COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

2017 Annual Report

COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

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Cover: Crevasse on the Greenland Ice Sheet. Photo: Jim Kastengren/CIRES

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Executive Summary & Research Highlights

From the Director

CIRES turned 50 this September, marking five decades of excellent and dedicated service to NOAA and its predecessor, the Environmental Science Service Administration. CIRES' founders focused on the importance of multidisciplinary research aimed at understanding the Earth system, and that value has not changed in 50 years. Our achievements and prominence, however, have changed—growing with every decade.

We had three great occasions in the last year to highlight CIRES' past accomplishments and envision our future: In the spring of 2017, we held a small celebration of our 50th anniversary, which included colleagues from the University of Colorado Boulder and from NOAA, presentations from a handful of past directors and students, and excellent camaraderie. In the fall of 2016, we hosted a team of international Reviewers, convened by NOAA, to assess our performance during the first half of our current ten-year award. And we had a similar review by the University of Colorado's Academic Review and Planning Advisory Committee, which examines the effectiveness and success of departments and institutes on the CU Boulder campus.

For me, what emerged from these three events was a powerful sense of CIRES scientists' involvement in questions of regional, national, and international importance, and the progress we continue to make in addressing these questions. We featured presentations about El Niño's impacts on California and the West and successful efforts to quantify the impact of oil and gas exploration on our planet's atmosphere. We showcased CIRES involvement in international efforts to better understand ozone pollution at the Earth's surface, and ozone hole recovery high in the stratosphere. We highlighted a team that developed the National Weather Service's next-generation forecast model for severe weather events such as tornadoes and blizzards. These were just a few examples to highlight our outstanding work and its direct relevance to people's lives. We also used the opportunity to highlight the many accolades that our scientists earn for their work. This year's awards and recognitions are highlighted in the Awards section of this report, on page 46, and it's worth calling out two here: CIRES researcher Anne Perring earned a Presidential Early Career Award for Scientists and Engineers, or PECASE, from the White House, and CIRES Fellow Jennifer Kay won a National Science Foundation CAREER award.

During this last year's events, we also highlighted the work of our graduate students and postdocs, in Ignite-style talks. CIRES scientists mentor and advise the next generation of world-class scientists, and from what I saw in the student talks, that mentorship is helping to create sharp, focused, communicative, and wholly impressive early career researchers.

I was gratified that CIRES received a rating of Outstanding from the reviewers, who clearly recognized and appreciated CIRES' contributions to science, education, and people's lives. In particular, I would like to thank Associate Director Bill Lewis and our former Associate Director for Science, Kristen Averyt, for their tremendous efforts in making our reviews so successful.

I reported this spring that Dr. Averyt would be leaving us to take on the Directorship of the Desert Research Institute in Nevada. While we miss her contributions to CIRES, we are delighted to welcome Dr. Christine Wiedinmyer, a highly accomplished atmospheric chemist, as our new Associate Director for Science.

It is also my great pleasure to welcome EarthLab to CIRES. This innovative new team of about 20 people, led by Jennifer Balch (Dept. of Geography) moved under the CIRES administrative umbrella July 1 this year.

This year, we grew the administrative team slightly, adding one new positions in Finance and one in HR, to help deal with relentless proposal writing by CIRES scientists, and the hiring of research scientists, staff, and students to meet our expanding needs.

Finally, I'm gratified to report that CIRES' scientific and administrative successes are reflected in our finances. In FY2017, our expenditures were nearly $88 million, which comprised roughly one-sixth of the University's research funding. About half of our support was from the cooperative agreement with NOAA, and we continued to leverage this investment, and support from the university, to secure more than $37 million in additional funding from diverse other sources.

We have had another excellent year at CIRES, and I want to extend my deepest appreciation to every member of our team, from our scientists, engineers and developers to our staff and students, who continue to make CIRES the great success that it is and an organization of which we can all be very proud.

Waleed Abdalati
CIRES Director

Photo: Glenn Asakawa/CU Boulder

CIRES: Science in Service to Society

The Cooperative Institute for Research in Environmental Sciences is an international leader in research, addressing some of the most pressing challenges facing the planet. Many of these challenges are priorities for NOAA, such as innovating new ways to better forecast severe weather events that threaten lives and property and conducting climate research useful to decision makers, from local to international levels. Since its inception as one of NOAA'S first cooperative institutes 50 years ago, CIRES has been helping NOAA achieve strategic goals by hiring and supporting some of the best and brightest Earth scientists and leveraging NOAA investments with partnerships and funding from other institutions around the world. Here we highlight a few of the past year's activities and successes as they align with NOAA's *Next Generation Strategic Plan*.

Weather-Ready Nation Goal

- During 2017, NOAA began using an improved "dynamical core" weather model, the Finite Volume on a Cubed Sphere (FV3), to provide better forecast guidance. That choice was made in large part due to work by CIRES scientists and colleagues who evaluated all cores under consideration to improve a critical National Weather Service global weather forecast model. (PSD-26)
- CIRES staff continued to support the Hurricane Weather Research and Forecasting model, testing code for public releases, creating and updating documentation and instructional materials, conducting tutorials, and answering questions from users. The team also developed a draft protocol for incorporating forecast-improving innovations into the NOAA operational global forecast system. (GSD-07)
- A series of peer-reviewed studies directly quantified how local and regional emissions from various sources (e.g., oil and gas exploration and the naturally ozone-rich stratosphere) contribute to summertime ozone problems. Ozone pollution is regulated because of the harm it does to people's lungs; it can also damage crops and other plants. (CSD-04)
- CIRES researchers helped develop and finesse several key products designed to help forecasters and managers in the aviation industry make safety-related decisions. One example is the expansion, to new airports, of a forecast tool used to verify gate approach and departure gate forecasts, with a focus on convection-related impacts. (GSD-06)
- Experts in the Space Weather Forecast Center successfully transitioned a research-based geospace model, developed at the University of Michigan, into operations at the National Centers for Environmental Prediction. The Geospace

Flood damage in east Boulder County, Colorado.
Photo: Lornay Hansen/CIRES

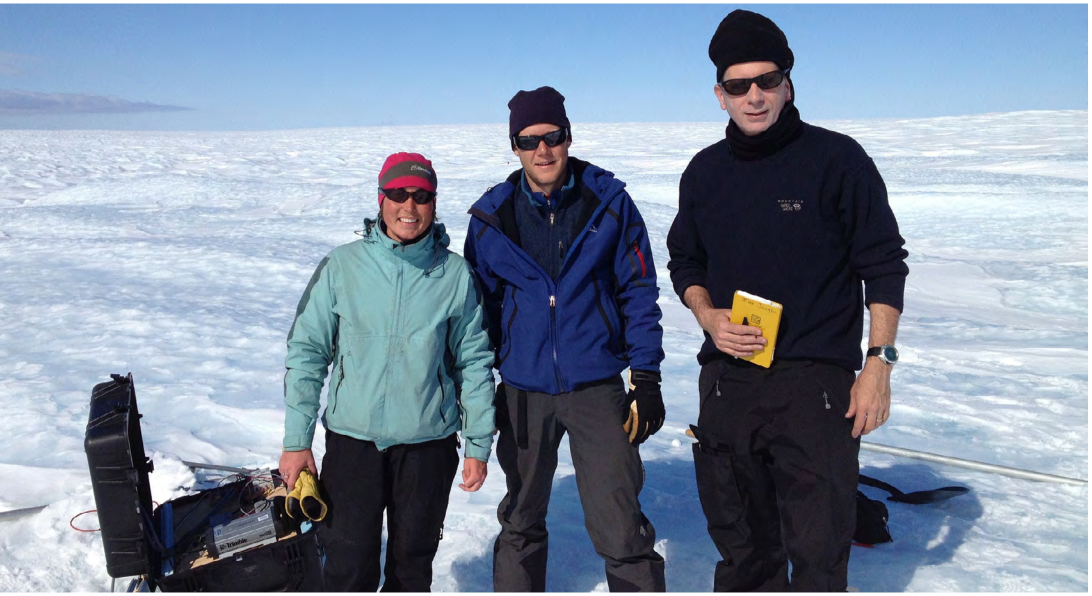
Model forecasts the geomagnetic impacts of space weather on Earth and low-Earth orbit; those impacts can include communication outages and power transmission problems. George Millward won a CIRES Outstanding Performance Award for this work. (SWPC-04)

Climate Adaptation and Mitigation Goal

- A CIRES scientist in NOAA's Chemical Sciences Division chairs the international Tropospheric Ozone Assessment Report. For TOAR, more than 220 scientists in 30-plus nations are producing the first comprehensive, global overview of tropospheric ozone distribution and trends at more than 9,000 global sites. Ozone pollution can damage human health and crops, and it affects climate. (CSD-03)
- CIRES researchers help collect long-term solar radiation data from a network of U.S. sites to support those who need to understand climate variability and potentially harmful ultraviolet radiation. The team also supports specific missions: in Alamosa, Colorado, for example, to make more accurate cloud forecasts for solar power generation; and in northern Arizona, to provide surface data to validate data from NOAA's new GOES-16 satellite. (GMD-01)
- In NOAA's Physical Sciences Division, CIRES researchers are working with colleagues to better understand and forecast seasonal sea surface temperatures in the California Current System—information that that can help those managing living marine ecosystems. (PSD-25)
- A two-millennia reconstruction of drought, the Living Blended Drought Product, is helping experts with the National Integrated Drought Information Service put recent droughts into longer perspective. The work by CIRES researchers and federal colleagues will eventually help researchers better understand and predict hydroclimate changes. (NCEI-11)
- The White House named CIRES' Anne Perring, an atmospheric scientist who works in the Chemical Sciences Division, as one of 102 young scientists and engineers to receive the prestigious Presidential Early Career Award for Scientists and Engineers. Perring, who began working for CIRES in 2009, focuses on characterizing and understanding atmospheric particles ("aerosols") and how they affect climate and air quality. (CSD-07)

Engagement Enterprise

- More than 3,000 users download data from the National Snow and Ice Center's Sea Ice Index pages every month, and many times that number of users view those data online monthly. The Index serves as a friendly, go-to source for sea ice information for scientists, teachers, students, and the general public, offering easy-to-sort and analyze maps depicting annual mean precipitation and temperature across the Arctic, maximum and minimum sea ice extent, mean cloud cover, and more. (NSIDC-01)



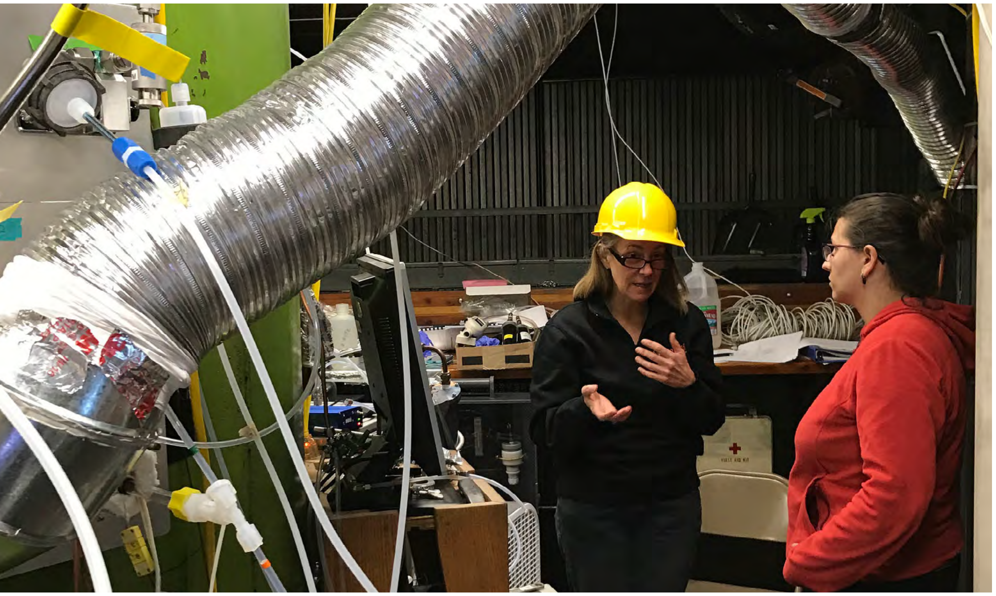
Fieldwork near the west coast of the Greenland Ice Sheet. Photo: Twila Moon/NSIDC

CIRES researchers have identified unique chemical emissions ratios or "fingerprints" of concentrated animal feedlot operations. Photo: Skeeze/pixabay

- One-third of people on this planet can no longer see the Milky Way, according CIRES scientists and colleagues who produced an innovative assessment of global light pollution with data from the NOAA/NASA Suomi NPP satellite. The paper highlighting this work earned the highest Altmetric score ever for the journal *Science Advances*. Nighttime lights data made available by a small team of CIRES and NOAA experts have fostered dozens of highly cited assessments on diverse topics, including international development, gas flaring, and illegal fishing. (NCEI-07)
- CIRES staff and colleagues have been key to developing, operationalizing, and improving the Meteorological Assimilation Data Ingest System, MADIS, which incorporates up-to-date observations from airlines, universities, state highway departments, and many other sources into weather forecast models. This year, the team brought in data from the Hydrometeorological Automated Data System, HADS; previously, HADS data couldn't be used at times when they would have previously been most effective at improving forecasts—during critical weather conditions. (GSD-01)

Science and Technology Enterprise

- Under the U.S. Extended Continental Shelf Project, CIRES staff and federal colleagues are compiling the geophysical data needed to establish the full extent of the U.S. continental shelf under international law—an effort that's critical to defining our maritime boundaries. (NCEI-13)
- CIRES staff and federal colleagues have worked to improve the skill of two critical numerical forecast models in use at National Weather Service forecast offices around the country: Rapid Refresh and High-Resolution Rapid Refresh. The team's work—including the addition of a hybrid vertical coordinate and use of stochastic parameter perturbations— improves forecasts of things like low-level winds and downward shortwave radiation, which are useful for the electric power industry. (GSD-11)
- During the El Niño Rapid Response experiment, science teams from NOAA facilities in Colorado, Maryland, Florida, and elsewhere collaborated to capture an unprecedented set of observations in the Tropical Pacific Ocean, El Niño's birthplace. Now, the team's data are available publicly and papers are in preparation or press. CIRES researchers comprised about half of the ENRR science team. (PSD-23)
- CIRES researchers are improving sophisticated models of the space weather system from the Sun to Earth, to better understand and forecast potentially damaging space weather impacts to infrastructure, such as power distribution systems. Two of three major, long-planned improvements have now happened: The WSA-Enlil solar wind propagation model is operational, as is the Michigan Geospace Model, which describes impacts to the Earth's magnetosphere. Next up: the Whole Atmosphere Model, due to be tested in the fall of 2017. (SWPC-03)



NOAA's Anne Middlebrook and University of North Carolina Chapel Hill's Sophie Tomaz prepare for an experiment in the Montana Fire Lab. Photo: Henry Worobec/University of Montana

NOAA and CIRES researchers targeted Salt Lake City's wintertime air pollution challenges in an aircraft mission this year. Photo: Mateoutah/Flickr

This is CIRES

CIRES' mission is to conduct innovative research that advances our understanding of the global, regional, and local environments and the human relationship with those environments, for the benefit of society.

Established in 1967, the Cooperative Institute for Research in Environmental Sciences (CIRES) facilitates collaboration between the University of Colorado Boulder and the NOAA. Our original and continuing purpose is to support NOAA's mission by facilitating research that crosscuts traditional scientific fields. By bringing scientists from CU Boulder departments and NOAA groups together into a network of CIRES divisions, centers, and programs, CIRES researchers can explore all aspects of the Earth system. These partnerships foster innovation, rapid-response capabilities, and an interdisciplinary approach to complex environmental challenges. The work of the CIRES enterprise strengthens the scientific foundation upon which NOAA's environmental intelligence services depend, and allows coordinated studies on a scale that could not be addressed by university research units or NOAA alone.

CIRES scientists and staff are affiliated with:

University of Colorado Boulder Departments

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

NOAA Earth System Research Laboratory (ESRL)

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

NOAA Centers

- National Centers for Environmental Information
- National Weather Service
  - Space Weather Prediction Center
  - Weather Forecast Office

CIRES research is organized into six divisions; every CIRES scientist falls into one division. Our four centers and several programs foster cross-fertilization of ideas and enable rapid response to emerging challenges. Some programs serve the whole institute.

Divisions

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

Centers

- Center for Limnology (page 20)
- Center for Science and Technology Policy Research (page 22)
- Earth Science and Observation Center (page 24)
- National Snow and Ice Data Center (page 27)

Insitutional Programs and Teams

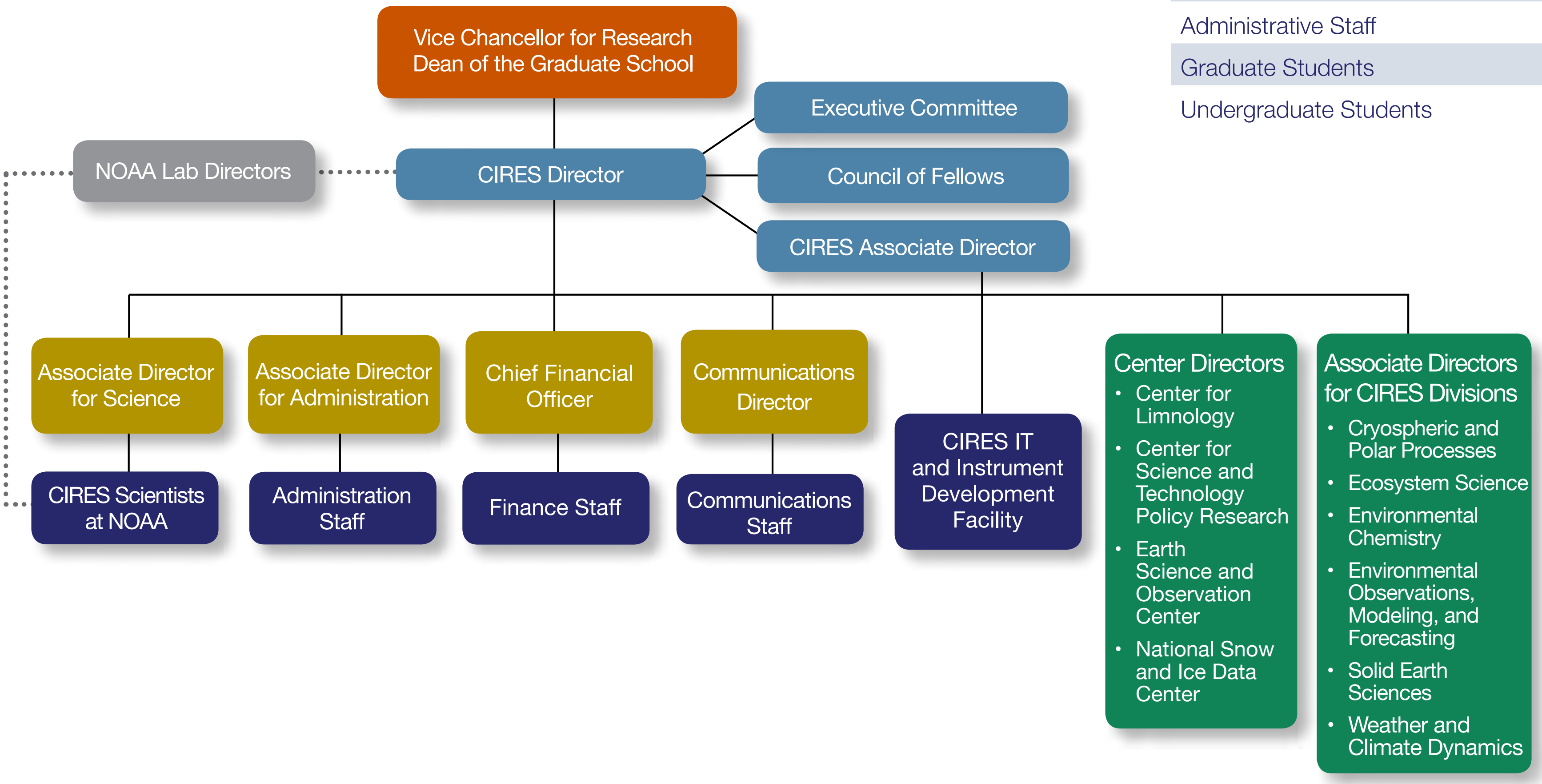
- Western Water Assessment (page 30)
- Education and Outreach (page 32)
- International Global Atmospheric Chemistry Project (page 34)
- Visiting Fellows (page 36)
- Innovative Research Program (page 39)
- Graduate Student Research Awards (page 40)
- Integrated Instrument Design Facility (page 41)
- Communications (page 42)

Organization

The Council of Fellows and the Executive Committee, with input from the CIRES Members' Council, advise CIRES Director Waleed Abdalati. The CIRES Centers—the Center for Limnology, the Center for Science and Technology Policy Research, the Earth Science and Observation Center, and the National Snow and Ice Data Center—and other programs link NOAA to nine university departments. Coordination among all these entities is facilitated through the CIRES administration.

The CIRES Team FY2017

Faculty Lines	21
Research Scientists	244
Associate Scientists	294
Visiting Scientists	12
Postdoctoral Researchers	25
Administrative Staff	36
Graduate Students	104
Undergraduate Students	107



Governance

Council of Fellows

The Council of Fellows constitutes the Board of Directors and is the chief advisory body of CIRES. Fellows are selected because of their outstanding achievements and abilities in diverse areas of environmental sciences. These university faculty, research scientists, and government scientists and Fellows form the core of our institute. Members of the Council of Fellows:

- provide leadership at all levels in environmental science,
- maintain an active scientific research and education program,
- support the CIRES infrastructure through indirect cost recovery and in-kind contributions,
- advise CIRES management, and
- contribute interdisciplinary expertise and participate 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. During this reporting period, the Council of Fellows met: September 22, October 20, November 17, and December 8 of 2016; and January 26, February 23, March 23, and April 20 of 2017. For more details about the 43 members of the Council of Fellows, please see page 10.

Executive Committee

The Executive Committee assists and advises the director in matters regarding strategic management of the institute. Members of the Executive Committee include the associate directors for CIRES' six divisions, four 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 three CIRES career tracks: 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

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. Annually, the Council of Fellows considers whether to entertain new Fellow nominations, which are drawn 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

CIRES is committed to enhancing diversity by extending its community and knowledge across the full spectrum of cultures and backgrounds. Staff in CIRES' Education and Outreach program, administration, and all science groups work to identify programs, mentorships, and other opportunities for CIRES to foster diversity and enrich our professional community (pages 44-45 highlight some specific diversity-oriented projects).

Members' Council

The CIRES Members' Council serves as an information and policy conduit between institute members and CIRES leadership. 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, 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 science symposium, the Awards Committee for CIRES Outstanding Performance Awards, and the CIRES Bike Share program.

Special Committees

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

Other CIRES Committees

Visiting Fellows (page 36)
Distinguished Lecturers (page 50)
Graduate Student Research Award (page 40)
Innovative Research Program (page 39)

Finance

During the university fiscal year of July 1, 2016, to June 30, 2017, CIRES had total expenditures of nearly $88 million, including the university portion (graph 1).

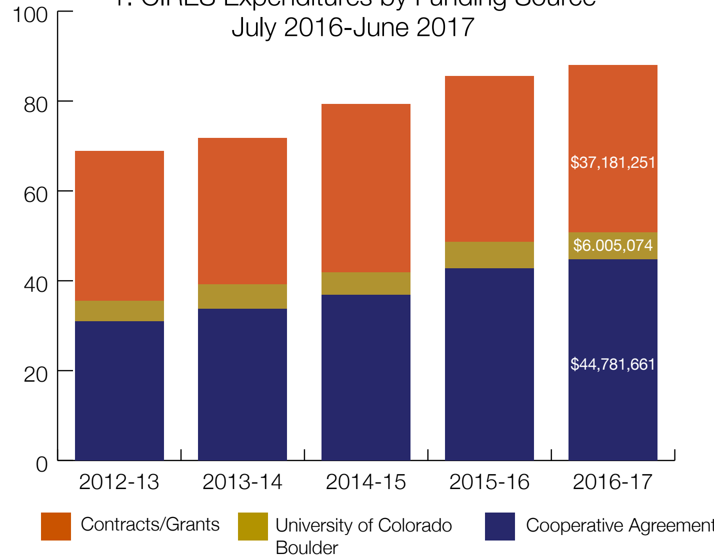
CIRES researchers enjoy enviable success in obtaining external research awards, which comprise ~42 percent of total expenses). Graph 2 breaks down our contracts and grant funding by main sources.

Graph 3 provides an overall look at our Cooperative Agreement funding, by task. Task I funding (further described in graph 4) is for CIRES administration and internal scientific programs, such as the Visiting Fellows and Graduate Student Research Award programs. Task II funds CIRES' collaboration with NOAA groups in Boulder, Colorado. Task III funds support individual CIRES investigators who conduct stand-alone projects under the umbrella of our Cooperative Agreement, at NOAA's request.

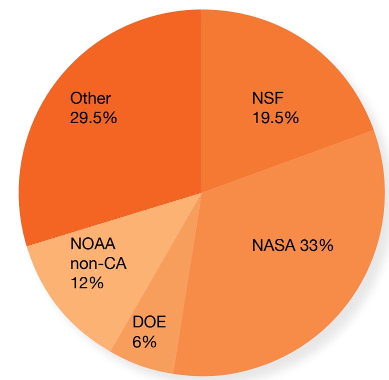
NOAA Cooperative Agreements	Start Date	End Date
NA12OAR4320137 CIRES Five-Year Cooperative Agreement	9/1/2012	8/31/2017
NA15OAR4320137 CIRES Five-Year Cooperative Agreement (new award no.)	9/1/2015	8/31/2017

***Please see page 134 for other active NOAA awards. Our other agency awards are represented in graph 2 above; they are too numerous to list in full here.**

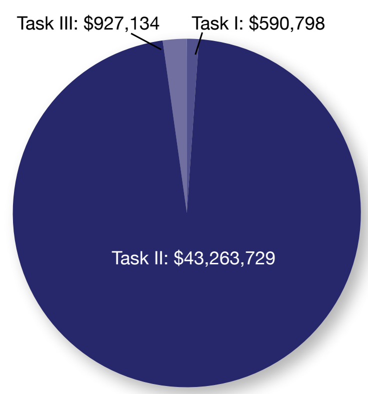
1. CIRES Expenditures by Funding Source July 2016-June 2017



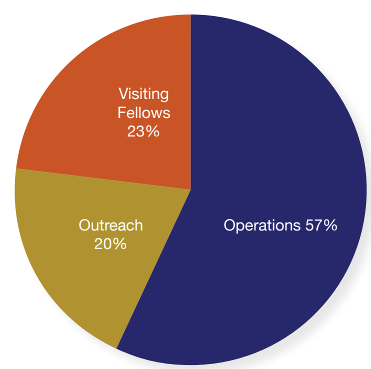
2. Contract/Grants by Source



3. Agreement Expenditures by Task July 2016-June 2017



4. Breakdown of Task I Expenditures, FY17



CIRES starts with people

In this section, we highlight the diverse environmental science work being done at CIRES, beginning with CIRES Fellows. Fellows pages are followed by reports on CIRES' centers (page 20) and programs (page 30).

We also report on our prestigious Visiting Fellowships (page 36), pioneering research funded by CIRES' Innovative Research Program (page 39), and graduate and undergraduate programs including diversity and award programs (page 44).

A more exhaustive description of CIRES projects, involving CIRES Fellows at NOAA and hundreds of other scientists and staff, can be found in the Project Reports (page 54).

CIRES Fellows

NOAA Scientists

Stan Benjamin
David Fahey
Christopher Fairall
Graham Feingold
Stephen Montzka

CU-Boulder Teaching Faculty

Waleed Abdalati
Roger Bilham
Maxwell Boykoff
Eleanor Brown
John Cassano
Xinzhao Chu
Shelley Copley
Lisa Dilling
Lang Farmer
Noah Fierer
José-Luis Jiménez
Craig Jones
Kris Karnauskas
Jennifer Kay
William M. Lewis Jr.
Ben Livneh
Peter Molnar
William Neff
R. Steven Nerem
Balaji Rajagopalan
Mark Serreze
Anne Sheehan
Robert Sievers
Kristy Tiampo
Margaret Tolbert
Greg Tucker
Veronica Vaida
Rainer Volkamer
Carol Wessman
Michael Willis
Paul Ziemann

CIRES Research Scientists

Richard Armstrong
Joost de Gouw
Fred Fehsenfeld
Timothy Fuller-Rowell
R. Michael Hardesty
Judith Perlwitz
Prashant Sardeshmukh

At left: Stefan Schwietzke prepares for a flight to measure methane emissions. Photo: Will von Dauster/NOAA. At right: Dauphin Island excursion for the National Ocean Sciences Bowl, attended by Education and Outreach students. Photo: Amanda Morton/CIRES

Waleed Abdalati
CIRES Director,
Professor of Geography

My research interests are in the use of satellite and airborne remote sensing techniques, integrated with in situ observations and modeling, to understand how and why the Earth's ice cover is changing, and what those changes mean for life on Earth. In particular, my research focuses on the contributions of ice sheets and high-latitude glaciers to sea level rise and their relationship to the changing climate. Toward that end, I have been heavily involved in the development of NASA's Ice Cloud and land Elevation Satellite (ICESat) and its successor, ICESat-II, and I have worked on cryospheric applications of various other satellites and aircraft instruments. Most of my research is supported by NASA, where I worked as a scientist for 12 years, before joining CIRES. In 2011, I returned to NASA on a two-year assignment as the agency's Chief Scientist, serving as principal adviser to the NASA Administrator on NASA science programs, strategic planning, and the evaluation of related investments.

