

CIRES ANNUAL REPORT

2011

COOPERATIVE
INSTITUTE FOR
RESEARCH IN
ENVIRONMENTAL
SCIENCES



Researchers from NOAA and the Cooperative Institute for Research in Environmental Sciences (CIRES) were among the first responders to measure the black smoke that rose from the water's surface during the Deepwater Horizon Oil Spill in the Gulf of Mexico. The earthquake this spring that moved Japan 12 feet closer to the United States was studied by CIRES geophysicists and featured on national television. The Arctic sea ice has melted to its second-lowest level on record (since 1979) as reported this fall by the CIRES National Snow and Ice Data Center. The U.S. Supreme Court is presiding over a case related to water-quality issues in the Florida Everglades and will consider CIRES water-quality research on Grand Lake, Colo., in its decision. The U.S. Department of the Interior announced in October that CIRES and the University of Colorado Boulder would play important roles in two new regional Climate Science Centers that will conduct climate-change research, with a focus on wildlife and ecosystems. Dark-colored dust that settles on snow in the Upper Colorado River Basin makes the snow melt early and robs the Colorado River of about 5 percent of its water each year, reveals a new study from CIRES scientists at the University of Colorado Boulder and NOAA. These are just a few highlights that make my life as CIRES Director so interesting and rewarding. We strive to explore all aspects of the Earth system to better understand all processes of our dynamic planet, which will help guide its management and conservation for future generations.

This coming year will be another milestone in the history of CIRES as we celebrate our 45th anniversary as a cooperative institute, the oldest such unit collaboration with NOAA. We also will submit a proposal to NOAA based on an open competition to continue this legacy for many more years. CIRES continues to engage in cross-disciplinary research in cryosphere, biosphere, atmosphere, geosphere and hydrosphere sciences; therefore, we organized and facilitated six mini-retreats on topics including remote sensing in geosciences, organic molecules in the environment, decision making under uncertainty and paleo-perspectives in climate change and two retreats on energy and the environment. The latter led to a new CIRES initiative to study the environmental effects of future energy solutions, in particular biomass and natural gas production.

CIRES had another exceptional year and showed healthy growth both in funding and research personnel. Again, we had a remarkable increase of 10 percent in research funding in FY11, with about half of our funding from the cooperative research with NOAA and the remaining funding from the National Science Foundation, NASA, other federal agencies and the University of Colorado, totaling more than \$64 million. Our research productivity remains very strong with 512 peer-reviewed publications in all the major research journals of our disciplines. The strong research funding and stellar publication record are the fruits of truly dedicated researchers (500), which include our 22 faculty lines, and excellent administrative staff (32) working with 96 graduate students and 86 undergraduate students as one team to advance our knowledge and understanding in environmental sciences. CIRES has grown to a 714-person institute, and we continue to remain a world leader in interdisciplinary research.

CIRES researchers and staff received a total of 35 awards, ranging from Distinguished Professor at the University of Colorado (Dr. Margaret Tolbert); Career Achievement Service to America Medal (Dr. Susan Solomon) for her research on the ozone hole; Honorary Doctor of Science, Oberlin College (Dr. Peter Molnar); Rosenstiel Award in



Marine and Atmospheric Science, University of Miami (Dr. Jose-Luis Jimenez); Baldi Memorial Lecture Award, International Society of Limnology (Dr. William Lewis); and the two-year appointment as Chief Scientist at NASA (Dr. Waleed Abdalati), to name a few.

CIRES welcomes three new Fellows to the Council of Fellows: Dr. Stanley Benjamin, ESRL/Global Systems Division, Dr. Steve Montzka, ESRL/Global Monitoring Division, and Dr. Judith Perlwitz, ESRL/Physical Sciences Division. The Graduate School has authorized the search for a new senior faculty in experimental atmospheric chemistry in support of the new CIRES Center for Atmospheric Chemistry, increasing our tenure track faculty lines in the graduate school to 23 in nine different departments and programs in the colleges of Arts and Sciences and Engineering and Applied Science.

This report summarizes ongoing research in six research themes: advanced modeling and observation systems, climate system variability, geodynamics, planetary metabolism, regional processes and integrating activities. Further, it provides a brief overview of research conducted by 38 CIRES Fellows, the research activities of CIRES' five scientific centers, education and outreach and the Western Water Assessment. Our research is broad, deep and innovative, and I am very proud to present you this report.

The annual report is a collaborative effort of a number of people in CIRES—researchers as well as administrative staff—and they all deserve credit for what you will find on the following pages. In particular, I would like to acknowledge the effort of Dr. Suzanne van Drunick, Brian Clark and Kristin Bjornsen, who were instrumental in coordinating this effort.

Enjoy your reading!

A handwritten signature in black ink that reads "Konrad Steffen". The signature is written in a cursive style.

Dr. Konrad Steffen



KONRAD STEFFEN/CIRES

The NSF research facility on top of the Greenland Ice Sheet (Summit Station), with a satellite dish for data transmission and communication.

