow complex drawings with visually distinct elements. At this stage, the project is complete until we identify additional funding.

In the effort to develop an AWIPS II collaboration prototype as part of the AWIPS II, developers in the Global Systems Division's Information Systems Branch (ISB) completed the prototype collaboration tool that allows internal NWS forecasters at different sites to share weather products, drawings, and other data within the AWIPS II environment. We turned over the code and functionality to Raytheon Technology Services Inc. to integrate into the core AWIPS II software. Raytheon implemented many of the prototype's concepts into its code. ISB developers were able to evaluate the implementation and provide feedback to help guide future versions of the software. The ISB team also demonstrated external-collaboration functions; this will enable forecasters to collaborate with external partners such as emergency managers. This would aid forecaster situational awareness and improve the NWS products disseminated to the public. We successfully demonstrated an end-to-end capability among Environment Canada, NWS Weather Forecast Offices, and ESRL's Global Systems Division (GSD).

With the prototype Hazard Services in AWIPS II, we commenced development for initial operating capability. Hazard Services is an extended project of AWIPS II that will provide a common user interface and process for issuing hazard products. It will streamline NWS watch, warning, and advisory operations, allowing forecasters to focus more on situational awareness and communication with partners. The common interface and process for issuing hazard products will have the potential to increase warning lead times which, in turn, may reduce the loss of life and property.

During the reporting period, the Hazard Services Team transitioned to the implementation of Production Version One (PV1) of Hazard Services for deployment to NWS forecast offices. This involved the creation of a Integrated Product Team (IPT) consisting of software engineers and scientists from ISB in Boulder, Colo., and Raytheon. PV1 began in fall 2012 and continued through spring 2013. During PV1, we designed a solid, extendable foundation for Hazard Services and implemented several major components. These components include the recommender framework, the product-generation framework, the data-access framework, interfaces to legacy applications, two new hydrologic recommenders, and several new product generators. In May, we held another face-to-face meeting, this time at Raytheon in Omaha, Neb. A goal of this meeting was to prepare PV1 Hazard Services for delivery to the test and evaluation sites. It also focused on developing a vision for Production Version Two (PV2) Hazard Services. By the end of May, developers were fully engaged on PV2 tasks. Work will continue toward Hazard Services IOC in spring 2014.

In addition to software development, we are also emphasizing testing and documentation. The IPT will ensure that Hazard Services is robust and can support the NWS hydrologic warning operations for IOC. During this time, the users will continue to be closely involved, providing feedback at weekly meetings and software demonstrations. We will carefully document this feedback and cull it for future requirements.

GSD-02 Science Education and Outreach

CIRES LEAD: ELIZABETH RUSSELL
NOAA LEAD: WILLIAM BENDEL
CIRES THEME: SCIENTIFIC OUTREACH AND EDUCATION
NOAA THEME: NOAA ENGAGEMENT ENTERPRISE

GOALS & OBJECTIVES

This project connects NOAA science to the public and to students and educators in the K-12 system.

ACCOMPLISHMENTS

The Science Education and Outreach Project has had a very busy and successful year thanks to the hard work and dedication of CIRES and collaborators. NOAA's Science On a Sphere (SOS) and NOAA's Data Visualizations and Games (DVG) Group have seen growth and improvement, leading to enhanced scientific environmental literacy and improved understanding, value, and use

of weather and water information through services to the public, including the K–12 education community.

From September 1, 2012, through May 31, 2013, we installed 11 new Science On a Sphere exhibits worldwide, including in Canada, Mexico, the Republic of Korea, People's Republic of China, Italy, and the United States. These new, permanent installations make SOS accessible to a broader audience and help to further spread NOAA science around the world. With these new installations, an estimated 32.9 million people see SOS every year. In addition, the traveling SOS exhibit made appearances at three conferences across the United States. The Science On a Sphere in the NOAA David Skaggs Research Center had 5,000 visitors during this period, including K-12 students, university students, the general public, and many other groups.

During this time, our team made available to users updates to the SOS software, to greatly augment the presenter experience. The updated features include annotation, zooming, and layering. All of these features have the goal of allowing the SOS presenter to interact more with the data shown on SOS, and they explain what are sometimes complex subjects in an understandable way to audiences. These are all features that have come at the request of the SOS Collaborative Users Group.

The SOS Collaborative Users Group Workshop took place November 2012 at the Aquarium of the Pacific in Long Beach, Calif. This proved to be a valuable time for introducing the new SOS software features and planning the path forward for future SOS work. The workshop also highlighted best practices for presenters, creative ways to engage audiences, and educational goals for the SOS Collaborative Users Group. During the workshop, we showcased new SOS data sets, thematic narratives, and productions, inspiring more ideas for future work.

The DVG Group continued work on the TerraViz 4D data visualization engine and the backend NOAA Earth Information Services (NEIS) core. New features include annotations; analytic tools; geolocated data scenes; the introduction of Keyhole Markup Language (KML) support; improved support for Web Map Services; an updated, faceted search screen; map tiling for progressive disclosure; and multiuser collaboration tools. Additionally, the group upgraded TerraViz to work with touchscreen kiosks and the zSpace holographic display.

During this time, the DVG Group worked on developing an educational video game that North Carolina A&T State University and NASA will use for outreach among minority high-school students considering STEM (science, technology, engineering, and mathematics) degrees. DVG was also involved with research in display and interface technologies including touchscreen kiosks, holographic displays, touchless interfaces like the Leap Motion Controller, and mobile technology. DVG was also a government pioneer in the use of cloud computing for data searching and delivery.

Members of DVG were active in the community, including teaching at CU-Boulder and participating in nearly a dozen industry organizations. During this period, group members presented NEIS and TerraViz to 22 groups and conferences, including to the head of NOAA and at the American Geophysical Union annual fall meeting. Two members of DVG received a Research and Service Initiative Award from the Cooperative Institute for Research in the Atmosphere, and one member received CIRES' Outstanding Performance Award. DVG's research efforts also appeared on the cover of Government Computer News and in various other publications.

GSD-03 Improving Numerical Weather Prediction

CIRES LEAD: CURTIS ALEXANDER
NOAA LEAD: GEORG GRELL
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project focuses on improvements in numerical weather prediction by use of models through improved model design and implementation and optimal use of new and existing observations.

ACCOMPLISHMENTS

The High-Resolution Rapid Refresh (HRRR) model remains a foundational component of the 2010–2013 Consolidated Storm Prediction for Aviation (CoSPA) forecast system used for convective weather guidance in both tactical and strategic flight planning in the national airspace. The National Weather Service, including the Storm Prediction Center, also extensively uses HRRR for severe-weather prediction.

During development of the Earth System Research Laboratory's 2013 Rapid Refresh (RAP) and HRRR forecast systems, we focused on efforts to 1) improve the depiction of the mesoscale environment through refinements to the RAP data assimilation, 2) introduce 3-km HRRR data assimilation for analysis of storm-scale information, and 3) enhance RAP and HRRR model physics for improved land surface and boundary layer prediction.

Our team updated the RAP data-assimilation system in Gridpoint Statistical Interpolation (GSI) using a hybrid Global Forecast System (GFS) 80-member ensemble Kalman filter and 3-D variational background error covariance estimate. This enhancement permits weather (flow) dependence in the model background error covariance estimate and has shown significant improvement in RAP forecasts with reduced root-mean-square (RMS) values for upper-level temperatures, humidity, and winds. This indicates a superior forecast of the mesoscale environment.

We made additional updates to improve the RAP snow-cover analysis by adding the capability to build and trim surface snow cover based upon a daily Interactive Multisensor Snow and Ice Mapping System analysis.

In the 2013 HRRR, we established 3-km data assimilation to incorporate storm-scale information using GSI that includes sub-hourly 3-km radar data assimilation during a preforecast hour (starting from a one-hour-old ESRL RAP analysis); 3-D variational assimilation of conventional observations; and a 3-km nonvariational cloud and precipitating hydrometeor analysis using radar reflectivity observations to retrieve rain and snow mixing ratios.

We used observed radar reflectivities as a proxy for the HRRR model latent-heating specification that replaces the model microphysics latent heating during four 15-minute periods of a cycled preforecast hour, with an emphasis on forcing observed convective structures from higher-reflectivity regions. We gave special attention to continuity of convective-scale structures originating from an accurate storm-scale analysis (initial condition) during much of the free forecast period (several hours). The 3-km assimilation has led to an improvement in very short-term forecasts (first few forecast hours) of air-mass thunderstorms and other small-scale convective structures in the real-time

2013 HRRR model forecasts.

We made an enhancement to the RAP and HRRR GSI retrieval of rain and snow hydrometeors from radar reflectivity observations. This enhancement results in a reversible diagnostic of model reflectivity in the Weather Research and Forecasting (WRF) model, both matching the observed reflectivity and consistent with the model microphysics scheme used in the RAP and HRRR. This update led to an improved analysis of radar reflectivity, including echo tops, and these initial conditions translated into improved reflectivity and echo-top analysis and forecasts from the RAP and HRRR.

Prior to the 2013 summer season, we updated the underlying WRF model of the HRRR and the parent RAP to include the official version 3.4.1 release. Additionally, we made RAP and HRRR model physics updates to expand the Rapid Update Cycle land surface model from six to nine levels for improved vertical resolution near the land surface and a reduced diurnal bias of surface temperature and humidity forecasts. We increased the surface roughness length to reduce the high bias in forecasted 10-m wind speeds. Finally, we changed the planetary boundary layer scheme from Mellor-Yamada-Janjic to an enhanced version of the Mellor-Yamada-Nakanishi-Niino scheme, for improved boundary layer prediction of temperature, water vapor, and wind.

GSD-04 Improve Regional Air-Quality Prediction

CIRES LEAD: STEVEN PECKHAM
NOAA LEAD: GEORG GRELL
CIRES THEME: AIR QUALITY IN A CHANGING CLIMATE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project focuses on improving the numerical models that combine atmospheric transport and atmospheric chemistry for the purpose of making air-quality forecasts for regions of interest and at specific locations.

ACCOMPLISHMENTS

Work continued on the development of the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) and the Flow-following finite-volume Icosahedral atmospheric Model coupled with Chemistry (FIM-Chem). Significant improvements to the WRF-Chem model include the Community Atmosphere Model 5 physics and the Modal Aerosol Module chemistry. The climate-modeling community commonly uses these numerical packages, and the improvements should allow for a closer collaboration with that community. In addition, at several conferences and workshops, our team presented model developments and results from scientific research, and the model-development team members continued international outreach through a WRF-Chem tutorial held in Sao Paulo, Brazil.

During 2012, we used the WRF-Chem model to produce daily real-time forecasts on a high-resolution domain, and we made the forecasts available to the community through Web pages and collaboration applications. The forecasts include the smoke from satellite-observed wildfires (Wildfire Automated Biomass Burning Algorithm, WFABBA, and the Moderate Resolution Imaging Spectroradiometer, MODIS, projects) as well as particles that interact with the regional meteorological forecast via absorption and reflection of downward shortwave radiation. The model generates the initial fine-particle aerosols for the forecast by using previous forecast data along with chemical-data assimilation via the Gridpoint Statistical Interpolation methodology. During the chemical-data-assimilation segment, the model uses observations from more than 380 cities across the lower 48 United States to refine the previous six-hour, three-dimensional weather/particle forecast fields. This is one of the first NOAA models to include chemical data assimilation in real-time forecasts, and so far, it has demonstrated a significant improvement in fine-particulate-matter forecasts.

On May 26, 2012, strong winds transported a narrow plume of fine particle smoke from the Whitewater-Baldy fires in New Mexico northward over Colorado, where the plume mixed down to the surface. Satellite data and observational reports revealed that a hazy, brown cloud of fine particles plagued the Colorado Front Range during the first part of the Memorial Day weekend. Due to the inclusion of wildfire smoke emissions and chemical-data assimilation, the real-time WRF-Chem forecasts produced by CIRES collaborators in the Global Systems Division captured remarkably well the narrow plume of fine particles from the New Mexico fires and its impact on Colorado air quality (http://ruc.noaa.gov/wrf/Hotitem2012.html).

GSD-05 Development of High-Performance Computing Systems

CIRES LEAD: CRAIG TIERNEY
NOAA LEAD: MARK GOVET
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will allow environmental applications of advanced computing to assimilate and use new technical developments in the field of high-performance computing.

ACCOMPLISHMENTS

Research related to high-performance computing (HPC) and support technologies continues to progress. Our group has mostly focused on developing software tools that improve the reliability and resiliency of HPC systems; understanding performance characteristics of different HPC systems; and developing future HPC technologies.

During the past year, we have completed a performance study by using NOAA's major applications across all NOAA Research and Development HPC systems. The results of this study have helped NOAA understand the architectural pros and cons of its heterogeneous environment. We presented results of this study at the European Center for Mid-Range Weather Forecasting's Workshop on High Performance Computing in Meteorology. NOAA also has used the results to properly measure how their systems accomplish work.

CIRES has been working with NOAA on research relating to application work-flow management for many years. The tools we've developed have been quite valuable to NOAA and CIRES researchers, allowing them to construct complex and reliable scien-

tific work flows. This past year, we re-engineered the entire system, now named Rocoto, to improve the functionality, reliability, and portability of work-flow management in NOAA.