Richard Armstrong
Adjunct Associate
Professor of Geography

In general my interests cover a wide range of snow and glacier topics: from snow metamorphism to avalanches—and glacier mass balance, glacier area, and mass change in response to a warming climate. Methodologies include both in situ and satellite data. My current focus is on determining how much river discharge originates as melting seasonal snow and how much as melting glacier ice across High Asia: the CHARIS project. This distinction is important because while seasonal snow cover returns every year, albeit in varying amounts, glaciers disappear as a result of a warming climate—and that water source is totally lost for the current era.

Stanley G. Benjamin
Chief, Assimilation and
Modeling Branch,
NOAA Global Systems Division

I am a senior scientist for advanced modeling systems at NOAA's Global Systems Division in Boulder, Colorado. My interests lie in data assimilation, including for clouds, radar and boundary layer, and global subseasonal coupled (atmospheric-ocean-aerosol) modeling and forecasting. Our group in GSD works closely with the National Weather Service on improving NOAA's operational models. We focus on improved frequently updated convection-allowing modeling for severe weather, aviation/transportation, hydrology, and energy applications. We also work on improving model representations of the boundary layer, land surface, and stable and convective clouds including aerosol interaction.

Roger Bilham
Professor Emeritus of
Geological Sciences

I am a research scientist in CIRES with interests in earthquake, landslide, and volcano processes and their impact on society. I use various terrestrial and remote sensing geodetic methods to capture the deformation of the Earth's crust, and engineering and historical investigative methods to quantify the damage they produce now, and have produced in the past several thousands of years. My current research includes four areas: quantifying limits to the storage of strain energy in the Himalaya, investigation of fault creep in Anatolia and California, global seismic hazards and the influence of corruption in the building industry, and tectonics of Colombia and the Caribbean.

Maxwell Boykoff
Director, Center for Science and
Technology Policy Research,
Associate Professor of
Environmental Studies

I am a CIRES Fellow, an Associate Professor in Environmental Studies with a courtesy appointment in Geography, and Director of the Center for Science and Technology Policy Research (CSTPR). I am also a Deputy Editor at the journal of *Climatic Change* and a Senior Fellow at the University of Oxford Environmental Change Institute. My research and creative work focus on cultural politics and environmental governance, creative climate communications, science-policy interactions, and climate adaptation. Through connected projects and collaborations, I examine how climate science and policy find meaning in people's everyday lives, and how this, in turn, feeds back into science and policy decision-making.

Eleanor C. Browne

Assistant Professor of Chemistry and Biochemistry

My group is primarily interested in developing instrumentation for measuring gases and aerosols in the atmosphere and in using this instrumentation to investigate how atmospheric processing affects the chemical composition of gases and aerosols. The group is specifically interested in organonitrogen and organosilicon compounds and investigates the fate of these compounds using laboratory and field measurements. My current work focuses on understanding the role of organonitrogen in new particle formation and growth, and in nitrogen deposition. The organosilicon work focuses on constraining the fate of organosilicon compounds that are found in personal care products and preferentially partition to the atmosphere.

John Cassano

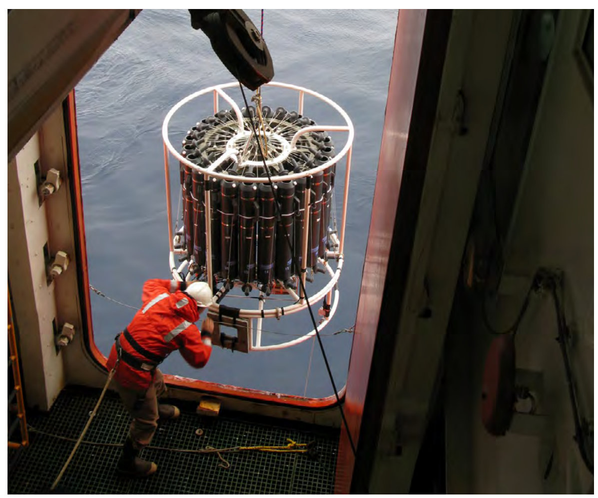
Associate Professor of Atmospheric and Oceanic Sciences

My research group studies the weather and climate of the polar regions to better understand the processes that link the atmosphere to the underlying ocean, sea ice, ice sheet, and land surfaces. We use in-situ autonomous observations, from automatic weather stations and unmanned aerial vehicles, satellite and reanalysis data, and numerical weather prediction and climate models in our research. We are synthesizing our understanding of polar climate processes through the development of a Regional Arctic System Model, which provides a framework for exploring linkages between the components of the polar climate system.

Xinzhao Chu

Professor of Aerospace Engineering Sciences

My research goal is to explore unknowns in the atmosphere, space, and beyond. My group works to explore advanced spectroscopy principles and develop new lidar technologies to push detection limits and make new discoveries. By making measurements with unprecedented accuracy, resolution, and coverage, we study the fundamental physical and chemical processes that govern the structures and dynamics of the whole atmosphere, and advance the understanding of the universal processes in the Earth's space-atmosphere interaction region and how they shape the atmospheres of Earth-like planets. In our quest to develop whole-atmosphere lidar and to explore the unmapped, we also aim to realize the full potential of lidar, making practical use of it to serve the world.



Launching instruments from the *Laurence M Gould* in an unusually calm Drake Passage. Photo: Michael Rhodes/ CIRES and NOAA

Shelley Copley

Professor of Molecular, Cellular and Developmental Biology

My lab studies evolution of bacteria in novel environments, and in particular the evolutionary potential lurking in the proteome due to inefficient side activities of enzymes that normally serve other functions. Current work focuses on determining how such "promiscuous" activities have been patched together into a pathway for degradation of pentachlorophenol, a toxic anthropogenic pollutant, and how the bacterium manages to survive the toxicity caused by pentachlorophenol and its degradation products. Other projects address how bacteria can adapt to deletion of an essential gene and the process by which new enzymes arise from promiscuous enzymes by a process of gene duplication and divergence.

Joost de Gouw

CIRES Senior Research Scientist, Adjoint Professor of Chemistry and Biochemistry

I am a senior research scientist with the Cooperative Institute for Research in Environmental Sciences. My main interests are the sources and chemical transformations of organic compounds in the atmosphere, the formation of ozone and secondary organic aerosol, and the impact that these processes have on air quality, climate change, and human health. To study these issues, I use measurements of organic compounds by mass spectrometry and gas chromatography. I am also interested in the environmental effects of energy production and use at present and in the future.

Lisa Dilling

Director, Western Water Assessment,
Associate Professor of Environmental Studies

I am an Associate Professor in the Environmental Studies program. My research focuses on understanding how society chooses to respond to environmental risks such as climate change. I use interdisciplinary, empirical methods to study questions such as how different views about the nature of risk affect the outcomes of decision processes. I am also interested in the tradeoffs involved in implementing new policies at the local scale and understanding how science can best support robust decision making in deeply uncertain contexts. My work has recently focused on drought and urban water management, climate change and public lands, geoengineering, and municipal policies regarding natural hazards.

David Fahey

Director, NOAA Chemical Sciences Division

As Director of the Chemical Sciences Division of NOAA's Earth System Research Laboratory, I look to advance scientific understanding of three major environmental and societal issues of our time; namely, climate change, air quality and the stratospheric ozone layer, through research on the chemical and physical processes that affect Earth's atmospheric composition. My personal research interests are focused on measurements of trace gases and aerosols in the troposphere and lower stratosphere and the interpretation of these measurements to advance process understanding and support decision making regarding emissions standards and regulations.

Chris Fairall

Team Lead, Boundary Layer Observations and Process, NOAA Physical Sciences Division

I am a physicist at NOAA's Earth System Research Laboratory in Boulder, Colorado, where I head the Boundary-Layer Observations and Processes team. I have spent decades developing and deploying air-sea interaction observing systems for NOAA ships and aircraft and have participated in nearly 50 research field programs and cruises from the Tropics to the Arctic Icecap. My work is devoted to making direct measurements for verifying and improving the representation of air-sea interaction processes (surface evaporation, absorption of heat, generation of waves, uptake of carbon dioxide) in climate models used for climate change projections.

G. Lang Farmer

Professor of Geological Sciences

My research centers on applications of trace element abundances and radiogenic isotopic data from natural materials to study the origin and evolution of Earth's lithosphere. Currently, my research group has used hafnium and neodymium isotope data from silicic sediments to investigate the paleogeography of ancient continets, used sediment isotopic data to study past instabilities in the East Antarctic Ice Sheet, investigated the origin of Mo-bearing granitic rocks in North America, and used space-time-compositions patterns in volcanic activity in western North America to assess the evolution the deep continental lithosphere beneath this region over the past 70 million years.

Fred Fehsenfeld

CIRES Senior Research Scientist, NOAA Chemical Sciences Division

I am a Senior Research Scientist with the Cooperative Institute in the Environmental Sciences of the University of Colorado. I am also a Fellow and Associate Director for the Environmental Chemistry Division of CIRES. Prior to leaving Federal Service, I was a Senior Scientist at ESRL of the Department of Commerce (DOC) National Oceanic and Atmospheric Administration (NOAA). My major area of interest is atmospheric chemistry, with emphasis on determination of the sources and processes that shape the ozone and aerosol distributions on regional to global scales and the implication for regional air quality and global climate understanding.

Graham Feingold

Research Scientist, NOAA Chemical Sciences Division

I am a research scientist at NOAA's Chemical Sciences Division, in Boulder, Colorado. My interests lie in aerosol-cloud-precipitation interactions and implications for climate change. My group's focus is on process-level studies using high resolution models and observations (aircraft and surface remote sensing) at the cloud scale (10s of meters to 100 km). We primarily study shallow clouds and how they are modified by particulate matter (aerosol) and how they might change in a warmer climate (the cloud feedback problem).

Noah Fierer
Associate Professor of Ecology and Evolutionary Biology

My group works at the interface of the fields of ecology and microbiology. We study those microscopic organisms, namely bacteria and fungi, that are abundant and ubiquitous in nearly every environment on Earth where they are critical to the functioning of ecosystems. Previous work has focused on those microorganisms living inside our homes, in soil, on the human body, and in the atmosphere. We explore the diversity of microbial communities, identify the fundamental controls on microbial processes, and examine the mechanisms by which microorganisms influence human health and the health of ecosystems.

The winter sun disappears behind the Flatirons in Boulder. Photo: Hannah Holland-Moritz/CIRES

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

My group studies space weather, specifically, the dynamics, energetics, chemistry, and electrodynamics of the thermosphere and ionosphere. When the Sun is active, the impact of solar variability, such as flares or coronal mass ejections, dominates space weather. Recently we have become increasingly aware of the impact of lower-atmospheric processes on space weather: A whole spectrum of waves is continually bombarding the upper atmosphere, and they originate from tropospheric convection, absorption of radiation by ozone and water vapor, sudden stratospheric warmings, jet stream adjustment, and ocean waves. To quantify the impact of this lower-atmosphere spectrum of waves, we have been working with our NOAA partners to build a whole atmosphere model (WAM). WAM can now simulate a large part of this neutral atmosphere wave spectrum.

R. Michael Hardesty
CIRES Senior Research Scientist

My research interests center around development, evaluation, and application of optical remote sensing techniques to investigate atmospheric processes. We use different lidar techniques to study a broad range of phenomena, including boundary layer dynamics, space-based measurement of winds, air pollution, and greenhouse gas emissions. Results of this research improve understanding and modeling of weather and climate processes, sources of particulate and gaseous air pollution, and renewable energy production.

José-Luis Jiménez
Professor of Chemistry and Biochemistry

My group studies aerosols, which are small particles suspended in air, with lifetimes of 1-2 weeks in the atmosphere. They have major effects on climate, human health, visibility, crops, and ecosystems. A large portion is composed of organic compounds. Important sources of these organic aerosols (OA) include anthropogenic pollution (cars, trucks), biogenic compounds (plants, soils), and biomass burning (agricultural, wild fires). Gas-phase chemistry followed by gas-to-particle conversion produces secondary OA (SOA) and inorganic species. The amount, properties, and evolution of aerosols from these sources are poorly characterized, and our group combines field, laboratory, and modeling research to better understand them.

Craig H. Jones
Professor of Geological Sciences

My research focus is on the deformation of continents with a special interest in the western United States. The West is one of the broadest elevated areas on Earth. If you took intro geology, you might think this was because everything in the West was shortened (and so the crust thickened) from about 200 to 50 million years ago, and then this was modified as the thick crust thinned out under its own weight in places like the Basin and Range. Were this the case, there would be little to do. But it is more complex. I've spent much of my career trying to understand the Sierra Nevada, and I've written a book, *The Mountains that Remade America* to be published by UC Press fall of 2017.

Kris Karnauskas

Assistant Professor of Atmospheric and Oceanic Sciences

My lab explores the dynamics of the coupled Earth system toward useful predictions of impacts ranging from marine ecosystems to human health. Specifically, we aim to understand the circuitry of the tropical ocean and atmosphere, its interaction with ecosystems and with higher latitude regions, how and why the climate system has changed in the past, and how climate will continue to change in the future–both naturally and as driven by human activities. Through teaching, I aim to equip students with the tools to investigate, communicate, and act intelligently on matters of global change.

Jennifer Kay

Assistant Professor of Atmospheric and Oceanic Sciences

I am an assistant professor in the Department of Atmospheric and Oceanic Sciences and a Fellow of CIRES at the University of Colorado at Boulder. I remain a visiting scientist at the National Center for Atmospheric Research, where I worked prior to joining CU Boulder. My research group investigates polar climate change, feedbacks, and variability, with a specific focus on connecting global coupled climate modeling with observed cloud, precipitation, and sea ice processes. I work at the nexus of observations and modeling to understand the processes controlling climate change and variability.

Wiliam M. Lewis Jr.

CIRES Associate Director, Professor of Ecology and Evolutionary Biology

My research at the CIRES Center for Limnology focuses on three themes: biogeochemistry, food web structure, and biological productivity of inland waters. I work with students and other collaborators to conduct biogeochemical studies in aquatic environments by use of quantitative measures of conversion rates for multiple forms of nitrogen, phosphorus, and carbon that reveal the rates of metabolic processes in aquatic ecosystems. Related food web studies include quantification of interactions across trophic levels within the food web, often by use of naturally occurring isotopes of nitrogen and carbon. Analyses of this type have been applied by myself and collaborators to Colorado lakes and streams as well as tropical waters of South America. Food webs are often manipulated by humans through by harvesting, stocking, pollution, or physical interventions in aquatic ecosystems. Thus, understanding of food web functions offers the possibility for reconstruction of altered food webs. Studies of biomass production parallel studies of food webs, but focus on overall energy flow across the main levels of the food web rather than the many specific pathways of nourishment as reflected by the food web. Biotic productivity varies greatly in natural environments, but also reflects human influences such as the release of nutrients to aquatic environments or suppression of productivity by physical or chemical alteration of aquatic ecosystems. Through the related fields of biogeochemistry, food web analysis, and quantification of biological production, studies of inland waters within CIRES demonstrate functions of both natural and impaired aquatic ecosystems.

Ben Livneh

Assistant Professor of Civil, Environmental, and Architectural Engineering

My research group explores the impacts of changing land-cover and climate on water resources. Specifically, we seek to quantify how the mean-state and variability of the hydrologic system are changing, to identify key processes and explore predictability. A component particular sensitive to change in the western U.S. is snowpack, serving as a natural reservoir to store winter precipitation and release it during the warm-season when it is needed most. Active areas of research include sediment transport, land-cover disturbance, hydrologic connectivity, forecasting, and estimating components of the surface water balance from space.

Peter Molnar

Professor of Geological Sciences

I teach a little and carry out research in the Department of Geological Sciences at the University of Colorado. I was trained as a seismologist, but most of my current work addresses either geodynamics or climate. I study how mountain ranges are built and how the dynamics of flow within the mantle affects the earth's surface. I also study how manifestations of geodynamic processes, like high mountain ranges and plateaus or ocean gateways, have affected climate on geologic time scales.

Stephen A. Montzka

NOAA Research Chemist

My research focuses on measuring and understanding changes in the chemical composition of the global atmosphere, particularly related to ozone-depleting substances, greenhouse gases, and hazardous air pollutants; identifying the role of natural and human-related influences on hemispheric to global-scale atmospheric composition; diagnosing variability in the atmosphere's oxidizing capacity, in terrestrial photosynthesis, and in stratosphere-troposhere exchange; quantifying fluxes of trace gases from the United States; and effectively communicating scientific results via national and international assessment reports.

William Neff

CIRES Senior Research Scientist

My research focuses on the stable atmospheric boundary layer (ABL) where the Earth's atmosphere interacts with its surface. The stable ABL occurs when the atmosphere is coldest near the surface. Improving our understanding of the stable ABL in high latitudes and its response to changing atmospheric dynamics and surface characteristics is important as the science community seeks to better forecast variability and changes in high-latitude climate.

R. Steven Nerem

Professor of Aerospace Engineering Sciences

My research involves using satellite-based geodetic techniques to monitor changes in the Earth's shape and gravity field. The former deals mainly with global and regional changes in sea level and vertical crustal motion. The latter deals with changes in the distribution of water and ice on the Earth's surface. My research group tries to decipher what is causing changes in these variables, including the impact of climate change. I am also interested in astrodynamics and work on developing satellite missions to measure these phenomena. I've been closely involved in the TOPEX, Jason-1, 2, 3, GRACE, and GRACE follow-on missions.

Judith Perlwitz

CIRES Senior Research Scientist, Team Lead, Attribution and Predictability Assessments, NOAA Physical Sciences Division

I am a research scientist at NOAA's Physical Sciences Division (PSD) in Boulder, Colorado. I am a member of PSD's Attribution and Predictability Assessments Team that seeks to understand the physical factors that cause observed regional and seasonal climate trends, and high-impact weather and climate events. We place a special emphasis on understanding the large-scale drivers that influence local and regional extreme events such as floods, droughts, and heat waves.

Balaji Rajagopalan

Professor of Civil, Environmental, and Architectural Engineering

My main research program is a diverse and interdisciplinary effort to enable sustainable water quantity and quality for the growing populations under increasing climate variability and change. This entails three interconnected themes: (1) Understanding the large-scale climate drivers of year-to-year and multidecadal variability and predictability of regional hydroclimatology and their extremes, (2) Developing ensemble hydroclimate projection tools with large-scale climate information and, (3) Coupling the projections with resources management and decision support system. In addition, I have keen interests in paleo and contemporary variability of Indian monsoon, big-data analysis and modeling techniques, water and wastewater quality, construction safety and building energy efficiency.

Contemplating impermanence beside a frost-shattered peak in the high Andes. Photo: Erika Schreiber

Prashant Sardeshmukh

CIRES Senior Research Scientist

I am a climate dynamicist with broad interests in the diagnosis, modeling, and predictability of large-scale weather and climate variations around the globe on time scales of days to centuries. Our team is engaged in documenting and understanding the regional aspects of ongoing climate changes, especially changes in extreme weather statistics, and determining to what extent they are anthropogenic or consistent with natural climate variability. We are also interested in documenting and understanding the actual as well as potential skill of weather and climate predictions, which are inherently limited due to the chaotic nature of the system, and how the current prediction systems need to be improved to achieve the potential skill.

Mark Serreze

Director, National Snow and Ice Data Center, Professor of Geography

I am an Arctic climate scientist and Director of the CIRES National Snow and Ice Data Center. Over the past two decades, my research has focused on making sense of the profound changes unfolding in the North—shrinking sea ice, rapidly rising temperatures—thawing permafrost—and what they mean not just for the Arctic's future but for the rest of the planet. I am also very active in science outreach and education. Today, more than ever, it is important that scientists reach out and make science more accessible and relevant to society.

Anne F. Sheehan

Professor of Geological Sciences

My research involves the use of geophysical methods, primarily seismology, but also including geodesy and electromagnetic methods, to understand mountain belts, subduction zones, and earthquakes. I am interested in the properties of the Earth's crust and mantle, the nature of lithospheric deformation, and the causes and consequences of induced seismicity. My group's field based projects include broadband and short period seismometer deployments, ocean bottom seismic and seafloor pressure gauge measurements, magnetotellurics, and geodesy.

A greenland glacier meets the Irminger Sea with a melange buffer. Photo: Alice DuVivier/CIRES

Robert E. Sievers

Professor of Chemistry and Biochemistry

I study analytical chemistry, pharmaceutical science, aerosols, microparticles and nanoparticles, inhalable vaccines and antibiotics, and supercritical fluids.

For more than 40 years my research group has conducted fundamental and applied studies of the formation of nanoparticle and microparticle aerosols and innovative methods for synthesis, purification, characterization of useful materials. Carbon dioxide-assisted nebulization provides superior aerosols. I am collaborating with medical professionals and engineers to develop new methods for delivery of aerosol particles useful in direct and painless administration of therapeutic drugs and vaccines against measles, influenza, infections, stress, COPD, and asthma. Two of the fourteen "Grand Challenges" identified by the Bill and Melinda Gates Foundation and the NIH Foundation as critical to world health have been addressed by my group.

In technology transfer, Sievers Instruments, Inc. and successor companies, Ionics-Sievers and GE Analytical, have manufactured 30,000 detectors and analyzers for 10,000 users for applications in trace analysis for environmental, water treatment, energy, pharmaceutical, and other applications from 1984 until the present.

Kristy Tiampo

Director, CIRES Earth Science and Observation Center, Professor of Geological Sciences

My research focuses on understanding the processes that govern natural and anthropogenic hazards. These studies incorporate large quantities of remote sensing data such as space-based differential interferometric synthetic aperture radar (DInSAR), GPS data, seismicity and gravity, in order provide insights into the nature and scale of these hazards. Specific projects focus on improvements in the quality of those data, development of innovative analysis techniques and assimilation into geophysical models of the underlying processes. As part of that effort we investigate the implications and consequences of hazards such as earthquakes, volcanoes, landslides, groundwater extraction, and induced seismicity on infrastructure and society.

Margaret Tolbert

Distinguished Professor of Chemistry and Biochemistry

I am a professor in Chemistry at the University of Colorado in Boulder. My research group focuses on clouds and aerosols in atmospheric chemistry. Research topics include stratospheric ozone depletion, cirrus cloud chemistry, tropospheric clouds and particles, the interaction between clouds and climate, and the chemistry of planetary atmospheres including Titan and Mars. Our work is laboratory-based; we use simulation chambers to identify key atmospheric aerosol processes important in different environments. Novel laboratory techniques include aerosol optical levitation, aerosol mass spectrometry, and aerosol optical techniques such as photo acoustic and Raman spectroscopies.

Early season snow in White River National Forest above Vail. Photo: Gijs de Boer/CIRES

Greg Tucker

Professor of Geological Sciences

My interests lie in geomorphology and landscape evolution. My group seeks to understand the physics of diverse geomorphic processes, and how these processes interact to shape terrain and move sediment. Some of our efforts are geared toward understanding the evolution of the Earth's surface over geologic time; others focus on contemporary issues such as gully development and erosional threats to toxic waste repositories. We also develop and share open-source software technology to support computational modeling of diverse earth-surface processes. Through teaching, I strive to equip students with the skills in writing and quantitative analysis that they need to understand, investigate, and make informed decisions about our fascinating and dynamic planet.

Veronica Vaida

Professor of Chemistry and Biochemistry

Our group is interested in building chemical complexity with sunlight: pectroscopic studies of atmospheric molecules, radicals and their complexes. My research interest focuses on issues of photoreactivity in planetary atmospheres, including the contemporary and ancient Earth. The approach employed to obtain the structure and dynamics of molecules, radicals, and their complexes involves a combination of spectroscopic, photofragment and theoretical techniques. Aqueous environments, especially water-air interfaces as available at the sea surface and on atmospheric aerosols are special reaction environments investigated by surface reflection spectroscopy.

Rainer Volkamer

Associate Professor of Chemistry and Biochemistry

I am an Associate Professor at the University of Colorado Chemistry Department in Boulder, Colorado. My teaching in Instrumental Analysis with Environmental Emphasis (undergraduate level), and Analytical Spectroscopy (graduate level) is often enhanced by my research in Atmospheric Chemistry to inform chemistry-climate interactions, energy and the environment. My research group develops instrumentation (in-situ optical spectroscopy and sub-orbital remote sensing) to solve analytical and physical chemistry problems in the real-world, to better quantify sources (air-sea exchange, urban, agriculture, biomass burning, etc), characterize aerosols (optical closure), and to probe mechanisms by which gases modify aerosols, oxidative capacity, atmospheric mercury, tropospheric O_3, and CH_4.

Carol A. Wessman

Professor of Ecology and Ecology and Evolutionary Biology, Director

My lab group seeks to gain insights on the dynamics between landscape structure and ecosystem functioning, with a strong focus on understanding ecosystem resilience and response to multiple disturbances. Our approach involves the use of field studies, remote sensing methodologies investigating temporal and spatial heterogeneity in ecosystem properties, and landscape and ecosystem theory. Current Research projects include: Subalpine forest response to multiple disturbances; Integration of field, UAV and satellite datasets for scaling canopy structure and species composition; Vegetation state transitions and forest recovery from large disturbances in the Southern Rockies; and Social-ecological systems in urban environments.

Michael Willis

Assistant Professor of Geological Sciences

My research revolves around questions about the changing cryosphere and time-varying topography with a particular interest in the contribution of glaciers and ice sheets to sea level rise. I also have a developing research track deciphering the processes involved with cascading hazards such as tsunamis, landslides, and coastal inundation. My lab combines fieldwork with geodetic and remote sensing tools and high performance computing resources to examine changing topography at a variety of scales. These changes are driven by a variety of mechanisms such as melting or accelerating glacier ice, eroding permafrost, and seismic events—processes that have a direct impact on society.

Paul Ziemann

Professor of Chemistry and Biochemistry

The primary focus of our group's research is to elucidate mechanisms by which volatile organic compounds emitted from biogenic and anthropogenic sources react in the atmosphere to form products that can create submicron-size organic aerosol particles. These reactions are complex and include photochemistry, gas-phase oxidation, and heterogeneous/multiphase reactions. The resulting particles affect global climate, visibility, and human health. We conduct experiments in large-volume environmental chambers under simulated atmospheric conditions and then identify and quantify organic gas and aerosol reaction products using a variety of analytical instruments and methods. This information is used to develop detailed, quantitative chemical reaction mechanisms for predicting organic aerosol formation, which can be used to improve air quality and global climate models.

At left: Adélie and gentoo penguins take refuge on an ice berg, near Anvers Island, Antarctic Peninsula. Photo: Glenn Grant/CIRES

Center for Limnology

The Center for Limnology conducts field and laboratory research of aquatic systems across Colorado. The following describes some research conducted in the last year.

Colorado Loses a Gold Medal

The famed coldwater trout fishery of montane Colorado is managed and protected by the Colorado Department of Parks and Wildlife (CPW) in cooperation with federal agencies. Some streams and rivers are designated as Gold Medal Fisheries; these waters have per acre of water surface at least 60 pounds of trout and at least 12 trout greater than 14 inches long.

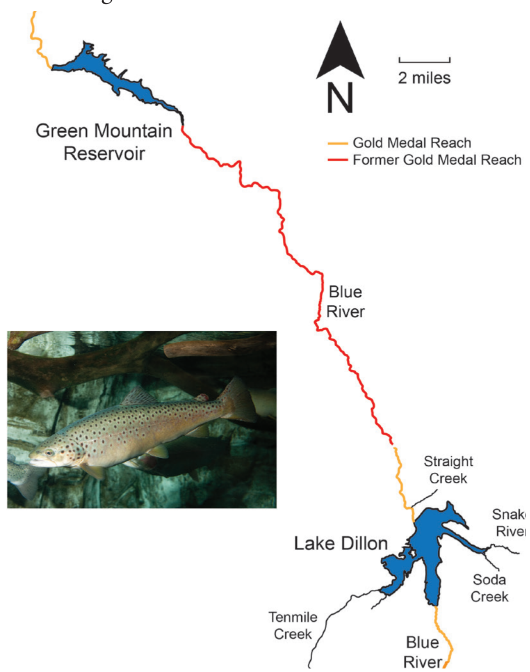


Figure 1: The Blue River, including Gold Medal status for trout. Insert: Brown Trout. Image: Jennifer Roberson and James McCutchan/CIRES

Figure 2: Opossum shrimp (*Mysis*, size ~1 cm) are valuable food for trout in Lake Dillon. Photo: Per Harald Olsen/Wiki Commons

Colorado's Blue River rises near the Continental Divide and descends through Summit County to Lake Dillon and Green Mountain Reservoir (Figure 1), beyond which it joins the Colorado River. The Blue River between the two reservoirs and below Green Mountain Reservoir in the past has had Gold Medal status. CPW determined in 2016, however, that the Gold Medal designation must be removed from most of the Blue River between the two reservoirs (Figure 1), where the fish population no longer meets the Gold Medal criteria.

Two clues about the cause for loss of Gold Medal status below Lake Dillon come from CPW fish biologists, who have shown that trout between the two reservoirs have poor body condition and fail to grow to lengths greater than about 12 inches. Lake Dillon has been considered an important food supply for the Blue River below the dam because of the lake's population of *Mysis* (freshwater shrimp, Figure 2), which reach the Blue River through outflow of the Lake Dillon dam. Studies by the CIRES Center for Limnology, supported by Summit County governments, show that the export of *Mysis* does occur but is too small to support growth of trout below Lake Dillon. In addition, the Center's studies show that invertebrates living on the river bottom do not include many of the invertebrate taxa that are favored for food by trout (Figure 2). Therefore, the fish below Lake Dillon are not well nourished.