Executive Summary and Research Highlights

CIRES: Science in Service to Society

The Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder was established in 1967 as NOAA's first cooperative institute. CIRES continues to be a world leader in interdisciplinary research and teaching across a diverse range of Earth system science topics. CIRES researchers use established and innovative approaches to study the cryosphere, ecosystems, weather and climate, solid earth and environmental chemistry, observations, modeling and forecasting. This summary highlights many of the past year's research accomplishments and activities, demonstrating how CIRES supports NOAA in meeting its strategic goals. In service to society, CIRES continues to communicate its research findings to help inform decision makers and the public about how to best ensure a sustainable environment.

On a broader scale, fiscal year 2011 (FY11, July 1, 2010 to June 30, 2011) was marked by natural disasters worldwide, including the 2011 Great East Japan Earthquake, the 2010 Russian Heat Wave and the aftermath of the 2010 Deepwater Horizon Oil Spill in the Gulf of Mexico, along with record droughts, tornados and temperature extremes in the United States, making CIRES' mission of forecasting and responding to severe weather and climate more

critical than ever. CIRES leads the way in this capacity, extrapolating data gleaned from the Japan megaquake to the United States, where seismologists expect a 9.0 earthquake to shake the Oregon-Washington Coast sometime in the next 200 years. The lessons learned from Japan are serving as an important template for forecast and disaster mitigation in the United States and elsewhere.

CIRES researchers met their forecasting goal by upgrading and extensively testing the Hurricane Weather Research and Forecasting (HWRF) model; developing advanced DART (Deep-ocean Assessment and Reporting of Tsunamis) programs for the early detection and warning of tsunamis; and creating 22 new digital elevation models of the U.S. coast. These representations of Earth's solid surface are fundamental for modeling and planning for tsunamis, hurricane storm-surges and sea-level rise.

Among CIRES' many other accomplishments, our scientists released a state-of-the-art product, MASIE-NH (Multisensor Analyzed Sea Ice Extent-Northern Hemisphere), which allows anyone to view current Arctic sea-ice coverage by region—information vital for transportation, commerce, ecosystem protection and climate understanding. Additionally, CIRES researchers spearheaded the writing, reviewing and editing of the 2010

international scientific state-of-understanding assessment report on the ozone layer and delivered it to the United Nations Environment Programme (UNEP), where it will inform policy decisions to protect the ozone layer. Advances were also made toward the deployment of an aerosol forecast system (similar to the national ozone forecast system), which will give early warning of high levels of these tiny, airborne particles harmful to human health.

In response to natural hazards, CIRES quickly mobilized around the Deepwater Horizon Oil Spill by diverting a cutting-edge research aircraft (the NOAA WP-3D) to the region to evaluate air-quality concerns, oil leakage rates and the risks posed to human health and wildlife. The researchers, who worked in collaboration with the U.S. Environmental Protection Agency and the Occupational Safety and Health Administration, discovered that approximately one-third of the oil evaporated into the atmosphere. After the deadly Russian Heat Wave in summer 2010, CIRES scientists statistically analyzed observations and ran climate models to conclude the event was due to natural variability and not climate change. The researchers cautioned, however, that extreme weather events could become more likely in the future as greenhouse gases continue to increase. Following the April 2010 eruptions of Eyjafjallajökull in Iceland, CIRES researchers ran real-time volcanic ash forecasts using the NOAA/CIRES FIM (Finite-volume Icosahedral Model) and used this data to refine the model in the event of future such eruptions.

CIRES had another exceptional year of research support during FY11, with total extramural research expenses of \$60,421,835 (increasing again by 10 percent or nearly \$5.7 million more than the previous year). The outlook for CIRES science remains strong, as CIRES' total budget, including university faculty support, was \$64,522,969. NOAA support through the Cooperative Agreement accounted for \$30,867,036 (48 percent); external research awards accounted for \$29,554,799 (46 percent); and university faculty support accounted for \$4,101,134 (6 percent).

CIRES supported 193 research scientists, 228 associate scientists, 29 visiting scientists, 28 postdoctoral researchers, 32 administrative staff, 96 graduate students and 86 undergraduate students. In total, CIRES supported 714 scientists, staff and students. In FY11, CIRES had 22 faculty lines. In total, CIRES researchers published 512 peer-reviewed publications during calendar year 2010.

The CIRES Council of Fellows welcomed Dr. Stanley Benjamin, Dr. Steve Montzka and Dr. Judith Perlwitz. Benjamin is a NOAA meteorologist working at the Earth System Research Laboratory (ESRL) Global Systems Division. His research focuses on numerical weather prediction, data assimilation and aviation meteorology. Montzka is a NOAA scientist at the ESRL Global Monitoring Division where he tracks trace atmospheric chemicals, including ozone and substitutes for ozone-depleting substances. Perlwitz is a CIRES atmospheric scientist working at the ESRL Physical Sciences Division exploring the two-way interactions between the troposphere and stratosphere, and mechanisms by which the stratosphere influences climate.