We continually research and develop new technologies to improve the reliability and user productivity of the NOAA HPC systems. By leveraging partnerships among CIRES, NOAA, and the NOAA HPC-integrator Computer Sciences Corp., we have made several improvements. These include tools to better manage memory usage of HPC applications; improved validation of the hardware health of live systems; and tools to monitor bandwidth and metadata usage on user, node, project, and application levels.

To research methods to effectively use next-generation architectural technologies, we are providing NOAA and CIRES researchers with access to these technologies. We continue to support development by using Nvidia Graphical Processing units. Also, we are working with Intel Corp. and its latest-generation Many Integrated Core coprocessors so NOAA and CIRES scientists can investigate how to design future HPC applications.

GSD-06 Verification Techniques for Evaluation of Aviation Weather Forecasts

CIRES LEAD: MATTHEW WANDISHIN
NOAA LEAD: JENNIFER MAHONEY
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: WEATHER-READY NATION

GOALS & OBJECTIVES

This project contributes to the prediction of specific weather related threats to aviation, thus potentially enhancing the safety of aviation.

ACCOMPLISHMENTS

Our team's accomplishments since September 2012 include:

- Completing the second version of the Lead-time and Displacement (LTD) assessment of the National Digital Forecast Database (NDFD). The assessment examined the performance of the National Weather Service (NWS) Forecast Office product, along with model forecasts, in the context of aviation terminal and en-route operations.
- Completing a prototype of the Event-based Verification and Evaluation of NWS Gridded Products Tool, which will extend the LTD assessment to provide ongoing, near-real-time forecast performance statistics.
- Completing 75 percent of an evaluation of the high-resolution version of the Current Icing Potential and Forecast Icing Potential products.
- Completing the beta version of the INtegrated Support for Impacted air-Traffic Environments (INSITE) decision-support tool, which is an update to last year's VERIFIED (VERification of Impact-translated Forecasts for IntEgrated Decision-making) tool. The Aviation Weather Center's National Airspace Meteorologists will use the tool as an aid for issuing Aviation Weather Statements.

GSD-07 Testbed Center for Numerical Prediction Development

CIRES LEAD: LIGIA BERNARDET
NOAA LEAD: ZOLTAN TOTH
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: Weather-Ready Nation

GOALS & OBJECTIVES

This project is directed toward maintenance and improvement of the hurricane prediction system and is supportive of government agencies and public information systems that provide hurricane warning.

ACCOMPLISHMENTS

Researchers at NOAA operations and in the research and development communities continue to use the Hurricane Weather Research and Forecast model and the Gridpoint Statistical Interpolator codes. To that effect, our group and our collaborators:

- Maintained the community and operational codes, synchronized to prevent divergence.
- Helped community users test and commit their code to the repository.
- Hosted developers committee meetings.
- Supported users by maintaining Web portals with data sets and documentation and staffing a help desk.

Additionally, we conducted tests to evaluate new code developments, which led to operational implementations both at NOAA's National Centers for Environmental Prediction and the Air Force Weather Agency.

NATIONAL GEOPHYSICAL DATA CENTER

NGDC-01 Enhancing Data Management Systems and Web-Based Data Access

CIRES LEAD: DAVID NEUFELD
NOAA LEAD: KELLY PRENDERGAST
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project focuses on improved data interoperability and usability through the application and use of common data management standards, enhanced access and use of environmental data through data storage and access, integration of data management systems, and long-term stewardship.

ACCOMPLISHMENTS

CIRES researchers at the National Geophysical Data Center (NGDC) are working collaboratively to enhance data management systems and improve Web-based data access for both the public and other scientists. Toward that end, CIRES and NGDC migrated to an agile software-development process this past year. As a result, the team produced a variety of new and enhanced software systems. The software we developed provides improved data-extraction services, robust metadata tools, online management of undersea feature data, and analyses used to determine new boundaries for the Extended Continental Shelf.

The NGDC Data Extract System (NEXT) provides a general data-access service for data managers through a simple and scalable retrieval architecture. This initial system supports three data sets and is expandable to support additional data sets with further development. The previous approach required the creation of a retrieval system for each data set, which resulted in code duplication and discrepancies in the features available. NEXT accommodates the unique features of each data set without the redundancy of the common data delivery functionality required by all the data sets, including security, system monitoring, and email notification.

The Enterprise Metadata Management Architecture (EMMA) is a system of tools and services to assist metadata management and re-use; standardize documentation through the use of International Standards Organization (ISO) formats; and enable discovery of scientific data. The tools include conversion of metadata from other format—such as Network Common Data Form Markup Language, Federal Geographic Data Committee, Sensor Observation Service, and Web Map Services—into International Standards Organization documentation standards. The system hosts and displays metadata by using Web Accessible Folders with dynamic custom views, and the metadata is discoverable through Esri Geoportal through the use of keyword and geospatial search criteria. EMMA includes a variety of assessment metrics for completeness and correctness of metadata content; provides diagnostic reports; and allows the visualization of these metrics over time. The EMMA team also provides to NOAA (as well as other federal agencies and international collaborators) training in ISO metadata documentation standards and in the usage of the EMMA tools.

The General Bathymetric Chart of the Oceans (GEBCO) Gazetteer is a new Web-based tool that allows public access to undersea feature names. With a secure login, it also allows the International Hydrographic Organization's Data Center for Digital Bathymetry and GEBCO sub-committee members to manage and maintain the database. The tool includes the ability to search for and display results on an interactive map and also includes programmatic access for end-users such as Google and Esri. To enhance the accuracy of the Gazetteer, we undertook a review of undersea feature locations. The review resulted in numerous improvements to the database. The Gazetteer interface is available at: http://ngdc.noaa.gov/gazetteer.

Lastly, in collaboration with NGDC, CIRES researchers developed the Extended Continental Shelf (ECS) Catalog software. This software provides production tools for a multi-agency collaboration aiming to determine and define the extent of the U.S. continental shelf beyond 200 nautical miles. The ECS project team uses this software to assemble a boundary extension submission to the United Nations, tracking data sets, analysis, documentation, and other arguments in support of the official request. Close interaction with the stakeholders provided rapid progress in the design, user interface, and supporting code.

NGDC-02 Enhancing Marine Geophysical Data Stewardship

CIRES LEAD: JENNIFER HENDERSON
NOAA LEAD: SUSAN MCLEAN
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project focuses on application of common management standards for environmental data supporting many NOAA research and operational endeavors. The project will reduce cost of data access through increased use of partnerships and integration of systems that leverage the value of data.

ACCOMPLISHMENTS

Since September 2012, staff with CIRES and the National Geophysical Data Center (NGDC) have added to NGDC's global marine geophysical archives 287 multibeam swath sonar surveys (327,262 nautical miles) and 665 trackline (single-beam bathymetry, magnetics, gravity, subbottom, and seismic reflection) surveys (2,237,667nautical miles) throughout all of the world's oceans. Both national and international organizations contribute to and retrieve marine geophysical data from the interactive databases. By using standard metadata, spatially enabled databases, robotic tape archives, and standards-based Web services, NGDC provides long-term archiving, stewardship, and delivery of data to scientists and the public. 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.

In the past year, CIRES and NGDC staff have continued to focus their efforts on the design and implementation of the ECS

database, referred to as the ECS Information Management System (IMS). IMS tracks the provenance of data and products used in an analysis to determine the extents of the U.S. extended continental shelf. NGDC and CIRES staff spent much of 2012 preparing for the NGDC-hosted Mock Gulf of Mexico ECS Regional Analysis Workshop (January 2013). Along with identifying, reviewing, and verifying the procedures, data, and products necessary to complete a U.S submission to the United Nation's Commission on the Limits of the Continental Shelf, the workshop also tested the ECS IMS capabilities to ensure system support for future Regional Analysis Workshops. We also tested the newly developed ECS Web Map Viewer, a map interface created to show the spatial coverage of all ECS-related data and products that have been uploaded into the ECS IMS. This includes geophysical surveys from a variety of federal government and academic sources and products from preliminary analyses conducted by ECS Project scientists.

In the effort to improve common metadata standards for data-product level (e.g., bathymetric and gravity grids and various seismic data products) and cruise-level data for both the ECS project and the IOCM program, we have continued to collaborate with scientists and data experts from several U.S federal agencies and academic science data centers. Staff have continued to generate both types of metadata records for all ECS-funded cruises and have made these records available to the public through the NGDC ECS Data Access website (http://www.ngdc.noaa.gov/mgg/ecs/cruises.html).

NGDC-03 Improved Geomagnetic Data Integration and Earth Reference Models

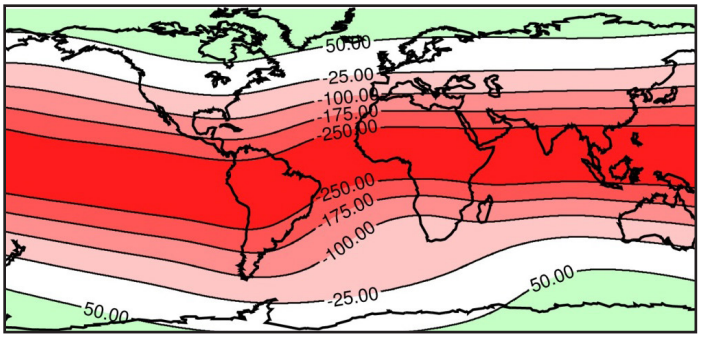
CIRES LEAD: H. STEFAN MAUS
NOAA LEAD: SUSAN MCLEAN
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will increase the volume and diversity of geomagnetic data that are integrated into improved, higher-resolution geomagnetic reference models of Earth, which are increasingly important for navigation.

ACCOMPLISHMENTS

Our team made advances in real-time modeling of Earth's geomagnetic disturbance field. A significant amount of the geomagnetic field's time variation is due to electric currents in the magnetosphere. Using the National Geophysical Data Center's Pomme geomagnetic model, we implemented a disturbance geomagnetic calculator. Two sets of real-time data streams drive the model. The first is the Disturbance storm-time (Dst) index of the U.S. Geological Survey geomagnetism program, which is derived from its global observatory network. The second is based on solar-wind measurements of NASA's Advanced Composition Explorer (ACE) satellite. The predicted fields compare favorably with measurements at observatories in the mid-latitudes. The predictions deteriorate at higher latitudes where stronger ionospheric currents, such as the auroral electrojets, dominate the disturbance field. Real-time specification of the geomagnetic field can play an important role in applications such as navigation, surveying, and the prediction of induced voltages in power grids. We implemented the real-time calculator as a cloud computing application at www.geomag.org/models/RTDFC.html. The calculator also allows the computation of historical geomagnetic disturbance fields going back to the year 2000.



Total field at Earth's surface for a magnetic storm in October 2003.

NGDC-04 Enhanced Coastal Data Services, Integration, and Modeling

CIRES LEAD: KELLY CARIGNAN
NOAA LEAD: SUSAN MCLEAN
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

The purpose of this project is to enhance the utility of coastal hazards data through the use of common data management standards, and increase the volume and diversity of data that can be integrated into hazard assessments and coastal elevation models at local, regional, national, and global scales.

ACCOMPLISHMENTS

CIRES staff at the National Geophysical Data Center (NGDC) developed three new digital elevation models (DEMs) and updated two existing DEMs that support NOAA's Tsunami Program. Our work updating existing DEMs with recently collected, high-resolution, lidar-based elevation data improves the models' accuracy, resulting in better forecasts and warnings of coastal hazards. We also archived 85 new lidar surveys at NGDC, thus supporting long-term data-storage needs of many NOAA agencies as well as DEM development.

Our scientific research into DEM development includes: quantifying the DEM uncertainty that various gridding interpolation techniques introduce between sparse bathymetric data; establishing standardized robust procedures for the building of consistent, companion-structured and -unstructured DEMs from common-source elevation data; and developing standardized, robust procedures for building a suite of consistent, routinely updated, nested, and telescoping coastal DEMs of the entire U.S. coastline.

To plan for the impacts of many coastal natural hazards, having water-level data is a crucial element. CIRES staff at NGDC ingest, process, and archive tide gauge data and deep-ocean bottom pressure data from several NOAA agencies. We then make these data available via online tools for researchers and modelers. Recent improvements include developing procedures for data verification and correction

of the post-event processing for high-resolution Deep-ocean Assessment and Reporting of Tsunamis (DART) tsunameters; adding to NGDC's database raw and processed high-resolution DART records for 2002–2012, along with real-time records for recent strong tsunamis; ingesting NGDC's 34 coastal, one-minute, raw and processed water-level data covering all tide gauges on U.S. Pacific Islands and Alaska and several important observations on the U.S. West Coast; and updating physical and socioeconomic data in the global historical tsunami database.

Following the devastating 2004 Indian Ocean tsunami, 181 U.S. tide gauges received an instrumental upgrade to enable collection of one-minute, real-time water-level sample data, allowing for the detection of even small amplitude tsunamis. Improvements to data processing have isolated the tsunami waves from records dominated by local tides and coastal effects. Observations show that tsunami-magnitude amplification depends on local features (i.e., bathymetry, estuary vs. open-coast tide gauge). Such findings highlight the importance of ongoing tide gauge water-level analysis and research to support science-based planning and management of coastal communities.