Inadequacy of invertebrate food for fish could be based on inadequacy of food for invertebrates, but the Center for Limnology has shown that amounts of chlorophyll (an index of algal abundance) on rocks within the stream are sufficient to sustain substantial populations of invertebrates. Several other factors are being investigated by the Center for Limnology and others. For example, algae that are

Invertebrates living on the river bottom do not include many of the invertebrate taxa that are favored for food by trout. Therefore, the fish below Lake Dillon are not well nourished.

available for food could consist of species that are not palatable to the invertebrates that are preferred by the fish (Figure 2). Another possibility is that the river water between the lakes is too cold, which results in low growth rate.

Persistence of Gold Metal classification for the Blue River downstream of Green Mountain Reservoir (Figure 1) may ultimately show by example what is wrong for trout in the Blue River between Lake Dillon and Green Mountain Reservoir. For example, temperatures for these two reaches of the Blue River differ only by a few degrees, which might seem insignificant, but in fact the difference causes shortening of the growing season for trout in the Blue River between the two reservoirs as compared with trout in the Blue River below Green Mountain Reservoir, which shows greater warmth because of its lower elevation.

A Blue River Working Group formed by CPW seeks explanations for loss of the Gold Medal status for the Blue River between the two reservoirs. The CIRES Center for Limnology, in collaboration with government scientists, is attempting to provide new information that will demonstrate the cause for impairment of fish populations below Lake Dillon, and will attempt to prescribe a cure that will restore Gold Medal status to the Blue River below Lake Dillon.

Figure 3: Stonefly larva, a macroinvertebrate found on the bottom substrate of the Blue River. Photo: James McCutchan/CIRES

Center for Science and Technology Policy Research

The Center for Science and Technology Policy Research (CSTPR) was initiated within the Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder in the summer of 2001 and was recognized as an official University center in the summer of 2002 as a contribution both to the CIRES goal of "promoting science in service to society" and to the University's vision of establishing research and outreach across traditional academic boundaries. The vision of CSTPR is to serve as a resource for science and technology decisions and those providing the education of future decision makers. Its mission is to improve how science and technology policies address societal needs through research, education, and service. CSTPR common themes are below.

Max Boykoff presenting at the 2016 United Nations Climate Change Conference in Marrakech, Morocco. Photo: Christine Pereira

CSTPR European Commission visitor Augusto Gonzalez. Photo: Ami Nacu-Schmidt/CIRES

- Science and Technology Policy: We analyze decisions at the science-policy interface, including making public and private investments in science and technology, governing the usability of scientific information, and critically engaging the scientific and technical construction of emerging issues.
- Innovations in Governance and Sustainability: We study innovations in governance and the complexity of sustainability challenges, including the development of (1) new institutions that transcend conventional political boundaries or bring actors together in new ways, (2) new tools and experimental interventions for inducing behavioral change or enabling participation in decision making, and (3) new forms of association in the creation and protection of collective goods.
- Drivers of Risk Management Decisions: We interrogate how individuals and institutions—at local, regional, national, and international scales—make decisions to respond and adapt to perceived risks, and what factors promote or inhibit effective decision making.
- Communication and Societal Change: We experiment and conduct critical analysis as we study communication strategies and engagement in varying cultural, political, and societal contexts.

Highlights

- CIRES Fellow Max Boykoff presented on three different panels during the United Nations Conference of Parties meeting (e.g. the U.N. climate talks) in Marrakech in November 2016.
- CIRES Fellow Lisa Dilling was awarded a Leverhulme Visiting Professorship, hosted by Oxford University, United Kingdom, where she spent her sabbatical during

The vision of CSTPR is to serve as a resource for science and technology decisions and those providing the education of future decision makers.

the 2016-17 academic year. She is collaborating with Professor Steve Rayner of Oxford to explore how cultural theory informs our understanding of the use of knowledge in adaptation decision making at the local level.

- CIRES Fellow Lisa Dilling was awarded a Grand Challenge Seed Grant for a project titled "Bringing Innovative Data Science Down to Earth."
- Several CSTPR graduate students received degrees in Environmental Studies: Meaghan Daly (Ph.D.); Elizabeth Koebele (Ph.D.); Lydia Lawhon (Ph.D.); Alexander Lee (Ph.D.); Lucy McAllister (Ph.D.); Rebecca Schild (Ph.D.); Michael Weiss (M.S.).
- CSTPR hosted several visitors including: Professor Justin Farrell (Yale); CIRES Visiting Fellows Sabbatical Program; Professor Jack Stilgoe (University College London); and Julia Schubert (Fulbright Doctoral Program). In addition, Augusto Gonzalez visited under the E.U. Fellowships Programme. He authored a CSTPR white paper on space commercialization and led an 8-session seminar on the European Union.
- CSTPR core faculty published in *Risk, Hazards & Crisis in Public Policy*; *Regional Environmental Change; Environmental Management*; *Environmental Communication*; *Water Resources Research*; *Energy for Sustainable Development*; *Journal of Moral Philosophy*; *Midwest Studies in Philosophy*; and *Taiwan Human Rights Journal*, among others.
- CSTPR faculty delivered public lectures on various science, technology, and policy research topics including "The Emergence of Policy Coalitions in the Aftermath of Extreme Events: Colorado's Flood Recovery in Comparative Context" (Deserai Crow) and "The Principle of Justice: From Economic to Environmental Justice" (Steve Vanderheiden).
- CSTPR created the Radford Byerly, Jr., Award in Science and Technology Policy in recognition of Byerly's contributions to and impact on the CSTPR community.

Lisa Dilling at workshop in Dar Es Salaam, Tanzania on knowledge co-production for adaptation in arid regions. Photo: Lisa Dilling/CIRES

Lauren Gifford, a Ph.D. candidate in Geography, won the first Byerly award in 2017.

- CSTPR organized the fourth competition to select two CU Boulder students to attend the American Association for the Advancement of Science "Catalyzing Advocacy in Science and Engineering" workshop in Washington, D.C. The 2017 winners were Adalyn Fyhrie (Astrophysical and Planetary Science) and Caroline Havrilla (Ecology and Evolutionary Biology). They met with members of Congress and their staff after the two-day workshop. The competition is supported by CSTPR, the CU Boulder Graduate School and Center for STEM (Science, Technology, Engineering, and Mathematics) Learning.
- The Red Cross/Red Crescent Climate Centre Internship Program placed Sierra Gladfelter in Zambia in the summer of 2016.

Earth Science and Observation Center

CIRES' Earth Science and Observation Center (ESOC) provides a focus for the development and application of novel remote-sensing techniques for all aspects of Earth sciences at CU Boulder. Our aim is to study natural and anthropogenic processes at all scales, from technique development in small test sites to understanding problems and patterns on regional and global scales. The long-term goal of ESOC research is to advance our understanding of the Earth system and its interactions with human society and activities through remote sensing observations.

Advancing Earth Science from Space

Every 10 years, NASA, NOAA, and the USGS, through the National Academy of Sciences, request a community-based prioritization of space-based Earth observations in which to invest. ESOC scientists play critical roles in this National Academies Study, with roles that range from the submission of proposals in response to requests for information to the leadership of the study, which is co-chaired by Waleed Abdalati, CIRES Director and an ESOC scientist.

In addition, ESOC scientists are representatives on technical subject committees and science teams, bringing remote sensing and scientific expertise to their respective fields. A partial listing of the technical subject committees and science that ESOC scientists presently serve upon include: NASA Soil-Moisture Active-Passive Mission, NASA Surface Water and Ocean Topography Mission, National Advisory Council on Water Information—Subcommittee on Sedimentation, the CloudSat and CALIPSO Science teams, the Western North America InSAR executive committee and the Alaskan Satellite Facility User Working Group.

Cryospheric Research

During 2016, our cryospheric research continued to focus on understanding changing processes in the Arctic. This research is broad and includes the following:

Glaciers and ice sheets

During 2016, we continued focusing on changes happening on the Greenland ice sheet in a warming climate. The research included monitoring and expanding the world's largest array of firn compaction measurements across the Greenland ice sheet, which support and validate current and future satellite altimetry products from NASA and the European Space Agency. Abdalati and his students have described a new feedback by which meltwater in Greenland has changed the porosity of the ice sheet, enhancing more runoff in future summers. We have characterized the nature and extent of crevasses around Greenland using satellite lidar data, and used optical satellite imagery to identify the sea-surface signatures of meltwater plumes around Greenland's fjords, important for understanding basal melt of outlet glaciers. ESOC's support also was instrumental in reporting and predicting the location and future melt of abandoned Cold War era military facilities currently buried under the surface of Greenland.

Michael Willis was involved in a major publication on the mass balance of the Greenland Ice Sheet, which pointed out that the glacial isostatic adjustment (GIA) models used for the region were flawed.

Land surface phenology in Greenland and links to cryospheric change

Recent greening of vegetation across the Arctic is associated with warming temperatures, hydrologic change and shorter snow-covered periods. We investigate trends for a subset of arctic vegetation on the island of Greenland, which is unique due to its close proximity to the Greenland Ice Sheet and the proportionally large connection to the Greenlandic population through the hunting of grazing animals. Localized, ground-based studies have suggested some vegetation is drying out, and we sought to determine how pervasive this phenomenon might be. Using a 15-year remotely sensed time-series Thompson analyzed the signal

Lena Delta, northern Siberia, ~ 73°10′52″N, 125°E. Image: ArcticDEM.org

Our aim is to study natural and anthropogenic processes at all scales, from technique development in small test sites to understanding problems and patterns on regional and global scales.

from Greenland vegetation to determine whether or not vegetation exhibited signs that were consistent with the drying hypothesis. While the productivity of most vegetated areas increased in response to longer growing periods throughout the study period, there were regions where vegetation productivity appeared to decrease in response to longer growing periods, suggesting a drying trend.

Arctic DEM

September marked the first public release of the Arctic DEM (ArcticDEM.org) a public/private attempt to re-map the entire Arctic region at a resolution of 2 meters. This is an ongoing effort sponsored by NSF, the Bluewaters Petascale computing facility, and the National Geospatial Intelligence Agency, with the release of Siberia occurring most recently. A mosaic of hundreds of elevation models is shown in this figure of the Lena Delta in far northern Siberia. All resulting data from the project are being made publicly available. In the spring of 2017 this work resulted in the first known observation of climate-driven river piracy due to the retreat of the Kaskawalsh Glacier in the Yukon.

Assessing the influence of Arctic cloud feedbacks on Arctic sea ice loss

Together with a CIRES Visiting Fellow from the Laboratoire de Météorologie Dynamique Professor Helene Chepfer, and sponsored by a NASA award, Jennifer Kay's group is using spaceborne lidar to measure the observed cloud response to Arctic sea ice loss (Morrison et al. submitted). The results isolate the cloud response to observed sea ice loss for the first time, and suggest that the impact of cloud feedbacks on observed Arctic sea ice loss has been modest.

Advising Investments in the Climate Model Enterprise

By some global measures, advances in the skill of climate model predictions and projections have been surprisingly hard to achieve. The climate sensitivity metric is the projected global average surface warming, at equilibrium, in response to a doubling of CO_2 concentration in the Earth atmosphere. Despite substantial gains in the fidelity of Earth System Model representations and simulations of climate-relevant processes, the uncertainty in climate sensitivity has remained between 1.5 °C and 4.5 °C for more than 30 years. The implications and magnitudes of societal impacts (e.g., sea level rise, drought, fire, etc.) can vary by wide margins over this span of uncertainty. Reducing uncertainty to refine estimates of societal impacts world-wide has been an important goal of the Climate Modeling Enterprise (CME); led by contributors to the Intergovernmental Panel on Climate Change, and tested in successive versions of Climate Model Intercomparison Projects (CMIPs). The "run-analyze-improve" cycle that characterizes the scientific and technical workflows, leading to advances in ESMs and improvements in CMIPs, takes about six years.

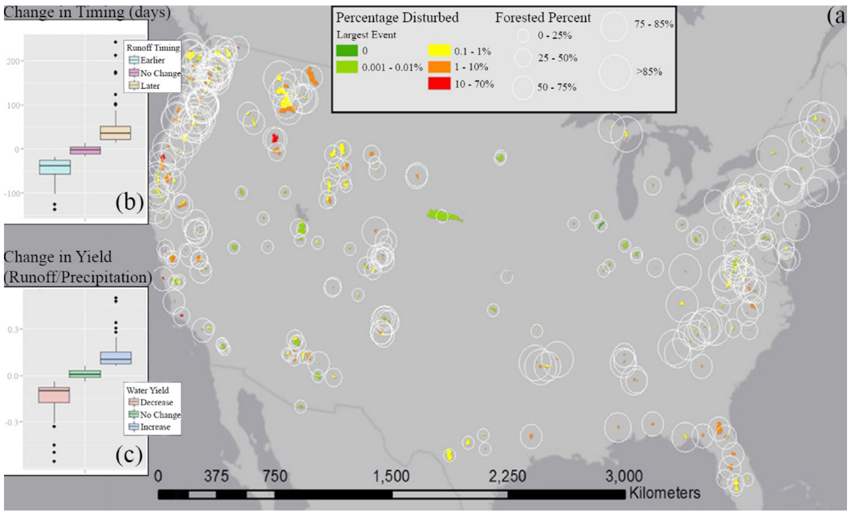
A major, anonymous philanthropist is interested in learning of prospects for "disruptive improvements" in the CME. The potential donor seeks to reduce the "run-analyze-improve" cycle time and foster innovations that will reduce uncertainty in climate sensitivity. Moreover, this philanthropist seeks a menu of options ranging from large grants for a few key investigators to the establishment of a standalone institute, with potential contributions in technical as well as scientific projects that would be beyond the scopes of existing climate science and climate modeling institutions. Ralph Milliff, a CIRES Senior Research Associate, is part of a small team advising the philanthropist organization and formulating investment options. Several community meetings and wide-ranging position papers have been prepared to document and guide this process over the past eight months. Decisions may begin unfolding in the second half of 2017.

Lidar Remote Sensing and Laser Spectroscopy

Remote sensing technology development—combined with atmospheric and space science observations, data analysis, and theoretical modeling—allows us to better understand the structure and dynamics of the whole atmosphere. Xinzhao Chu's research group completed an 11th trip to Antarctica in early February, and the excitement of working on the McMurdo lidar campaign is still as vivid as it was in its early years. The infrastructure at McMurdo enables first-rate science to be conducted at the bottom of the world, including our work in lidar technology development and atmospheric/space science study for probing space and atmosphere. Recent discoveries from these lidar observations in Antarctica are challenging the understanding of electrodynamics, chemistry, composition, and energetics in Earth's geospace environment. Recent results, with Michael Jones, include lidar observations of stratospheric gravity waves and ionospheric effects of magneto-acoustic-gravity waves.

Hydrological Research

Remotely-sensed hydrological research is a primary focus for the NASA Surface Water and Ocean Topography (SWOT) Mission, NASA's first ever hydrologically-dedicated satellite mission. In addition to ocean research, the NASA SWOT Mission will study global inland surface water, including lake and wetland elevations, extents and volumes, as well as large river water discharge. In most of the world outside of the United States, inland surface water is one of the least known global processes. For example, of the approximately 41,000 large rivers over 100 meters in width, only about 2,400 have river discharge gages. In advance of the satellite launch that is expected in 2021, annual research using an airborne platform has focused on developing the algorithms in support of the SWOT satellite. In 2017, ESOC scientist, J. Toby Minear, as part of the SWOT project, is participating in the NASA Arctic and Boreal Vulnerability Experiment (ABOVE) project, one of the largest NASA field campaigns ever. Numerous overflights of ten different aircraft flying various radar, lidar, optical and EM instruments are occurring at sites stretching from the Midwest, through Canada and into



Hydrologic Response: (a) Percent of forest cover in a large-sample of national watersheds and their degree of disturbance, (b) watershed grouping based in the change in the centroid of runoff timing following disturbance, either early, no-change-, or later runoff timing, and (c) change in total annual streamflow (or water yield) following disturbance, where watersheds either saw decreased, no-change, or increased water yield. Image: ESOC/CIRES

northern Alaska. The NASA Arctic and Boreal Vulnerability Experiment project field campaign occurs between May and September, with more than a dozen SWOT sites being flown. By having different instruments overflying the same sites, much has been learned already about the phenomenology of these different remote sensing techniques, and has led to improvements in algorithms for NASA missions as well as improvements in hydrological research.

Most people assume that greater forest disturbance will result in more water flowing out of watersheds. Not necessarily so, is the finding from recent research between the Livneh laboratory and collaboration with the University of Alaska, Southeast. By combining 30-m global forest disturbance datasets with long-term, ongoing USGS streamflow observations, ESOC scientists were able to accurately monitor when and where disturbance occurs, and tie that disturbance to disruptions in the water outputs of critical watersheds across the nation. Using a large-sample of watersheds with high quality data from southern Florida to northwest Washington, ESOC scientists found that after a forest disturbance event, streamflow can increase or decrease depending on critical landscape factors, as described below.

Highly disturbed, arid watersheds with low soil-to-water contact time ratios are the most likely to see increases in water yield following disturbance, with response magnitude positively correlated with the extent of disturbance. Watersheds dominated by deciduous forest with low bulk density soils generally showed reduced yield post-disturbance. Post-disturbance streamflow timing change was associated with climate, forest type, and soil. Snowy coniferous watersheds were generally insensitive to disturbance, whereas watersheds with finely textured soils and flashy runoff were more sensitive. This was the first national scale investigation of streamflow post-disturbance using fused gage and remotely sensed data at high resolution, yielding important insights to anticipate changes in streamflow that may result from future disturbances.

Hazards Studies

This research seeks to provide a comprehensive understanding of the processes that govern natural and anthropogenic hazards. Studies focuses on the integration of large quantities of remote sensing data—such as space-based Global Positioning System (GPS) data, differential interferometric synthetic aperture radar, seismicity and gravity—to provide critical information on the nature and scale of these hazards. ESOC researchers are investigating the implications and consequences of hazards such as groundwater extraction, volcanic unrest, and induced seismicity on infrastructure and society. For example, as part of an ongoing induced seismicity project in Kristy Tiampo's group, we identified the first hydraulic fracturing- or frack- induced earthquakes in North America. Induced seismicity is largely caused by the disposal of wastewater produced during oil and gas operations. Up until this work, the direct triggering of events by fracking itself was considered rare or even nonexistent. This result provides new insights into the mechanisms surrounding induced seismicity.

ESOC scientist, Minear, along with collaborators across CU Boulder including the departments of Computer Vision and Geological Sciences, have started on a project to modify 3D computer vision hardware and algorithms to measure remotely sensed velocities of Earth science hazards. Fast-moving mass flow processes in the Earth sciences, such as debris flows, snow avalanches, rock falls, floods, and steep streams, are some of the most difficult and often dangerous measurements to collect, and are nearly impossible to measure with traditional direct-contact sampling methods. The goal of this study is to develop an inexpensive hardware and software system that can be used to measure velocities of these difficult Earth science hazards. The initial application utilizes a stereo-camera robotic vision system to estimate surface velocities in a steep stream. A prototype version of the hardware, running the modified software, has been able to measure surface velocities in the stream. A more sophisticated version is now in development.

Finally, Livneh, Minear, Tiampo and Willis successfully obtained NASA funding for a study of cascading fluvial and landslide hazards in the western United States.

National Snow and Ice Data Center

The mission of the National Snow and Ice Data Center (NSIDC) is to improve our understanding of Earth's cryosphere, including sea ice, lake ice, glaciers, ice sheets, snow cover, and frozen ground. NSIDC manages, distributes, and stewards cryospheric and related data from Earth-orbiting satellites, aircraft, and surface observations, from NASA, NOAA, and the National Science Foundation. NSIDC also facilitates the collection, preservation, exchange, and use of local Arctic knowledge and observations, and conducts research into the changing cryosphere. Selected highlights from June 1, 2016, to May 31, 2017, follow.

Passive Microwave Satellite Transition

The NASA NSIDC Distributed Active Archive Center (DAAC) distributes passive microwave data from the U.S. Department of Defense Defense Meteorological Satellite Program Special Sensor Microwave Imager/Sounder series of satellites. These data are the basis of several NSIDC data sets and many cryospheric research applications, notably to monitor and study ice sheet surface conditions and Arctic and Antarctic sea ice. In 2016, the sensor in this series that NSIDC was using, F16, began to experience intermittent failures and data drop outs, necessitating a transition to the next satellite/sensor, F18. NSIDC had anticipated the eventual transition and was already ingesting F18 data, and was able to utilize F18 data immediately on a provisional basis. The transition and intercalibration of data (to ensure a long time series) was accomplished in less than two months.

Sea Ice Index Version 2

The NOAA@NSIDC program released Version 2 of the Sea Ice Index (http://nsidc.org/data/seaice_index), a highly-used data set offering sea ice extent values, sea ice imagery, and more in ready-to-use formats. Changes include streamlining the processing by rewriting old code to Python, using

NASA Operation IceBridge captured this photograph of Greenland's South Glacier, which drains the Geikie Plateau and flows into Scoresby Sound to the north. Note Geikie's characteristic knife-edge ridges and prominent horizontal rock layering, especially in the foreground. The NSIDC DAAC archives and distributes scientific data collected by Operation IceBridge. Photo: John Sonntag/NASA

the most recently available version of the NASA Goddard Space Flight Center input sea ice concentration data, adjusting three procedures in the Sea Ice Index processing routine, and giving an updated look to images and graphs for ease in reading the images. The new version improved data quality for the entire time series, from 1978 to present.

Mapping Land Ice Velocities Across the Globe

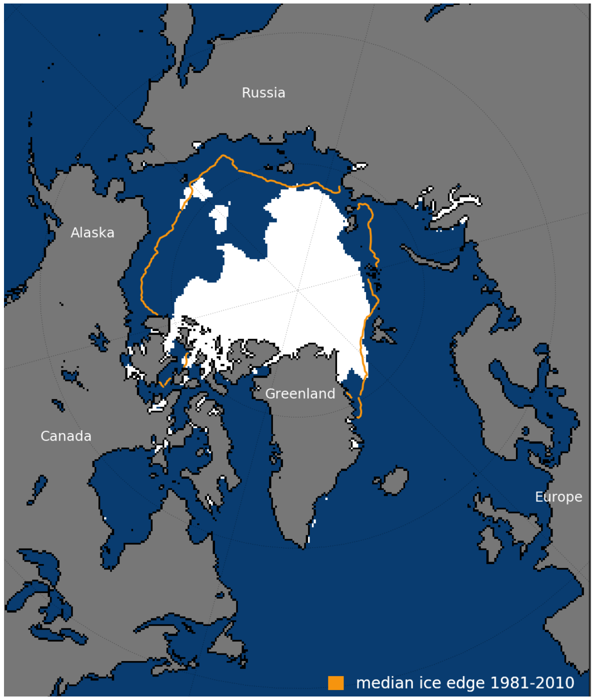
NSIDC released a new data set, "Global Land Ice Velocity Extraction from Landsat 8." GoLIVE is a NASA-funded effort that serves as a processing and staging system for near-real-time global ice velocity data derived from Landsat 8 panchromatic imagery. The GoLIVE product website (http://nsidc.org/data/golive) provides links to the dataset documentation and data access through the new GoLIVE Map Application. The map application allows users to spatially search for and download land ice velocities from May 2013 to present.

The Northern Bering Sea: Our Way of Life

The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) project at NSIDC released a website focused on the cultural and ecological significance of the northern Bering Sea. The Northern Bering Sea: Our Way of Life (https://eloka-arctic.org/communities/elders) highlights large hunting and fishing areas, overlaid with the distribution of key species. It illustrates that the whole northern Bering Sea is a storehouse that supports the way of life for indigenous peoples of the region. The Northern Bering Sea: Our Way of Life is a project of the Bering Sea Elders Group, with support from the Alaska Marine Conservation Council.

A New Tool to Map Potential Avalanches

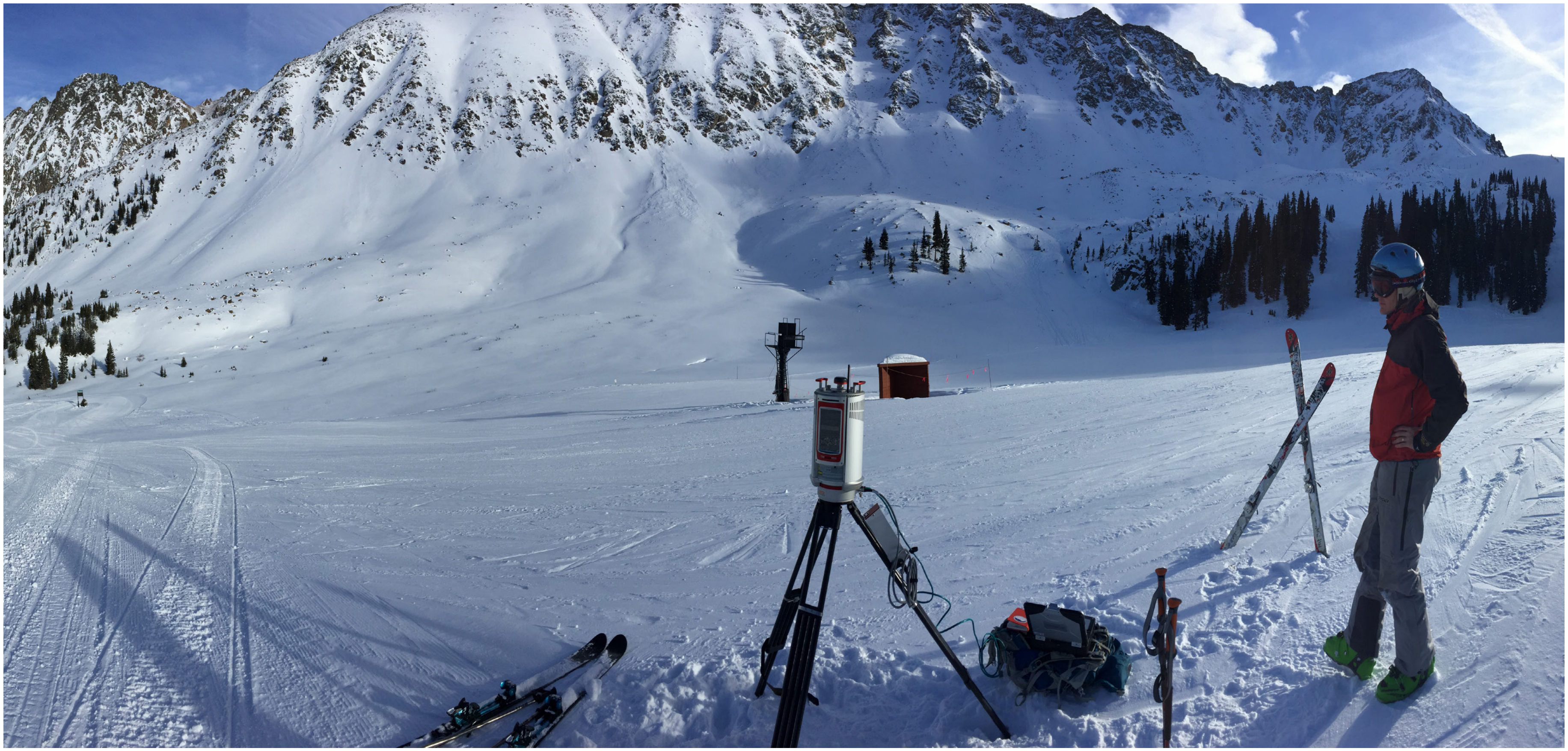
NSIDC researcher Jeffrey Deems and his colleagues have developed a new application for laser-scanning (lidar) systems that map snow depth at very high resolution, and tested it at Colorado's Arapahoe Basin Ski Area, in collaboration with Colorado Department of Transportation (CDOT) avalanche control snow safety teams. The researchers have been using the laser scanner system to craft detailed maps of the slopes in summer, without snow, and then comparing them to snow-covered slopes months later. This new tool safely maps snow depth in steep terrain, making avalanche control safer and more efficient.



Arctic sea ice extent in September 10, 2016 was 4.14 million square kilometers, the minimum extent for the year and the second lowest year in the satellite record from 1979 to 2016. More: http://nsidc.org/data/seaice_index.

At the edge of the shorefast ice, Barrow, Alaska. Photo: Matthew Druckenmiller/CIRES/NSIDC

NSIDC manages, distributes, and stewards cryospheric and related data from Earth-orbiting satellites, aircraft and surface observations.



A researcher prepares to use a laser scanning (lidar) unit to scan snow depth at the Arapahoe Ski Basin Ski area in Keystone, Colorado. Photo: Jeff Deems, NSIDC/CIRES

Arctic Sea Ice Ends the Summer Low

At the end of the 2016 melt season, Arctic sea ice extent stood at second lowest in daily average and fifth lowest in monthly average over the satellite record from 1979 to present, according to analysis by NSIDC scientists. Sea ice extent retreated to its lowest point, 4.14 million square km on Sept. 10, 2016, then grew rapidly. At the end of the month, sea ice extent averaged 4.72 million square km. This year's minimum extent statistically tied with the 2007 minimum, when Arctic sea ice extent was measured at 4.15 million square km on Sept. 18. The record low Arctic sea ice minimum occurred in 2012. The analysis was posted on NSIDC's Arctic Sea Ice News and Analysis web site (http://nsidc.org/arcticseaicenews).

Western Water Assessment

Western Water Assessment (WWA) is one of 10 NOAA-funded Regional Integrated Sciences and Assessments (RISA) programs across the country, covering Colorado, Utah and Wyoming. The WWA team conducts innovative research in partnership with decision makers in the Rocky Mountain West, helping them make the best use of science to manage for climate impacts. By keeping the needs of decision-makers front and center in designing and conducting research, WWA generates usable and actionable research results and information products.