CIRES researchers who received awards and honors in FY11 are too numerous to list in this summary, but a sample of recognized expertise and service includes the selection of four CIRES Fellows to be lead authors for the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report. They include Konrad Steffen and

Tingjun Zhang (cryosphere), Judith Perlwitz (global to regional detection and attribution of climate change) and Steve Nerem (sea-level change). Other notable recognitions of CIRES Fellows include the selection of Waleed Abdalati, Director of CIRES Earth Science and Observation Center and Associate Professor of Geography, to serve as NASA's Chief Scientist for a two-year appointment beginning in January 2011. Professor William Lewis Jr., Director of the CIRES Center for Limnology, was the invited speaker for the Baldi Lecture at the triennial congress of the International Society for Limnology. Margaret Tolbert was named CU Distinguished Professor—the University's highest faculty honor. David Noone, Associate Professor in the Department of Atmospheric and Oceanic Sciences, and Noah Fierer, Associate Professor in the Department of Ecology and Evolutionary Biology, received the prestigious National Science Foundation (NSF) CAREER Award.

CIRES facilities are also making news. The National Science Foundation awarded \$525,000 to the CIRES National Snow and Ice Data Center, to reduce the data center's carbon footprint and become one of the most energy-efficient data centers in the United States. The completion of the new "Green Data Center" is expected in late 2011. The new Center for Atmospheric Chemistry—a collaboration between CIRES and the Department of Chemistry and Biochemistry—will enable researchers to investigate the impact of aerosols on the environment by helping to resolve the differences between the observed and modeled particle-related cooling influence on Earth's surface. The new laboratory likely will become one of the top three in the United States and will support two new faculty lines. CIRES also became part of two new Department of Interior Climate Science Centers in the Southwest and North Central regions that were created to conduct and coordinate research on climate change and ecosystems.

The Western Water Assessment (WWA)—a NOAA Regional Integrated Sciences and Assessments program created in 1999 as a joint program with CIRES—completed the Colorado Climate Preparedness report and database to facilitate adaptation-planning strategies for the state. Related research by WWA includes the recent findings that dark-colored dust settling on high-elevation snowpack in the Colorado River headwaters causes earlier snowmelt and evaporative losses of nearly 5 percent of the average total annual flow in the river.

CIRES Education and Outreach group serves the community through its science education projects that provide professional development for science educators and scientifically robust climate and energy materials for teachers and students. This group also leads a K-12 program placing graduate students in socioeconomically diverse local schools to enhance science, technology, engineering and math skills. CIRES is involved in other important efforts to improve diversity in Earth system research. We have been a longtime supporter of the Significant Opportunities in Atmospheric Research and Science (SOARS) program, which is a learning community and mentoring program for promoting ethnic and gender equity in the atmospheric and related sciences. New this year, CIRES established a Diversity Committee for staff and scientists to identify opportunities for underrepresented ethnic groups and women to pursue advanced degrees in science.

Communication of CIRES' research and activities reached a broad audience through 23 press releases that

generated wide media coverage; a dynamic website featuring expanded multimedia that includes 16 new videos and several podcasts; and new editions of our popular periodic magazine, *Spheres*.

CIRES proudly continued support of its established competitive programs that provide research and education opportunities to visiting scientists, innovative CIRES scientists and graduate students. This past year, the CIRES Visiting Fellow Program supported seven sabbatical and five postdoctoral scientists conducting diverse research on the role of erosion in mountain building, Arctic coastal communities, three-dimensional ice-sheet models, climate change impacts on water resources at Shasta Lake, interdecadal variability in Sierra Nevada aquatic ecosystems, novel microbial degradation of pentachlorophenol, spectroscopic studies of Titan particles and other topics.

The Innovative Research Program is designed to stimulate a creative and interdisciplinary research environment within CIRES by supporting novel, unconventional or fundamental pilot or exploratory studies. Six inventive proposals were funded on diverse topics that include: secondary organic aerosol formation from evaporated crude oil; nitrogen fixation by blue-green algae to better understand the global nitrogen cycle and nutrient limitation in aquatic ecosystems; novel lidar technology to extend measurements of wind, temperature and possibly aerosols to the stratosphere and troposphere; development of a lower boundary layer radar for wind energy research; development of an instrument for laboratory experiments of contact nucleation to investigate this ice formation mechanism that occurs at temperatures much warmer than other mechanisms; and development of a novel air sampling technology to improve the study of the sources and sinks of greenhouse gases and ozone-depleting substances.