The planning required to collect and disseminate hazard-event data is extensive. Following a damaging or fatal event, NGDC begins to collect and integrate data and information from many people and organizations into the hazards databases. We regularly update the resulting report to incorporate the most recent news and observations. Providing timely access to authoritative data and information ultimately benefits researchers, state officials, the media, and the public.

NGDC-05 Enhanced Stewardship of Space Weather Data

CIRES LEAD: JUSTIN MABIE
NOAA LEAD: WILLIAM DENIG
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will ensure future availability of NOAA's space weather data.

ACCOMPLISHMENTS

Computer system upgrades have resulted in failure of some legacy data management code. Specifically, the McNish-Lincoln Sunspot Number Forecast model became inoperative. This model is essential for a wide array of applications, including predicting high-frequency radio limitations for Army communications on the battlefields of Afghanistan. Our team reworked this legacy code to function on a modern 64-bit computer, and the forecast continues to serve our customers.

We modernized the master observatory list of the International Association for Geomagnetism and Aeronomy (IAGA). This list had previously served the single purpose of assigning new observatory codes, and we updated it to include a robust selection of metadata fields. We did this at the request of IAGA to support database development efforts at the British Geological Survey. We also modernized the process for developing the National Geophysical Data Center's Solar Indices Bulletin and Geomagnetic Indices Bulletin, and these products are in full production.

Our team collected a library of data from the Vertical Incident Pulsed Ionospheric Radars (VIPIR) at Wallops, Va., and San Juan, Puerto Rico, and backed it up in a custom tape library. Efforts are underway to migrate these data to the Comprehensive Large Array Data Stewardship System (CLASS). We developed a binary reader to read Raw In-phase and Quadrature (RIQ) data files from the Volumetric Imaging and Processing of Integrated Radar (VIPIR) instruments in Interactive Data Language (IDL). We made upgrades to the Wallops VIPIR site, and in cooperation with the University of Texas Applied Research Labs, we installed a new ionospheric radar in Austin, Texas. We set up the Wallops VIPIR to record ionospheric disturbances during Superstorm Sandy. This work demonstrated a new and innovative use of the radar capabilities and data. Additionally, we repaired on-site damage caused by the superstorm, and researchers there continued the longstanding climatology with minimal interruption.

NGDC-06 Satellite Anomaly Information Support

CIRES LEAD: JUAN RODRIGUEZ
NOAA LEAD: JANET GREEN
CIRES THEME: SPACE WEATHER UNDERSTANDING AND PREDICTION
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

Data and research from this project will be used to provide space environmental data and tools to satellite operators and designers.

ACCOMPLISHMENTS

The Satellite Anomaly Information Support project involves the development of products and services for satellite operators and designers. These products and services can include: improved-quality (e.g., reprocessed) environmental data; new tools; detailed post-anomaly environmental assessments; and specification of extreme space environmental conditions.

Prior to 2011, the data from the new particle instruments—the MAGnetospheric Electron Detector (MAGED) and the MAGnetospheric Proton Detector (MAGPD)—on Geostationary Operational Environmental Satellite (GOES) 13, GOES-14, and GOES-15 were not processed into calibrated fluxes. During this period, we completed the initial processing of the complete set of 2006–2010 MAGED and MAGPD data archived at the National Geophysical Data Center (NGDC). Before we can release the data to the general public, our group still needs to make several refinements to the data, the need for some of which we uncovered during the processing effort.

We developed a tool to produce 24-hour averages of omnidirectional differential electron fluxes from 40 keV to 2,500 keV. This tool ingests the one-minute-averaged archived fluxes and produces one-month files in comma-separated-variable format. We ran this tool for specific disturbed periods requested by a customer.

Regarding implementation of the SAIS Web portal itself, we have been writing a Web application based on a similar one written by former CIRES software engineer Peter Elespuru. We created the app by using the most recent version of the framework, while adding support for visualization of data from the GOES Space Environment Monitor DataService Web Application Programming Interface.

In this area of Web services, we also made progress on the Auroral People Empowered Products (PeEP). Using Auroral Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION) Prime with integration of Twitter and Flickr, the Auroral PeEP project aims to develop a Web interface intended for public education on auroras. In addition, this project has opened the possibility of validating OVATION Prime via crowd-sourced auroral observations. We are collaborating on this project with a small but growing team of students from Cornell University. We designed the initial demo version of the website and are currently building and analyzing the Twitter data set. Since mid-March, we have been archiving about 27,000 tweets per day. Accomplishments include creation and management of these databases; an algorithm that determines relevancy of tweets to auroral phenomena; and visualization of the data.

We delivered an oral presentation on PeEP at the American Geophysical Union fall meeting in San Francisco (Codrescu et al. 2012).

We also contributed to a manuscript, led by former CIRES research scientist Paul Loto'aniu, based on our earlier "Tiger Team" assessment of the space environment at the time of the Galaxy 15 anomaly. We submitted this manuscript to the *Space Weather* journal for peer review. In January 2013, the editor of the journal highlighted this paper (not by name) at the American Meteorological Society meeting in Austin, Texas, saying that both he and the reviewers want this paper to serve as the model for future anomaly assessments published in *Space Weather*. The manuscript is currently under revision in response to referee comments.

NGDC-07 Remote Sensing of Anthropogenic Signals

CIRES LEAD: KIMBERLY BAUGH
NOAA LEAD: CHRISTOPHER ELVIDGE
CIRES THEM: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

The purpose of this project is to increase capacity for investigation and assessment of changing patterns of global economic activity.

ACCOMPLISHMENTS

During the past year, our group started the transition from using the Defence Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) as our primary satellite-image source for nighttime lights and fire products to using data from the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS). The higher spatial resolution and additional infrared bands have allowed our group to make significant advances in mapping combustion sources and nighttime lights.

We have developed a global nighttime VIIRS combustion-source product called Nightfire. The Nightfire algorithm takes as input the nighttime VIIRS Moderate resolution data (M-bands) along with the VIIRS day-night-band (DNB). The algorithm then makes preliminary estimates of combustion-source location, temperature, radiant heat, and combustion-source size.

Our group also has started to perform an atmospheric correction on the VIIRS data to get more accurate estimates of combustion parameters. We developed the atmospheric correction by using the MODerate resolution atmospheric TRANsmission (MODTRAN) model with input of atmospheric profiles from the NPP Cross-Track Infrared Microwave Sounding Suite data. We packaged the Nightfire products in 24-hour increments, and the products are available online for review: http://www.ngdc.noaa.gov/eog/viirs/download_viirs_fire.html.

In addition to the Nightfire product, our group has completed most of the algorithm development necessary to start producing monthly cloud-free nighttime-lights composites using the VIIRS DNB data. We have developed tools to: run a terrain correction on latitude/longitude values provided with the VIIRS DNB data; reproject the DNB imagery; create cloud-masks using M15 data; and correct the VIIRS cloud-mask provided as a retained intermediate product from the cloud Environmental Data Records production.

We have algorithms to identify areas of stray-light, moonlit areas, and dark-nighttime areas. Using 23 nights from April and October 2012, we made a preliminary nighttime-lights composite that became the base layer to NASA's "black marble" press release at the 2012 American Geophysical Union meeting. This data is available online at http://www.ngdc.noaa.gov/eog/viirs/download_viirs_ntl.html.

NGDC-08 Development of Space Environment Data Algorithms and Products

CIRES LEAD: JAMES MANLEY
NOAA LEAD: WILLIAM DENIG
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will develop the algorithms and products necessary to support use of the Geostationary Operational Environmental Satellite R-Series (GOES-R) satellite data for describing space weather, with particular attention to damaging solar storms.

ACCOMPLISHMENTS

Our group's work on GOES-R is split between two different tasks: calibration/validation and Level 2+ product development for the space weather instruments. To address the ongoing calibration/validation tasks, the team participated in meetings and performed document review for all instruments under the project's technical oversight. This effort includes ensuring that the Space Environment In-Situ Suite (SEISS) Ground Processing Algorithm is scientifically and algorithmically correct. We provided inputs on recent changes to instrument requirements that potentially could impact the needs of the customer (the National Weather Service). In addition, we performed validation activities on items related to the Space Weather Level 1b products such as the Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) proxy spectrum and the Solar Ultraviolet Imager (SUVI) Filter Diffraction Analysis.

Specific accomplishments include:

- Successful completion of the GOES-R SUVI sensor Preliminary Design Review for all Phase III algorithms.
- Successful demonstration of prototype algorithms for the SUVI Phase III products, such as solar coronal hole boundaries.
- Improvement of the implementation of the Phase II SUVI Thematic Map. This is necessary for quality proxy data for testing and validation of Phase III products.
- Assessment and evaluation of the calibration of the GOES-NOP-series EUVS sensor.
- Evaluation of the data processing and calibration coefficients and determination of the correct values for developing true solar EUV irradiance measurements. This effort will greatly improve the quality and value of the GOES-R algorithms and data products.
- Development of proxy data sets for testing and evaluating GOES-R algorithms.
- Development of a prototype version of the GOES-R Magnetometer Sudden Impulse Detection Algorithm and completion of a successful Preliminary Design Review for this algorithm.
- Creation of a GOES-R Magnetometer section of the program calibration and validation plan.
- Support of multiple reviews of the instrument and algorithm design for the GOES-R Magnetometer.
- Continued support of the National Geophysical Data Center as a technical advisor in the GOES-R SEISS hardware and Level 1b algorithm development.
- Development of plans for the validation of the algorithm, which create proxy spectra from the GOES-R EXIS. We presented these at the GOES-R Preliminary Design Review.

Papers and presentations associated with the year's activities include participation in the 4th International High Energy Particle Precipitation into the Atmosphere Workshop in Boulder, Colo., October 9-11, 2012. Also, at the American Meteorological Society meeting in Austin, Texas, January 6-10, 2013, we gave the following presentations:

- The GOES-R Sudden Impulse Detection Algorithm (poster); Rowland et al.
- GOES-R solar extreme-ultraviolet irradiance: requirements, observations, and products (poster); Machol et al.
- Development of a proxy data set for the Energetic Heavy Ion Sensor (EHIS) in the GOES-R space environment in-situ suite (poster); Bharath et al.
- Improved space weather monitoring for GOES-R (invited oral); Denig et al.
- Automatic analysis of EUV solar features using solar imagery for the GOES-R SUVI (poster); Darnel et al.

Additionally:

- During Boulder Solar Days in Boulder, Colo., March 19, 2013, CIRES scientist Jonathan Darnel gave an oral presentation, "Using GOES-R data for solar observations."
- At the Space Weather Workshop in Boulder April 16 to April 19, 2013, Juan Rodriguez gave a poster presentation, "Intercalibration of GOES 8-15 solar proton measurements."
- During the Workshop on Inter-Calibration and Degradation of EUV Instruments in Brussels, Belgium, April 15 to April 18, 2013, Janet Machol gave an oral presentation, "Preliminary calibrations of GOES EUVS."

Other papers and presentations below are cited in full in the Appendices:

Hartlet et al. 2012
Machol et al. 2012a
Machol et al. 2012b
Rodriguez et al. 2012
Rowland and Weigel 2012

NGDC-09 Enhanced Ionosonde Data Access and Stewardship

CIRES LEAD: TERRY BULLETT
NOAA LEAD: ROB REDMON
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will improve the utility of ionosonde data through the application of common data management standards in support of space weather forecasting.

ACCOMPLISHMENTS

The ionosonde data project team obtained several new data sources this period and made advancements on existing instruments. In the area of new sensors, we refurbished a government-surplus ionosonde and installed it in Austin, Texas. This provides better coverage over the United States and regional support for specific data users.

We installed a new generation Volumetric Imaging and Processing of Integrated Radar (VIPIR) instrument on the equator near Kisumu, Kenya, to monitor the ionosphere in this region. Advanced VIPIR research sensors in Virginia and Puerto Rico received software and data-processing upgrades of Dynasonde software, for investigating waves and tides in the ionosphere and also to provide high-resolution routine ionosphere-monitoring data. This greatly increases the real-time utility of data from these sensors.

We adapted commercial-analysis software used to process third-party ionogram data. This allows us to extract ionogram-scaled characteristics from ionogram data produced by an ionosonde in Taiwan. This makes this instrument useful for real-time use in ionospheric modeling and propagation forecasts.

Our team provided technical data to Japan's National Institute of Information and Communications Technology (NICT) regarding the ionosonde equipment we used under this project. These data were key to NICT's instrument-upgrade decisions.

We developed a new design for a receiving loop antenna and tested it for the high-frequency radar systems, expanding the flexibility of this instrumentation.

Finally, we collected data from 65 stations worldwide and distributed them to real-time and scientific users. Archive additions exceeded 900 gigabytes of routine data and 20 terabytes of high-resolution, research-quality data.

NGDC-10 Enhanced CORS Data Access and Stewardship

CIRES LEAD: FRANCINE COLOMA
NOAA LEAD: WILLIAM DENIG
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will use models to determine causes for variation in space weather, with implications for infrastructure protection.