R2X in the RISA Network

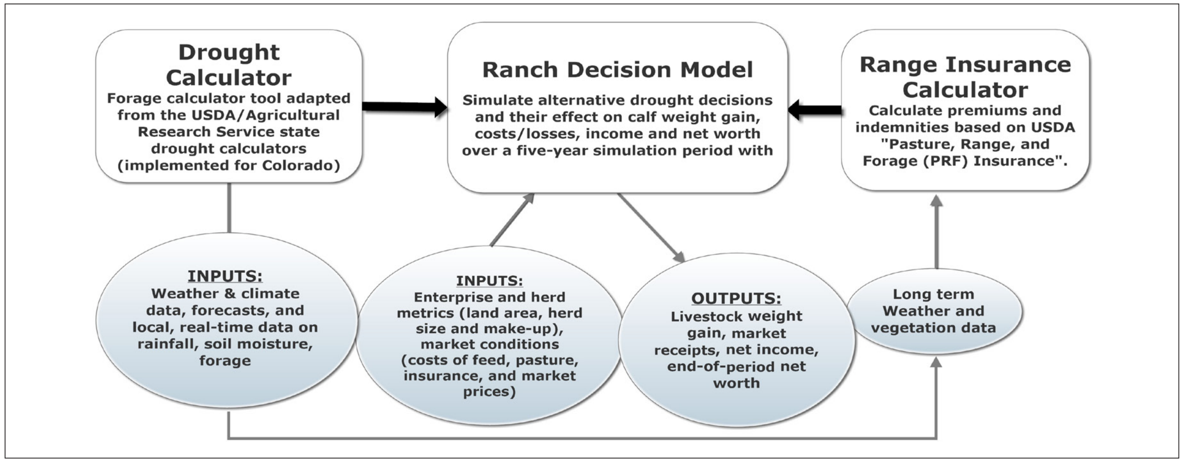
The transition of research to operations (R2O), applications (R2A) or commercialization (R2C), known collectively as R2X, is a key goal across NOAA. In 2017, WWA surveyed the RISA network to learn more about the factors that help or hinder the process of R2X within both the research and recipient organizations. According to the survey, most RISA programs explicitly encourage research transitions and dedicate resources in support of those transitions. The most successful R2X transitions were for planning, improve warnings (tornado, drought, fire, flood), forecast or tool development, improved drought/flood monitoring, data input for models, improving decision making, informing water and resource managers, and informing the broader operational system. Projects tended to be successful when there was buy-in from the recipient organization, a need was filled, there was engagement with users or it significantly advanced understanding. R2X transitions tend to be unsuccessful when there is a lack of manpower and monetary resources, a lack of planning, and a lack of social capital with the recipient organization.

Future Outdoor Water Use in the Jordan Valley, UT

The Jordan Valley Water Conservancy District (JVWCD) in Utah is working with WWA on future outdoor water use in a changing climate. WWA provided projections of potential evapotranspiration (PET), and past trends in PET and its components to help JVWCD understand how water demand may change in the future. Using downscaled climate data, past trends in PET and projections of future outdoor watering season length, a model of observed PET and outdoor water use was developed. This model was then used to predict future outdoor water use based on projections of future potential evapotranspiration.

Drought, Ranching and Insurance Response

Partnering with the USDA Northern Plains Climate Hub, WWA is working with ranchers and range extension professionals to develop drought decisions support tools. WWA researchers combine a drought decision model for ranching with drought impact calculators developed by the USDA Agricultural Research Service. By conducting simulations of decision making, we test the sensitivity of a particular decision to droughts of varying duration and intensity or repeat drought events. The model is also used to test the effect of USDA's Pasture, Forage and Range Insurance Program, an important drought management tool for ranchers, and will eventually help ranchers decide whether they should purchase the insurance by calculating the likely pay-off of the insurance program. This project aims to help ranchers make herd management decisions in extreme drought, given uncertainties about the market, feed prices, and next year's climate. Pasture, rangeland, and forage land occupy roughly 55 percent of the land in the United States—the largest extent of managed land in the country. With nearly 43 million acres insured and nearly $71 million in indemnities paid out in 2016, the USDA Pasture, Rangeland, and Forage Insurance Program is the nation's third largest agricultural insurance program. Insurance claims are linked to NOAA's gridded precipitation data so any changes in precipitation/drought trends will have a significant impact on the financial viability of the insurance program and on the livelihoods of ranchers across the United States.



Drought, Ranching, and Insurance Response Model structure. Image: WWA

In northern Nevada, cattle feed was hard to come by during 2014, when already dry rangeland dried further. Photo: Frederic J. Brown/AFP/Getty Images

CIRES Education and Outreach

The CIRES Education and Outreach group works across the spectrum of geosciences education, including teacher professional development, digital learning resources, student programs, workforce projects, program evaluation and more. This year the CIRES EO group continued to reach community college students, and to help students communicate about environmental change, supported the implementation of science standards in climate and energy science, helped graduate students to include community engagement within their research work and more.

Some example projects are described below.

Teacher Education

The CLEAN collection (cleanet.org) is a peer-reviewed digital repository of climate and energy learning resources and is syndicated through NOAA's Climate.gov. This year, the collection of 650 resources was recognized as part of the Friends of the Planet award by the National Center for Science Education. The project developed new processes and exemplars for using CLEAN resources within new next generation curricular units.

CIRES EO developed new next generation curricula in partnership with the Denver Public Schools, Denver charter schools, and researchers focused on curriculum co-development and resiliency education. New materials focus on understanding local and global climate change and on addressing food waste in schools, a contributor to climate-sensitive emissions.

The Climate Academy, a virtual resource to help educators understand important climate science concepts, was developed as a legacy product from previous courses and workshops.

Pre-college Students and Public

Pre-college students make videos about local climate impacts through the Lens on Climate Change project, with the support of science researchers, graduate students and film students. Diverse student groups have formed within Colorado school districts, within the Trinidad State Junior College's Math and

Top: Poudre High School students excited to compete at the 2017 Trout Bowl regional NOSB competition. They placed second overall. Photo: David Oonk/CIRES. Bottom: CIRES Director Waleed Abdalati poses with the 2017 RECCS group. Photo: Lesley Smith/CIRES

CIRES Education and Outreach supported the implementation of science standards in climate and energy science.

Science Upward Bound program and in partnership with the I Have a Dream Foundation. The program has demonstrated positive impacts on participants' knowledge and attitudes about climate change, as compared to a control group.

GLOBAL, an NSF CAREER grant awarded to Dr. Jen Kaye, includes an education research component designed to test the hypothesis that approaching climate science learning through engagement with material about polar bears will lead to more student engagement and learning. Student engagement is measured by multiple methods, including direct measurement of skin conductance using physical sensors.

The Backcountry Limnology project engages outdoor enthusiasts and Colorado students in a citizen science project to help characterize changes to alpine lakes within climate models. Participants work with scientists to understand the larger context, are trained in collection of water temperature and turbidity data, and upload data to a website for use by climate modelers.

CIRES EO completed the 18th year of hosting a regional competition, the Trout Bowl, as part of the National Ocean Sciences Bowl in February 2017. In April 2018, CIRES EO will host the first NOSB national competition without a nearby coastline. During the national competition 125 top students from around the country will compete for the top title.

Undergraduate & Graduate Education

The Research Experiences for Community College Students (RECCS) project supports community college students to conduct research at CIRES, NOAA and in partnership with the Boulder Critical Zone Observatory. To date, all RECCS students have completed the program and 64% have transferred to or have graduated from a 4-year STEM program. RECCS students are diverse along many dimensions, including first-generation college attendees, people of color, and veterans.

CIRES provides program and project evaluation services to a wide variety of STEM education partners. Of note this year is evaluation for two undergraduate focused projects. UTMOST, a mathematics education project, assesses the utility of online interactive textbooks for teaching foundational quantitative skills in undergraduate courses. CIRES EO also provides external evaluation services for a summer research experience for undergraduates in solar and space science, and provides internal evaluation support for CIRES EO projects.

Early career geoscientists express a desire to engage with communities as part of their research agenda. CIRES EO partnered with the American Geophysical Union and with experts across campus to offer a series of workshops and talks focused on skills needed to work with communities, including developing a feasible community research project, engaging in community dialogue and exhibiting cultural sensitivity and respect when working with communities.

2017 Trout Bowl winners, Liberty Common High School. Photo: David Oonk/CIRES

International Global Atmospheric Chemistry

The atmosphere is the integrator of the Earth system. Human emissions of pollutants and long-lived greenhouse gases into the atmosphere have caused dramatic transformations of the planet, altering air quality, climate and nutrient flows in every ecosystem. Understanding the global atmosphere requires an international network of scientists providing intellectual leadership in areas of atmospheric chemistry that need to be addressed, promoted and would benefit from research across disciplines and geographical boundaries. Acknowledgement of this need led to the formation of the International Global Atmospheric Chemistry (IGAC) Project in 1990. IGAC is sponsored by the international Commission on Atmospheric Chemistry and Global Pollution and a global project of Future Earth.

CIRES is reporting on IGAC's accomplishments for three reasons: The IGAC International Project office is hosted by CIRES; IGAC Executive Officer Megan L. Melamed is a CIRES Research Scientist III; and funding for IGAC — which comes from NSF, NASA and NOAA—comes in through CIRES' Cooperative Agreement with NOAA.

IGAC's mission is to facilitate atmospheric chemistry research towards a sustainable world. This is achieved through IGAC's three focal activities: fostering community, building capacity, and providing leadership.

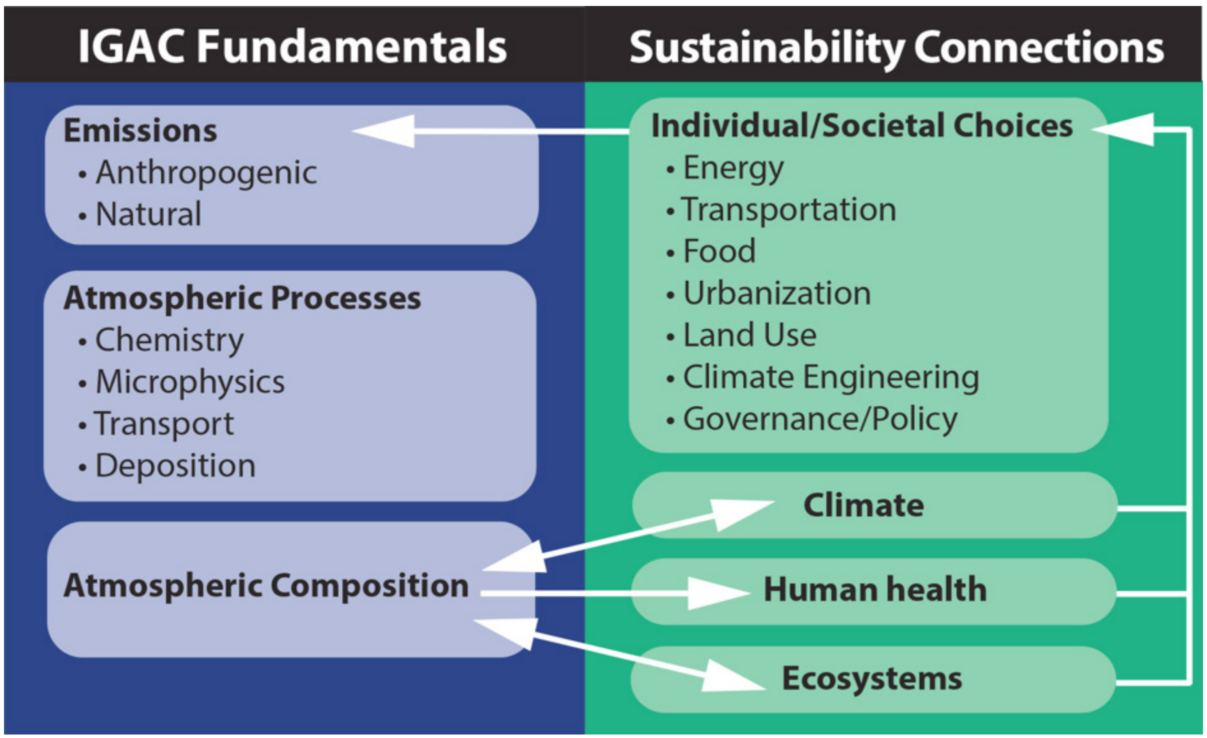


Figure 1. IGAC Vision Diagram.

Fostering Community

IGAC is an open international community of scientists researching topics related to atmospheric chemistry (air quality, climate change, carbon and nitrogen cycles, impacts on human health and ecosystems, etc.) that is actively collaborating across geographical boundaries and disciplines in order to contribute to addressing the most pressing global change and sustainability issues through scientific research. The IGAC biennial science conference and the facilitation of numerous thematic workshop every year provides opportunities to build cooperation and disseminate scientific information across IGAC international community.

Building Capacity

IGAC builds scientific capacity through its early career program and national and regional working groups. The IGAC early career program allows scientists to join an international network early in their career, which puts the cogs in motion to facilitate atmospheric chemistry research at an international level for years to come. The IGAC national and regional working groups create a strong cohesive community of atmospheric scientists in emerging countries/regions that together have a sum greater than their parts and connects these scientists to the larger IGAC community to foster international collaboration.

Providing Leadership

IGAC provides intellectual leadership by identifying and fostering activities on current and future areas within atmospheric chemistry that would benefit from research across geographical boundaries and/or disciplines. IGAC's vision is to link fundamental scientific research on emissions, atmospheric processes and atmospheric composition to global change and sustainability issues such as human health, climate, ecosystem and how individual and societal responses feedback onto the core research-led foci of IGAC.

Figure 2. Participants of the 2016 IGAC Early Career Short Course. Photo: IGAC

Accomplishments

From June 2016 to May 2017 the following were achieved by IGAC:

- Sponsored seven scientific activities;
- Endorsed three scientific activities;
- Fostered three national/regional working groups;
- Hosted the 14th IGAC Science Conference 26-30 September 2016 in Breckenridge, Colorado, with 494 participants, representing 36 countries. 40% of the participants were early career scientists and 70 of them received travel support to attend the conference. CIRES was a proud sponsor.
- Hosted the First IGAC Early Career Short Course 23-25 September 2016 in Boulder and Breckenridge, CO. A selected group of 36 participants from 19 countries engaged in this intensive three-day early career short course; and
- Financially sponsored or endorsed 18 workshops across the world on a range of scientific topics related to atmospheric chemistry.

More information can be found at igacproject.org.

Visiting Fellows

With partial sponsorship by NOAA, CIRES offers Visiting s at the University of Colorado Boulder. Every year, CIRES awards several fellowships to visiting scientists at two levels, postdoctoral and senior. These fellowships promote collaborative and cutting-edge research. Since 1967, 345 people have been Visiting Fellows at CIRES, including former CIRES Directors Susan Avery and Konrad Steffen.

Sebastien Chevrot

Sabbatical Fellow
CNRS, Observatoire Midi Pyrenees
Project: Imaging the deep architecture of continental orogens by full waveform inversion of teleseismic body waves - The Bighorn Mountains
Sponsor: Anne Sheehan, Peter Molnar

Sebastien Chevrot is a CNRS senior scientist working at the Observatoire Midi Pyrenees in Toulouse, France. He is visiting CIRES this summer to work with Anne Sheehan, Vera Schulte-Pelkum, and others to study the deep architecture of the Bighorn Mountains and Tibetan Plateau. Detailed images of the deep architecture of continental orogens, in particular of their density structure, is crucial to unravel the relative importance of tectonics and climate change for the long term evolution of mountain ranges. However, the deep roots of continental orogens remain largely elusive, owing to the limited spatial resolution of conventional tomographic imaging techniques. Chevrot will be using his newly developed full waveform inversion methods to revisit the data from the Bighorn and Hi-Climb temporary experiments, to obtain high resolution images of lithospheric structures beneath the Bighorn Mountains and Tibetan Plateau. These images will be a valuable source of information to understand the structure and formation of continental orogens, and the long term support of high reliefs.

Justin Farrell

Sabbatical Fellow
Yale University
Project: Using Computational Social Science to Examine Influences on Climate Policy
Sponsor: Max Boykoff

Justin Farrell is working with Max Boykoff, and others at CIRES, to expand his computational social science approach for understanding how climate change has become such a polarized issue in the United States. Continuing to blend network science with large-scale machine learning text analysis, Farrell will focus on expanding his methodological framework for improving our understanding about how the communication of science is produced and disseminated within connected networks and subnetworks of organizations. CIRES is an ideal institutional home for this sort of interdisciplinary and collaborative research program on cultural and political conflict over climate change. As a native of Cheyenne, Wyoming, Farrell is excited about returning to the region, but is especially excited about the opportunities for exchanging ideas with affiliates who may not work in quantitative social science, but bring a different and unique perspective that will be mutually beneficial.

Jennifer Henderson

Postdoctoral Fellow
Virginia Tech
Project: Identifying the Dynamics of Vulnerability in Community Water Usage along the Front Range
Sponsor: Lisa Dilling

Uwe Karst

Sabbatical Fellow
University of Münster, Germany
Project: Aerosols meet Imaging Mass Spectrometry
Sponsor: Bob Sievers, Jose Luis-Jimenez

Elizabeth Maroon

Postdoctoral Fellow
University of Washington
Project: How does the Atlantic Meridional Overturning Circulation influence the pace of anthropogenic surface warming?
Sponsor: Jen Kay, Kris Karnauskas

Jen Henderson will work with CIRES Fellow Lisa Dilling, Director of the Western Water Assessment, and Rebecca Morss and Olga Wilhemi, of NCAR, to understand the complex nature of water-related vulnerabilities that arise in communities preparing for climate change and climate variability. She will study these dynamics of vulnerability through a qualitative, empirical analysis of current and future water use and management practices for two mid-size cities in Colorado. Henderson hypothesizes that this work will reveal how adaptations made to water use strategies in one place within the system may have unintended, and perhaps unseen, consequences at another point in the system. By looking at different stressors these communities experience, she hopes to make visible groups that have become more vulnerable to water issues and reveal common problems that transcend the situatedness of a particular issue and relevant dissimilarities that result in vulnerabilities of different types and scope. Henderson is looking forward to working with scholars in Boulder and communities across the Front Range to advance an understanding of local climate related impacts and offer decision makers a valuable analysis of emerging vulnerabilities.

Uwe Karst is currently the Chair of Analytical Chemistry in Münster. His research main interests include hyphenated techniques, with particular focus on pharmaceutical analysis, elemental speciation and metallomics. In his project at CIRES, two different combined aspects of aerosols and imaging mass spectrometry will be investigated. One part of the project deals, in cooperation with Jose-Luis Jimenez, with the development of a novel combination of laser ablation (LA) and aerosol mass spectrometer for improved limits of detection in tissue imaging. Samples of rat lungs will be investigated. The interface of the aerosol mass spectrometer and the experimental conditions will be adapted to the flow rate coming from the LA under consideration of the fact that for imaging analysis, transient signals are obtained. In the second part of the project, in cooperation with Bob Sievers, an analytical method that allows monitoring the distribution of low molecular weight pharmaceuticals in tissues after supercritical fluid-assisted drug delivery will be developed. First, dry particles of the pharmaceuticals of interest will be generated using supercritical fluid-assisted nebulization. Antibiotics are a particularly interesting class of compounds and will be the substances of choice. Uwe is excited to return to CIRES after more than 20 years and looks forward to (re)establish interdisciplinary cooperations with colleagues from various research areas.

Elizabeth Maroon will work with Jennifer Kay, Kristopher Karnauskas, and others at CIRES to study how the Atlantic Meridional Overturning Circulation (AMOC) interacts with the atmosphere to set the pace of global warming. Much of the excess heat trapped by greenhouse gases is absorbed by the ocean, which slows the rate of surface warming. As a result, the ocean plays an important role in setting how fast the surface warms. To improve our climate projections, we must have a full understanding of how the atmosphere and ocean interact to influence the rate of ocean heat uptake. The AMOC is a key component of the ocean circulation. While climate models show that the AMOC slows with greenhouse warming, how the AMOC influences ocean heat uptake is not well understood. Elizabeth will study how the AMOC's strength, heat transport, and circulation vary in coupled ocean-atmosphere climate models. Because the AMOC can influence both tropical and extratropical climate through its heat transport, the interaction of regional atmospheric climate feedbacks with the AMOC will also be examined. Elizabeth completed her PhD at the University of Washington and is excited to join the research community at CIRES, especially because it was an undergraduate internship with CIRES scientists that started her career.

Amanda Maycock

Sabbatical Fellow
University of Leeds, UK
Project: Tropical tropopause layer processes and their coupling to climate
Sponsor: Perlwitz, Jen Kay, Fahey (Split cost arrangement with Karen Rosenlof)

Amanda Maycock is working with Karen Rosenlof, David Fahey, Judith Perlwitz, Jennifer Kay, and others at the NOAA to study the representation of the tropical tropopause layer (TTL) in global chemistry-climate models. The TTL is a region of the atmosphere between 14-18 km in the tropics that is distinguished by a combination of chemical, dynamical, physical and radiative characteristics from the troposphere below and the stratosphere above. Most air that is transported from the troposphere to the stratosphere passes through the TTL—the so-called 'gateway' to the stratosphere—and it is thus of central importance in the global chemistry-climate system. However, state-of-the-art global models show little convergence in representing TTL characteristics in the current climate, and exhibit large differences in the predicted response of the TTL to future changes in greenhouse gases. This source of uncertainty limits our ability to make accurate predictions of major environmental changes anticipated this century, such as ozone recovery and climate change. During her visit, Amanda will work with researchers to analyze key processes in current global models that may contribute to this uncertainty, and evaluate them against new observational datasets. The goal is for this to provide valuable new insights for developers and users of chemistry-climate models.

Renee McVay

Postdoctoral Fellow
California Institute of Technology
Project: Aqueous-phase formation of secondary organic aerosol during wildfires: A modeling study
Sponsor: Joost de Gouw

Renee McVay is collaborating with Joost de Gouw and members of the NOAA ESRL Chemical Sciences Division to model secondary organic aerosol (SOA) formation during wildfires with the regional model WRF-Chem. Biomass burning is the largest contributor to organic aerosol emissions globally, which have important climate and health consequences. Aerosols are either emitted directly (primary organic aerosols) or formed via gas-to-particle conversion during aging of smoke plumes (SOA). The potential of wildfires to form SOA is still very uncertain. McVay will be working to update SOA formation in WRF-Chem by including non-traditional pathways to SOA, such as aqueous-phase reactions, that have heretofore been neglected but have the potential to form significant SOA. These updates will be constrained by environmental chamber experiments. Simulations using the updated WRF-Chem will be compared to field measurements of organic aerosols in wildfires as part of the Fire Influence on Regional and Global Environments Experiment (FIREX) campaign. This project will enhance understanding of SOA formation during wildfires and the dependence of this formation on chemical and meteorological conditions. This knowledge will enable better predictions of air quality, weather, and climate effects of wildfires. The updated WRF-Chem model will also be useful to fire managers and first responders for weather forecasting during wildfires.

Ivar van der Velde

Postdoctoral Fellow
Center for Isotope Research, NED
Project: Using atmosphere-biosphere data assimilation to improve terrestrial biosphere models and the N. American carbon balance
Sponsor: Steve Montzka, John Miller, GMD

Dr. Ivar van der Velde is a meteorologist with a keen interest in the land-atmosphere exchange processes of atmospheric trace gases. He is working together with Dr. John Miller and Dr. Stephen Montzka at NOAA ESRL's Global Monitoring Division to study the global terrestrial carbon dioxide sink with a focus on North America. This sink remains uncertain in a warming world where droughts may be more extreme and more frequent. The impact of droughts is likely to be net carbon release, potentially leading to more extreme drought conditions. These feedbacks between the terrestrial carbon cycle and climate are poorly understood and represent a first order uncertainty in climate prediction. It is therefore critical to improve the representation of the terrestrial biosphere in carbon-climate models. The main research goals are to improve our understanding of the large-scale moisture controls on carbon dioxide fluxes. This will be valuable for the plant-physiological research community and will help define where NOAA should measure CO_2 and C^{13} in the United States and around the globe in order to better understand the drivers of carbon exchange variability. In his spare time Ivar can be found exploring Colorado's hiking trails and investigating the quality of Boulder's brewery pubs.

Innovative Research Program

The CIRES-wide competitive Innovative Research Program (IRP) supports novel, unconventional, and/or fundamental research that may quickly provide concept viability or rule out further consideration. The program stimulates a creative research environment within CIRES and encourages synergy among disciplines and research colleagues.

Awards for 2017

Pliocene temperatures from the tropics: the Eastern Cordillera of Colombia Lina Perez-Angel, Peter Molnar

Novel particulate aerosol sampling design capable of withstanding high winds in polar and high mountain regions Mark Serreze, Alia Khan

Toward a more comprehensive picture of snowpack evolution through the integration of time-lapse photography, high-resolution snow modeling, lidar data, and in situ observations Jeffery Deems, Mark Raleigh

Direct spectroscopic detection of tropospheric chlorine radicals Andrew Rollins, Joshua Schwarz

Estimating temporal variations in ocean circulation using magnetic satellite data Manoj Nair, Neesha Schnepf

Combining satellite and acoustic remote sensing data with a numerical model to characterize the vertical structure of marine ecosystems Kristopher Karnauskas, Carrie Wall

Citizen science, showerheads, and the ecology of an emerging disease Noah Fierer, Matt Gerbert

Nowcasting Geoelectric Hazard on United States Power Grid Anne Sheehan, Daniel Feucht

Application of computer vision to Earth Science problems: An initial application using 3D scene reconstruction and image velocimetry to estimate surface water velocities in rivers J. Toby Minear, Christoffer Heckman, Robert Anderson

Photo: Pexels.com

Graduate Student Research Awards

To promote student scholarship and research excellence, CIRES supports a Graduate Student Research Award (GSRA) program with the aim of attracting the best talent to CIRES at the outset of their graduate careers, as well as to enable graduating seniors to complete and publish their research results. Any current or prospective Ph.D. student advised by a CIRES Fellow is eligible for this one-time award opportunity. Incoming graduate students must be accepted into a graduate level program at the University of Colorado Boulder to qualify.

The CIRES GSRA is granted in the form of a Research Assistant position for one or two semesters at 50 percent time. The award includes a monthly salary, fully paid tuition, and a partially paid premium (90 percent) towards the Buff Gold insurance plan. Funding for prospective students may be used in their second year if a Teaching Assistantship covers their first year. Students may receive a 50 percent research award for one or two semesters.

At right are the recipients for this reporting period (June 1, 2016–May 31, 2017).
http://cires.colorado.edu/education/graduate-student-fellowships/

Tobin Hammer
Project: The role of gut bacteria in passion-vine butterfly pollination
Advisor: CIRES Fellow Noah Fierer, Ecology and Evolutionary Biology

Jake Flood
Project: How do microbes tolerate the stresses involved in the degradation of pentachlorophenol (PCP)?
Advisor: CIRES Fellow Shelley Copley, Molecular, Cellular and Developmental Biology

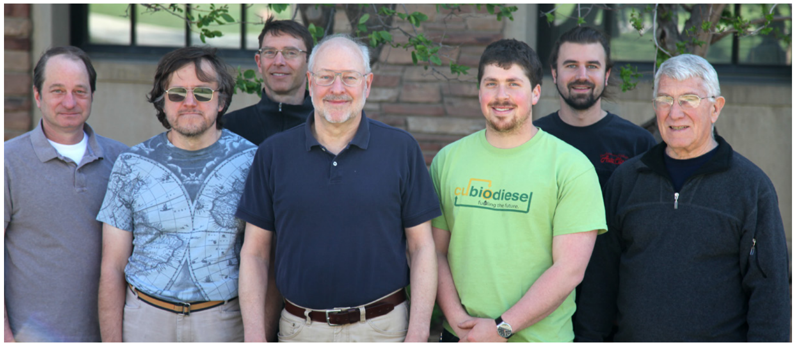
Vineel Yettella
Project: Warming influence on ENSO: new Insights from a novel decomposition method
Advisor: CIRES Fellow Jennifer Kay, Atmospheric and Oceanic Sciences)

Erin McDuffie
Project: The Role of Heterogeneous Chemistry in Understanding Wintertime Air Pollution
Advisor: NOAA scientist Stephen Brown

Erin McDuffie operating research aircraft in data collection test flight. Photo: Erin McDuffie

Aerial view of Salt Lake City—location of Erin McDuffie's work. Photo: Mateoutah/Flickr

Integrated Instrument Development Facility

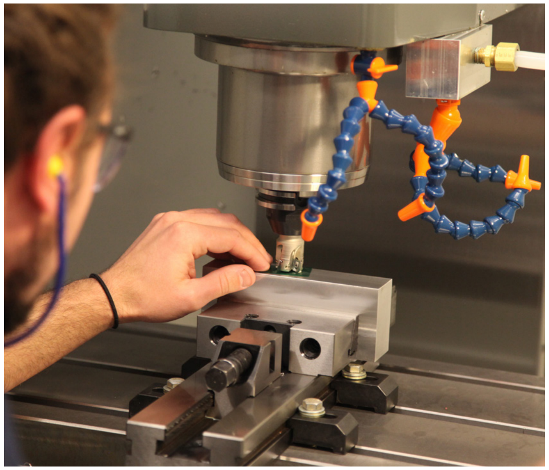


CIRES Integrated Instrument Development Facility's staff. Left to right: Ken Smith, Yehor Novikov, Jim Kastengren, Don David, Kenny Wine, Danny Warren, Wayne Winkler. Photos: Robin L. Strelow/CIRES

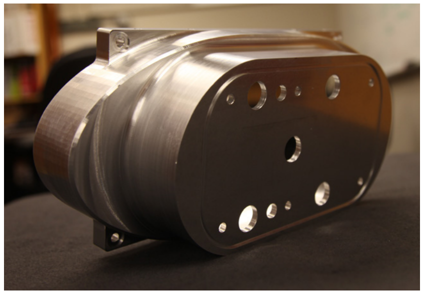
The Integrated Instrument Development Facility (IIDF) is operated in partnership between CIRES and the University of Colorado Boulder Department of Chemistry and Biochemistry. The IIDF is multi-faceted, consisting of design, precision machine, electronics, and scientific glassblowing shops dedicated to the design and fabrication of scientific instrumentation. Staffed by two Ph.D. scientists, three engineers, and a technician, the team has more than 120 years of experience designing and building scientific instruments.