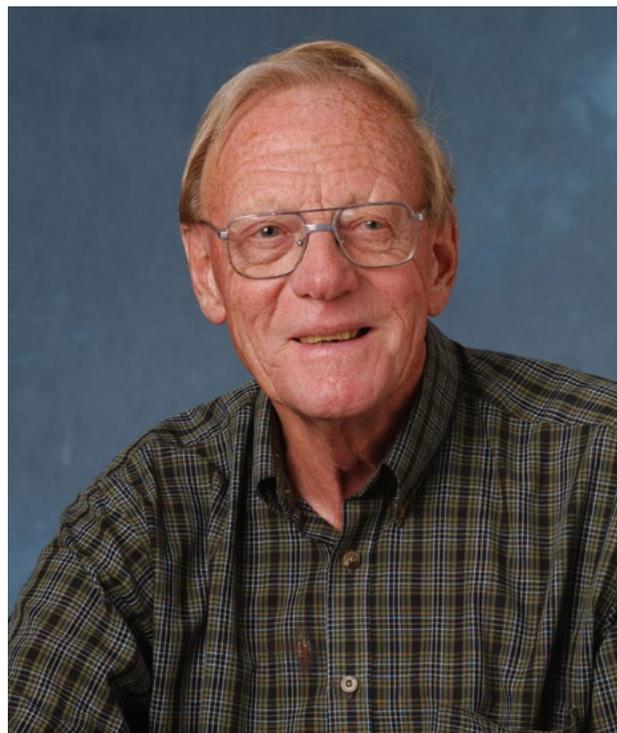
The CIRES Distinguished Lecture Series featured five prominent speakers: David Goldston, U.S. Natural Resources Defense Council, "Loving science to death: Problems at the intersection of science and policy"; Mike Hulme, University of East Anglia, "Why we disagree about climate change"; Daniel Jacob, Harvard University, "Mercury in the environment: Where does it come from, where does it go?"; Andrew Revkin, Pace University, "Are we stuck with 'blah, blah, blah bang?"; and Peter Rhines, University of Washington, "Exploring the cold oceans of the North."

CIRES continues to support strongly its expanding graduate student enrollment through fellowships and sponsorship of its Graduate Student Association. CIRES offers two graduate student fellowships. The CIRES Graduate Student Research Fellowship was awarded to nine doctoral students, who are advised by CIRES Fellows, with dissertation topics that include determining emissions and chemistry of atmospheric trace species in the laboratory and field; atmospheric processing of methylglyoxal in aqueous environments; acquisition of atmospheric data such as wind vectors and air density; formation and evolution of supra-glacial lakes on glaciers in the Himalaya and Karakoram; electromagnetic study of crust and mantle electrical conductivity beneath the Rio Grande Rift; forecasting and uncertainty treatment in hydrologic modeling; scaling and parameterization of oceanic mesoscale eddies; and decision makers' demand for climate change adaptation information. The ESRL-CIRES Fellowship will be awarded in 2011-12 and funded by participating divisions at ESRL.

CIRES participated in, organized and sponsored numerous events in FY11. Highlights include a special seminar on "Arctic seasons: An Inuit perspective"; a panel on Japan's recent disaster; and workshops on "Deepwater Horizon Data," "Energy and the Environment," the "Colorado River Basin" and "Mountain Pine Beetle and Water." In December 2010, we wished a fond retirement to Distinguished Professor and longtime CIRES Fellow Roger G. Barry, who directed the World Data Center for Glaciology (WDC) since 1976. Under Barry's leadership, the WDC/National Snow and Ice Data Center grew from a staff of two in 1977 to about 90 in 2008, when he stepped down as Director. A leader in the cryospheric science community, Barry shares a legacy of discovery about Arctic and mountain climates and cryospheric processes, climate change and collaborations incorporating indigenous environmental knowledge into scientific weather analysis. He published four textbooks and more than 200 scientific papers and chapters, and he inspired nearly 60 graduate students.

This annual report is an accounting of collaborative research goals described in the CIRES-NOAA July 1, 2010, to Sept. 30, 2012, Scientific Workplan, year one. The report is organized by NOAA's six scientific themes identified in the Cooperative Agreement—advanced modeling and observing systems, climate variability, geodynamics, planetary metabolism, regional processes and integrating activities.

We dedicate this report to Dr. George Colvin Reid who passed away on May 6, 2011, at age 81. Reid was a founding fellow of CIRES, a NOAA physicist who helped pioneer climate research since the 1970s, recipient of the Gold Medal for Distinguished Achievement in the Federal Service presented by President Jimmy Carter and a Nobel Laureate for his contribution as an IPCC author.



CIRES founding Fellow George Colvin Reid



Iceland's Eyjafjallajökull volcano spews ash into the air in April 2010.

ISTOCK

Contributions to NOAA's Vision

CIRES' fundamental research priority—to enhance the understanding and prediction of Earth's environment—complements NOAA's priorities, articulated in *New Priorities for the 21st Century: NOAA Strategic Plan FY05–FY10*. CIRES' cross-cutting, interdisciplinary research supports the four Mission Goals identified in the NOAA Strategic Plan: Ecosystems, Climate, Weather and Water, and Commerce and Transportation. The following are examples of CIRES research in support of these goals.

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

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

During the 2010 BP Deepwater Horizon Oil Spill, CIRES scientists were at the front lines of research investigating the dynamics, chemistry and impacts of the spill. Several important results emerged, including the discovery of a new set of oil-vapor chemicals that form organic aerosols (a harmful air pollutant) as well as estimates of the exposure risks of marine species to potentially toxic compounds such as benzene.