ACCOMPLISHMENTS

This project supports activities across four of the six NOAA line offices: Oceanic and Atmospheric Research (OAR), National Ocean Service (NOS), National Weather Service (NWS), and National Environmental Satellite, Data and Information Service (NESDIS). CIRES accomplishments are as follows:

- NOS line office (primary mission): In collaboration with the National Geodetic Survey (NGS), CIRES has continuously operated the mission-critical NOAA-NOS parallel NGS Continuously Operating Reference Stations (CORS) facility located at the National Geophyscial Data Center (NGDC) in Boulder, Colo. This remote facility independently ingests, processes, and distributes Global Navigation Satellite Systems data in parallel with the main CORS facility located in Silver Spring, Md. Each CORS facility provides users access to Global Position System (GPS) data, tools, and products and, hence, access to the National Spatial Reference System.
- Project tool completed for NGS (primary mission): CIRES has designed, developed, and demonstrated for NGS the CORS "Internet Collector" data-collection software.
- NESDIS line office: CIRES and collaborators have successfully transitioned all of the NGS CORS data archive holdings held in the NESDIS NGDC tape archive to the Comprehensive Large Array-data Stewardship (CLASS) system. This accomplishment utilized a CIRES-designed software tool called the CLASS pre-ingestor. This accomplishment has improved dissemination and will enable users to order historical CORS data online.
- OAR line office: To enhance resiliency for a weather-ready nation, CIRES and NGDC continue to provide low-latency GPS data as input into the OAR Earth System Research Laboratory's GPS-meteorology model.
- NWS line office: CIRES and NGDC also continue to enhance resiliency for a weather-ready nation by providing low-latency GPS data as input into the NWS Space Weather Prediction Center's United States–Total Electron Content model.

NGDC-11 Enhanced Stewardship of Data on Decadal- to Millennial-Scale Climate Variability

CIRES LEAD: CARRIE MORRILL
NOAA LEAD: DAVID M. ANDERSON
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

Data and research from this project will improve confidence in our understanding of oceanic, atmospheric, and hydrologic components of the climate system.

ACCOMPLISHMENTS

Our collaboration with the Past Global Changes (PAGES) 2k network culminated in our team archiving the most comprehensive global compilation of climate data for the last 2,000 years. This data set consists of regional-temperature reconstructions and the underlying raw time series upon which the reconstructions are based. Data appear in lists and maps and comprise a valuable collection for other researchers. With partner data managers, we established new protocols that have led to more comprehensive metadata and associated data being preserved for each individual proxy record. This is critical to maximize the usefulness of the data to other scientists, since it allows them to reprocess underlying features of the records such as the chronology or proxy calibrations.

We also accumulated and analyzed paleoclimate data and climate model simulations focused on what's known as the "8.2 ka event," a cooling episode 8,200 years ago. Paleoclimate scientists have targeted this event for data collection and data-model comparisons because it is the most recent analogue to the expected future changes in Atlantic Ocean circulation. By comparing model simulations of the event to paleoclimate data, we can test the skill of models being used to make climate projections.

Our compilation of paleoclimate data consists of 262 time series from 114 sites and also documents the global scope of temperature and precipitation changes during the event. In many regions, these climate changes were larger than those of any other abrupt event of the last 11,500 years. To enable model-data comparisons, we requested model simulations of this event from several groups internationally. Our collection of paleoclimate data is now in permanent archives and is available to the public in a structured format. Archiving climate-model output is part of an ongoing project to ingest results from the Paleoclimate Modelling Intercomparison Project. Resulting products appear below.

PAGES 2k Consortium. 2013. Continental-scale temperature variability during the past two millennia. *Nature Geosci.* 6:339-346. Boulder (CO): National Oceanic and Atmospheric Administration's National Climatic Data Center. Available from: http://hurricane.ncdc.noaa.gov/pls/paleox/f?p=519:1:::::P1_STUDY_ID:14188

Morrill, C, DM Anderson, BA Bauer, R Buckner, EP Gille, WS Gross, M Hartman, and A Shah. 2013. Proxy benchmarks for intercomparison of 8.2 ka simulations. *Climate of the Past.* 9:423-432. Boulder (CO): National Oceanic and Atmospheric Administration's National Climatic Data Center. Available from: http://hurricane.ncdc.noaa.gov/pls/paleox/f?p=519:1:::::P1_STUDY_ID:14192

NGDC-12 Historical Surface Marine Meteorological Data Stewardship: The International Comprehensive Ocean-Atmosphere Data Set

CIRES LEAD: SCOTT WOODRUFF
NOAA LEAD: JAY LAWRIMORE
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

Data and products from this project will continue to improve confidence in our understanding of oceanic and atmospheric components of the climate system.

ACCOMPLISHMENTS

Work continued towards completing the transition of legacy ICOADS activities and infrastructure from NOAA's Earth System Research Laboratory to the agency's National Climatic Data Center (NCDC). We continued to refine the next version of the International Maritime Meteorological Archive format, which, together with its access software, will enhance ICOADS data stewardship and access, and also serve as a key foundation for the ICOADS Value-Added Database project. Work continues on implementing and documenting the new merged Global Telecommunication System (GTS) product, which (once operational) will provide ICOADS users with enhanced near-real-time monthly updates extending beyond the ending date of the latest delayed-mode update, presently Release 2.5, covering 1662-2007. This new product combines GTS data from NCDC with data from NOAA's National Centers for Environmental Prediction (NCEP). General planning and long-range preparations proceeded toward the next delayed-mode update: Release 3.0. We participated regularly in regular NCDC meetings discussing the future development of sea-surface temperature analyses based on ICOADS.

Woodruff reviewed (as a Core member and past Chairperson of the Expert Team on Marine Climatology of the Joint World Meteorological Organization(WMO)/Intergovernmental Oceanographic Commission Technical Commission for Oceanography and Marine Meteorology [JCOMM] and related task teams) a variety of draft publications and reports, including: a revised chapter for the Guide to Meteorological Instruments and Methods of Observation (WMO No. 8), a white paper on WMO Data Policy for the Global Framework for Climate Services (GFCS), and Recommended Algorithms for the Computation of Marine Meteorological Variables (forthcoming JCOMM Technical Report 63).

NATIONAL SNOW AND ICE DATA CENTER

NSIDC-01 Maintain and Enhance the Sea Ice Index as an Outreach Tool

CIRES LEAD: FLORENCE FETTERER
NOAA LEAD: ERIC KIHN
CIRES THEME: SCIENTIFIC OUTREACH AND EDUCATION
NOAA THEME: NOAA ENGAGEMENT ENTERPRISE

GOALS & OBJECTIVES

The product of this project will attract and engage the interest of students and teachers as well as the general public.

ACCOMPLISHMENTS

Our team added daily data to the Sea Ice Index product archive. This was a major addition. Prior to this, the site deliberately archived only monthly ice extent numbers and images, because the monthly data are more reliable and in keeping with the purpose of the product. However, the Arctic Sea Ice News and Analysis site, with tens to hundreds of thousands of users each month, relies on a Sea Ice Index daily view. We saw it as necessary, then, to archive the daily product and to make easy-to-understand information available on how the daily and monthly products differ.

In associated work during this period, we completed a major update and improvement to the Sea Ice Index site architecture, and we overhauled the product documentation to include an explanation of how we make the products and a complete, clearer description of all Sea Ice Index products. The documentation now includes: flow charts to make data-processing steps easier to follow; explanation on how the median edge position is determined and why it is used; clearer explanation of coverage and resolution; more information on accuracy; a tutorial on how to use the Browse Image Spreadsheet Tool to quickly compare images from past years; and a short section on how the product has evolved from 2002 to 2012.

We also functionally redesigned the Sea Ice Index Web site so it is easier to find and compare earlier years of Sea Ice Index data and to check up on trends and anomalies in sea ice extent. These changes make it easier to understand the information the data holds and find and use Sea Ice Index products.

NSDIC-02 Update and Maintain Educational Resources for the Cryosphere

CIRES LEAD: FLORENCE FETTERER
NOAA LEAD: ERIC KIHN
CIRES THEME: SCIENTIFIC OUTREACH AND EDUCATION
NOAA THEME: NOAA ENGAGEMENT ENTERPRISE

GOALS & OBJECTIVES

This project brings unique reference materials to educators and researchers.

ACCOMPLISHMENTS

Our group's outreach, education, and historical-data-publication activities resulted in publication of the Web page titled "All About Arctic Climatology and Meteorology." This page contains information on topics such as arctic climate versus weather; water sky and ice blink phenomena; and highs, lows, and the Arctic Oscillation. We designed the site for educators and high-school students. It consistently ranks in the top 10 of the National Snow and Ice Data Center's (NSIDC) Web pages.

We also published in digital format a data set comprised of historical Greenland snow accumulation data from 1911 to 1981. Geologist Dr. Carl S. Benson, currently professor emeritus at the University of Alaska, Fairbanks, provided scientific field-study notebooks describing his traverses of Greenland from 1952 to 1955. The notebooks contain data on Greenland snow accumulation, snow temperature, stratigraphy, ice-sheet facies, and snow densification. We scanned and published online these notebooks, but other material in NSIDC's analog archive remains at risk. Working toward a solution, staff at the newly named Roger G. Barry Archives and Resource Center (ARC) embarked on a fundraising mission. A new brochure explains the archive's value to the nation and asks for donations.

A Preserve America Initiative Grant assisted the archivist in creating the Web page titled "First 25 Years: The History of the World Data Center for Glaciology and NSIDC in Boulder, Colo." This page offers organized, digitized material documenting NSIDC's beginnings when the U.S. World Data Center (WDC) for Glaciology moved to Boulder, Colo., in 1976. A National Research Council recommendation and an agreement between NOAA and the University of Colorado Boulder resulted in the NSIDC designation in 1982.

NSIDC-03 Update, Improve, and Maintain Polar Region Data Sets

CIRES LEAD: FLORENCE FETTERER
NOAA LEAD: ERIC KIHN
CIRES THEME: MANAGEMENT AND EXPLOITATION OF GEOPHYSICAL DATA
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will ensure availability of data on polar ice and glaciers for research purposes.

ACCOMPLISHMENTS

Our team published six new data collections for this project and updated several others. These data collections come to us from sources as varied as U.S. Navy submarines (Expendable Conductivity, Temperature, and Depth data from the Submarine Arctic Science Program) and the World Glacier Monitoring Service, Zurich, Switzerland. More information is at http://nsidc.org/noaa/news.html.

A CU-Boulder undergraduate student assisted in the publication of Arctic Sea Ice Charts from the Danish Meteorological Institute, 1893–1956. The publication of the digital version of these charts was an important step in providing supporting material for an imminent sea-ice reanalysis effort.

PHYSICAL SCIENCES DIVISION

PSD-01 Relationship of Air Quality to Weather

CIRES LEAD: TIM COLEMAN
NOAA LEAD: ALLEN WHITE
CIRES THEME: AIR QUALITY IN A CHANGING CLIMATE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will show how well models can predict air quality under specific weather conditions at locations where air quality typically is poor.

ACCOMPLISHMENTS

Our team collected, processed, and distributed observational data such as sodar reflectivity, surface energy balance fluxes, and 20-meter-tower meteorological data from the Uintah Basin Ozone study in Utah. With this processed data, scientists can compare the data with numerical models to see how well a model simulates state boundary layer.

PSD-02 Diagnosis of Climate Forcing by Ocean Surface Temperatures

CIRES LEAD: PRASHANT SARDESHMUKH
NOAA LEAD: RANDALL DOLE
CIRES THEME: CLIMATE FORCING, FEEDBACKS, AND ANALYSIS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will show the relationship between regional climate changes around the globe and ocean-surface-temperature changes. Climate changes may be forced to a large extent by both natural and anthropogenic changes in sea-surface temperatures.

ACCOMPLISHMENTS

To deepen our understanding of changes in the mean climate and climate variability during the last 140 years, we recently completed a study using large ensembles of three distinct types of observational and model-simulation data sets of the 1874–2010 period. The first type, the Twentieth Century Reanalysis version 2 (20CRv2) data set, is a 56-member ensemble of global atmospheric reanalyses at six-hourly resolution, produced by an international team led by CIRES and Physical Sciences Division scientists. These reanalyses come from an assimilation of atmospheric-surface-pressure observations in an ensemble Kalman filter-based assimilation system in which nine-hour forecasts serve as background "first guess" fields at each analysis time. The nine-hour forecasts originate from the National Centers for Environmental Prediction (NCEP) Atmospheric General Circulation Model (AGCM), with specified observed sea-surface temperatures (SSTs), sea ice, and radiative forcings.

The second type of data set, which we refer to as the Atmospheric Model Intercomparison Project Twentieth Century (AMIP20C) data set, is a 56-member ensemble of AGCM simulations of the 1874–2010 period; we generate it using the same NCEP AGCM used to produce the 20CRv2 data set and with identical specifications of time-varying SST, sea ice, and radiative forcings.

The third type of data set is a multimodel ensemble of 62 Coupled Model Intercomparison Project phase 5 (CMIP5)–coupled climate-model simulations of the same 1874–2010 period with observed radiative forcings downloaded from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) archive at daily resolution.