State-of-the-art instruments have been designed and built for CIRES, as well as many departments at the University of Colorado Boulder, other major universities, and research institutions worldwide. A number of these instruments have been commercialized, one of which was patented, and are now in production by private companies.

IIDF capabilities and services include: Microprocessor-based instrumentation; data acquisition software; LabView programming; multi-Layer printed circuit boards; wire electric discharge machining; CNC Lathe and 2,3,4 Axis Mills; CAD design modeling; optical systems; ultrahigh vacuum (UHV) chambers; tungsten inert gas welding and brazing for UHV; precision grinding; electro polishing; electroplating; exotic materials processing; cryogenics; lab equipment and appliances repair; refrigeration servicing glassblowing; vacuum dewar evacuation; metallizing and special coatings; and vacuum leak detection.
http://cires.colorado.edu/iidf

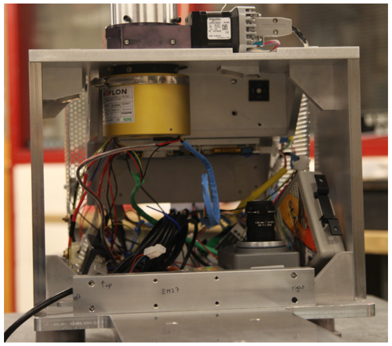


Danny Warren setting up a Computer Numerically Controlled (CNC) milling machine. Photo: Robin Strelow/CIRES



Outer cover of a new instrument to be flown on an aircraft pod for measuring optical properties of all atmospheric aerosols. The cover is machined in one piece from a solid block of aluminum. Photo: Katie Weeman/CIRES

Digital mobile solar tracker developed in the Volkamer group to quantify trace gas emissions from agriculture and area sources such as forest fires—modified for aircraft use. Photo: Katie Weeman/CIRES



The CNC machine milling the above aluminum instrument cover. Photo: Katie Weeman/CIRES

National Park Service

Communications

CIRES is committed to communicating the institute's scientific discoveries to the scientific community, decision-makers, and the public. CIRES communicators collaborate closely with NOAA, CU Boulder, the American Geophysical Union (AGU), our centers, and colleagues in academic and government institutions around the globe. During the 2016 reporting period (June 1, 2015 to May 31, 2016), communications efforts included 56 news releases (highlights follow), media relations, videos, social media, blogs, promotion of CIRES research during meetings, and more. CIRES scientists and research were highlighted frequently in the media, receiving coverage in, for example: *Scientific American*, *Smithsonian Magazine*, the *Washington Post*, *Newsweek*, UPI, *Christian Science Monitor*, *The Economist*, *Popular Science*, CBS News, atlantic.com, newyorker.com and many other local, national, and international media outlets.

News releases

Milky Way Now Hidden from One-Third of Humanity

Mounting Tension in the Himalaya

Greenland and the Legacy of Camp Century

Accounting for Ozone

A New Way to Find and Fix Methane Leaks

Preventing Human-Caused Earthquakes

2016 Ties With 2007 for Lowest Sea Ice Minimum

Wastewater Injection and Induced Seismicity

Planetary Tomography

Study Finds Fossil Fuel Methane Emissions Greater Than Previously Estimated

The "Fingerprint" of Feedlots

Distant Impacts: Smoke, Dust from Pacific Northwest Fires affect Colorado's Air Quality

Sea Ice Hits Record Lows in November

On the Origin of Life in the Galapágos Islands)

When Good Ozone Goes Bad

Preparing for the Worst

NOAA Instruments Aid Forecasters During Epic California Winter

Snowex: Science Supporting Water Management

The Crowd & The Cloud Series Features CIRES Director

As U.S. Drilling Surged, Methane Emissions Didn't

Modern River Piracy

High-Altitude Aircraft Data May Help Improve Air Quality Models, More

Webcasts, photos, social media, and blogs

CIRES communications provides webcasting services for institute seminars, workshops, and meetings; develops short education and newsy videos; and provides compelling photographs that highlight our science and scientists. We also maintain a robust social media presence and support scientists with their blogs.

http://www.facebook.com/CIRESnews
http://www.twitter.com/CIRESnews
https://www.flickr.com/photos/cires-photos
http://ciresblogs.colorado.edu

Blogs

CIRES blogs highlight researchers in the field: attracting attention from readers around the world. Our special shout out goes to the very popular El Niño Rapid Response blog from the profile NOAA mission to the tropical Pacific.

El Nino Rapid Response

FIREX

Posidon

South Pole Ozone

Unmanned Aircraft on Alaska's North Slope, 3

[Air Quality in Salt Lake City: A Twin Otter Aircraft Study]

[Antarctic UAVs]

[Under the Surface of the Greenland Ice Sheet]

[INPOP: Exploring Arctic Clouds Formed by Aerosol Particles]

[Fires, Asian, and Stratospheric Transport—Las Vegas Ozone Study (LVOS)]

[Research Experience for Community College Students in Critical Zone Science]

[It doesn't get any more North than this! Traveling to Alert station in the Canadian Arctic]

Videos

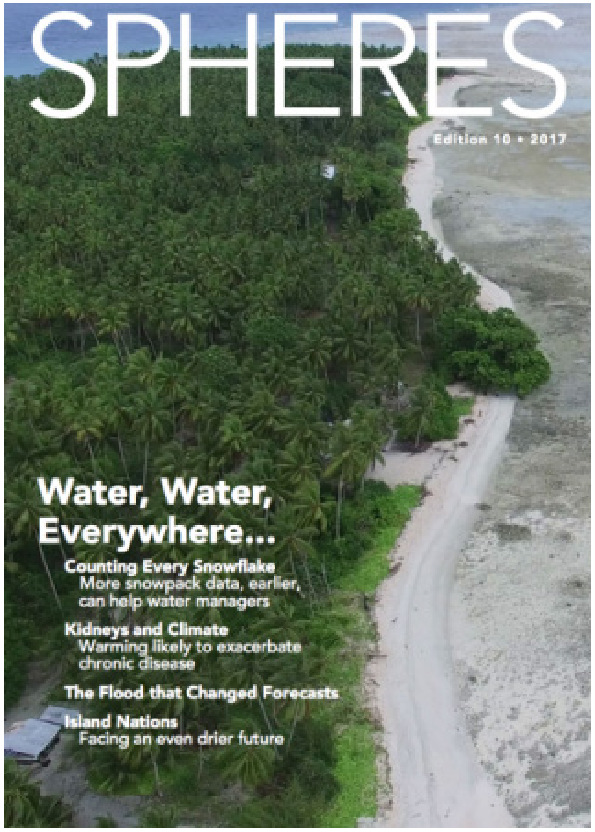
The CIRES Communications team works with colleagues in NOAA and the University of Colorado Boulder to produce short, newsy videos to engage diverse audiences.

http://www.youtube.com/CIRESvideos

Greenland Glaciers

FIREX Fire Lab 2016 intensive setup

Avalanche: snow depth mapping followed by real avalanche



Spheres science magazine

Produced by the CIRES communications group, *Spheres* magazine highlights the diverse research conducted at CIRES. Our scientists study all aspects of the Earth system, including the atmosphere, cryosphere, hydrosphere, geosphere, and biosphere. These spheres of expertise give our magazine its name.

During this reporting period, we produced the tenth edition of *Spheres*, "Water, Water Everywhere…", focusing on CIRES research on our watery world.

http://cires.colorado.edu/spheres

Educating undergraduate students and involving them in hands-on research are both part of CIRES engagement on campus. Our institute also oversees and participates in diversity programs designed to encourage involvement in atmospheric and other Earth sciences. The next three pages describe a few of last year's highlights.

Research Experience for Community College Students (RECCS)

In the summer of 2015, after a year-long pilot program, CIRES and the Institute of Arctic and Alpine Research (INSTAAR) received funding from the National Science Foundation to provide two additional years of the RECCS program, which gives summer research experiences to undergraduates from underserved communities. With this grant, CIRES and INSTAAR offer paid summer research opportunities for 10 Colorado community college students. These research opportunities offer a unique opportunity to conduct research, both field- and laboratory-based; work in a team with scientists; learn basic research, writing, and communication skills; and present research at a science conference.

http://cires.colorado.edu/education/outreach/projects/reccs

RECCS intern Rebecca Holmes helping install seismometers in Greeley, CO. Photo: Justin Ball

RECCS students learn about making field observations and think about possible research questions at CU's Mountain Research Station. Photo: Lesley Smith

RECCS Students

Henry Arndt
Mentor: Kristy Tiampo
Project: The Gold Standard of Hyperspectral Remote Sensing

Lady Grant
Mentor: Tess Brewer and Noah Fierer
Project: Aluminum Phosphate Solubilization of Fungal and Bacterial Communities in Tropical Soils

Rebecca Holmes
Mentor: Kyren Bogolub
Project: Induced Seismicity in Greeley, Colorado: The Effects of Pore Pressure on Seismic Wave Character

Alex McPherson
Mentor: John Ogren
Project: Developing data analysis techniques for observed aerosol optical properties and wind direction at Mauna Loa Observatory

Joseph Miotke
Mentor: Jimmy McCutchan
Project: Quantifying the Role of Phosphorus from the Crater Gulch Watershed in Grand Lake Transparency

Anjelique Morine
Mentor: Rick Saltus and Manoj Nair
Project: Can We Correctly Identify Magnetic Anomalies Through the Crowdmag Application In Order to Better Navigate?

William Radmacher
Mentor: Candida Dewes and Imtiaz Rangwala
Project: The Effect of Climate Variability on Drought in the Great Plains

Sheen Skinner
Mentor: Tasha Snow
Project: Effects of wind speed, atmospheric and sea surface temperature on calving events at Helheim Glacier

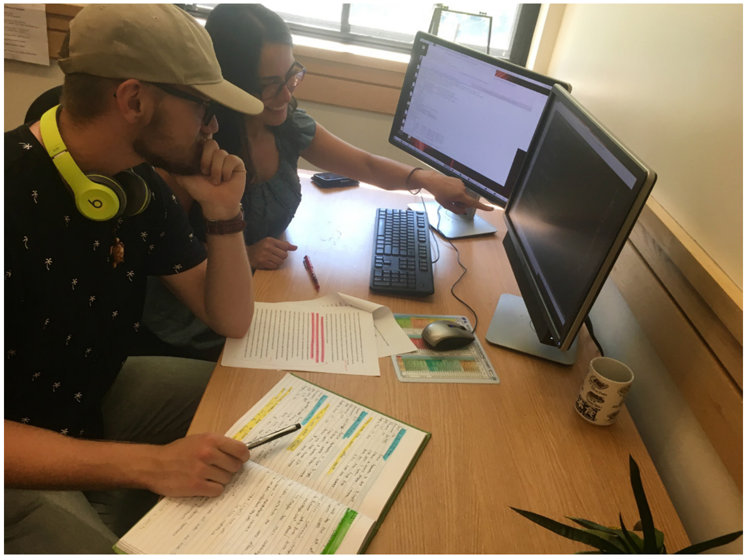
Jason Swain
Mentor: Juliana Dias
Project: Quantifying the Influence of Mountain Elevation on Colorado Weather Forecasting Inaccuracies

Research Experiences in Solid Earth Sciences (RESESS)

RESESS at Unavco in Boulder, Colorado, is a summer research internship program aimed at increasing the diversity of students in the geosciences.
http://resess.unavco.org

RESESS Students

Zachary Little
Project: Automated Diatom Analysis Applied to Traditional Light Microscopy: A Case Study Investigating VisualSpreadsheet®
CIRES Communications Mentor: Magali Barba



RESESS student Zachary Little collaborating with his CIRES communications mentor Magali Barba. Photo: Katie Weeman/CIRES

Anny Sainvil
Project: The Role of Megathrust Earthquakes on Episodic Tremor and Slip Events within the Southern Cascadia Subduction Zone
CIRES Communications Mentor: Neesha Schnepf

Significant Opportunities in Atmospheric Research and Science (SOARS)

SOARS is a learning community and mentoring program for promoting ethnic and gender equity in the atmospheric and related sciences—broadening participation in these fields. The National Center for Atmospheric Research created and administers the highly regarded four-year mentorship and research program for protégés majoring in an atmospheric science or a related field.
http://www.ucar.edu/soars

SOARS Protégés

Marcel Corchado-Albelo
Project: New Coronal Magnetic Field Energy Diagnostic to Enhance Space Weather Predictions
CIRES Research Mentor: Hazel Bain

Keenan Eure
Project: The Influence of ENSO on the North Pacific through Daily Weather Changes
CIRES Research Mentor: Matt Newman

Tony Hurt
Project: Examining the variability of diurnal signals across the equatorial Pacific basin associated with ENSO
CIRES Research Mentor: Juliana Dias
CIRES Writing Mentor: Lesley Smith

Ebone Smith
Project: Observing, Analyzing, and Simulating Variations of Daily Precipitation: The Impact of El Niño/Southern Oscillation on Kiritimati Island
CIRES Research Mentors: Leslie Hartten, Xiao-Wei Quan

Undergraduate Research Opportunities (UROP)

This program funds research partnerships between faculty and undergraduate students at CU Boulder. UROP-supported work is diverse, including traditional scientific experimentation and the creation of new artistic works. The program awards research assistantships, stipends, and/or expense allowances to students who undertake an investigative or creative project with a faculty member.
http://www.colorado.edu/suep/about-urop

UROP students

Michael Kristofich
Project: Identification of beneficial gene deletions in a strain of E. Coli that lacks an essential gene
Mentor: Shelley Copley

Samuel Wasserman
Project: Three Dimensional Digital Mapping of Potential Bridge Sites
Mentor: Michael Willis

Abigayle Clabaugh
Project: Modeling Effects of Climate Change on Ocean Acidification
Mentor: Kristopher Karnauskas

Selected 2016 Awards

The breadth and number of achievements by CIRES researchers and staff speak to the quality of research conducted at the Institute. From lifetime achievement awards to recognition of emerging young talent, CIRES scientists are among the best of the best at what they do. Among the premier awards received by CIRES scientists during the 2016-2017 reporting period was a Presidential Early Career Award from the White House for Anne Perring and three teams that earned medals from the U.S. Department of Commerce.

CIRES Awards

The CIRES Members Council (page 8) convenes an award committee every year, to assess nominations submitted by NOAA supervisors, CIRES colleagues, and others. The CIRES Outstanding Performance Awards—given in Science and Engineering and in Service—are targeted at projects that are novel, high impact and show remarkable creativity or resourcefulness. The CIRES Director selects the Ph.D. student recipient of the Reid Fellowship every other year, after reviewing nominations made by graduate advisors.

CIRES Outstanding Performance Awards

The CIRES Outstanding Performance Awards are targeted at projects that are novel, high impact, and show remarkable creativity or resourcefulness. In the Science and Engineering category, this may involve any work that is related to the scientific process (forming and testing hypotheses to further our understanding of the environmental sciences). In the Service category this may involve any work that facilitates, supports, enhances, or promotes work in the environmental sciences.

Science and Engineering

Gilbert Compo in NOAA's Physical Sciences Division won for leading the development of the 20th Century Reanalysis, which relies only on surface pressure records and extends back more than 100 years.

Derek Hageman in NOAA's Global Monitoring Division, for outstanding software development to support his division's mission to collect and understand accurate, long-term atmospheric data.

George Millward in NOAA's Space Weather Prediction Center, for his uncommon scientific creativity in transitioning an academic geospace model into operations.

Service

Kelly Carignan and Matthew Love in NOAA's National Centers for Environmental Information, won for developing a 5-day tutorial in coastal digital elevation modeling, which forged strong U.S.-Canadian collaborations on tsunami safety and preparedness.

Marc Cloninger and Andrea Dietz on CIRES' Finance team won for being "world-class enablers," going above and beyond to help CIRES scientists navigate budgets, proposals, and university and NOAA systems.

Sandy Starkweather in NOAA's Physical Sciences Division won for her leadership and coordination of the Interagency Arctic Research Policy Committee's Arctic Research Plan.

George C. and Joan A. Reid Scholarship Award, 2017

Neesha Schnepf in NOAA's National Centers for Environmental Information (NCEI), is this year's recipient of the George C. and Joan A. Reid Award, made possible by the Reids' generous contribution to an endowed scholarship fund. Schnepf works in the NOAA NCEI geomagnetism group and is a PhD student in the University of Colorado

Gilbert Compo

Andrea Dietz and Marc Cloninger

Neesha Schnepf

Joan and George Reid

Boulder's Department of Geological Sciences. Advised by CIRES scientist Manoj Nair (NOAA NCEI) and CIRES Fellow Anne Sheehan (Geological Sciences), Schnepf studies the magnetic field associated with oceanic flow, and using variations in that field to determine more about issues such as tsunami propagation, the electrical structure of the lithosphere, and the circulation of ocean water.

CIRES Medals

CIRES scientists are often integral to NOAA award-winning science and engineering teams but cannot be given certain federal awards, such as the prestigious Department of Commerce Gold and Bronze medals. The CIRES Director recognizes the extraordinary achievements of CIRES scientists working in partnership with federal colleagues.

CIRES Gold Medal for scientific/engineering achievement

Michael Burek, Michele Cash, Stefan Codrescu, Tom DeFoor, Ratina Dodani, Richard Grubb, Jeff Johnson, Paul Loto'ainu, Alysha Reinard, William Rowland, and Meg Tilton were part of a team awarded a Department of Commerce Gold Medal in 2016 for their work on the Deep Space Climate Observatory mission, NOAA's first operational space weather satellite. The CIRES scientists were critical to a team from the National Weather Service and the National Environmental Satellite, Data, and Information Service.

CIRES Gold Medal for scientific/engineering achievement

Gilbert Compo, Chesley McColl, and Prashant Sardeshmukh were part of a team in NOAA's Physical Sciences Division recognized with a Department of Commerce Gold Medal in 2016. Compo, Sardeshmukh and McColl and NOAA's Jeff Whitaker created the 20th Century Reanalysis, a pioneering reconstruction of global weather and extremes using only surface pressure observations.

CIRES Bronze Medal for scientific/engineering achievement

Many CIRES scientists were part of a multi-institutional team that won a Department of Commerce Bronze Medal in 2017, for the El Niño Rapid Response Field Campaign. Federal and CIRES scientists in the Physical Sciences Division of NOAA, the Aircraft Operations Center, and the NOAA ship *Ronald H. Brown* were involved in the mission.

International Awards

Waleed Abdalati, CIRES Director, Department of Geography, was selected to give the Tyndall Lecture at the December 2016 meeting of the American Geophysical Union: "Earth from Space: The Power of Perspective"

Jeffrey Deems, National Snow and Ice Data Center, received a visiting fellowship to work with the Snow Hydrology Research Group at the Swiss Federal Institute for Snow and Avalanche Research, in Davos, Switzerland.

Lisa Dilling, Director of CIRES' Western Water Assessment, won the Leverhulme Visiting Professor Award from the UK Leverhulme Trust.

Bob Evans of NOAA's Global Monitoring Division received the Joseph C. Farman Award, from the International Ozone Commission, granted to outstanding scientists who have created and used high-quality, long-term time series of atmospheric measurements.

Lisa Dilling

Florence Fetterer

Jeff Deems

Alysha Reinard

Florence Fetterer in the National Snow and Ice Data Center was a co-recipient of the Alan Berman Research Publication Award from the Naval Research Laboratory for a 2015 publication in *Cryosphere*. Fetterer also was part of the team awarded the 2016 International Data Rescue Award in the Geosciences from Elsevier and the Interdisciplinary Earth Data Alliance for their efforts in digitizing the Roger G. Barry Archive.

Noah Fierer, **Jose-Luis Jimenez, Julienne Stroeve and Mark Serreze** were recognized as "2016 Highly Cited Researchers" by Clarivate Analytics.

R. Michael Hardesty, affiliated with NOAA's Chemical Sciences Division, won a lifetime achievement award from the International Coordination-group for Laser Atmospheric Studies for "sustained outstanding and innovative achievements in the areas of lidar techniques, technologies, and observations."

Birgit Hassler in NOAA's Chemical Sciences Division received the Dobson Award from the International Ozone Commission, for an early career scientist who published outstanding work in the atmospheric sciences.

Dale Hurst in NOAA's Global Monitoring Division, won the World Meteorological Organization's Professor Vilho Väisälä Award for an outstanding research paper.

Jennifer Kay, CIRES Fellow, Department of Atmospheric and Oceanic Sciences, earned the American Meteorological Society Henry G. Houghton Award, given to promising young or early-career scientists who have demonstrated outstanding ability.

Lora Koenig of the National Snow and Ice Data Center was elected by the cryospheric community to serve as President of the American Geophysical Union's Cryosphere Focus Group.

Larisza Krista, who works in National Centers for Environmental Information, served as keynote Speaker at the Royal Astronomical Society Specialist Meeting, Royal Astronomical Society (UK).

Stuart McKeen in NOAA's Chemical Sciences Division was part of a team awarded the 2016 Haagen-Smit Award Elsevier Press for an exceptional paper published in the journal *Atmospheric Environment*.

Judith Perlwitz, CIRES Fellow, NOAA Physical Sciences Division, was elected a Fellow of the American Meteorological Society.

Irina Petropavlovskikh, in NOAA's Global Monitoring Division, was elected as Secretary of the International Ozone Commission—a 4-year, once-renewable position of leadership.

Allen Pope, National Snow and Ice Data Center, was named as one of "Sixteen Young Leaders Who Will Influence the Future of the Arctic" by the digital journalism project Arctic Deeply.

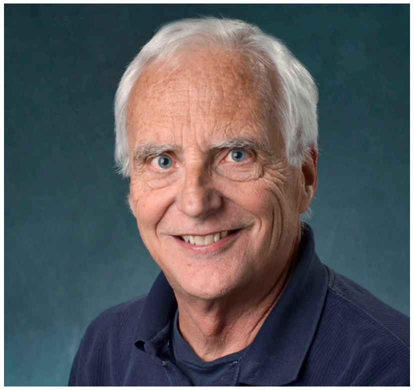
Anne Sheehan, CIRES Fellow, Geological Sciences, won the Zealand Geophysics Prize, given by the Royal Society of New Zealand.

Lesley Smith in the CIRES Education and Outreach group, was honored as a Fellow of the Association for the Sciences of Limnology and Oceanography.

Nikolay Zabotin of NOAA Physical Sciences Division was elected to senior membership to the IEEE.

National and Other

Ravan Ahmadov, William Dubé, Jessica Gilman Abigail Koss, Brian Lerner, Rui Li, Stuart McKeen, David Parrish, Christoph Senff, Colm Sweeney, Chelsea Thompson, Patrick Veres, Rebecca Washenfelder, Carsten Warneke, and Bin Yuan from NOAA's Global Monitoring and Chemical Sciences divisions were co-authors on a paper that received an Outstanding Scientific Paper award in



R. Michael Hardesty

Lora Koenig

Allen Pope

Ravan Ahmadov

2017, from the NOAA Office of Oceanic and Atmospheric Research. The paper, published in *Nature* in 2014, was "High winter ozone pollution from carbonyl photolysis in an oil and gas basin," DOI:10.1038/nature13767.

Audra McClure-Begley, Geoff Dutton, Emrys Hall, Alexander Haugstad, Eric Hintsa, Dale Hurst, Allen Jordan, Richard Mclaughlin, Fred Moore, David Nance, Andrew Rollins, Troy Thornberry, and Laurel Watts in NOAA's Global Monitoring Division, were part of a team that earned a Group Achievement Award from NASA for the ATTREX (Airborne Tropical Tropopause Experiment) mission to advance understanding of the physical processes of the tropical tropopause layer and its role in the Earth's climate.

Christopher Bond, Daniel Crumly, Amanda Leon, and Siri Jodha S. Khalsa in the National Snow and Ice Data Center were part of the SMAP (Soil Moisture Active Passive) Science Data System Team awarded a NASA Group Achievement Award.

Aditya Choukulkar, Emiel Hall, Mike Hardesty, Gary Hodges, John Holloway, Gerd Hubler, Guillaume Kirgis, Kathleen Lantz, and Christoph Senff, NOAA-based scientists in the Global Monitoring and Chemical Sciences divisions, were part of a team who shared a NASA Group Achievement Award for their work on the DISCOVER-AQ mission (Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality).

Dave Costa, Leslie Hartten, Darren Jackson, Paul E. Johnston, Don Murray, and Dan Wolfe in NOAA's Physical Sciences Division, were part of a NOAA team recognized with the NOAA Research Employees of the Year award, not available to non-federal scientists. The group of federal and cooperative institute scientists was honored for rapidly implementing and supporting a complex, multi-platform, multi-organizational field campaign to observe a rare, high-intensity El Niño event in the central, equatorial Pacific.

Raina Gough, Margaret Tolbert Group, was elected by NASA to serve as a "Participating Scientist" on the Mars Science Laboratory mission, 2016-2019.

Leslie Hartten in NOAA's Physical Sciences Division was honored with the NOAA Office of Oceanic and Atmospheric Research's Diversity Award for exemplary service, serving as a mentor to many interns from various ethnic backgrounds at NOAA Boulder throughout the years.

Anne Perring, recipient of the prestigious Presidential Early Career Award for Scientists and Engineers (PECASE). Photo: CIRES/NOAA

Jose-Luis Jimenez, CIRES Fellow, Department of Chemistry and Biochemistry, was elected as a Fellow of the American Association for Aerosol Research (AAAR).

Jennifer Kay, CIRES Fellow, Department of Atmospheric and Oceanic Sciences, earned a National Science Foundation (NSF) CAREER Award, the NSF's most prestigious award in support of junior faculty who exemplify the role of teacher-scholars.

Amanda Leon, in the National Snow and Ice Data Center, was part of an interagency team working on the NASA Soil Moisture Active Passive (SMAP) Applications Program, which won the Federal Laboratory Consortium's Interagency Partnership Award.

Peter Molnar, CIRES Fellow, Geological Sciences, gave named lectures at Utah State University (Forster Lecture) and Lamont-Doherty Earth Observatory, Columbia University (Jardetzky Lecture).

Anne Perring in NOAA's Chemical Sciences Division, was awarded a Presidential Early Career Award for Scientists and Engineers (PECASE) in early 2017, one of 102 young scientists and engineers to receive this recognition. The PECASE is the highest honor bestowed by the U.S. government on early career scientists.

Jennifer Taylor in CIRES' Education and Outreach was part of a team awarded the Climate Education and Resiliency for Denver Public Schools category of the CU Office for Outreach and Engagement Outreach Award for Interdisciplinary/Interdepartmental Faculty Groups.

Ronald Weaver, principal investigator and manager of the Snow and Ice Distributed Active Archive Center (DAAC) at CIRES' National Snow and Ice Data Center, was one of nine people honored by the University of Colorado Boulder Regents in 2016. Weaver was awarded the University Medal in recognition of his lasting contributions to climate research and data management.

Events

Analytical Chemistry Seminars

Mitchell Alton Cell membrane conditions on C-Reactive protein binding (10/16)
Benjamin Deming Measurements of peroxy radical loss rates on laboratory surfaces (10/16)
Jeff Pierce Exploring the evolution of biomass-burning aerosol in chambers and the atmosphere (11/16)
Bob Sievers Industrial hemp: opportunities in R & D in Colorado's fastest growing industry (11/16)
Randall Chiu UV photochemistry of carboxylic acids at the air-sea boundary: A relevant source of glyoxal and other OVOC in the marine atmosphere (1/17)
Megan Harries Closing the loop on phase equilibrium: connecting fundamental volatility measurements of complex fluids with applications of headspace detection (1/17)
Annmarie Carlton Aerosol liquid water: a valentine to the Clean Air Act (2/17)
Xuan Zhang Understanding the molecular signature of atmospheric organic aerosols using Ion mobility mass spectrometry (2/13)
Jonathan Raff Atmospheric chemistry of nitrogen oxides at soil-air interfaces (2/17)
Jeff Smith Cannabidiol-dependent modulation of cognitive learning and synaptic function (2/17)
Jason Surratt Secondary organic aerosol formation from atmospheric oxidation of isoprene: implications for air quality, climate and public health (3/17)
Federico San Martini Secretariat for the implementation of the montreal protocol (3/17)

CSTPR Noontime Seminars

Bruce Evan Goldstein, Claire Chase, Lee Frankel-Goldwater, Jeremiah Osborne-Gowey, Julie Risien, Sarah Schweizer Collaborating for system change: learning networks for city resilience, wildfire protection, climate adaptation, and impactful science (9/16)
Abby Benson, Nicholas Valcourt, Angela Boag, Sarah Welsh-Huggins "Catalyzing advocacy in science and engineering" workshop student competition panel discussion (9/16)
Augusto González EU space policy (10/16)
Jeffrey Zax Student expertise and the legislative process (10/16)
Alan Hurd Collaboration in energy and materials sustainability (10/16)
Jessica Smith Supraregulatory agreements and public perceptions of unconventional energy development in Colorado (1/17)
Elizabeth McNie Transitioning research to operations in an applied science program (2/17)
Deserai Crow The high water mark: policy lessons learned from Colorado's 2013 floods (2/17)
Julia Schubert Addressing climate change as an engineering challenge: scientific expertise in U.S. geoengineering politics (2/17)
Jason Delborne Emerging biotechnologies and public engagement: reflections on the NASEM Report on gene drives (3/17)
Justin Farrell Climate change politics and machine learning (3/17)
Jack Stilgoe Machine learning, social learning and the governance of self-driving cars (3/17)
Kathleen Hancock Renewable energy in Africa: findings

CIRES' Distinguished Lecture Series brings in outstanding scientists, historians of science, science policy makers, science journalists, and others, who take imaginative positions on environmental issues and can establish enduring connections after their departure.