In other work, CIRES researchers developed 17 community and five regional seamless, integrated, bathymetric-topographic Digital Elevation Models (DEMs) of U.S. coasts, including Alaska, Hawaii and the Virgin Islands. The DEMs are instrumental in the modeling of coastal processes, such as storms, sediment transport, ocean currents and sea-level rise; ecosystem management and habitat research; coastal and marine spatial planning; and community preparedness and disaster mitigation for hazards such as tsunamis and hurricanes.

CIRES researchers also played a key role in education and outreach, producing a "Coastal DEM Best Practices" handout; interactive online magazines; and a Gulf of

Mexico DEM that *National Geographic Magazine* used as the source of bathymetry for its October 2010 award-winning map "Gulf of Mexico: A Geography of Offshore Oil."

Related highlights include the addition of 230 multibeam swath sonar surveys (covering 904,199 nautical miles) and 26 trackline surveys (67,462 nautical miles), throughout all of the world's oceans, to the National Geophysical Data Center's (NGDC) global marine geophysical archives. This data, used by numerous national and international organizations, also support two U.S. mapping efforts: the Extended Continental Shelf (ECS) project and the Integrated Ocean Coastal Mapping (IOCM) program.

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

CIRES is a world leader in climate science research relevant to NOAA's climate mission goal, and in FY11 contributed significantly to all three categories of NOAA's climate-related programs: 1) climate observations and monitoring, 2) climate research and modeling, and 3) climate service development. Some highlights are described below, but CIRES accomplishments in this goal are extensive, and a full accounting can be found in the Themes section (page 82).

One major advance toward these goals is the completion and publication of the Twentieth Century Reanalysis (20CR) project, an international effort led by CIRES and NOAA researchers to produce a comprehensive global atmospheric circulation data set spanning the period 1871 to the present. The 20CR data set is widely available through a web interface and serves as a valuable resource for climate research and model validation.

In other timely research, CIRES scientists presented an analysis of the 2010 Russian Heat Wave, incorporating an interactive map and plots of climate-model simulations. Additionally, in support of NOAA's goal to serve society with climate products, CIRES and the U.S. National Ice Center created an important new sea-ice analysis product: the Multisensor Analyzed Sea Ice Extent–Northern Hemisphere (MASIE-NH), which allows anyone to view and download sea-ice coverage by region for latest day

and the last four weeks. Closer to home, the CIRES-NOAA Western Water Assessment published the final report of the Colorado Climate Preparedness Project, outlining climate impacts and adaptation strategies for the state.

CIRES scientists also played a pivotal leadership role in coordinating, authoring, reviewing and editing the 2010 international scientific state-of-understanding assessment report on the ozone layer, which was delivered to the United Nations Environment Programme (UNEP). Updated every four years, this key assessment informs decisions made under the Montreal Protocol to prevent ozone-layer depletion.

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

Weather. CIRES researchers support NOAA's mission to provide essential information on weather by advancing numerical weather model forecasting through model improvements and assimilation of data collected in observational field campaigns, ongoing monitoring and from satellite missions. In FY11, CIRES continued its leadership in weather forecast through the release of the Weather Research and Forecasting with Chemistry model (WRF-Chem) version 3.3, which features many performance-enhancing additions, such as greater coupling between chemistry and physics modules and the incorporation of new chemical mechanisms. The community Hurricane Weather Research and Forecasting (HWRF) model also was upgraded and extensively tested, a process that employed 1,190 cases from 53 storms in the North Atlantic and Eastern North Pacific basins for the 2008, 2009 and 2010 seasons. CIRES scientists made state-of-the-art improvements to the Flow-following finite-volume Icosahedral Model (FIM)—used in weather-research modeling—including incorporating volcanic ash from eruptions such as the major volcanic eruption of Iceland's Eyjafjallajökull in April 2010.

To address health concerns about particulate matter aerosols, NOAA and the National Weather Service have made it a priority to deploy an operational national PM2.5 aerosol forecast system, similar to the national ozone forecast system currently in place. Toward that end, CIRES researchers have made advances to develop reliable aerosol forecast capabilities, particularly in respect to the model accuracy of secondary organic aerosols. Another milestone made in measuring aerosol absorption is the completion of a new 3-wavelength, 5-channel photo-acoustic aerosol absorption spectrometer. This high-sensitivity instrument was deployed onboard the NOAA P-3 research aircraft during the 2010 CalNex field campaign, a major multi-agency mission exploring the intersection of climate change and air quality in California.

Water. In the wake of recent events such as the Deepwater Horizon Oil Spill and political debate over climate change, Congress, reporters, bloggers and the general public continue to rely heavily upon NOAA data sets and ask questions about how they were collected. In response, NOAA and CIRES scientists are spearheading the initiative to provide high-quality metadata for hundreds of data sets across NOAA using the ISO (International Standards Organization) 19115-2 and related standards. They also are developing a collection of metadata authoring, archiving and access tools known as the Enterprise Metadata System (EMS).