These three distinct types of data sets enable us to make cleaner separations of radiatively forced versus internal-natural climate variability than previously possible. We do this by interpreting the long-term variability in the 20CRv2 observational data set as a combination of internal chaotic, SST-forced, and radiatively forced variations; the variability of the ensemble-mean responses in the AMIP20C simulations as a combination of responses to both natural and radiatively forced SST variations; and the variability of the multimodel mean responses in the CMIP5 simulations as responses to the radiative-forcing variations.

The most important new result from this study is that the observed trends in many circulation variables during the second half (1943–2010) of the record are much weaker or nonexistent when calculated over the full record (1874–2010). We anticipated this conclusion in the original paper describing the 20CR project, but the new results put it on a solid footing and are much more comprehensive. The weakness of circulation trends during the full 136-year period has important implications for our understanding of the atmospheric-circulation response to global warming, and it casts doubt on inferences drawn about this response by many published studies that consider only the second half of the record. Consistent with the weak observed long-term circulation trends, we find that the long-term trends in the ensemble-mean AMIP20C and multimodel ensemble-mean CMIP5 simulations are also weak.

PSD-03 Diagnosis of Natural and Anthropogenic Contributions to Climate Variability, Including Changes in Extreme Weather Statistics

CIRES LEAD: PRASHANT SARDESHMUKH
NOAA LEAD: RANDALL DOLE
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

A clearer separation of natural variations from anthropogenic influences in the climate system over the last 140 years will help explain climate variability better and improve the capacity for climate predictions.

ACCOMPLISHMENTS

Is global warming significantly affecting daily weather extremes? The answer to this trillion-dollar question depends on not just the mean shifts in the probability density functions (PDFs) of daily anomalies, but also on changes in the variance and shape of the PDFs. To assess the change in daily weather variability, we have used a simple measure of "storminess" at every point on the globe:

the RMS (root-mean-square) 24-hour difference in sea-level pressure (SLP). We derived maps of the long-term mean stormines from an observational data set (specifically, the Twentieth Century Reanalysis version 2, 20CRv2) and a climate-model-simulation data set (Coupled Model Itercomparison Project phase 5, CMIP5) of the 1874–2010 period. These maps generally agree well with one another. The mean storminess is about 10 millibars (mb) in the extra-tropical storm-track regions, i.e., the day-to-day variation of SLP in these regions is typically about 10 mb.

We have also produced maps of the change in the mean storminess from the first half of the record (1874–1942) to the second half (1940–2010). These changes are about 1 percent of the long-term mean storminess in the CMIP5 simulations and somewhat larger (3 percent to 5 percent) in the 20CRv2 data set, but these larger values are not statistically significant. The maps of the long-term change in storminess in the 20CRv2 and CMIP5 data sets are also not mutually consistent except in the mid-latitudes of the southern hemisphere, where we see a small but statistically significant enhancement of storminess.

This evidence of generally weak statistically significant changes in the mean SLP and daily SLP variability does not necessarily imply similar weak changes in the statistics of extreme daily SLP anomalies. This is because the PDFs of daily SLP variability are not Gaussian and are, therefore, determined by more than their first two statistical moments (mean and variance). The third and fourth moments (skewness and kurtosis) also come into play. To address this issue, we have used the first four moments to fit so-called SGS (Stochastically Generated Skewed) PDFs to the histograms of daily anomalies; we then used the fitted PDFs to draw inferences about changes in tail probabilities. We have initially focused on the PDFs of daily indices of four prominent modes of SLP variability: the North Atlantic Oscillation (NAO), the North Pacific Oscillation (NPO), the tropical Pacific Walker Circulation (PWC), and the Annular Antarctic Oscillation (AAO). We have fitted SGS distributions to the histograms of these indices in both the first and second halves of our 136-year record and assessed the statistical significance of any apparent changes in the PDFs through extensive Monte Carlo integrations with a "weather generator" model whose parameters are consistent with those of the fitted SGS distributions.

Applying this rigorous significance-testing procedure to changes in the statistics of the four circulation indices, we find no significant change in the mean of the NAO and NPO, and a small but significant positive shift in the mean of PWC and AAO from the first to the second half of the 136-year record. For the PDF as a whole, we find no significant changes in the PDFs of the NAO and NPO. The small positive mean shifts of the PWC and AAO PDFs are associated with increased probabilities of large positive values and reduced probabilities of large negative values. But these changes are much smaller and statistically insignificant for extreme positive values, beyond about 2.5 standard deviations. This result again highlights the importance of not drawing conclusions about the statistics of extremes from shifts of the mean.

PSD-04 An Experimental Approach to Climate Data and Web Services

CIRES LEAD: CATHERINE SMITH
NOAA LEAD: RANDALL DOLE
CIRES THEME: SCIENTIFIC OUTREACH AND EDUCATION
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project addresses regional use of climate information.

ACCOMPLISHMENTS

Using a Linear Inverse Model, our team is creating experimental forecasts of annually averaged global surface temperatures. We are making the forecasts available at http://www.esrl.noaa.gov/psd/forecasts/decadal/.

We also made available a wind-forecast project designed to enhance forecasts for wind-energy production. It is located at: http://www.esrl.noaa.gov/psd/psd3/wfip/. This Web page provides vertical cross sections of instrument data at various locations as well as cross sections made using the High-Resolution Rapid Refresh model.

Additionally, our team implemented a Web page for producing trajectory plots from various reanalysis data sets.

CIRES personnel have partnered with National Climate Predictions and Projections to provide Regional Climate Information on monthly to centennial timescales. Specifically, the partnership, which includes the North Central Climate Science Center is working to produce downscaled forecasts to connect climate science and understanding to ecosystem modeling.

Team members in the Physical Sciences Division produced and distributed a South American precipitation data set and made the data set available for interactive plotting. See http://www.esrl.noaa.gov/psd/data/gridded/data.southamerica.html.

We added and refined a set of Web pages for comparing and plotting reanalysis and other data sets. These are located at http://www.esrl.noaa.gov/psd/data/writ/. They include a mapping page, a trajectory page, and a time-series extraction page.

We also added several new data sets including those of Japanese air temperature, the Climate Research Unit 4, and the Global Historical Climate Network Climate Anomaly Monitoring System gridded air temperature data set. These are helpful for monitoring climate change, among other uses.

We upgraded the Thematic Real-time Environmental Distributed Data Services Data Server and added time-series aggregation of files split by time.

We are updating the teleconnection forecast time series (for Pacific North America, East Pacific, and the North Atlantic Oscillation) in real time and making available the ascii values as well.

We put the reforecast2 experimental forecast product online at: http://www.esrl.noaa.gov/psd/forecasts/reforecast2/. The reforecast project uses an ensemble of 11 forecasts to make probabilistic products.

PSD-05 Prediction of Extreme Regional Precipitation and Flooding

CIRES LEAD: DAVID KINGSMILL
NOAA LEAD: MARTY RALPH
CIRES THEME: REGIONAL SCIENCE AND APPLICATIONS
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project specifically addresses regional climate predictions.

ACCOMPLISHMENTS

Our group completed a study that characterized kinematic and thermodynamic structures of Sierra barrier jets (SBJs), atmospheric rivers (ARs), and their interaction from February14 -16, 2011, when a winter storm made landfall in northern California. Our team used a suite of scanning and profiling Doppler radars, rawinsondes, and Global Positioning System (GPS) receivers to document these structures across the Central Valley and up the western Sierra slope to the crest along an approximately 200-kilometer segment of the Sierra.

The winter storm occurred in two episodes, each having an AR that made landfall. Low-level winds in the SBJ observed during Episode 1 were southeasterly and embedded in a stably stratified air mass. Southwesterly winds associated with the AR overlaid the SBJ along an interface that sloped upward from southwest to northeast with a southwestern extent at the western edge of the Central Valley. In contrast, low-level winds in the SBJ observed during Episode 2 were more southerly and embedded in a less-stable air mass. Southwesterly winds associated with the AR overlying the SBJ tilted upward from southwest to northeast with a steeper slope, but did not extend as far southwest.

Another accomplishment relates to the cloud radar onboard the CloudSat satellite. We applied simultaneous retrievals of rain rate and ice-water path to observations of ARs over the northeastern Pacific Ocean during three consecutive cool-season periods (2006–2007, 2007–2008, and 2008–2009). Since the CloudSat measurements allow direct partitioning of rain types (i.e., no-brightband rain vs. brightband rain), we derived statistics for rain occurrences, the extent of AR rain bands, and rain rates for different rain types as a function of AR strengths, temperatures, and locations. We showed that overall brightband rain rates exceed those of non-brightband by a factor of 2 to 2.5. We also derived statistics between rain rates and amount of ice phase in the vertical atmospheric column for brightband rains with ice-phase presence aloft. We aimed for these statistics to provide observational context for verification of AR models over the ocean.

Other accomplishments focused on Web displays of hydrometeorological data for use by researchers and weather forecasters in assessing and monitoring extreme precipitation events along the U.S. West Coast. In addition to maintenance of previously developed products, we developed new products to allow users the ability to filter site data and image products based on various criteria such as site ID, instrument categories, data formats, agency type, data types, and site status. Also, we developed a new real-time display that overlays real-time and historical scanning radar data.

PSD-06 Diagnosis and Prediction of Subseasonal Climate Variations

CIRES LEAD: PRASHANT SARDESHMUKH
NOAA LEAD: RANDALL DOLE
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project attempts an improvement in basic knowledge through a novel combination of models that could extend weather prediction beyond two weeks.

ACCOMPLISHMENTS

A new paradigm of convectively coupled equatorial waves (CCEW) has become popular in tropical meteorology during the last 15 years. This represents a modification of the Matsuno-Gill paradigm of tropical waves as eigenmodes of tropical disturbances on a background state of rest. The modification is apparently due to coupled interactions between deep atmospheric convection and the circulation dynamics that are ignored in the Matsuno-Gill theory. The modified CCEW paradigm has led to a conceptual framework in which most researchers currently perform and interpret observational, diagnostic, and predictability studies of subseasonal tropical variations (which have significant global impacts). But even after hundreds of studies, the glove doesn't quite fit. It still is not clear, for instance, to what extent deep convective variability on subseasonal scales drives the circulation variability; is organized by the circulation variability; or is, indeed, strongly coupled to the circulation variability as claimed.

To address this fundamental issue, we are conducting a study of internal tropical atmospheric variability through a Linear Inverse Modeling (LIM) approach. This involves estimating the appropriate dynamical linear evolution operator for tropical disturbances through the zero-lag and time-lag covariances of the circulation and humidity fields. We are using 30 years of European Reanalysis (ERA)–Interim data for this purpose. The LIM procedure yields both the effective dynamical evolution operator for tropical anomalies and the statistical structure of the effectively stochastic forcing of those anomalies. Preliminary results from this analysis are already revealing. They show that the wavelike eigenmodes of the linear evolution operator are not mutually orthogonal, as they are in the Matsuno-Gill or the CCEW paradigm, and this non-orthogonality is important in influencing the growth and decay of observed tropical anomalies. They also show that not all of the important predictable dynamics are associated with wavelike modes, as the CCEW paradigm implicitly assumes. Coupling of the circulation and humidity does, however, affect the evolution of some modes, though not in a manner anticipated in the CCEW paradigm.

PSD-07 Sensor and Technique Development

CIRES LEAD: ANDREY GRACHEV
NOAA LEAD: CHRIS FAIRALL
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

Technology development such as described in this project is the basis for increased sophistication of measurement, which in turn supports improved modeling and prediction.

ACCOMPLISHMENTS

Our team completed a report on a July 2012 cruise aboard the NOAA ship Hi'ilakai, and we submitted it to the NOAA Climate Observations Division. The group did the first eddy correlation measurements of carbon monoxide (CO) fluxes over the ocean. This involved working with an instrument manufacturer to use a modified version of the fast CO sensor suitable for seagoing deployment (Blomquist et al. 2012).

We also conducted a series of laboratory humidity sensitivity tests on three commercially available fast carbon dioxide (CO_2) sensors. We continued the tests with a deployment of two sensors on the *research vessel Revelle* during the Dynamics of the Madden-Julian Oscillation (DYNAMO) cruise. This study has shown the surprising sensitivity of eddy covariance CO_2 fluxes to a small error in the humidity crosstalk coefficients. Our results suggest a factor-of-five improvement in eddy covariance CO_2 flux measurements (Blomquist et al. 2013).

The group completed theoretical and computational simulations for a new technology for a sonic anemometer. This involves applying acoustic tomography processing to improve the spatial/temporal response. We are working to get NOAA to offer a Small Business Innovation Research (SBIR) grant to attract a commercial vendor (Vecherin et al. 2013).

We repackaged the Physical Sciences Division's W-band cloud radar to allow installation on a NOAA WP-3D research aircraft. We completed one trial fitting in Tampa, Fla., in April 2013. Modifications are underway, and we will install and test the radar on a WP-3D in July 2013.

Blomquist, BW, L Bariteau, JW Edson, CW Fairall, JE Hare, WR McGillis, BJ Huebert, SD Miller, and ES Saltzman. 2013. Advances in ship-based air-sea CO_2 flux measurement by eddy covariance. *J. Geophys. Res.* Submitted.

Vecherin, SN, VE Ostashev, CW Fairall, DK Wilson, and L Bariteau. 2013. Sonic anemometer as a small acoustic tomography array. *Bound.-Layer Meteorol.* Submitted.