Thomas Painter: A snow hydrologist's apology: Ruining the mystery of mountain snows (9/16)

Richard J. Johnson: Climate change and the evolution of humans (1/17)

Roger S. Pulwarty: Slow onsets, abrupt changes, and fast reflexes: Research on adaptation in a changing world (4/17)

from the social sciences (4/12)
Sierra Gladfelter Anticipating disaster: local dependence on formal climate information vs. traditional ways of knowing (4/17)

Cryospheric and Polar Processes Seminar

Mark Vardy The Sociology of sea ice visualizations: 14 preliminary swaths (9/16)
Kelsi Singer The Pluto System as revealed by New Horizons (9/16)
Mark Raleigh Dusting for the fingerprints of dust-on-snow in the Upper Colorado River Basin (9/16)
Ann Windnagel The Sea Ice Index: a resource for cryospheric knowledge mobilization (9/16)
Mary Jo Brodzik A new era for NSIDC's gridded passive microwave data: Using image reconstruction to enhance spatial resolution of the satellite passive microwave historical record (10/16)
Ariel Morrison CALIPSO observations of the cloud response to recent Arctic sea ice loss (10/16)
Richard Kelly Remote sensing of seasonal snow water equivalent: instruments of opportunity, systemic inertia, curiosity-driven science and future prospects (10/16)
Michael Willis Uh-Oh. Abrupt collapse of an Arctic ice cap (11/16)
Alia Lauren Khan Quantifying sources, distribution, and processing of light absorbing aerosols in the cryosphere: a comparison of dissolved and refractory black carbon in polar and high mountain regions (11/16)
Allen Pope, Shelley Knuth, Bruce Loftis Polar Research Coordination Network seminar (11/16)
Jennifer Kay New progress in leveraging spaceborne radar and lidar to advance Arctic cloud-climate research (2/17)
John J. Cassano Probing the Antarctic atmospheric boundary layer with autonomous observing systems (2/17)
Mark Serreze Variability, trends, and predictability of seasonal sea ice retreat and advance in the Chukchi Sea (2/17)
Ed Blanchard-Wrigglesworth Butterflies and polar bears: understanding Arctic sea ice predictability (2/17)
John Behrendt The potential for positive feedback between West Antarctic Ice Sheet (WAIS) deglaciation, decompression-melt-induced volcanism, and resultant sea-level rise (3/17)
The Influence of the Arctic frontal zone on Summer cyclone activity today and in the future (4/17)
Sebastian Schmidt Understanding the atmospheric drivers of Arctic sea ice variability: the role of past and future aircraft experiments (4/17)
Abigail Ahlert, Alexandra Jahn Definitions matter: Arctic sea ice melt and freeze onset (4/17)

Education & Outreach Events

RECCS Summer Internship (6/16)
NSTA 2016 - STEM Forum & Expo (7/16)
Earthworks Reunion (8/16)
Colorado Science Conference Booth (11/16)
Trout Bowl 2017 (2/17)
Lens on Climate Change (3/17 and 7/17)
National Ocean Sciences Bowl - Finals Competition (4/17)
Climate Education & Resiliency for Denver Public Schools (4-5/17)
CLEAN-NGSS Harmonics Project (5/17)

Miscellaneous

Uwe Karst Visiting Fellow Seminar: An image says more than a thousand words:âÊMass spectrometric imaging and complementary techniques in pharmaceutical and biomedical analysis (6/16)
Jack Waldorf, Abby Benson, Heather Ben FOSEP Discussion, CSTPR (8/16)

A young student from the Education and Outreach Lens On Climate Change program films her peers at Chautauqua park. Photo: Ben Rand/Colorado Film School

Augusto González EU discussion series at CSTPR (9/16)
CGA Beyond Academia Career Panel (9/16)
Maggie Tolbert CGA grant writing workshop (10/16)
Raj Pandya Engaged scientist series public lecture (10/16)
Karen McNeal Are they engaged? The use of skin biosensors to monitor participant attention in formal and informal learning settings (10/16)
Peter Weiss Environmental program seminar: genuine wealth, native efforts at sustainability (10/26)
StoryEarth: Bringing Story & Science of Earth Alive! (11/16)
Is academia right for me? CIRES academic career panel (11/16)
CIRES IRP Poster Session and Reception (11/16)

Pieternel Levelt CIRES Special Seminar: OMI, TROPOMI, TROPOLITE: towards 1 x 1 km2 air quality and emission monitoring (12/16)
CGA Academic budget training workshop (2/17)
CGA Social hour at Cheba Hut (3/17)
CGA Open Forum: The role of scientists in a changing political climate (3/17)
Alexandra Jahn Impact of changes in the Arctic Ocean freshwater budgets on AMOC strength (3/17)
Stand Up for Climate Change: An experiment with creative climate comedy (3/17)
Atmospheric Organics: The Cubism of Atmospheric Chemistry (3/17)
Citizen Science TV Series Preview and Discussion (3/17)
Xiaoxi Liu, Derek Price Measurements of emissions from agricultural fires and wildfires in the U.S (4/17)
Michelle Gabrieloff-Parish, Heidi McCann, Susan Sullivan Engaged scientist series: science is culture (4/17)
Lunch with CIRES Distinguished Lecturer - Roger S. Pulwarty (4/17)
Kelly Chance North American pollution measurements from geostationary orbit with Tropospheric Emissions: Monitoring of Pollution (TEMPO) (4/17)
CGA Job Mentoring Mashup: Outside academia (4/17)
Zachary Finewax Products and yields from the gas-phase oxidation of benzenediols (4/17)
Jennifer Richler Publishing with nature journals (4/17)
David De Haan Turning brown in the sun: aldehydes, aqueous aerosol, and evaporating cloud droplets (4/17)
Kirsti Kauppi Celebrating Finland's centennial: what makes Finland great for education, research & innovation (4/17)
Elizabeth Maroon The influence of the Rocky Mountains on the ocean's meridional overturning circulation (5/17)
WWA/NIDIS Webinar: Evaporative Demand Drought Index (EDDI): tracking the atmospheric demand side of drought for monitoring and early warning (5/17)
CIRES Rendezvous 2017 (5/17)
WWA/NIDIS Webinar: Decision making in the face of drought by western range livestock producers (5/17)

...and Happy 50th, CIRES!

Nancy and Robert Sievers, former CIRES Director, at a CIRES 50th anniversary event. Photo: Matthew Price/CIRES

Dr. Gary Matlock, NOAA's Deputy Assistant Administrator for Science, speaks during a spring 2017 celebration of CIRES' 50th anniversary. Photo: Matthew Price/CIRES

CIRES Director Waleed Abdalati and CIRES Event planner Linda Pendergrass at a CIRES 50th anniversary event in May 2017. Photo: Matthew Price/CIRES

Red fern in Ubud, Bali.
Photo: Matthew Price/
CIRES

Project Reports

Project reports by theme

Key acronyms in this section

CSD	NOAA ESRL Chemical Sciences Division
CU Boulder	University of Colorado Boulder
ESRL	NOAA Earth System Research Laboratory
GMD	NOAA ESRL Global Monitoring Division
GSD	NOAA ESRL Global Systems Division
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
OAR	NOAA Office of Oceanic and Atmospheric Research
PSD	NOAA ESRL Physical Sciences Division
SWPC	NOAA NWS Space Weather Prediction Center

Project reports, alphabetized

- Office of Oceanic and Atmospheric Research (OAR)
- National Environmental Satellite, Data, and Information Systems (NESDIS)
- National Weather Service (NWS)

Air Quality in a Changing Climate

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

■ CIRES Lead: Andy Neuman ■ NOAA Lead: Tom Ryerson

NOAA Theme: Weather-Ready Nation

Goals & Objective

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.

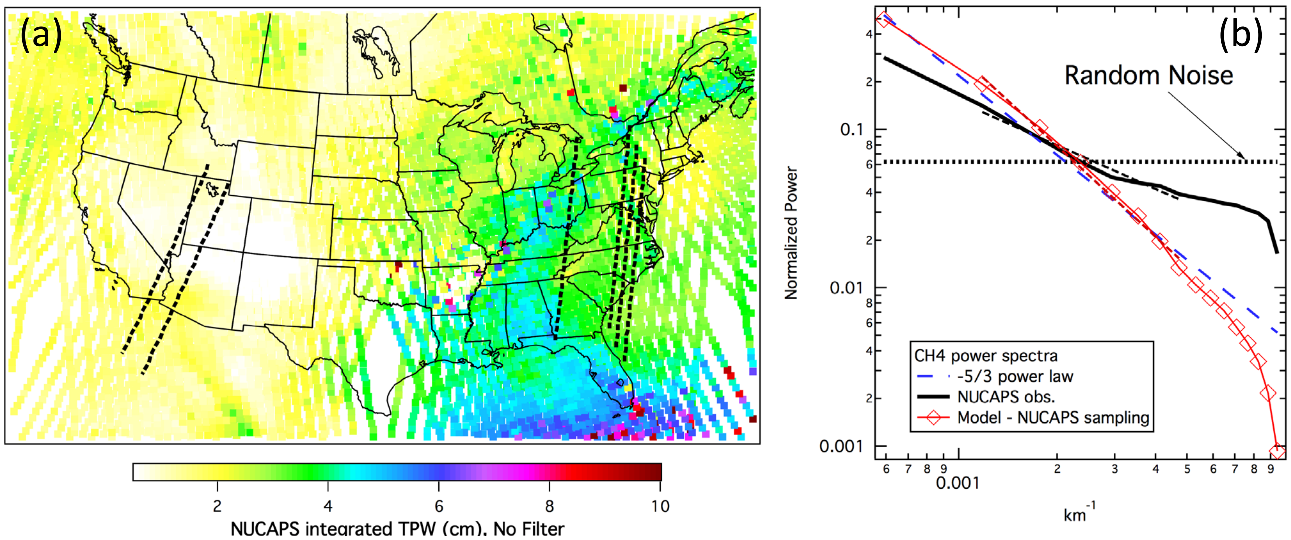
Accomplishments

Our team led several intensive regional field studies conducted to enhance understanding of air quality and climate, using a variety of measurement platforms and locations. Our results from these field studies improve scientific understanding of emissions, atmospheric chemistry, and transport to support effective mitigation strategies and improve models to estimate future climate and air quality.

Our California Baseline Ozone Transport Study (CABOTS) made precise ozone measurements aloft to help the state of California understand the contributions of transport to the high surface ozone present in the San Joaquin Valley and to quantify California's starting point for complying with the federal ozone standard. From late May through August 2016, the CABOTS field campaign used the Tunable Optical Profiler for Aerosol and oZone lidar (TOPAZ) to measure the vertical distribution of atmospheric ozone and aerosols. Understanding the variations in ozone entering California is becoming increasingly important as the state strives to meet the stricter federal ozone standard.

In the summer of 2016, we operated reactive nitrogen, ozone, and particle instruments aboard the NASA DC-8 aircraft in support of the NASA Atmospheric Tomography mission. Our field intensive work obtained global-scale in situ measurements by continuous airborne vertical profiling, to quantify the processes that control the short-lived climate

CSD-01: UWFPS 2017 participants with the NOAA Twin Otter at the Salt Lake City International Airport, January 2017. Image: R. Militec and S. Brown



CSD-02: (a) WRF-Chem model domain and NUCAPS total precipitable water (TPW) for 1 June 2013, with no quality control (QC) filtering. Six tracks are shown, each comprising 32 NUCAPS profile locations used for this day in the scale variance analysis. (b) Normalized power spectral density of 500 hPa CH_4 from NUCAPS (black) and from the WRF-Chem model (red) plotted versus wavenumber. The -5/3 power law slope (blue) and random noise (black dash) are also shown. Image: CIRES and NOAA

forcing agents methane and ozone in the atmosphere.

From October - November, 2016, we performed extensive measurements at the Fire Science Laboratory in Missoula, Montana as part of the Fire Influence on Regional and Global Environments Experiment (FIREX). FIREX is a multi-year study of western North American fires assessing the impact of biomass burning on climate and air quality. Our team performed these laboratory studies of emissions and short-term processing of multiple fuel types in preparation for examining fire influences on the atmosphere during a 2019 large-scale field campaign.

The urban air basins along Utah's Wasatch Mountains experience severe particulate matter air pollution, with concentrations that exceed the federal standard on many winter days. Our Utah Winter Fine Particulate Study (UWFPS) used an instrumented NOAA Twin Otter aircraft to examine the sources and geographical variability of this pollution. During January and February 2017, we measured particle concentrations and composition, and gas phase particle precursors over Salt Lake City and the adjacent regions.

CSD-02: Chemistry, Emissions, and Transport Modeling Research

■ CIRES Lead: Stu McKeen ■ NOAA Lead: Michael Trainer

NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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

From June 2016 to May 2017, we submitted quarterly reports to NOAA's Joint Polar Satellite System program (JPSS), documenting the progress of this cooperative project. The variance scaling properties of NOAA W-P3 aircraft data and model results (Weather Research and Forecasting Chemistry, WRF-Chem) in the middle troposphere for the SENEX-2013 (Southeast Nexus) study period were derived for 10 chemical and meteorological variables in the 10- to 200-km length-scale range. Both the model and aircraft data exhibit remarkable similarity in the scaling properties of all variables, close to the -5/3 scaling law for isentropic turbulence, thus illustrating the dominance of atmospheric turbulence in determining their scaling properties. We did a similar analysis for several variables within the NUCAPS (NOAA Unique Combined Atmospheric Processing System) satellite retrievals supplied by JPSS collaborators over the 100- to 1000-km length-scale range. While some satellite variables (e.g. 500 millibar water vapor, ozone, temperature) follow the -5/3 scaling law, methane and carbon monoxide depart significantly from the expected scaling, and exhibit characteristics of a noisy signal. Our consultations with NUCAPS collaborators led to two additional retrieval datasets being tested with stricter quality control filters, but with no improvement in the variance scaling. We extended the Fourier analysis of the satellite data to provide an estimate of the spatial averaging necessary to provide useful information. For both CH_4 and CO this required vertical averaging from 100 millibar to the surface, and ~300-km horizontal averaging.

GSD-04: Improve Regional Air Quality Prediction

■ CIRES Lead: Ravan Ahmadov ■ NOAA Lead: Georg Grell

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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.

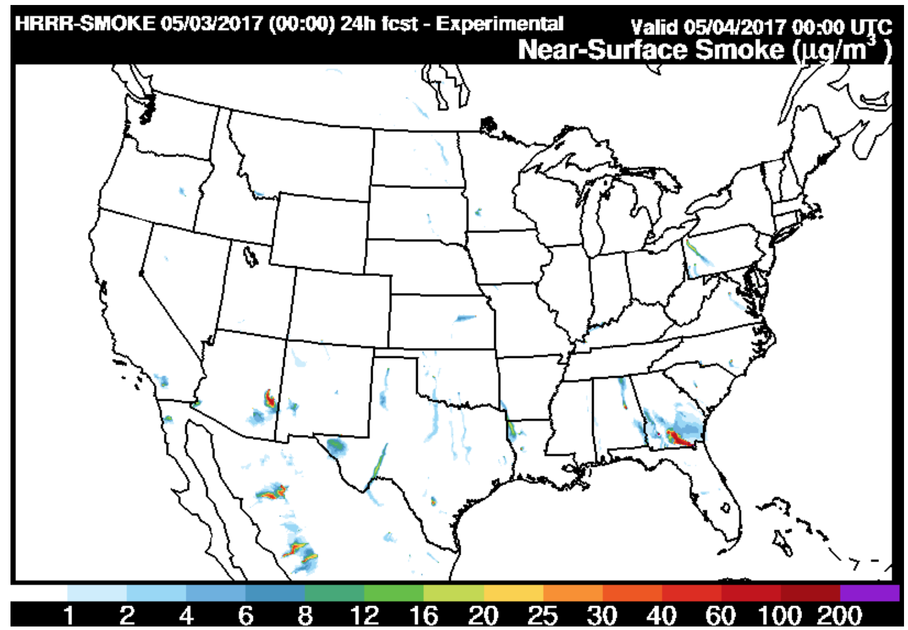
Accomplishments

In June 2016 we coupled High Resolution Rapid Refresh (HRRR) model with smoke. The HRRR-Smoke has been running in real time since June 2016. Every six hours a new HRRR-Smoke simulation starts to forecast smoke for next 36 hours. We estimate the biomass burning emissions using JPSS satellite-based fire radiative power data obtained in real time. We visualize and provide the HRRR-Smoke output to users via the following web-page: https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/

In addition to the continental United States (CONUS) domain, we also set up real-time HRRR-Smoke for the 3km-resolution Alaska domain.

Our team evaluated the HRRR-Smoke model for August, 2016.

We organized a WRF-Chem tutorial in February 2017 at the National Center for Atmospheric Research in Boulder, Colorado. There were about 40 participants from the United States and other countries. Lectures on a number of topics and hands-on exercises were offered during the tutorial.



GSD-04: HRRR-Smoke forecast smoke concentrations over the continental United Status, CONUS domain for May 4, 00UTC. https://rapidrefresh.noaa.gov/hrrr/HRRR-smoke/. Image: NOAA

Climate Forcing, Feedbacks, and Analysis

CSD-03: Scientific Assessments for Decision Makers

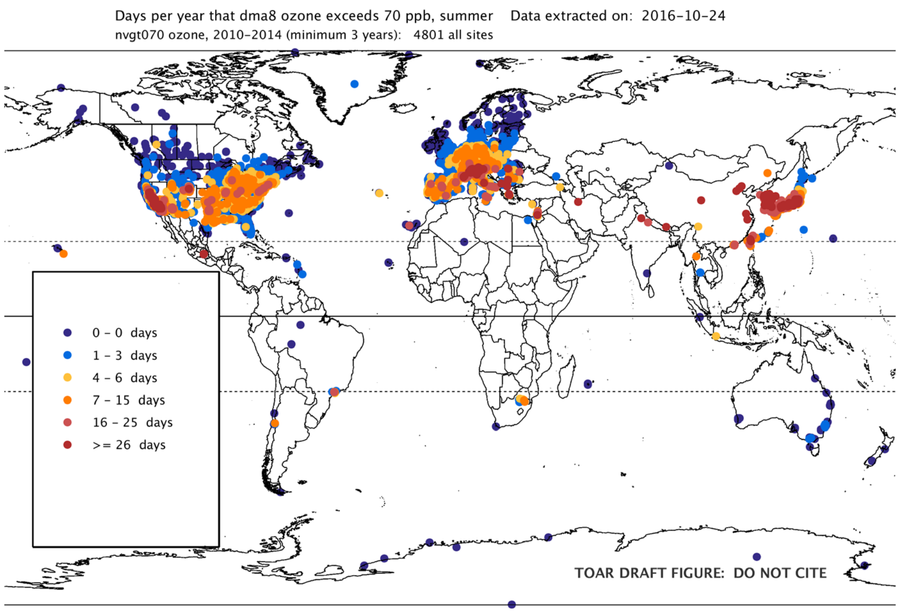
■ CIRES Lead: Owen Cooper ■ NOAA Lead: David Fahey
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

This project will provide credible assessments of environmental science relevant to decision making.

Accomplishments

Our team's Tropospheric Ozone Assessment Report (TOAR) will provide the first comprehensive overview of tropospheric ozone's present-day distribution and trends from the surface to the tropopause (the boundary between the troposphere and the stratosphere)



CSD-03: Number of days per year (averaged over 2010-2014) that the maximum daily 8-hour average ozone value exceeds 70 ppb (the US ozone standard). This plot shows ozone data from the TOAR Surface Ozone Database which contains ozone metrics at all available ozone monitoring sites (a total of 4,801 sites) around the world. Ozone metrics produced by the Tropospheric Ozone Assessment Report (Schultz et al., 2017), available at: https://doi.pangaea.de/10.1594/PANGAEA.876108 Schultz, M, et al. (2017), Tropospheric Ozone Assessment Report: Database and Metrics Data of Global Surface Ozone Observations, *Elementa: Science of the Anthropocene*, in press.

using all available surface ozone observations.TOAR is chaired by CIRES Senior Scientist Owen Cooper and driven by the voluntary contributions of over 220 scientists and data providers from over 30 nations, representing research on all seven continents.

A major milestone in our efforts was the September 2016 completion of TOAR's surface ozone database. The database contains hourly ozone observations from over 9,000 sites worldwide. From these data, we calculated ozone exposure and dose metrics consistently for all sites for analysis of the impacts of ozone on human health, vegetation and climate (an example is shown in Figure 1). Our database also provides station metadata based on the information from global gridded datasets of human population, satellite detected tropospheric NO_2, a bottom-up surface emission inventory of nitrogen oxides, satellite-detected land-use data, and satellite-detected nighttime lights of the world. Using these datasets TOAR was able to classify sites as being rural or urban using an objective and consistent methodology.

We used output from the TOAR database to develop the analyses for the three TOAR papers that describe the global ozone distribution and trends relevant to human health, vegetation, and climate. For the first time scientists have been able to conduct an observation-based assessment of the regions of the world with the greatest exposure to ozone, as well as the regions where ozone is decreasing or increasing (where monitoring data are available).

When we complete TOAR, it will consist of eight peer-reviewed publications in the non-profit, open access journal, *Elementa: Science of the Anthropocene*. By May 31, 2017, three of the eight papers were complete and ready for submission to *Elementa*. We will complete the remaining five papers by September 2017.

CSD-04: Effects of Emissions on Atmospheric Composition

■ CIRES Lead: Carsten Warneke ■ NOAA Lead: Tom Ryerson
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

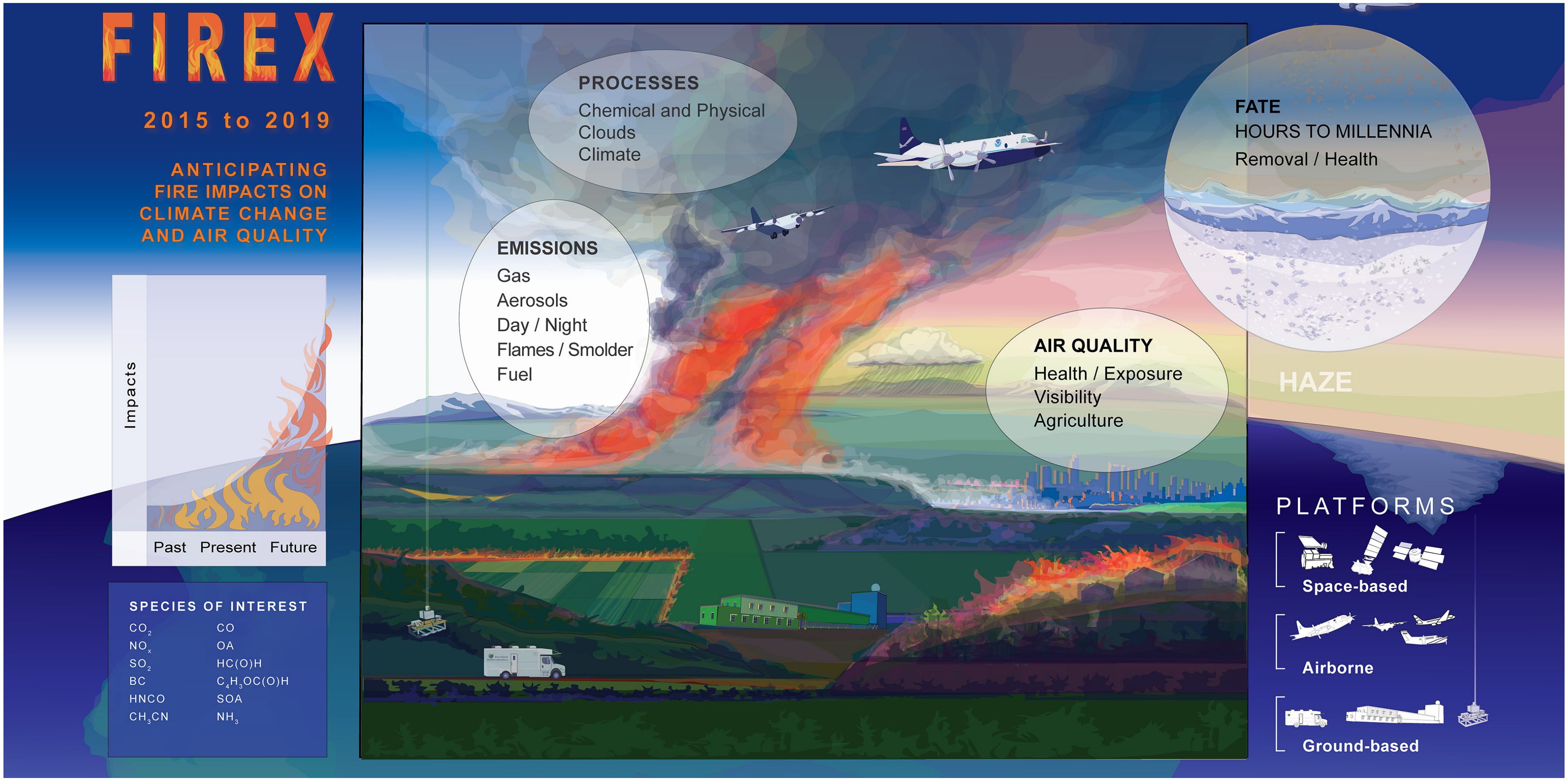
This project will provide and test new and improved quantifications of surface emissions of important trace gases, aerosols and greenhouse gases to determine their relevance for pollution, air quality and climate.

Accomplishments

Biomass burning emissions

As anthropogenic emissions, such as vehicle exhaust, are decreasing, an important focus for our research is on biomass burning emissions, because wildfires have become a large factor in air quality in the United States.

The Fire Influence on Regional and Global Environments Experiment (FIREX) is a multi-year study of western North American fires to assess the impact of biomass burning



CSD-04: Image: http://www.scribearts.org and NOAA

on climate and air quality. As part of FIREX, many CIRES researchers lead and took part in extensive measurements at the Fire Science Laboratory in Missoula, Montana in 2016 to determine emissions of gases and aerosols from the most common fuels in the western United States. This "Firelab" experiment brought together the largest set of common and novel instruments to look at biomass burning emissions in the most detail to date.

One example of our novel results obtained at the Firelab is that the pyrolysis of lignin, which partly consists of highly functional aromatics, emits functional aromatics. At low temperature burning, the emitted aromatics are highly functional and get less and less functionalized the higher the fire temperature. Using these results, we could determine separately the emission ratios for volatile organic compounds (VOCs) for the smoldering and flaming phase of the fire. These emission studies will form the underpinnings for examining fire influences on the atmosphere during the large-scale FIREX field campaign in 2019.

Other biomass burning related research showed that glyoxal emissions from agricultural biomass burning may be significantly overestimated and that nitrogen-containing VOCs such as the commonly used biomass burning tracer acetonitrile are poor tracers for domestic burning, because the domestically used fuels have low nitrogen content.

Oil and gas production emissions

We continued analysis of SONGNEX (Shale Oil and Natural Gas Nexus) emissions data from oil and gas extraction operations. VOCs measured from aircraft during SONGNEX showed that mixing ratios of aromatics were frequently as high as those measured downwind of large urban areas. In the Permian Basin, emitted VOCs included a number of underexplored or previously unreported species, including nitrogen heterocycles such as pyrrole and pyrroline, H_2S, and a diamondoid (adamantane).

CSD-05: Laboratory Studies of Fundamental Chemical and Physical Processes

■ CIRES Lead: Dimitris Papanastasiou ■ NOAA Lead: Jim Burkholder
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

This project will use specific laboratory techniques to measure the rates, reaction pathways, and product distributions of homogeneous and heterogeneous processes that play a role in air quality, climate, and stratospheric ozone depletion.

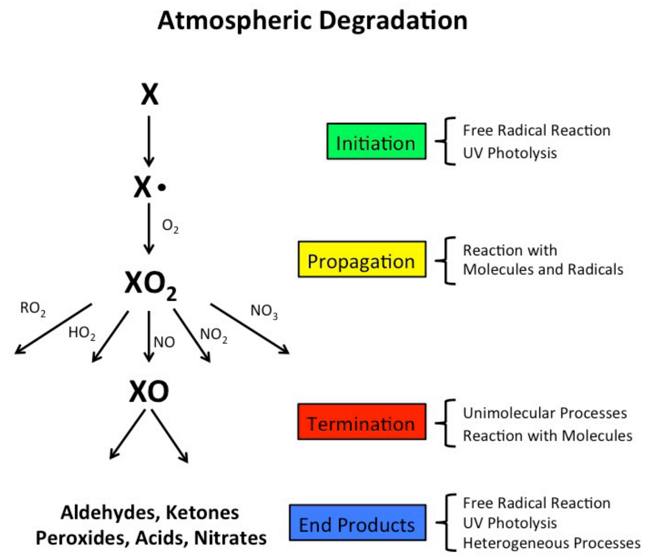
Accomplishments

Hydrofluoroolefins (HFOs), because of their short atmospheric lifetime and low global warming potential (GWP), are considered potential replacement compounds for the hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) used in several applications, . During the past year, we have completed studies of the atmospheric degradation and GWP of $(CF_3)_2CFCH=CHF$ (HFO-1438ezy(E)) and $CHF=CF_2$ (HFO-1123). We determined that HFO-1438ezy(E) and HFO-1123 are short-lived, with atmospheric lifetimes of ~36 and ~1 day, respectively. Using the lifetime and infrared absorption spectra measured in these studies, we determined GWP values (100 year time horizon) of 2.2 and 0.004 for HFO-1438ezy(E) and HFO-1123, respectively.