CIRES researchers are leading the way in the early detection and warning of tsunamis by developing a set

of programs for the control, validation, processing and visualization of Deep-ocean Assessment and Reporting of Tsunamis (DART) data. The NOAA Tsunami Warning Centers, along with hazard managers, researchers and other parties, use DART to improve forecasting and understanding of tsunamis. CIRES scientists also processed and presented real-time DART data from the Chilean Feb. 27, 2010, and Tohoku March 11, 2011, earthquakes and tsunamis.

In related work, the NGDC's Natural Hazards database can now be explored using a powerful new interactive map interface that integrates historical tsunami events, significant earthquakes, volcanic eruptions and water-level data from open-ocean buoys and coastal tide gauges.

As record drought and heat beset the U.S., CIRES researchers continued pioneering development of a diagnostic/forecast tool for probabilistic forecast of seasonal drought and pluvial conditions. Work also continues, in collaboration with Bureau of Reclamation researchers, on reservoir-operations models, and with The Nature Conservancy and University of Washington on the modeling of water flows relevant to ecological applications. Additionally, CIRES staff briefed water managers throughout the country, including Colorado, the Southeast and California, on critical water issues such as runoff prospects, drought situations and river-basin predictions.

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

The Space Physics Interactive Data Resource (SPIDR) is an online system that allows customers to access space weather data sets, including geomagnetic, ionospheric and cosmic-ray data, along with Defense Meteorological Satellite Program (DMSP) satellite images (which display such features as aurora, city lights, fires and cloud coverage). CIRES scientists contributed to several new features—including a downloadable desktop graphical application for creating and executing workflows, as well as a new web-service interface that allows easier access to the web-service middle ware. These advances bring SPIDR's web services to a much larger community of science-data customers. In recognition of these accomplishments, the SPIDR team received a NGDC customer-service award and a NASA software award.

In support of NOAA's project goal to provide spatial and temporal depictions of human activities, CIRES and NOAA researchers developed a radiance-calibrated nighttime-lights product using data collected by DMSP satellite F16. This system overcomes the problem of saturation and allows bright urban cores to be resolvable. The product already has been used in studies of economics, stocks of metals and carbon emissions.

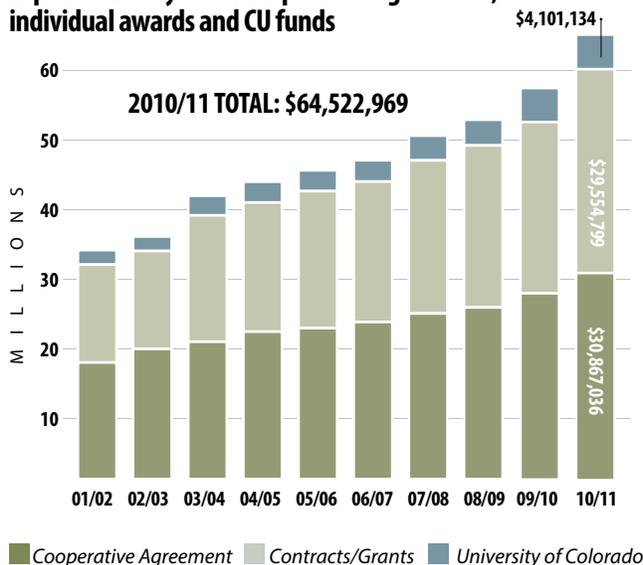
To aid in year-round transportation capabilities in the Arctic Ocean, NOAA researchers at the National Snow and Ice Data Center published a new data set as part of a multi-year program sponsored by the U.S. Maritime Administration: Arctic Marine Transportation Program 1979–1986. The data set will advance the program's goal to define environmental conditions in the Bering, Chukchi and Beaufort Seas; obtain data to improve design criteria for ice-worthy ships and offshore structures; and demonstrate the operational feasibility of commercial icebreaking ships along possible future Arctic marine routes.

This Is CIRES

The Cooperative Institute for Research in Environmental Sciences (CIRES) is a scientific research institute established in 1967 between the University of Colorado at Boulder and the National Oceanic and Atmospheric Administration (NOAA). CIRES maintains an interdisciplinary environment for research on the geosphere, biosphere, atmosphere, hydrosphere, and cryosphere. Institute scientists conduct environmental research that strengthens the scientific foundation upon which NOAA's many services depend. CIRES' long history of successful collaborations with NOAA allow coordinated studies on a scale that could not be addressed by university research units on their own.

CIRES' direction is provided through its Council of Fellows and an advisory Executive Committee. The Institute fosters interdisciplinary science through five centers that bridge traditional boundaries—the National Snow and Ice Data Center, the Center for Limnology, the Center for Science and Technology Policy Research, the Climate Diagnostics Center, and the Earth Science and Observation Center.

Expenditures by NOAA Cooperative Agreement, individual awards and CU funds



CIRES links the University of Colorado Boulder to NOAA.