PSD-08 Cloud, Aerosol, and Water Vapor Observations and Research

CIRES LEAD: MATTHEW SHUPE
NOAA LEAD: TANEIL UTTAL
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project provides state-of-the-art measurements of climate-related variables over a broad geographic area.

ACCOMPLISHMENTS

A preeminent theme of CIRES cloud observational work relates to Arctic mixed-phase stratiform clouds. In collaboration with colleagues, we recently used multiyear satellite observations to demonstrate that liquid-containing clouds occur frequently across the Arctic. In 2008, CIRES researchers took part in the Arctic Summer Cloud Ocean Study (ASCOS), an observational campaign from an icebreaker stationed near the North Pole. Using multisensor observations from this experiment, we conducted a detailed study of low-level, stratiform, mixed-phase clouds to examine the atmospheric mixing processes associated with these clouds (Shupe et al. 2013a). Following on this theme, a collaborative analysis has led to a multiyear characterization of cloud microphysical and radiative properties at the Eureka station in northern Canada (Cox et al. 2013) and an evaluation of the effect of aerosols on these clouds (Hildner et al. 2013). Many of the cloud microphysical and dynamical properties data sets associated with these studies are now in the data archive of the Department of Energy's Atmospheric Radiation Measurement Program.

A number of research activities recently have emerged from the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project, which is an observational activity at Summit Station atop the Greenland Ice Sheet (GIS). ICECAPS observations include cloud radar, lidar, microwave and infrared radiometers, precipitation sensor, and twice-daily radiosondings. The project had two recent, high-profile cover stories. The first was an overview of the project appearing in the *Bulletin of the American Meteorological Society* (Shupe et al. 2013b). The second, in *Nature*, offered an explanation of the important role clouds played in the extreme GIS melt event of July 2012 (Bennartz et al. 2013). Additional ICECAPS papers have examined the low-level atmospheric stability (Miller et al. 2013) and documented a new cloud lidar for looking at ice-crystal orientation (Neely et al. 2013).

CIRES researchers participated in the Storm Peak Cloud Properties Validation Experiment (StormVex) in 2010–2011 near Steamboat Springs, Colo. This experiment targeted mixed-phase cloud processes in a mountainous environment and their impact on precipitation development. The experiment led to two recent papers. These papers examine the potential of using scanning, ground-based radar to characterize snow/ice crystal habit (Matrosov et al. 2012) and to correct for radar-reflectivity biases due to oriented ice crystals (Marchand et al. 2013).

CIRES researchers have coordinated with NOAA personnel to evaluate the utility of an array of dropsonde measurements made from a large, unmanned aircraft system over the central Arctic. We used these atmospheric profile measurements to examine processes related to the

Polar Vortex, low-level boundary layer structure, and also to evaluate model reanalysis products (manuscript in preparation).

We use a number of modeling tools to examine Arctic cloud, aerosol, and atmosphere properties. A high-resolution, large eddy simulation model formed the basis for a sensitivity study that considered the relative importance of moisture sources from above and below a mixed-phase cloud layer (Solomon et al. 2013). This study found that as long as a moisture reservoir was present either above or below, the cloud could be sustained for a day or more, but the cloud would collapse without these reservoirs. Additionally, we used high-resolution models to improve our understanding of aerosol effects on the lifetime and properties of liquid water in these mixed-phase clouds (de Boer et al. 2013a).

Finally, we used a variety of measurements to evaluate how reanalyses and global climate models simulate the Arctic atmosphere and clouds (manuscripts in preparation) and to illustrate the struggles faced by climate models in simulating aerosol-cloud interactions (de Boer et al. 2013b).

Cox, CJ, DD Turner, PM Rowe, MD Shupe, and VP Walden. 2013. Cloud microphysical properties retrieved from downwelling infrared radiance measurements made at Eureka, Nunavut, Canada (2006–2009). *J. Appl. Meteor. Clim.* Under review.

de Boer, G, T Hashino, GJ Tripoli, and EW Eloranta. 2013a. A numerical study of aerosol influence on mixed- phase stratiform clouds through modulation of the liquid phase. *Atmos. Chem. Phys.* 13:1733-1749.

de Boer, G, S Menon, SE Bauer, T Toto, and A Vogelmann. 2013b. Evaluation of aerosol-cloud interactions in the GISS ModelE using ASR observations. *J. Geophys. Res.* Accepted.

Hildner, R, GJ Tripoli, EW Eloranta, and G de Boer. 2013. Observational evidence for anthropogenic effects on Arctic boundary layer clouds over Eureka, Nunavut. *J. Appl. Meteor. Clim.* Under review.

Marchand, R, GG Mace, AG Hallar, IB McCubbin, SY Matrosov, and MD Shupe. 2013. Enhanced radar backscattering due to oriented ice particles at 95-GHz during StormVex. *J. Atmos. Oceanic Technol.* Under review.

Miller, NB, DD Turner, R Bennartz, MD Shupe, MS Kulie, MP Cadeddu, and VP Walden. 2013. Surface-based inversions above central Greenland. *J. Geophys. Res.* 118:495-506.

Neely III, RR, M Hayman, R Stillwell, JP Thayer, RM Hardesty, M O'Neill, MD Shupe, and C Alvarez. 2013. Polarization LIDAR at Summit, Greenland for the detection of cloud phase and particle orientation. *J. Atmos. Ocean. Technol.* Forthcoming.

Shupe, MD, POG Persson, IM Brooks, M Tjernström, J Sedlar, T Mauritsen, S Sjogren, and C Leck. 2013a. Cloud and boundary layer interactions over the Arctic sea-ice in late summer. *Atmos. Chem. Phys. Diss.* 13:13191-13244.

Shupe, MD, DD Turner, VP Walden, R Bennartz, M Cadeddu, B Castellani, C Cox, D Hudak, M Kulie, N Miller, RR Neely III, W Neff, and P Rowe. 2013b. High and dry: New observations of tropospheric and cloud properties above the Greenland Ice Sheet. *Bull. Amer. Meteor. Soc.* 94:169-186.

Solomon, A, MD Shupe, POG Persson, H Morrison, T Yamaguchi, G Feingold, PM Caldwell, and G de Boer. 2013. The sensitivity of springtime Arctic mixed-phase stratocumulus clouds to surface layer and cloud-top inversion layer moisture sources. *J. Atmos. Sci.* Under review.

PSD-09 Air-Sea Interactions

CIRES LEAD: ANDREY GRACHEV
NOAA LEAD: JIAN-WEN BAO
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project provides measurements of climate-related variables at the state of the art over a broad geographic area.

ACCOMPLISHMENTS

During the reporting period, our team did not conduct any field deployments, but we reported in several publications research results from previous studies (Angevine et al. 2012; De Szoeke et al. 2012; Helmig et al. 2012; and McBride et al. 2012). Publications in 2013 include Rodriguez-Alvarez et al.

Our group created a data and science synthesis Web page for the Variability of the American Monsoon Systems Ocean-Cloud-Atmosphere-Land study. See http://people.oregonstate.edu/~deszoeks/synthesis.html. Several publications on this have appeared (most recent is De Szoek et al. 2012). We submitted a review paper that is now in revision (Mechoso et al. 2013). Another 2013 publication in submission is Ghate et al.

Our work on sea-spray effects on hurricanes has continued in model studies during investigations into physical parameterizations on hurricane structure (Bao et al. 2012; and Gopalakrishnan et al. 2013). We released the latest version of the hurricane flux parameterization in January 2013 (ftp://ftp1.esrl.noaa.gov/users/cfairall/onr_droplet/parameterization/version11_kb/).

We made the results from the Gas Exchange III field program publically available as the Coupled Ocean–Atmosphere Response Experiment gas flux algorithm version 3.1: ftp://ftp1.esrl.noaa.gov/users/cfairall/bulkalg/gasflux/COAREG31_vectorized. We have extended this work to carbon monoxide (Blomquist et al. 2012).

Ghate, VP, BA Albrecht, MA Miller, A Brewer, and CW Fairall. 2013. Turbulence and radiation in stratocumulus topped marine

Research vessel Revelle.

boundary layer: a case study from VOCALS-Rex. *J. Geophys. Res.* Submitted.

Gopalakrishnan, G, F Marks, JA Zhang, X Zhang, JW Bao, and V Tallapragada. 2013. A study of the impacts of vertical diffusion on the structure and intensity of the tropical cyclones using the high-resolution HWRF system. *J. Atmos. Sci. 70:524–541.*

Mechoso, CR, R Wood, R Weller, CS Bretherton, AD Clarke, H Coe, CW Fairall, JT Farrar, G Feingold, R Garreaud, C Grados, JC McWilliams, SP de Szoeke, SE Yuter, and P Zuidema. 2013. Ocean-cloud-atmosphere-land interactions in the southeastern Pacific: the VOCALS Program. *Bull. Am. Meteorol. Soc.* Forthcoming.

Rodriguez-Alvarez, N, DM Akos, VU Zavorotny, JA Smith, A Camps, and CW Fairall. 2013. Airborne GNSS-R wind retrievals using Delay-Doppler maps. IEEE Trans. *Geosci. Remote Sens.* 51:626-41.

PSD-10 Physical Processes Controlling the Arctic Surface Energy Budget

CIRES LEAD: OLA PERSSON
NOAA LEAD: JANET INTRIERI
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project provides analysis and modeling of climate-related processes with a focus on those affecting the mass balance of Arctic sea ice and Arctic soil temperatures.

ACCOMPLISHMENTS

During our team's research to understand the Arctic surface energy budget, we focused on the interactions among: long-range atmospheric transport, cloud formation/microphysics, surface energy budget, impacts on sea-ice internal structure during the Arctic winter, and boundary-layer coupling processes. These studies included modeling efforts using either a highly nested version of the Weather Research and Forecasting model or a pure Large-scale Eddy Simulation (LES) model.

One analysis focus was on processes during a 12-day period in early January during the Surface Heat Budget of the Arctic Ocean (SHEBA) program, with key results showing that long-range transport of mid-level heat/moisture through the Fram Strait led to supercooled clouds over the Beaufort Sea, producing large increases in longwave radiation, significant surface warming, and thermal waves penetrating the sea ice. Mesoscale modeling and examination of reanalysis output showed that both had difficulties producing the supercooled liquid water in these clouds necessary for the energy transfer to the surface.

During the Arctic Summer Cloud Ocean Study (ASCOS), we conducted another observational study of Arctic stratocumulus clouds over the Central Arctic pack ice. It showed that overturning in these clouds is, at times, coupled with surface eddies and, at other times, uncoupled. Because aerosols occurred in greater concentrations within the cloud mixed layer and only increased near the surface when coupling occurred, the study suggests that the aerosol source in the near-surface environment over sea ice is primarily from long-distance advective processes and vertical coupling within the boundary layer. Furthermore, it suggests that a primary source for cloud condensation nuclei (CCN) in Arctic mixed-phase clouds, which are key for the surface energy budget and documented in another study, is through long-range transport rather than from local sources. The paper resulting from this study did not address, however, to what extent the coupling impacts the surface energy budget.

Finally, an LES modeling study showed the importance of a moisture inversion above Arctic stratocumulus clouds for maintaining these clouds. These results are topics of various conference presentations and manuscripts that we've either submitted or are preparing. In collaboration with international colleagues under the National Science Foundation (NSF) Cloud-Atmospheric boundary layer-Surface project and the Department of Energy Cloud project, we are conducting studies of boundary layer turbulent structures and cloud-surface coupling, using data from the ndirect and Semi-Direct Aerosol Campaign (ISDAC) and ASCOS field programs. A number of collaborative papers are at various stages, with the aim of including them in the ASCOS special issue.

Our team completed some work on the NSF Study of Environmental Arctic CHange grant by processing data from Eureka and comparing surface energy budgets at Alert and Eureka. Though only 2.5 degrees latitude separate these sites and they are on the same Canadian Arctic island, the soil active layer in summer persists for 91 to 95 days in Eureka and only 50 to 55 days in Alert. Differences in the winter snowfall and evolution appear to be the key factors producing this difference in the summer soil.

In addition, we completed and published a detailed study on the applicability of local similarity theory for surface energy fluxes in the very stable Arctic environment. We also began (but did not complete) further work to provide better quality-assessment of the radiation data at Eureka. We gave a presentation on this topic at the First Tiksi Science Meeting in St. Petersburg, Russia.

During 2012, our team spent a significant amount of time organizing and advancing the concept of an interdisciplinary observatory drifting in the Arctic Ocean (Multidisciplinary drifting Observatory for the Study of Arctic Climate, MOSAiC) to launch within the next five years in collaboration with international colleagues. A key component of MOSAiC would be to better understand the temporal and spatial variability of the surface energy budget over the Arctic Ocean. We also held a science-plan writing workshop in Germany in May 2013. We then made presentations on this concept at a variety of venues throughout the year, including a white paper submitted to the Arctic Observing Summit.

PSD-11 Distributions of Raindrop Size

CIRES LEAD: CHRISTOPHER WILLIAMS
NOAA LEAD: ROB CIFELLI
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project provides basic scientific information on raindrop size, which will support improved accuracy in estimation of rainfall based on cloud characteristics.