In a separate project, we evaluated a series of the persistent greenhouse gases, perfluorinated amines (PFAm), $(C_xF_{2x+1})_3N$ (x=2-5), which are used as heat transfer liquids. Our study evaluated various atmospheric removal pathways as well as the GWP values for these PFAms. We evaluated the removal of PFAm by UV photolysis and O(1D) reaction. Based on the experimental data and 2-D model calculations, we found that the lifetime of PFAm with respect to UV photolysis and O(1D) is more than 50,000 and 22,000 years, respectively. Our findings suggest that the atmospheric lifetimes of PFAms are most likely determined by upper-atmospheric loss process (e.g. Lyman-a photolysis), with estimated lifetimes greater than ~3,000 years.

Methyl isocyanate (MIC), CH_3NCO, is a toxic compound emitted in the atmosphere by combustion and agricultural-related processes, thus raising concerns about its potential health impact. The atmospheric fate of MIC is currently not well characterized. In this past year, we completed an extensive set of experiments to evaluate MIC's removal by reaction with OH and Cl atoms, as well as to characterize the mechanism and products that are relevant under atmospheric conditions. We presented results from this study at two internationally recognized conferences.

Permethylsiloxanes are used in many personal care products and have been recently detected in the atmosphere, where they decompose by reaction with OH radicals. These reaction products might contribute to new particle and secondary organic aerosol formation. We measured infrared absorption spectra of linear and cyclic permethylsiloxanes (a total of 8 compounds) and their OH radical reaction rate coefficients in this project.



CSD-05: A trace gas (X) in the atmosphere undergoes transformation processes leading to a variety of stable end-products. This project aims to better understand the key processes that define the atmospheric lifetime, fate and products of trace gases and their impact on climate, air quality and stratospheric ozone. Image: CIRES and NOAA

References:

Baasandorj et al. 2016.
Papadimitriou et al. 2016.

CSD-06: Aerosol Formation, Composition, Properties, and Interactions with Clouds

■ CIRES Lead: Barbara Ervens ■ NOAA Lead: Dan Murphy

NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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

Aerosol formation, composition, properties

Remote sampling of mineral dust and other climate-relevant aerosol: We participated in the NASA Atmospheric Tomography field campaign to sample the vertical and geographic distribution of aerosol species in the remote Pacific and Atlantic basins. During the first two deployments, we measured aerosol size and composition for species with high relevance to global climate, including particle nuclei, mineral dust, biomass burning particles, and sea salt. We are comparing our measured aerosol products to predictions from different global models to investigate long-range transport, aerosol removal, and potential to affect cloud formation.

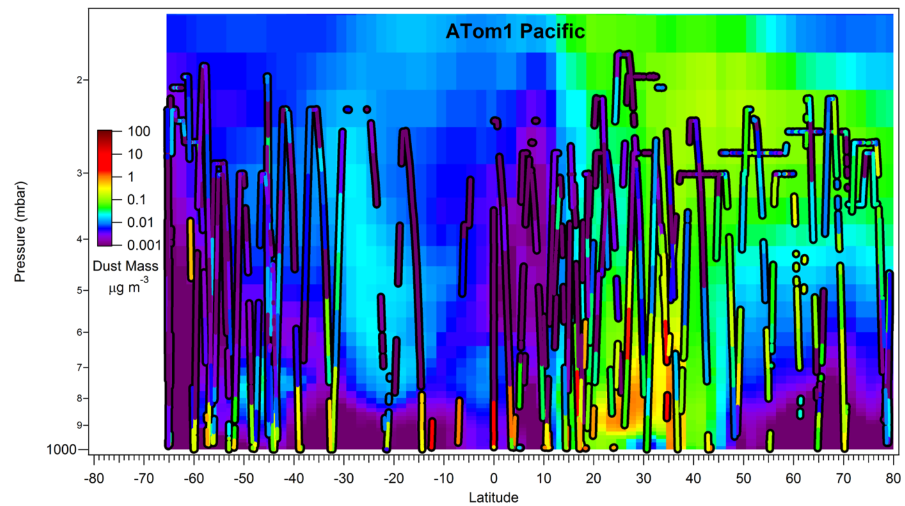
Anthropogenic influence on lower stratospheric aerosol: We used the Community Earth System Model to predict the anthropogenic component of lower stratospheric sulfate and organic aerosol by comparing pre-industrial and modern emissions scenarios. In situ aircraft measurements helped us validate the model predictions. Simulations indicate that non-volcanic stratospheric aerosol optical depth has increased 77 percent since preindustrial times, and anthropogenic organic aerosol constitute a significant fraction of that increase (Yu et al., 2016).

Aerosol pH and secondary organic aerosol formation: Using measured aerosol and gas phase composition in combination with a thermodynamic model, we accurately determined aerosol pH in an urban environment (Guo et al., 2017). These results lead to improved quantification of reactive uptake of some gas phase species onto aerosol particles, as some reactions strongly depend on pH.

Aerosol mass formation in clouds: We developed a new parameterization of sulfate and secondary organic aerosol formation in clouds. We showed, based on process model studies, that the number of microphysical cloud parameters (number of drop size classes) can be greatly reduced to one representative size: = effective diameter, which is proportional to the volume-to-surface ratio of the drop population (McVay and Ervens, 2017).

Representation of clouds in models

Radiation effects on clouds: To explore thermal radiation effects on cloud formation, cloud properties and cloud field properties, we implemented a 3D thermal radiative transfer code (Klinger and Mayer, 2016) into our large-eddy simulation and coupled it to our bin-microphysics scheme.



CSD-06: Preliminary data comparing aircraft measurements of mineral dust aerosol mass over the Pacific Ocean (colored lines) with output from the Community Earth System Model (colored background). Image: Karl Froyd/CIRES and NOAA

Network Theory to Understand Cloud Systems: With CIRES Innovative Research Project funding,we completed an analysis of the structure and arrangement of cellular stratocumulus clouds based on interpreting large-eddy simulation output as a dynamic cellular network. The network analysis finds the cellular pattern to be scale-invariant. A simple network model can explain the arrangement of cloud cells from stratocumulus-specific versions of cell division and cell merging.

Stratocumulus properties: We investigated the role of mesoscale organization for the properties of a low, non-precipitating stratocumulus cloud using large-eddy simulations. We found that entrainment, cloud water content, and the cloud radiative effect depend on the aspect ratio of mesoscale organization, and that entrainment is driven by vertical motion. As a consequence, high-resolution stratocumulus simulations exhibit a hitherto unrecognized domain size dependence that may carry over to large scale models (Kazil et al., 2017). Furthermore, we developed a Lagrangian large-eddy simulation approach for use with large-scale reanalysis data to investigate aerosol-cloud interactions.

References

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

■ CIRES Lead: Troy Thornberry ■ NOAA Lead: Ru-Shan Gao
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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

We made measurements of black carbon aerosol mass loadings in the remote atmosphere over both the Pacific and Atlantic oceans as part of the NASA Atmospheric Tomography (ATom) mission deployments in August 2016 and February 2017. Sampling spanned latitudes from the Arctic to Antarctic and heights from near the surface to 12 km altitude. We began analysis of the observations and published a manuscript in Aerosol Science and Technology, describing the optimization of the measurement of black carbon in aqueous samples using the Single Particle Soot Photometer (SP2) instrument.

We flew a Wideband Integrated Bioaerosol Sensor (WIBS) instrument on a NOAA Twin Otter in June 2016, making vertical profile measurements of fluorescent bioaerosol particle number over forested and grassland environments. Analysis of the observations is underway. We published a manuscript in Atmospheric Measurement Techniques describing a new method for laboratory calibration of the WIBS instrument to improve quantitation, consistency, and repeatability.

We flew 10 Printed Optical Particle Spectrometers (POPS) on balloonsondes from Lhasa, Tibet, and Kunming, China, to study the Asian tropopause aerosol layer that is produced by the Asian Summer Monsoon. We submitted a manuscript to Proceedings of the National Academy of Science describing POPS observations of the Asian tropopause aerosol layer and modeling studies estimating the Asian Monsoon contribution to stratospheric aerosol in the northern hemisphere.

We published a paper describing POPS measurements made in 2014 from a series of small UAS flights in Svalbard, Norway. We combined the POPS measurements with those from a miniature radiometer to derive a comprehensive set of aerosol optical properties.

We deployed the NOAA Chemical Sciences Division's SO_2, H_2O, O_3 and POPS

CSD-07: NASA WB-57F high-altitude research aircraft in Guam after completing the first science flight of the Pacific Oxidants, Sulfur, Ice, Dehydration and Convection mission on October 12, 2016. CIRES scientists in NOAA's Chemical Sciences Division operated four of the 11 instruments in the payload. Photo: Troy Thornberry/CIRES and NOAA instruments on the NASA WB-57 aircraft for the POSIDON (Pacific Oxidants, Sulfur, Ice, Dehydration and Convection) mission from Guam in October 2016. This mission produced the first in situ measurements of SO_2 in the tropical tropopause layer over the western Pacific Ocean and investigated the distribution of O_3 in the region during a time of widespread deep convection. Analysis of the data is underway.

We published manuscripts in Atmospheric Measurement Techniques and Geophysical Research Letters describing the development of the new SO_2 instrument and analysis of measurements made during the Volcano Investigation Readiness and Gas-phase and Aerosol Sulfur (VIRGAS) mission flown in October 2015. Those measurements provide a constraint on the flux of gas-phase SO_2 into the stratosphere and its contribution to the stratospheric sulfate aerosol layer.

We also published a manuscript in the Journal of Geophysical Research: Atmospheres describing the development of a new parameterization of the ice water content—optical extinction relationship for cold tropical tropopause layer cirrus clouds based on observations from the 2014 Airborne Tropical Tropopause Experiment (ATTREX) deployment from Guam.

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

■ CIRES Lead: Betsy Andrews ■ NOAA Lead: Patrick Sheridan

NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

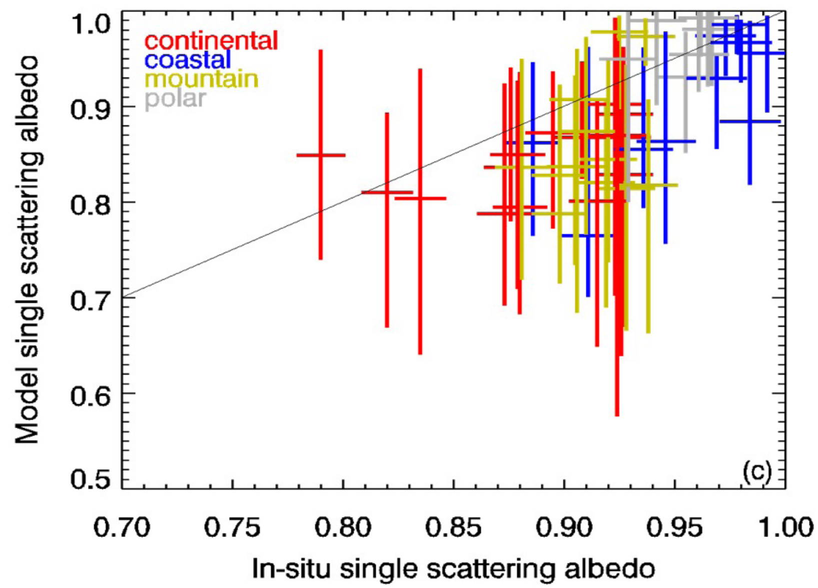
This project makes use of aerosol measurements from long-term monitoring sites and shorter-term deployments to analyze trends in aerosol properties, transport and aerosol radiative forcing.

Accomplishments

This has been quite a productive year for our project. In the reporting period our small group authored or co-authored more than ten articles in peer-reviewed journals relating to this project. Another two papers are accepted but not yet published, the first of which is related to the Arctic aerosol data sets. The second Arctic aerosol data set paper should be submitted this summer. We also have an additional manuscript currently in revisions.

Our proposal to the Department of Energy's Atmospheric Science Research (DOE/ASR) program was funded in September 2016. This proposal will fund research into aerosol hygroscopicity, specifically developing a climatology from the network of hygroscopicity measurements over the last two decades and using this climatology to investigate how well global models simulate aerosol hygroscopicity. The hygroscopicity project is one part of a wider project using surface in-situ measurements to evaluate global models. The first part of the project looks at how well models simulate aerosol optical properties at low humidity conditions. In the last year, we've attended several workshops related to this research and made numerous presentations on our results at various international conferences. The research on the low humidity model/measurement comparisons has advanced enough over the last year that we are currently writing a manuscript.

To support long-term monitoring sites in the federated aerosol network, we implemented a new version of the data acquisition software at more than half of the stations. The new software allows us to better manage network data over the long-term. An additional three sites (all in Spain) have been added to the network. We are still in discussion with potential collaborators for network sites in Oregon and New Mexico.



GMD-03: Comparison of the annual aerosol single scattering albedo from surface in-situ measurements and model simulations. Vertical bars indicate range of simulated values for 14 models. Horizontal bar crosses at median value of all model results. Colors indicate site type. Models tend to simulate a darker (less reflective) aerosol then is observed by in-situ measurements. This is the opposite of what is found when model simulations are compared to retrievals of column absorption optical depth at ambient conditions. Image: E. Andrews and AeroCom modelling community modellers and GAW aerosol monitoring network scientists

References:

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GMD-04: Studies of Greenhouse Gas Trends and Distributions

■ CIRES Lead: Gabrielle Petron ■ NOAA Lead: Pieter P. Tans

NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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 one (CFCs, HFCs, 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.

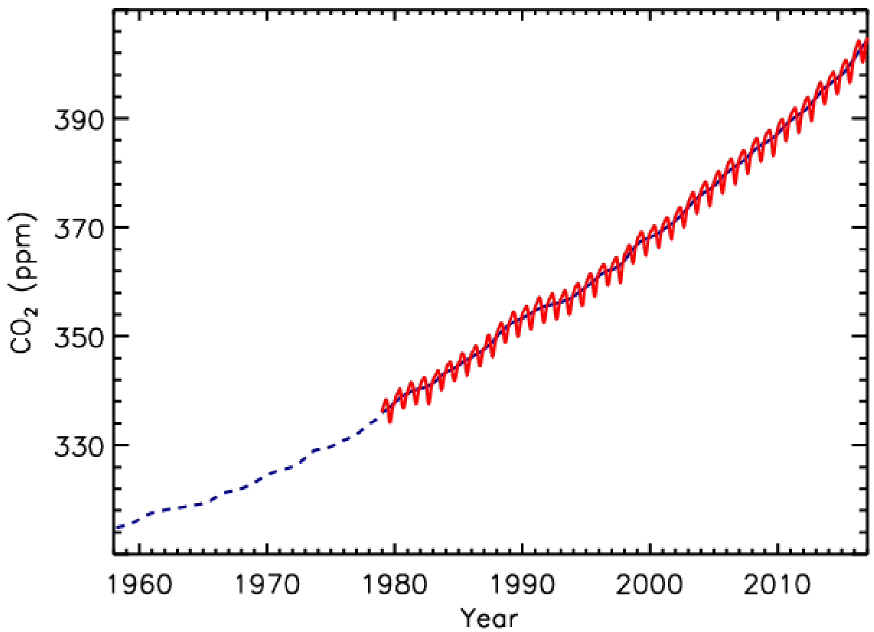
Accomplishments

Measurements from 2016 show that carbon dioxide (CO_2) and methane (CH_4) global abundances continue to increase at record levels. The year 2016 saw the second largest annual increase in global CO_2 (2.98 ppm/yr) since the beginning of the measurement record in 1959—second only to 2015 (3.03 ppm/yr in 2015). This is presented on the web at http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html.

Atmospheric CH_4 has been on the rise since 2007 after a period of leveling off between 1999 and 2006. The annual increase in global mean CH_4 was 7.74 ppb /yr in 2016 which is slightly above the average annual increase of the past 10 years (7.03 ppb/yr) but lower than the annual increases in 2014 and 2015.

The NOAA Annual Greenhouse Gas Index details the evolution of the direct impact of different greenhouse gases on global radiative forcing. We updated this in 2017 to include 2016 measurements: http://www.esrl.noaa.gov/gmd/ccgg/aggi.html. We released, for the first time in 2016, a near-real-time CO_2 data product called ObsPack. Quarterly data releases support the near-real time comparison with other measurements, as well as the near-real time evaluation of satellite products and carbon cycle forward and inverse models. All ObsPack data packages are accessible from: https://www.esrl.noaa.gov/gmd/ccgg/obspack/data.php.

All calibrated measurement records produced by our group are publicly available. Our visualization tools and regularly updated measurement and model analysis products provide additional information and interpretation of the observation.



GMD-04: Globally averaged CO_2 monthly mean dry air mole fraction (red). The 1979-2016 record is based on globally distributed measurements from NOAA's Global Monitoring Division. Prior to 1979, we show an average of Scripps Institution of Oceanography measurements at Mauna Loa, Hawaii, and the South Pole, with no correction, to estimate a global mean. The dashed blue curve shows a deseasonalized fit through the data. Image: Ed Dlugokencky/NOAA

PSD-20: Stochastic and Scale-award Parameterizations Informed by Observations

■ CIRES Lead: Prashant Sardeshmukh ■ NOAA Lead: Cecila Penland
NOAA Theme: Science and Technology enterprise

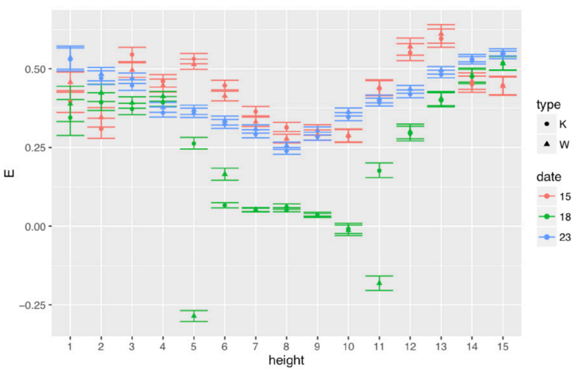
Goals & Objective

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

Accomplishments

Ensemble prediction systems are essential for effective probabilistic weather and climate prediction. For robust decision making using such systems, an accurate accounting of uncertainties in both the forecast model and the observations used to initialize the model forecasts is critical. Our project focuses on the uncertainties in representing physical processes in atmospheric models. This uncertainty has two components: one directly related to the uncertainty in the model parameterizations of unresolved physical processes, and the other to the cascade to large scales of the local physical uncertainties by the flow dynamics.

We are developing a method that is more general and suitable for accounting for the model physics uncertainty than those currently used at major operational weather prediction centers. It is underpinned by a physically based stochastic differential equation that can efficiently generate the stochastically generated skew (SGS) probability distribution that is commonly seen in the statistics of atmospheric variables (Sardeshmukh, Compo, and Penland 2015 *Journal of Climate*). This method gives us the ability to represent the non-Gaussian aspects of the ensemble forecast probability distributions.



PSD-20: Estimated values of the tail-heaviness parameter E of the probability distribution of small-scale vertical velocities in stratiform cloud decks in the eastern Pacific Ocean on 15, 18, and 23 Nov 2008. Two different methods of data processing, labeled "K" and "W," yielded similar results. Height is measured in "gates," with Gate 1 indicating the top of the cloud and subsequent gates spaced at constant height (50m) intervals from that height. It was found that the height of the cloud top varied by as much as 400m, indicating that E depends on local physical conditions rather than absolute height. Image: C. Penland, C.R. Williams, A. Koepke, P. D. Sardeshmukh/CIRES

Our approach is to base the parameterizations on direct measurements of the appropriate variables. For example, precipitation is closely related to tropospheric vertical velocity. Thus, one aspect of our project has been the detailed examination of the turbulent vertical wind distributions from radar data taken at Darwin, Australia, and from a ship in the tropical East Pacific Ocean, the so-called VOCALS data set. Our instruments require clouds to register data, and we measure height from the top of the cloud. Our data were coarse-grained into time series at a sampling interval of one minute, and the SGS distribution was fitted to the resulting time series. The SGS distribution has three parameters, one of which (E) describes the fatness of the tails relative to that of a normal (Gaussian) probability distribution. Our other parameters are related to the variance and skewness of the distribution.

We obtained consistent results for turbulent vertical wind in the absence of a strong mean component, i.e., in the absence of strong convection. In all physical situations of this type, we found that the parameter E, indicating the probability of extreme kinetic energy events, was strongest toward the top and bottom of the cloud, and weakest in the center. This effect is shown for three days in November 2008 in the figure.

PSD-22: Predictive Understanding of Tropical-Extratropical Coupling, Moisture Transport and Heavy Precipitation

■ CIRES Lead: Darren Jackson ■ NOAA Lead: George Kiladis
NOAA Theme: Science and Technology Enterprise

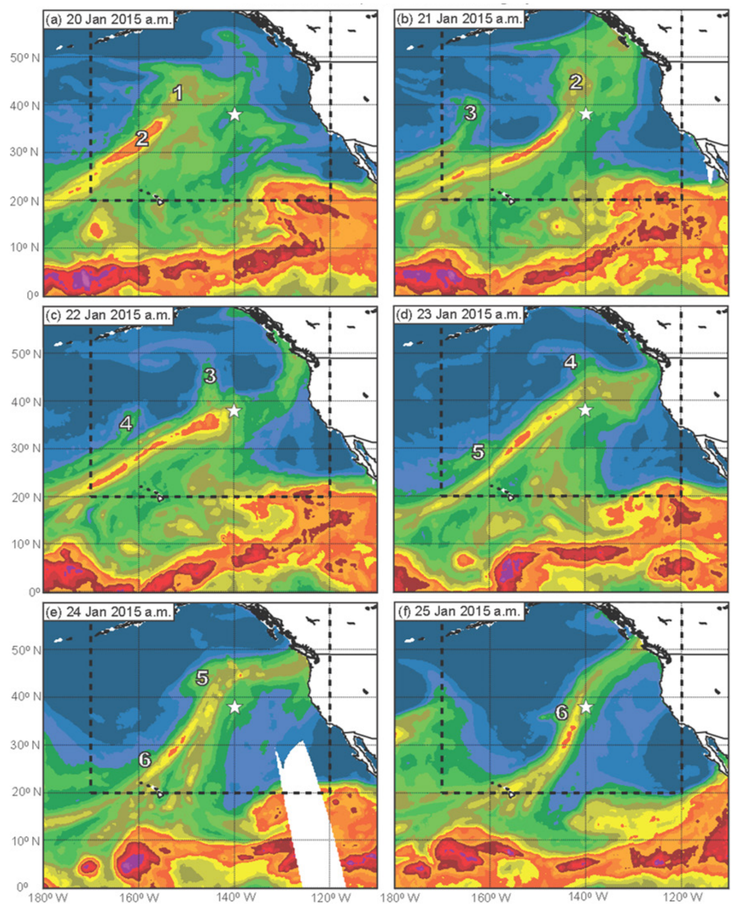
Goals & Objective

This project will better characterize heavy precipitation events by using observations to improve process understanding and will evaluate heavy precipitation distributions and forecasts in weather and climate models.

Accomplishments

We conducted process studies of atmospheric rivers (AR) along the U.S. West Coast using a diverse set of observations and modelling techniques. The team's CalWater 2015 field program produced a unique set of observations from ship, aircraft, and land to conduct these process studies. A diagnostic study of a British Columbia AR landfall associated with heavy precipitation during the CalWater 2015 field campaign revealed the kinematic and thermodynamic structure of a long-lived AR that resulted in heavy precipitation in British Columbia. We integrated profile information from rawinsondes and dropsondes, radar observations from ship and aircraft, and surface sensible and latent heat flux observations from the ship in this study to develop a detailed description of processes associated with an AR.

We identified six transient frontal waves along the AR and the evolution of the AR structure and precipitation, described in a journal article that has been accepted for publication. In a separate AR study examining precipitation processes along the U.S. West Coast, we took aerosol observations along the coast of central California, which show an unexpected local source of ice nucleating particles (INP) contributing to precipitation along the coastal mountains during an wintertime AR event. These results highlight the need to examine both water vapor transport and aerosol contributions to precipitation processes along the West Coast.



PSD-22: (a) – (f) Composite SSMIS satellite imagery of integrated water vapor constructed from polar-orbiting swaths between 0000 and 1159 UTC on 20-25 January 2015. The dashed box in each panel shows the main region of interest for the study. Bold numbers mark the six frontal waves along the atmospheric river; the white star denotes the position of the NOAA *Ron H Brown*. Image: NOAA ESRL Physical Sciences Division

We conducted model simulations using three climate models to investigate how the El Niño/Southern Oscillation (ENSO) impacts precipitation along the U.S. West Coast. Simulations conducted for a 34-year period (1979-2013) examined atmospheric circulation and precipitation patterns based on various ENSO states (El Niño, La Niña, neutral, all). Our results showed that precipitation and atmospheric circulation patterns remained similar for these different ENSO states, but wetter years have a greater frequency of precipitation days than drier years. We found these wetter years were associated with El Niño.

PSD-23: Lead the Planning and Execution of Large-Scale National and International, Multi-Institutional Field Campaigns to Observe and Understand the Coupled Behavior of the Atmosphere Over Land, Oceans, Ice, and Snow

■ CIRES Lead: Matt Newman ■ NOAA Lead: Allen White

NOAA Theme: Science and Technology Enterprise

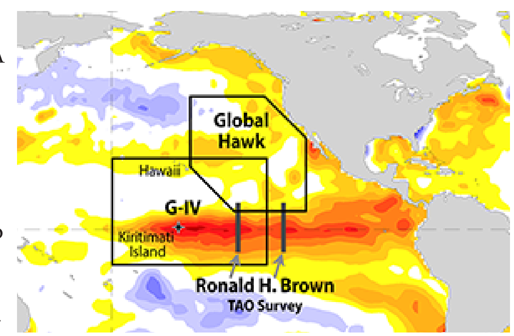
Goals & Objective

This project specifically addresses regional climate predictions.

Accomplishments

We conducted two major field programs under this project: the El Niño Rapid Response Experiment (ENRR) and the Southern Ocean Seagoing Air-Sea Flux System deployment as part of the CAPRICORN project (Clouds, Aerosols, Precipitation and Atmospheric Composition Over the Southern Ocean). More information can be found at https://www.esrl.noaa.gov/psd/news/2016/020516.html and https://www.esrl.noaa.gov/psd/news/2016/042516.html.

For ENRR, PSD was involved in observations from many places and platforms: Christmas Island, the NOAA research vessel *Ronald H. Brown*, the NOAA G-IV aircraft, and NASA's Global Hawk aircraft. The goal of ENRR was to capture observations of tropical convection and coupling to mid-latitudes during the strong El Niño in the winter of 2015-2016. ENRR data are available in the PSD archive. We have just started research on the observations, but a few papers have been submitted including an overview to the



PSD-23: Mission map for the ENRR project. Image: Ryan Spackman/NOAA.

Bulletin of the American Meteorological Society (Dole et al., Advancing Science and Services during the 2015-16 El Niño: The NOAA El Niño Rapid Response Field Campaign).

For the Southern Ocean study, we installed NOAA's seagoing Air-Sea Flux System on a new research vessel, the research vessel Investigator, operated by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). We are collaborating with CSIRO and scientists from the Australian Bureau of Meteorology to investigate the interaction of air-sea fluxes and boundary layer clouds, which will help expand the very sparse database of measurements in the Southern Ocean. The cruise was south of Hobart, New Zealand from March 12 - April 20, 2016. The PSD flux system operated at full efficiency; data are available at ftp://ftp1.esrl.noaa.gov/psd3/cruises/CAPRICORN_2016/Investigator/flux/. The CAPRICORN project added significantly to our limited inventory of direct flux observations at high latitudes.