University of Colorado Boulder

- Aerospace Engineering Sciences
- Atmospheric and Oceanic Sciences
- Chemistry and Biochemistry
- Civil, Environmental, and Architectural Engineering
- Ecology and Evolutionary Biology
- Electrical and Computer Engineering
- Geography
- Geological Sciences
- Molecular, Cellular, and Developmental Biology
- Physics
- Environmental Studies

CIRES Divisions

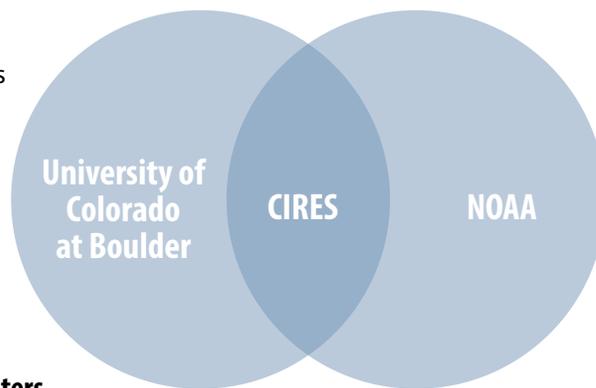
- Cryospheric and Polar Processes
- Ecosystem Science
- Environmental Chemistry
- Environmental Observations, Modeling, and Forecasting
- Solid Earth Sciences
- Weather and Climate Dynamics

Interdisciplinary Research Centers

- Climate Diagnostics Center
- Center for Limnology
- Center for Science and Technology Policy Research
- National Snow and Ice Data Center
- Earth Science and Observation Center

Programs

- Education & Outreach
- Western Water Assessment



NOAA at Boulder Earth System Research Laboratory (ESRL)

- Chemical Sciences Division
- Global Monitoring Division
- Global Systems Division
- Physical Sciences Division

NOAA Centers

- National Geophysical Data Center
- Space Weather Prediction Center

CREATING A DYNAMIC RESEARCH ENVIRONMENT

CIRES has created a number of programs and initiatives to stimulate interdisciplinary collaborations between CIRES, NOAA and university departments. Below, we summarize our main programs.

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. In the West, many of the impacts of climate change will be delivered through changes in the hydrologic cycle that have affected, and will continue to affect, water resources. WWA has focused on building relationships and networks of decision makers and has used these relationships to develop practical research programs and useful informational products. WWA involves researchers and staff from ESRL's Physical Sciences Division; CIRES' Center for Science and Technology Policy Research and Center for Limnology; NOAA's National Climatic Data Center; CU-Boulder's Natural Resources Law Center, Institute for Behavioral Studies, Environmental Studies Program and Center for Advanced Decision Support for Water and Environmental Systems; and other researchers based at Utah State University and the University of Wyoming. WWA's mission is to identify and characterize regional vulnerabilities to, and impacts of, climate variability and change, and to develop information, products, and processes to assist decision makers throughout the Intermountain West. WWA addresses NOAA's mission, strategic goals and cross-cutting priorities, as well as other congressional NOAA mandates, including the U.S. Global Change Research Act and the U.S. Climate Change Science Program. WWA is funded by NOAA's Climate Program Office.

■ www.colorado.edu

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. Our work emphasizes scientific inquiry, links to current research and foundational concepts in geosciences education.

Programs for educators include Inspiring Climate Education Excellence, the Climate Literacy Energy Awareness Network and the Colorado Collaborative of the Center for Ocean Science Education Excellence. Student programs include the National Ocean Sciences Bowl, after-school activities for students underrepresented in science and fellowships for graduate students participating in a K-12 education project. Climate communications workshops, support for education activities, and research-proposal preparation assistance support scientists.

■ cires.colorado.edu/education/outreach

Innovative Research Program

The purpose of the CIRES-wide competitive Innovative Research Program is to stimulate a creative research environment within CIRES and to encourage synergy between disciplines and research colleagues. The program encourages novel, unconventional and/or fundamental research that may quickly provide concept viability or rule out further consideration. Activities are not tightly restricted and can range

from instrument development, lab testing and field observations to model advancement. Funded projects are inventive, often opportunistic, and do not necessarily have an immediate practical application or guarantee of success. Each year, an interdisciplinary committee selects the award recipients, and the results of their research are presented the following year at a poster reception. The 13th annual Innovative Research Program in 2011 funded six projects, including research into the formation of secondary organic aerosols from evaporated crude oil, developing radar for renewable energy research and the development of novel lidar technologies for profiling the whole atmosphere.

■ cires.colorado.edu/science/pro/irp

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 masters and doctoral students every other year with the support of NOAA's Earth System Research Laboratory.