ACCOMPLISHMENTS

During the past year, our team described and published a dual-frequency retrieval technique that uses 50- and 920-Mhz radar spectra to estimate the vertical air motion in precipitating clouds (Williams 2012). The dual-frequency retrieval technique uses a 50-MHz radar to observe both the vertical air motion and precipitation motion, while a 920-MHz radar observes just the precipitation motion. By analyzing the Doppler velocity spectra, we use the 920-MHz radar precipitation signal to mask-out the precipitation signal in the 50-MHz radar spectra, leaving just the vertical air motion signal.

We applied the dual-frequency air motion retrieval technique to two data sets. The first data set included five rain events during the Mid-latitude Continental Convective Cloud Experiment (MC3E), from April to May, 2011. And the second data set included two wet seasons of 50-Mhz and 920-MHz radar spectra from Darwin, Australia (seasons 2005–2006 and 2006–2007). After estimating the vertical air motions, we estimated the raindrop size distribution (DSD) in the vertical rain column. The MC3E air motion and DSD estimates are now in the Department of Energy's Atmospheric Radiation Measurement (ARM) public archive. Researchers at the Centre for Australian Weather and Climate Research in Melbourne, Australia, are evaluating the Darwin air motion estimates before they become open to the public.

We used the dual-frequency vertical air motion estimates from Darwin to check the veracity of vertical air motions estimated using the dual-Doppler technique and two scanning radars. After comparing the vertical air motions near the profiler site, we processed more than 1,000 radar volumes to construct statistical profiles of vertical air motion in the Darwin area during the Tropical Warm Pool-International Cloud Experiment, January 2006. Details of this study appear in Collis et al. (2013).

During the MC3E field campaign, four vertically pointing radars operated next to each other. Two of the four radars are well-calibrated (specifically, the 35-GHz Ka-band ARM zenith radarm KAZR, and the 2.8-GHz S-band radar), and we used them to check the calibration of the other two radars (the 915-MHz and 449-MHz radars). We determined that the 915-MHz profiler data need extra signal-processing steps to calibrate the profiler data. Details appear in Tridon et al. (2013).

Collis, S, A Protat, PT May, and CR Williams. 2013. Statistics of storm updraft velocities from TWP-ICE including verification with profiling measurements. *J. Appl. Meteor. Climatol.* Forthcoming.

Tridon, F, A Battaglia, P Kollias, E Luke, and CR Williams. 2013. Signal post-processing and reflectivity calibration of the Atmospheric Radiation Measurement program 915 MHz wind profilers. *J. Atmos. Oceanic Technol.* Forthcoming.

PSD-12 Analysis of the Causes of Extreme Weather Events

CIRES LEAD: JUDITH PERLWITZ
NOAA LEAD: RANDALL DOLE
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: WEATHER-READY NATION
PROJECT DESIGNATOR: PSD-12

GOALS & OBJECTIVES

This project will promote more accurate forecasting of extreme events.

ACCOMPLISHMENTS

Our team published a paper on the causes of the 2011 Texas heatwave. We also submitted a paper on the causes of the record warmth in the central and eastern United States during March 2012, when daily temperature anomalies at many locations exceeded 20 degrees Celsius. In the paper, we examine how physical factors spanning climate and weather contributed to that record warmth.

Over this region, March temperatures have warmed by approximately 1 degree Celsius since 1901. This long-term regional warming is an order of magnitude smaller than temperature anomalies observed during the event, indicating that most of the extreme warmth must be explained by other factors. Several lines of evidence strongly implicate natural variations as the primary cause for the extreme event. The 2012 temperature anomalies had a close analogue in an exceptionally warm March that occurred in the United States more than 100 years earlier. This provides observational evidence that natural variability alone could produce an extreme event similar to March 2012.

Coupled model forecasts and simulations forced by observed sea-surface temperatures (SSTs) show that forcing from anomalous SSTs increased the probability of extreme warm temperatures in March 2012 above that anticipated from the long-term warming trend. In addition, forcing associated with a strong Madden-Julian Oscillation further increased the probability for extreme U.S. warmth and provided important additional predictive information on the timing and spatial pattern of temperature anomalies. The results indicate that the superposition of a strong natural variation similar to March 1910 on long-term warming of the magnitude observed would be sufficient to account for the record warm March 2012 U.S. temperatures.

We conclude that the extreme warmth over the central and eastern United States in March 2012 resulted primarily from natural climate and weather variability, a substantial fraction of which was predictable.

Hoerling, M, et al. 2013. Anatomy of an extreme event. *J. Climate.* 26:2811–2832.

PSD-13 Effects of the Tropical Ocean on Weather and Climate

CIRES LEAD: LESLIE HARTTEN
NOAA LEAD: CÉCILE PENLAND
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will help build a basis for forecasting climate variability associated with the temperature and moisture conditions in and over the tropical oceans, which have effects on climate in large portions of the United States and Central America as well as around the globe.

ACCOMPLISHMENTS

Our team's accomplishments fall into two distinct subtopics. One involves using observations from field programs and employing novel techniques to study lower-tropospheric processes in the East Pacific. The other involves using global gridded data sets to investigate the contribution of short-term variability centered above the North Atlantic to longer-term variability in the tropical Atlantic.

Stratocumulus (Sc) clouds occur frequently over the cold waters of the southeastern Pacific Ocean. Data collected during two Pan American Climate Study research cruises in the tropical East Pacific offer many opportunities to study various structural aspects of this Sc-topped marine boundary layer (MBL). The focus during the past year has been on understanding gaps in detectable wind-profiler reflectivities during boreal fall cruises in 2000 and 2004. After rigorously quality-controlling the data, we found many instances with no measureable atmospheric signals through a depth of up to several hundred meters, often for an hour or more.

We used rain gauge data from the fall 2004 cruise to calibrate the profiler, which allowed us to convert signal-to-noise ratio to both equivalent reflectivity, Z_e, and the structure-function parameter of the index of refraction, Cn2. Profiles of minimum detectable Z_e indicate this 915-megahertz profiler was not detecting cloud particles. Considering the gaps in terms of Cn2 profiles allows us to understand them as indications of reduced "top-down" buoyancy processes and/or reduced turbulent intensity. Previous researchers have demonstrated both of these are associated with decoupling of the Sc-topped MBL. The absence of valid profiler reflectivity in this setting may, therefore, be used as a proxy for decoupled conditions. In November 2012, we submitted a manuscript describing these results to the *Journal of Applied Meteorology and Climatology* for its 2012 Special Collection on International Symposium for the Advancement of Boundary-Layer Remote Sensing 2012 presentations (Hartten et al. 2013). Reviewers requested various revisions, which we returned in March 2013, and one reviewer requested additional observational verification of decoupled MBL conditions, which we've nearly completed.

The North Atlantic Oscillation (NAO) is a rapidly decorrelating system that strongly affects the climate of the Atlantic and the surrounding continents. Although the NAO itself is basically unpredictable on seasonal timescales, our research during the past year shows that NAO forcing has a significant impact on north tropical Atlantic (NTA) SSTs evolving on those timescales.

The largest sensitivity to the NAO index is in the North Atlantic, especially during boreal summer. The high sensitivity during July is especially notable because both NAO variability and the correlation between NAO and stochastic forcing in the NTA region are weakest June through August. Even though this sensitivity occurs north of our NTA region, the linear deterministic dynamics spatially redistribute the forcing over time. In the north tropical and subtropical Atlantic, our analysis indicates that the NAO has a strong effect on surface winds, whose weakening during the negative phase of the NAO and strengthening during the positive phase directly affect NTA SSTs. Results employing linear inverse modeling imply that quantitative knowledge of the NAO index and of its convolution with deterministic SST dynamics would nearly double forecast skill of north tropical Atlantic sea-surface tmperature (SST) at lead times greater than nine months. These results could constitute a goal for General Circulation Models (GCMs) and could help either validate coupled GCMs or identify processes incompletely captured in them. A manuscript presenting this work (Penland et al. 2013) is nearly ready for submission.

Hartten, LM, and PE Johnston. 2013. Stratocumulus-topped marine boundary layer processes revealed by the absence of profiler reflectivity. *J. Appl. Meteor. Clim.* In revision.

Penland, C, and LM Hartten. 2013. Stochastic forcing of north tropical Atlantic sea-surface temperatures by the North Atlantic Oscillation. *Geophys. Res. Lett.* In preparation.

PSD-14 Forecasts for Wind Energy

CIRES LEAD: LAURA BIANCO
NOAA LEAD: JAMES WILCZAK
CIRES THEME: SYSTEMS AND PREDICTION MODELS DEVELOPMENT
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will quantify improvements made to numerical weather prediction models by assimilating in new observations and by developing and implementing new model physical parameterization schemes.

ACCOMPLISHMENTS

The U.S. Department of Energy sponsored a joint research project with NOAA and private industry to improve wind-energy forecasts, the Wind Forecast Improvement Project (WFIP). The key elements of this program have been:

1) From August 2011 to September 2012, one-year deployment of extensive meteorological observing systems (10 915-mHz and two 449-mHz wind-profiling radars, 12 sodars, several instrumented tall towers, and approximately 400 nacelle anemometers) in two regions with significant wind-energy production;

2) Assimilation of these observations into the research version of the hourly updated NOAA Rapid Refresh (RAP) model and the High-Resolution Rapid Refresh (HRRR) model run nationwide at 13-km (RAP) and 3-km (HRRR) resolution;

3) Evaluation of the benefits of these improved wind forecasts on electrical utility operations, including financial savings (more efficient use of wind turbines), especially for ramp-events in the zero- to six-hour forecast timeframe.

In the framework of WFIP, we were prepared to extensively quality-control the data, and we worked on a combination of well-accredited algorithms and newly developed ones to remove any contamination from the data before assimilating them into the models.

During the course of the campaign, we continuously performed statistical analyses to prove that we were, indeed, improving the forecast. On the other side, since we were continuously updating or modifying the models during the length of the campaign, this "on the road" analysis is only preliminary, not final.

Once we reached the end of the campaign, we decided to focus our attention on two weeks for each season and rerun the models (fixed versions of them now) for data-denial experiments (with and without extra observational data-set assimilation) on these weeks only, to produce a consistent statistical study. We started by choosing two weeks in winter (one in December 2011 and one in January 2012) and then compared the forecasts of the model outputs with the tall towers observations.

Improvements were certainly noticeable, particularly up to forecast hour six, so the first real outcome of the WFIP campaign showed very encouraging results. We have presented results relative to the winter weeks at various conferences and meetings as well as at monthly meetings with the other parties involved in the campaign.

We moved on with the selection of the summer period (we selected two weeks in June 2012), and we reran the models with and without assimilating the extra data to see the impact the forecast would experience. The summer experiment showed a positive impact from assimilating extra data as well, and we moved on to choosing the two spring weeks (in April 2012). In May 2013, we obtained the run of the model without the extra data-set assimilation, and we are waiting to obtain the output from the run with extra data assimilation in order to start analyzing the results for the spring season.

Another very important study started inside the WFIP framework is the development of a "Ramp Tool" to identify ramp events in a series of data and compare observed events with modeled ones. The definition of a ramp is still very unclear, and it can change from operator to operator. We experimented with different methods to automatically identify different types of ramps in a time series of data. We then developed a method to match events in different time series (observed and modeled ones) that we want to compare, and we finally developed a metric to rate the skill of a model in identifying ramp events.

PSD-15 An Assessment of Skill and Reliability of Regional Climate Predictions

CIRES LEAD: KATHY PEGION
NOAA LEAD: ROBERT WEBB
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will provide decision makers with a better understanding of the skill and reliability of regional climate information.

ACCOMPLISHMENTS

Using state-of-the-art models for deterministic skill measures, our team assessed the current seasonal forecast skill of temperature and precipitation for forecasts initialized in late summer 2012 and valid in spring 2013. Specifically, we have focused on six-month lead forecasts with August initial conditions. These forecasts are valid March through May.

We performed the assessment using the current National Centers for Environmental Prediction (NCEP) operational seasonal forecast model, the Climate Forecast System version 2 (CFSv2), and the suite of experimental seasonal forecasts from the National Multi-Model Ensemble (NMME) project of which CFSv2 is a contributor. At the time we performed the analysis, NMME consisted of eight models of varying ensemble size and forecast length and three variables: sea-surface temperature, 2-meter temperatures, and precipitation. Six of these models make forecasts long enough to be useful for this analysis. Results indicate that in the Missouri River Basin, neither the individual model ensemble means nor the NMME ensemble mean have useful correlation skill (defined as a correlation greater than 0.3) at these long lead times. These results are not surprising since there is no signal from the El Niño Southern Oscillation (ENSO) in this region to provide long-lead skill and since summer is a time of weak tropical forcing.

Further assessment of skill in the Missouri River Basin indicates that for forecasts initialized in August, even at short lead times (two weeks to one month), the skill of temperature and precipitation is generally less than correlations of 0.3.

We also analyzed the current limits of predictability over the Missouri River Basin for temperature and precipitation using the NCEP/CFSv2 model and compared that skill with the skill of perfect model forecasts. We again focused on forecasts initialized in August and valid March through May. Perfect model skill is an estimate of the upper limit of predictability, but we know it to be an overestimate since models are much better at predicting themselves than nature.