■ cires.colorado.edu/education/cu/gsrp

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

Visiting Fellows Program

CIRES annually conducts a competitive Visiting Fellows program that promotes collaborative research at the forefront of scientific knowledge. Fellowships of up to one year are awarded to Ph.D. scholars (Postdoctoral Fellowships) and faculty planning sabbatical leave (Sabbatical Fellowships). Visiting Fellows conduct interdisciplinary research in areas such as atmosphere and ocean processes, cryospheric processes, ecology and ecosystems, regional/global environmental variability and change, global water cycle, advanced observing systems, geophysics, global health, science and technology policy research, and space weather. Selections for the Visiting Fellows program are based in part on the likelihood of interactions between the Visiting Fellows and the scientists at CIRES 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 over 265 Visiting Fellowships. Recipients have included previous CIRES Director Susan Avery and current Director Konrad Steffen.

■ cires.colorado.edu/collaboration/fellowships

Rendezvous!

More than 400 people attended the CIRES Members' Council's fifth annual Rendezvous research symposium on April 22, 2011. This half-day, institute-wide symposium featured 100-plus posters showcasing the depth, breadth and quality of the science being conducted at CIRES. Director Konrad Steffen spoke about the "State of the Institute," and presented awards for outstanding performance, years in service and other scientific achievement.

■ cires.colorado.edu/events/rendezvous/contacts

CIRES CENTERS

CIRES supports five centers, described below. Although many CIRES scientists are not affiliated with Centers, these centers help provide structure and identity for significant areas of research within the Institute.

Center for Limnology

Limnology is the scientific study of the life and phenomena of inland water, including lakes, rivers, streams, and wetlands. The CIRES Center for Limnology exists to promote research and teaching related to inland aquatic ecosystems. This year, Center research included studies of the biogeochemical effects of pine bark beetles on montane watersheds in Colorado; comparisons of food web structures in Rocky Mountain National Park lakes that contain fish and lakes that lack fish; study of the metabolism of the South Platte River downstream of Denver; and work on the purple-tinted Little Gaynor Lake in Boulder County, which supports high densities of bluegreen algae.

■ cires.colorado.edu/limnology

Center for Science and Technology Policy Research

CIRES' Center for Science and Technology Policy Research conducts research, education, and outreach to improve the relationship between societal needs and science and technology policy. Current projects include studies of how urban water managers respond to shortages, alternative approaches to limiting greenhouse gas emissions to the atmosphere, Colorado's vulnerability to drought, the role of non-governmental organizations in ecosystems management, and how the media portray climate change issues. Center research is reported via research articles, books, and several outreach methods, including a regular newsletter, research briefings, faculty blogs, news media, and frequent seminars and workshops.

■ cires.colorado.edu/science/centers/policy

Climate Diagnostics Center

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

■ cires.colorado.edu/science/centers/cdc



Earth Science and Observation Center

CIRES' 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. This year's research included climate monitoring on the Greenland Ice Sheet and the development of a model to understand glacial dynamics; a study of the inversion-related effects of climate change on air quality in the western United States; ongoing work to understand the ecosystem effects of disturbances in western forests; the development of sophisticated lidar instruments to study the atmosphere; water cycle studies; and the planning of future satellite and aircraft missions.

■ cires.colorado.edu/esoc

National Snow and Ice Data Center

The National Snow and Ice Data Center (NSIDC) supports research into Earth's frozen realms: the snow, ice, glaciers, ice sheets, and frozen ground that make up the cryosphere. NSIDC manages and distributes scientific data, creates tools for data access, supports data users, performs scientific research, and educates the public about the cryosphere. This year's research activities were diverse, ranging from a reanalysis of decades-old image files to obtain information on Arctic sea ice extent in 1966 (years before the current satellite record), to a study linking Inuit knowledge and statistical weather analysis. NSIDC researchers continued reaching out to public and research communities about annual Arctic sea ice minimum extent measurements and other data, through the Arctic Sea Ice News and Analysis website.

■ cires.colorado.edu/science/centers/nsidc



MICHAEL STUDINGER/NASA

This view from a NASA DC-8 aircraft flying over the Antarctic Peninsula gives a glimpse of the ice sheet and the glaciers that Operation IceBridge is observing with an array of onboard remote-sensing instruments. The mission ensures a continuous set of observations that may help scientists understand changing ice mass for Earth's ice sheets, glaciers and sea ice.



The southern lights at McMurdo, Antarctica.

ZHIBIN YU/CIRES

**COOPERATIVE INSTITUTE FOR RESEARCH
IN ENVIRONMENTAL SCIENCES**

**Agreement No. NA17RJ1229
Extension Award: NA10OAR4320142**

University of Colorado Boulder UCB 216
Boulder, CO 80309-0216

Phone: 303-492-1143

Fax: 303-492-1149

email: info@cires.colorado.edu

<http://cires.colorado.edu>

CIRES Director

Konrad Steffen

CIRES Associate Director

William M. Lewis, Jr.

Annual Report Staff

Suzanne van Drunick, Coordinator

suzanne.vandrnick@colorado.edu

Brian Clark, Design

Kristin Bjornsen, Editor

*Cover image: The aurora borealis and a lidar beam
create a fantastic light show in Sondrestrom, Greenland,
at the Sondrestrom Research Facility. PHOTO BY RYAN NEELY/CIRES*