The result of this analysis indicates that even for perfect model forecasts, there is only minimum skill (correlations less than 0.3) over most of the MRB, though correlations are between 0.3 and 0.4 in eastern North and South Dakota for temperature. This further emphasizes the fact that there is little potential for skill of temperature and precipitation forecasts initialized in summer at these long lead-times.

Our team also met with partners and decision makers to present these preliminary results and understand the variables and timescales of management concerns and needs. Specifically, we traveled with NOAA partners to Omaha, Neb., to meet with the U.S. Army Corps of Engineers (USACE) from April 27-28, 2013. At this meeting, we presented preliminary results and engaged with the USACE management and decision makers to understand their needs; what aspects of our analysis are useful to them; and what specific analyses would be

beneficial to meet their needs. Our goals for the coming year resulted from that meeting. We learned several things critical to the direction of this project, including:

- USACE is primarily interested in precipitation forecasts for the MRB. Other variables are not critical to their specific operations, though snowpack may, at times, be important.
- Skill in the upper vs. lower Missouri River Basin is important because of the location of their controls.
- Even if skill is low at long lead times, they would like to know at what lead times there is skill for spring and summer.
- The public and political arenas often expect them to have more skill during El Niño/La Niña times, so they would like clear documentation of the skill for these times.
- May is a key month for their operations.
- Predictability is not particularly useful information to them.

PSD-16 Understanding and Explaining the Role of Extremes in Missouri Basin Flooding

CIRES LEAD: XIAOWEI QUAN
NOAA LEAD: ROBERT WEBB
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will support NOAA's Mission Goals "To understand and predict changes in climate, weather, oceans, and coasts" and "To share that knowledge and information with others" by providing the credible science that other agencies, state, and local decisions makers, and the private sector require.

ACCOMPLISHMENTS

Our team conducted several ensemble climate model simulations including:

1) Multi-hundred year "control" runs of the two Atmospheric General Circulation Models (AGCM), forced with 1979–2010 climatological annual cycle of sea-surface temperatures and sea ice;

2) 20-member Atmospheric Model Intercomparison Project–type simulations of two AGCMs—the Community Atmosphere Model 4 and the European Centre Hamburg 5—forced with observed 1979–2012 SSTs and sea-ice evolution;

3) A 500-year fully coupled run of the Community Climate System Model 4 (CCSM4), forced with preindustrial radiative forcing; and

4) A 1,000-year fully coupled run of CCSM4, forced with present-day radiative forcing.

PSD-17 Understanding How Tropical SSTs Influence Atmospheric Variability

CIRES LEAD: TAO ZHANG
NOAA LEAD: MARTIN HOERLING
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This project will promote more accurate prediction of North American climate variability beyond a simple linear response to ENSO forcing.

ACCOMPLISHMENTS

Our team completed 50-member Atmospheric Model Intercomparison Project (AMIP) runs and 30-member, empirical-orthogonal-function (EOF) sea-surface-temperature (SST) runs of the Global Forecast System version 2 (GFSv2) model that covered the period 1979 to 2012. We presented the results from the simulations at the U.S. Climate Variability and Predictability Research Program ENSO Diversity Workshop in Boulder, Colo.

Preliminary results show that there are two dominant flavors of El Niño and two distinguishable teleconnections associated with the El Niño flavors. El Niño/La Niña SST asymmetry can yield two distinguishable teleconnections. Amplitude variability of leading SST EOF also yields two distinguishable teleconnections.

We also have submitted a paper on the causes of the March 2012 record warmth of the central and eastern United States (Dole et al. 2012)

Finally, we are preparing another draft for *Geophysical Research Letters*. The lead author is Chris Funk, and the title will be "Predicting and attributing recent East African spring droughts with dynamical-statistical climate model ensembles."

Dole, R, et al. 2012. The making of an extreme event: Putting the pieces together. *Bull. Amer. Met. Soc.* Submitted.

PSD-18 Linking Changes in Climate to Wate Resources Management Outcomes

CIRES LEAD: JON EISCHEID
NOAA LEAD: MARTIN HOERLING
CIRES THEME: EARTH SYSTEM DYNAMICS, VARIABILITY, AND CHANGE
NOAA THEME: CLIMATE ADAPTATION AND MITIGATION

GOALS & OBJECTIVES

This work is to explain to decision makers what climate variables are potentially responsible for different water-resource-management outcomes.

ACCOMPLISHMENTS

Progress in this project relies on information that has not yet been provided by the U.S. Army Corps of Engineers. CIRES will report on progress in the next annual report to NOAA.

SPACE WEATHER PREDICTION CENTER

SWPC-01 Space Weather Information Technology and Data Systems

CIRES LEAD: DAVID STONE
NOAA LEAD: STEVEN HILL
CIRES THEME: SPACE WEATHER UNDERSTANDING AND PREDICTION
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will determine the necessary research data systems and infrastructure required to successfully implement the empirical and physical scientific models of the space weather environment.

ACCOMPLISHMENTS

Our team transitioned the Wang-Sheeley-Arge (WSA)–Enlil model into operations. For this work, federal team members received the NOAA Silver Medal of Achievement. We also lead the development of a new, advanced version of the WSA-Enlil model that allows for continuous updating of the ambient solar wind.

Our team provided project leadership for several important efforts: porting of software implemented on Red Hat Enterprise Linux (RHEL) 4.x servers to RHEL 5.x and virtualizing critical hardware systems as the Space Weather Prediction Center (SPWC) prepares for Continuity of Operations.

Our group successfully led the Development and Transition Section to an Agile development methodology, which better integrated change management and provided greater planning visibility for project efforts. A group member served as scrum master, product owner, and project manager for a team of five federal employees tasked with the design, implementation, and rehosting of SWPC's public website. This individual helped the organization establish a Web-content development team, collected the team's editing requirements, developed a customized Content Management System workflow (using Drupal), and trained the team on its use.

We prototyped the Solar Ultraviolet Imager (SUVI) thematic-maps software product by using data from NASA's Solar Dynamics Observatory Atmospheric Imaging Assembly instrument. We developed the software to implement the Space Environmental Anomalies Expert System model, creating three different graphical plots to help diagnose geosynchronous vehicle anomalies caused by space weather.

Our team resolved many residual issues from the migration of the Advanced Composition Explorer (ACE) processing software to a modern Linux system. This code migration was particularly challenging because an outside contractor only partially completed it, and this project team had to finish it.

Further, our project team led the database design and implementation for three major SWPC software projects. The quality of the data models and schemas we developed resulted in increased software-team productivity and decreased maintenance.

Lastly, this project team continued to provide operational support for the following critical systems:

- ACE processor,
- Geostationary Environmental Satellite processor and preprocessor,
- WSA-Enlil,
- Air Force and Institute for Science and Engineering Simulation Message Decoder processor,
- Polar Orbiting Environmental Satellite processor, and
- Microsoft SQL Server Space Weather Data Store.

SWPC-02 Enhancement of Prediction Capacity for Solar Disturbances in the Geospace Environment

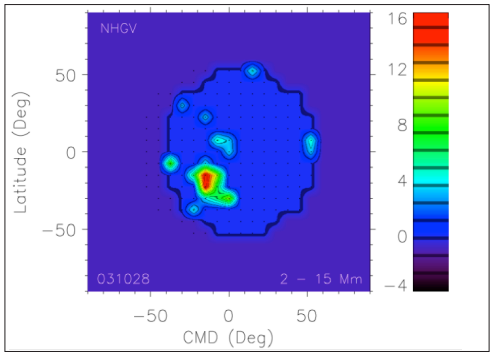
CIRES LEAD: ALYSHA REINARD
NOAA LEAD: VIC PIZZO
CIRES THEME: SPACE WEATHER UNDERSTANDING AND PREDICTION
NOAA THEME: WEATHER-READY NATION

GOALS & OBJECTIVES

This project will advance preparedness for solar storms affecting communication, transportation, and other U.S. infrastructure.

ACCOMPLISHMENTS

Our team has begun to produce daily plots of the normalized helicity gradient variance (NHGV) over the disk. NHGV provides a measure of the potential for flaring. The figure shows an example in which we saw high values of NHGV about one day before an X10 flare occurred.



Map of the portion of the solar disk in which we can measure NHGV (±60 degrees). The region in the lower left that reaches large (red) values of NHGV produces an X10.0 flare on the following day.

SWPC-03 Analysis of the Role of the Upper Atmosphere in Space Weather Phenomena

CIRES LEAD: TIM FULLER-ROWELL
NOAA LEAD: RODNEY VIERECK
CIRES THEME: SPACE WEATHER UNDERSTANDING AND PREDICTION
NOAA THEME: SCIENCE AND TECHNOLOGY ENTERPRISE

GOALS & OBJECTIVES

This project will use models to determine causes for variation in space weather, with implications for infrastructure protection.

ACCOMPLISHMENTS

Simulations with the Global Ionosphere Plasmasphere model driven by winds from the Whole Atmosphere Model (WAM) show significant longitudinal and day-to-day variations in the ionospheric parameters. Under fixed solar and geomagnetic activity levels,

we estimate the contributions of lower-atmosphere tides to the longitudinal and day-to-day variability in the upper atmosphere. We find larger relative variability in the nighttime than in the daytime, which is consistent with observations. The perturbations from the lower atmosphere contribute about half of the observed variability in the ionospheric F2 peak plasma density under moderate solar activity and geomagnetic quiet conditions. Simulations also suggest that the wave-4 and wave-3 longitudinal variations in the equatorial vertical drifts during September are dominated by the diurnal (D), eastward-propagating (E), nonmigrating tides with zonal wave numbers 3 (DE3) and 2 (DE2), respectively. (Fang et al. 2013)

We used WAM fields at high temporal resolution (three-minutes) to drive the Retterer ionospheric irregularity model. We presented first results from this new multiscale model of the formation and evolution of equatorial plasma bubbles and the turbulence associated with them. We created the model by using the winds and electric fields from a consistent combination of a whole-atmosphere and global-scale ionosphere/electrodynamic model to drive a mesoscale model of plasma irregularity formation. With the realistic structure and variability inherent in the winds driven by forcing from lower altitudes, there is no need to force the irregularity model with artificial density perturbations. The resulting ionospheric disturbances provide the seed for the development of plasma instabilities, removing the need for the assumptions needed to specify an artificial seed.

APPENDICES

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Publications by the Numbers

CIRES scientists and faculty published 528 peer-reviewed papers during calendar year 2012. The table below tabulates publications by affiliation of first author. CIRES scientists and faculty published many addtional non-refereed publications in 2012. These publication counts are only one measure of CIRES' 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

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CIRES Lead Author	177	165	188	141	130	110	158	137	238	186
NOAA Lead Author	31	56	20	81	73	99	79	63	41	30
Other Lead Author	183	134	145	289	264	385	342	312	293	312
Total	**391**	**355**	**353**	**511**	**467**	**594**	**579**	**512**	**572**	**528**

PUBLICATIONS

Journal Articles

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Personnel Demographics

CIRES Personnel Breakdown 2012–2013*

Category	Total CIRES Personnel	NOAA-supported CIRES Personnel	Highest Degree Earned by NOAA-supported Personnel B.S.	M.S.	Ph.D.
Faculty	17	0			
Research Scientist	197	112	0	0	112
Visiting Scientist	38	6	0	0	6
Postdoctorate Researcher	29	6	0	0	6
Associate Scientist	252	144	60	75	9
Administrative	32	28	22	5	1
Total > 50% NOAA support		**296**	**82**	**80**	**134**
Undergraduate Students	83	42	0	0	0
Graduate Students	131	14	13	1	0
Received < 50% NOAA Support		**78**	**17**	**22**	**39**
Total CIRES personnel	**779**				

* Includes CIRES employees receiving NOAA funding anytime between July 2012 and June 2013

CIRES Personnel in NOAA Boulder Laboratories*

NOAA Organization	Total CIRES Personnel
OAR's ESRL**	**253**
ESRL Director's Office	11
Chemical Sciences Division	72
Global Monitoring Division	47
Global Systems Division	38
Physical Sciences Division	85
NESDIS/NGDC	**49**
NWS/SWPC	**29**
Total NOAA	**331**
Obtained NOAA Employment in Last Year	1

* Counted on May 1, 2013
** NOAA Office of Oceanic and Atmospheric Research's Earth System Research Laboratory

Active NOAA Cooperative Agreements

Record number	Description	Time frame	Funding amount
NA12OAR4320137	New Cooperative Agreement	September 2012–August 2017	$ 7,860,609*
NA10OAR4320142	Current Cooperative Agreement	June 2010–September 2013	$ 83,881,705
NA080AR4320914	This record number references two shadow awards still active under the old Cooperative Agreement (NA17RJ1229, 2001–2011):		
	Roger Pielke Sr. and Lixin Lu: Downscaling Global Climate Forecast System seasonal predictions for hydrological applications using the Regional Atmospheric Modeling System (RAMS)	May 2008–April 2011	$ 292,186
	Walter Meier: A product development team for snow and ice data records	June 2009 –May 2012	$618,836

*provided by NOAA as of May 31, 2013 for the first nine months of the New Cooperative Agreement.