PSD-24: Enhancing Predictability of Weather and Climate Extremes

■ CIRES Lead: Judith Perlwitz ■ NOAA Lead: Martin Hoerling

NOAA Theme: Science and Technology Enterprise

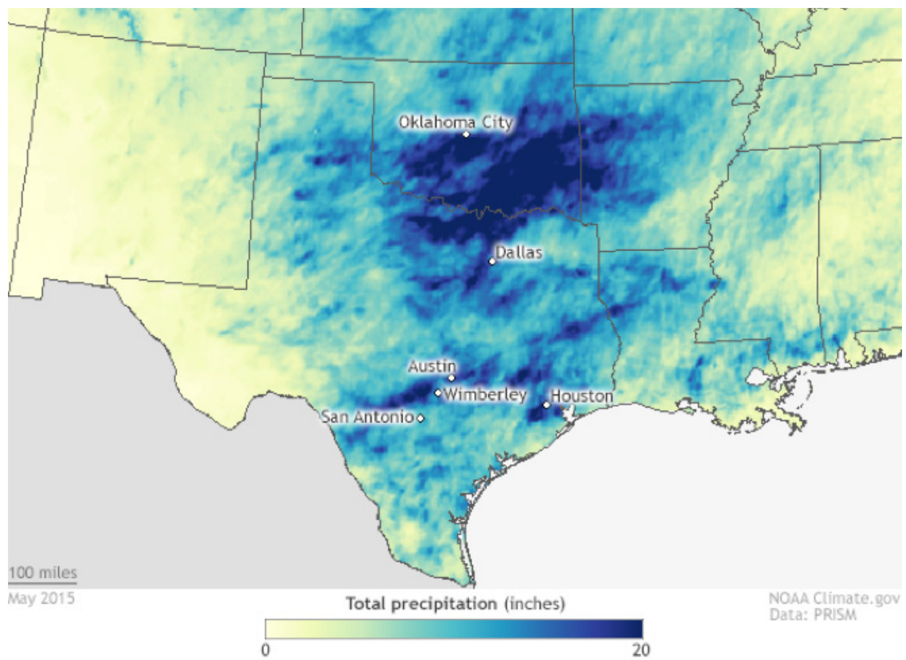
Goals & Objective

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

Accomplishments

Our team conducted several studies during the reporting period related to the attribution of extreme events. They include:

1. A paper on diagnosing human-induced dynamic and thermodynamic drivers of extreme rainfall, such as the one that triggered the May 2015 floods over Texas and Oklahoma (Cheng et al., submitted to *J. Climate*).
2. A study on how austral summer southern Africa precipitation extremes are forced by the El Niño-Southern Oscillation and the subtropical Indian ocean dipole (SIOD) southern Africa extremes. Model results show that the probability of extreme wet seasons is greatly increased during La Niña, especially when combined with a positive SIOD and greatly decreases during El Niño regardless of SIOD phasing (Hoell et al., submitted to *Climate Dynamics*).
3. A study on the linkage between the failed winter rains over Southern California and the strong El Niño during 2015/16. Our analysis using large ensembles of model simulations reveals that the December-February 2016 winter dryness was not a response to global boundary forcings nor was the extreme magnitude of observed 1998 wetness entirely reconcilable with a boundary-forced signal (Zhang et al., submitted *J. Climate*).
4. A study on the physical explanations for the unprecedented warm equatorial Pacific Ocean temperatures during El Niño 2015/16. Our results reveal that this record warm event appeared to reflect an anthropogenically-forced trend; whether they reflect changes in El Niño variability remains uncertain. (Newman et al., submitted to *Bulletin of the American Meteorological Society*, Special Issue on Explaining Extreme Events of 2016).
5. A study on the causes of the Record-Breaking U.S. Mid-Atlantic Snowstorm "Jonas." We found that over the last century, extreme Mid-Atlantic snowstorms like Jonas have become more frequent. In contrast, model simulations suggest that anthropogenic climate change has made such storms less likely. (Wolter et al, submitted to *Bulletin of the American Meteorological Society*, Special Issue on Explaining Extreme Event of 2016)
6. A study on Extreme California Rains During Winter 2015-16 and related teleconnections. We found that the failure of heavy rains in Southern California during the strong El Niño of 2016, compared to the flooding rains of 1983, does not constitute a climate change effect. (Quan et al., submitted to *Bulletin of the American Meteorological Society*, Special Issue on Explaining Extreme Event of 2016)
7. Research on the relationship between droughts and heatwaves: We developed a conditional framework to assess whether there are detectable anthropogenic forced changes in the coupling strength between drought and heat wave.



PSD-24: Total rainfall across the Southern Plains in May 2015. Image: NOAA Climate.gov and PRISM climate group at Oregon State University

PSD-26: Next Generation Global Prediction System

■ CIRES Lead: Phil Pegion ■ NOAA Lead: Jeff Whitker

NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project supports the objective of an integrated environmental modeling system by enhancing the predictive accuracy of earth system models through better use of observations (through data assimilation), improved modeling, and reliable forecast products (through post-processing).

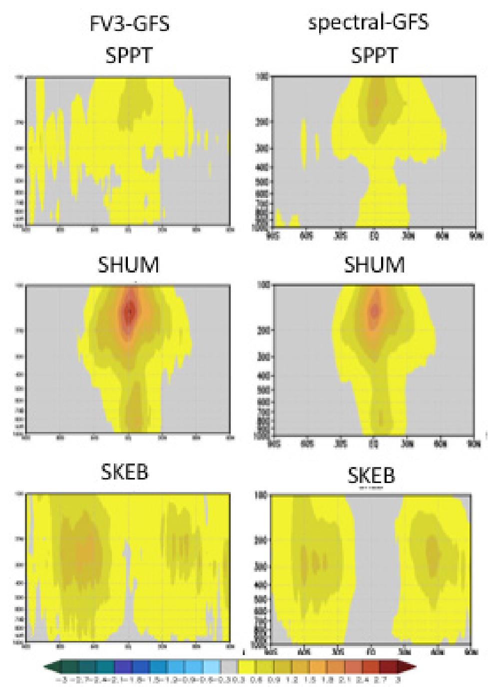
Accomplishments

We completed the dynamical core selection process in August, 2016 with the release of the final report, available at https://www.weather.gov/media/sti/nggps/NGGPS%20Dycore%20Phase%202%20Test%20Report%20website.pdf. Our report recommended the selection of Geophysical Fluid Dynamics Laboratory's (GFDL) Finite Volume Cubed-Sphere (FV3) Dynamical Core to replace the current spectral dynamical core that is in the Global Forecast System (GFS). A few months later, GFDL released the model code that contains the FV3 dynamical core integrated with the GFS physics suite. This model is referred to as the FV3-GFS.

Since the release of the FV3-GFS, we focused our work on porting the GFS stochastic physics suite, which operates in spectral space, to work on the FV3 grid (a cubed sphere). The initial port was just for the two simpler stochastic physics schemes: Stochastically Perturbed Physics Tendencies and stochastically perturbed boundary layer humidities. We tested the performance of these two schemes in cycled data assimilation and medium range forecasts. After determining the performance of these two schemes met expectations, we focused on the more complicated scheme, Stochastic Kinetic Energy Backscatter, which requires an estimate the amount of kinetic energy dissipated by the dynamical core, and passing this to the physics along with a 3-dimensional quasi-random pattern.

NCEP incorporated the FV3-GFS model into the NOAA Environmental Modeling System (NEMS) framework in March of 2017 and the stochastic physics suite was ported to the NEMS based FV3-GFS shortly thereafter. The model's sensitivity to the stochastic physics in medium range forecasts (figure) is similar to the old GFS model, but there are enough differences that tuning will be need to optimize the model's performance. We delivered the implementation of all three schemes to The National Centers for Environmental Prediction in the spring of 2017 for further testing and tuning.

Since the NEMS based FV3-GFS will replace the aging spectral model, the next generation of reanalysis and reforecasts should also use the new model. In order to proceed with this new model, and work out any bugs, we have started a low-resolution 'scout' reanalysis and reforecasts. The purpose of a scout run is to make sure all of the machinery for producing a reanalysis and reforecast is in place and working properly before switching to production with the full resolution system, which will use tremendous amounts of computing resources.



PSD-26: Zonal average of change in ensemble spread of zonal wind [m/s] for 20-member ensembles valid for 120-hour forecasts. Left column is from experiments with FV3-GFS and right column is experiments with the old spectral GFS. Top row shows the change in ensemble spread from SPPT, middle row is for SHUM, and bottom row if for the SKEB. Changes in ensemble spread are relative to ensemble forecasts with no stochastic physics. Results are average over forecasts in August 2014 (31 forecast for GFS, 7 forecasts for FV3-GFS). Image: CIRES/NOAA

Management and Exploitation of Geophysical Data

NCEI-01: Enhancing Data Management Systems and Web-Based Data Access

■ CIRES Lead: David Neufeld ■ NOAA Lead: Drew Saunders

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

In the 2016-17 reporting period, our software development teams supported projects for the Center for Coasts, Oceans, and Geophysics, an Enterprise Security and Remediation Advancement project, and a new OneStop data discovery initiative. The Center for Coasts, Oceans, and Geophysics efforts resulted in the deployment of a Satellite Product Analysis and Distribution Enterprise System, simplified the process of adding trusted nodes and ability to extract data for the Crowd-Sourced Bathymetry project, and supported the ingest and long-term archiving of data for the U.S. Extended Continental Shelf project.

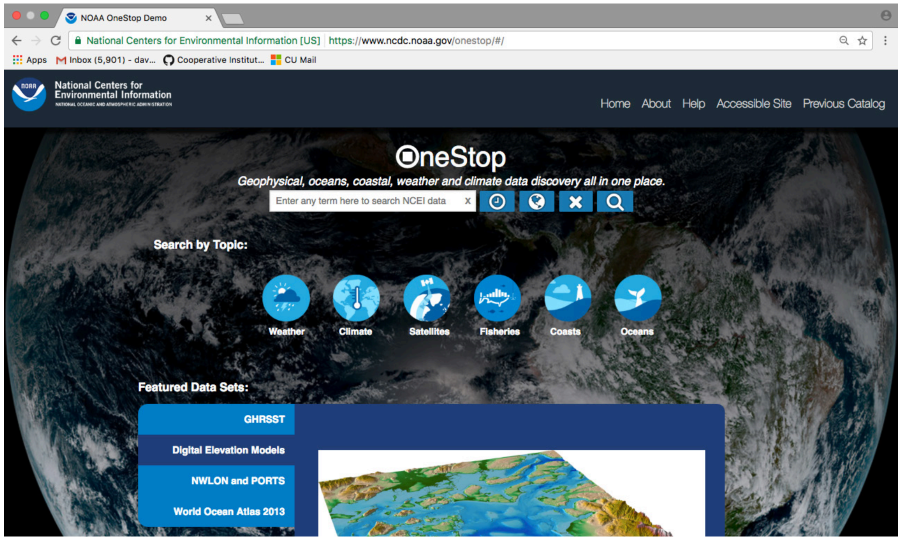
For the ESRA project, our team focused on planning and designing a new demilitarized zone of the network, migrating from HTTP to secure HTTPS, migrating applications from Java 7 to Java 8, and testing and moving software off of RedHat Enterprise Linux 5 to RHEL 7 (which is a more up-to-date and secure version of the Linux operating system). We made a number of infrastructure improvements to update our development infrastructure, incorporating current versions of build and repository services. ESRA also took part in the adoption of Ansible, a software technology to streamline configuration and deployment to enhance the process of getting new software into production.

Security scanning and review became part of our standard deployment process and a number of network configuration changes were requested to provide access to the NCEI security scanning tools. The OneStop project provides a search-and-discovery portal for all of the National Environmental Satellite, Data, and Information Service and may be expanded to support all of NOAA. Our team designed and implemented a flexible architecture spanning a data-ingest back-end API up through a front-end client facilitating data research, discovery, and access. More specifically this entailed: A Groovy/Gradle ETL process for pulling data from multiple sources and optionally writing either to local storage or an ElasticSearch index; an ElasticSearch Index updated and defined via an application interface; a Spring Boot Groovy JSON-API-inspired application designed to be flexible in its support of both NOAA clients as well as external partner client applications; and a React/Redux front-end with consistent data flow for highly controllable data search and discovery. OneStop's user interface relies on high quality metadata—NCEI's Enterprise Metadata Management Architecture (EMMA) supports complete documentation to describe NOAA's science data.

Our EMMA team was the first cross-location software development team in NCEI. The team's efforts resulted in a refactor of all EMMA applications for migration to the secure servers at NCEI-North Carolina—which achieved another first: a high-speed connection from web servers in North Carolina to database servers in Colorado over the NOAA N-Wave enterprise network.

A key component of EMMA is the Chameleon Editor for easily configurable and standards-independent metadata editing. This application is being given extended capabilities, flexible branding, and APIs to provide NOAA OneStop with superior metadata allowing the new Search GUI to provide relevant results and improved documentation for the public of the thousands of dataset collections we archive.

A common theme across the software development teams is a focus on delivering robust, high quality solutions that support NCEI's enterprise systems. The Geographic Information Systems team developed/enhanced geospatial web services and interactive maps to improve data discovery and access for NCEI. A new set of services provides visualization and access to bathymetric data from the multibeam archive. We made enhancements to the Water Column Sonar, Natural Hazards, and Bathymetric Data Viewers. Our groups created new maps and services to support the Passive Acoustic Data Archive, North Atlantic Seabed International Working Group, Defense Meteorological Satellite Program Nighttime Lights products, the Earth Magnetic Anomaly Grid geomagnetic model, and a prototype NCEI Arctic Portal.



NCEI-01: Landing page for the OneStop data discovery portal developed, tested, and released by the software development team for NCEI. Image: NOAA/NCEI

NCEI-02: Enhancing Marine Geophysical Data Stewardship

■ CIRES Lead: Carrie Bell ■ NOAA Lead: Jennifer Jencks
NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

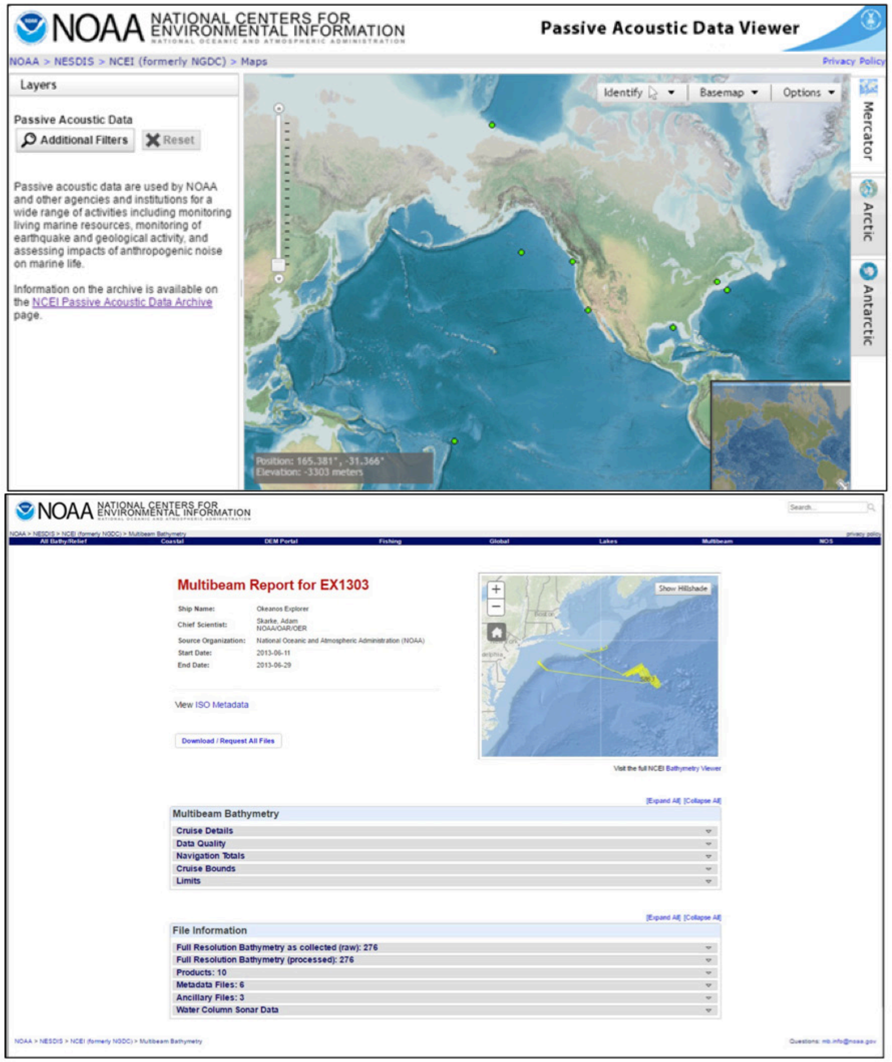
Both national and international organizations contribute to and retrieve marine geophysical and geological data from our National Centers for Environmental Information (NCEI) interactive databases. We provide long-term archiving, stewardship, and delivery of data to scientists and the public by utilizing standards-compliant metadata, spatially enabled databases, robotic tape archive, and standards-based web services. Since June 2016, we have added 72 multibeam swath sonar surveys (166,619 nautical miles) and 152 trackline (single-beam bathymetry, magnetics, gravity, subbottom, and seismic reflection) surveys (665,729 nautical miles) conducted throughout the world's oceans to NCEI's global marine geophysical archives.

We have expanded the water column sonar data archive to over 33 terabytes of data, and made improvements to the functionality and performance of the project's data access web page (https://maps.ngdc.noaa.gov/viewers/water_column_sonar/) to enable researchers and the public to query, discover, and request these data. As a result, we have delivered over 20 TB of data to the public. We developed and integrated visualization imagery to illustrate complex sonar data in a single image into the web page to assist users in understanding the quality and content of the data before submitting data requests.

The development of a passive acoustic archive has progressed through the support of a NOAA Big Earth Data Initiative (BEDI) project. We have developed a pipeline to transfer data from the data provider to the archive and then to the public through a new web-based data access page (https://maps.ngdc.noaa.gov/viewers/passive_acoustic/; figure).

Our marine geophysical data support multiple ongoing U.S. mapping efforts, such as the Integrated Ocean and Coastal Mapping (IOCM) program and the International Hydrographic Organization's (IHO) Crowdsourced Bathymetry (CSB) initiative.

The CSB project, championed by the IHO and funded by NOAA's Office of Coast Survey, sets out to empower mariners to "map the gaps" within the current ocean floor coverage. NCEI-CO and CIRES software development and GIS staff successfully completed a 3-month effort to harden and improve the current data ingest pipeline for crowdsourced bathymetry data. Data providers can submit xyz, csv, or geoJson formats for automated ingest, and other formats are ingested with minimal code changes. Like most datasets at



NCEI-02: New web-based data access page for passive acoustic data archived at NCEI (top), and improved data access page for the multibeam bathymetry archive at NCEI (bottom). Image: CIRES/NOAA

NCEI-CO, users can discover, filter, and access CSB data via a map viewer (https://maps.ngdc.noaa.gov/viewers/csb/).

We developed new HTML database access pages for the multibeam bathymetry archive (figure 2) to replace the outdated and unsupported interface database pages, and which are more functional and visually pleasing. Important information—like cruise metadata, ArcGIS map showing the cruise track, and download links for all the data files—are displayed for users to easily access. Most importantly, there is now a direct link to NCEI's extract system that allows users to asynchronously request all files from the cruise with a single click. This functionality resolves a previously identified security issue and ends a two-year gap in service.

NCEI-03: Improved Geomagnetic Data Integration and Earth Reference Models

■ CIRES Lead: Arnaud Chulliat ■ NOAA Lead: Rob Redmon

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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 completed a major update of the Earth Magnetic Anomaly Grid at 2-arcmin resolution (EMAG2). EMAG2 is a global compilation of regional magnetic anomaly grids and marine and airborne magnetic data archived at NOAA/NCEI. We leveled data in different areas using a satellite-based, spherical harmonic representation of the large-scale crustal magnetic field. In this new release, we included more data in the grid, and improved the large spatial scales through a revised processing. EMAG2 is used by the public in a wide range of applications, from research into the geological and tectonic evolution of the lithosphere, to resource exploration and science education.

While EMAG2 depicts the total field (scalar) magnitude of the Earth's magnetic field, some applications such as accuracy-sensitive navigation and directional drilling require knowledge of the field direction and not just its absolute value. We addressed this need with the Enhanced Magnetic Model (EMM), which combines a high-resolution crustal magnetic field model inferred from EMAG2 and a core field model inferred from satellite measurements collected by the European Swarm constellation. Over the past year, we developed new algorithms to invert EMAG2 and Swarm data, and updated the EMM with the most recent grid and satellite data available.

Unlike geomagnetic sources in the solid Earth, magnetic sources in the atmosphere and near-Earth space vary rapidly and are strongly affected by space weather. NOAA's High Definition Geomagnetic Model–Real Time (HDGM-RT) provides real-time estimates of external magnetic fields derived from measurements by Swarm satellites, ground-based magnetic observatories, and the Deep Space Climate Observatory (DSCOVR). Over the past year, our new model describing variations caused by ionospheric currents at mid- and low-latitudes was added to HDGM-RT, resulting in smaller errors at these locations. We also updated both HDGM-RT and its non-real-time version (HDGM) to 2017 using the latest Swarm data. HDGM models are used by well planners to compute magnetic reference values, and they contribute to mitigating the health, safety, and environmental risks of directional drilling.

The our team also conducted research on electric currents and magnetic fields in the ionosphere, ocean-induced magnetic fields, and the global electrical structure of the upper mantle.

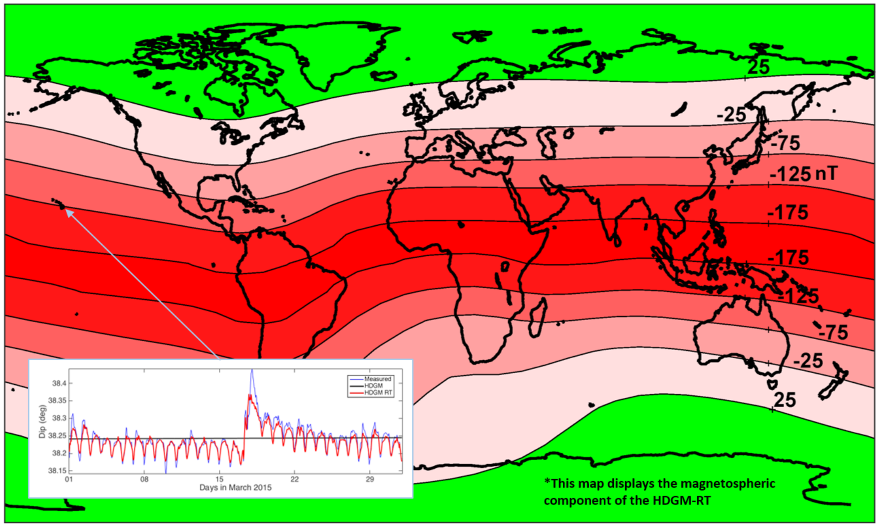
NCEI-04: Enhanced Coastal Data Services, Integration, and Modeling

■ CIRES Lead: Kelly Stroker ■ NOAA Lead: Emily Rose

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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



NCEI-03: HDGM-RT map of total field (F) disturbance, and magnetic dip disturbance at Honolulu observatory during a large geomagnetic storm in March 2015. Image: National Centers for Environmental Information

NCEI-07: Earth Observation Group, NOAA National Centers for Environmental Information

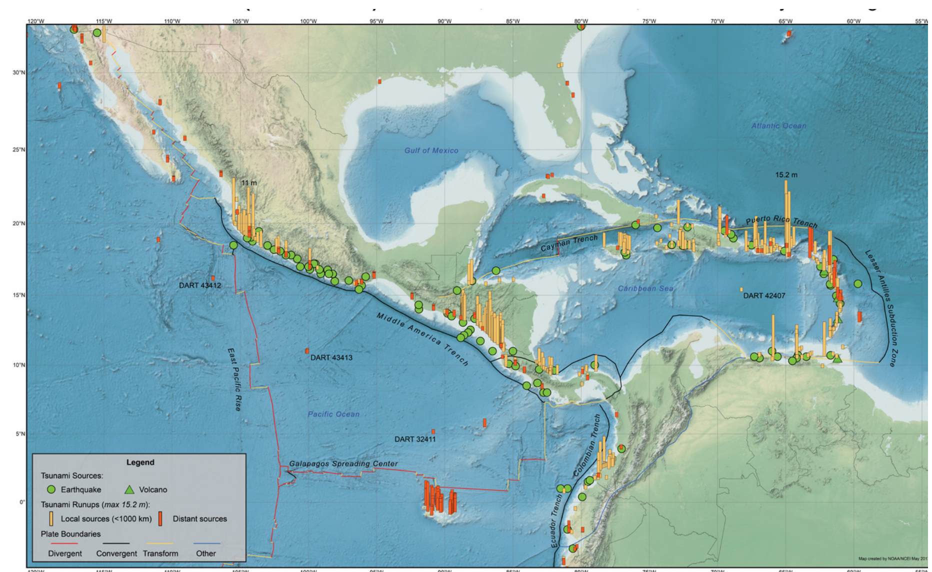
can be integrated into hazard assessments and coastal elevation models at local, regional, national, and global scales.

Accomplishments

Our team continues to update and maintain the Historical Natural Hazards Event Database throughout the year based on new references and new field studies. At the request of the NOAA National Weather Service's International Tsunami Information Center (ITIC), we prepared a qualitative tsunami hazard review for American Samoa, Samoa and Tonga as well as for the Caribbean, Central America, Mexico, and adjacent regions. As an authoritative voice in historical tsunamis, CIRES team members, through NCEI, were invited to participate as trainers at the 2016 ITIC Training Programme (ITP-Hawaii) and provided training on the end-to-end tsunami warning chain, emphasizing decision-making using the Pacific Tsunami Warning Center (PTWC) Enhanced Forecast Products. We also developed historical tsunami source maps for sub-regions in the Pacific to support the Pacific Tsunami Warning and Mitigation System (PTWS) Pacific Wave Exercise 2017 and updated global source maps that continue to be requested as educational and training tools.

Building digital elevation models (DEMs) for the National Tsunami Warning Centers and the National Tsunami Hazard Mitigation Program (NTHMP) continues to be a priority task for our NCEI team. This year, we developed six new digital elevation models (DEMs) in support of NOAA's Tsunami Program and five new DEMs to support the National Tsunami Hazard Mitigation Program. We built a DEM for Grenada to support modeling tsunami generation, propagation, and inundation and in support of a Tsunami Ready pilot project in Grenada funded by NOAA and the U.S. Agency for International Development's Office of U.S. Foreign Disaster Assistance.

During 2016-2017, we began work to meet the requirements of the COASTAL Act (Consumer Option for an Alternative System to Allocate Losses) Capabilities Development Plan.



NCEI-04: CIRES, NCEI, and co-located World Data Service for Geophysics and the International Tsunami Information Center (a United Nations/NOAA partnership) have collaborated to produce a map showing the tsunami hazard for Caribbean, Central America, Mexico, and Adjacent Regions. Image: CIRES and NOAA

We identified and evaluated coastal elevation datasets, including source data, and created a DEM gap analysis report that assessed the quality of existing data and identified areas lacking DEM coverage based on both the spatial and temporal considerations. The comparison of existing modern DEMs with up-to-date available source topographic and bathymetric data helped us to inform the process of determining area(s) of interest for proposed DEM development.

We archived nearly 3.25 TB of coastal lidar data between June 2016 and May 2017. Noteworthy data submissions include post-Hurricane Matthew topographic-bathymetric lidar for an area of the U.S. Atlantic Coast stretching from southern Florida to North Carolina, as well as multiple lidar acquisitions collected for Puerto Rico between 2015-16. We will integrate these data into digital elevation models planned for FY18.

Our group continues to ingest, process, archive, and disseminate tide gauge data and deep ocean-bottom pressure recorder data from several NOAA centers. The DART (Deep-ocean Assessment and Reporting of Tsunamis) data inventory timeline we introduced in 2016 has identified gaps in data coverage and prompted our data provider to rescue and submit several data packages that has resulted in the protection of an additional five million dollars of initial investment. In 2017, we greatly improved user discovery of tide gauge data and products through a visual timeline inventory, with links to station pages, including time-series plots and data access links. We overlaid dates and heights of reported tsunami events, as recorded in the Historical Natural Hazards Events Database, on the timelines to help with tsunami-focused data discovery. Our staff continue improving the technology for processing diverse high-resolution water-level observations to isolate tsunami and other extreme event signals. We implemented a new tidal analysis code to process complex trends and added to the processing pipeline tide gauge stations from the regional networks of the two tsunami warning centers.

NCEI-05: The ionosonde field site at Cayey Puerto Rico. Photo: Justin Mabie/ CIRES

NCEI-05: Enhanced Stewardship of Space Weather Data

■ CIRES Lead: Justin Mabie ■ NOAA Lead: William Denig

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

Accomplishments

Management of historical analog data was transferred to the NCEI archive branch, however we still provide the scientific expertise to assist in data management. We conducted a reboxing effort of all data stored in the dry storage at the NCEI warehouse in Boulder, Colorado; an important step in being able to locate data and eventually move the data to a permanent storage facility. We have continued to successfully disseminate ionosonde data despite difficulties that have arisen due to IT security needs.

The Mid-Atlantic Regional Space Port has resumed operations and we made observations of acoustic waves produced by an ISS resupply rocket. We published a paper in *Geophysical Review Letters* demonstrating the capability to observe rocket-generated acoustic waves at high altitudes.

We have continued field site maintenance at Boulder, Colorado; Wallops, Virginia; and Cayey, Puerto Rico.

NCEI-07: Remote Sensing of Anthropogenic Signals

■ CIRES Lead: Kimberly Baugh ■ NOAA Lead: Chris Elvidge

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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 CIRES staff collaborated with NOAA scientists to complete development of the first annual global nighttime lights product using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day Night Band (DNB). We made the VIIRS Nighttime Lights (VNL) product using cloud-free, low-moon data from 2015. It's the result of the completion of algorithm development which separates ephemeral from persistent light sources and separates lights from non-light areas. Processing to fill out the VNL time series from 2012-2016 is underway and should be completed by the end of 2017.

We also been refining our VIIRS Boat Detection (VBD) algorithm to reduce false detections that occur due to the South Atlantic Anomaly, aurora, and atmospheric glow. The current version (v2.3) of VBD is now running globally and our effort is underway to process this version back to the start of the VIIRS data record in 2012. The long time series has allowed special studies quantifying the effectiveness of fishery closures in the Philippines using an index developed at NCEI called the VBD Closure Index or VCI. The VCI rates the effectiveness of fishery closures by comparing boat detection numbers within the closure boundaries before and after the start date of the closure. Numbers range from -100 to 100, with 100 signifying total closure effectiveness.

Our team also put out global estimates for flared gas volumes by country for 2016. We updated flare locations using the VIIRS Nightfire product (VNF) for 2016. We used this new set of flare locations, along with the Nightfire-derived radiant heat values, to estimate country-level gas flaring volumes for 2016.

NCEI-08: Launch of the GOES-R satellite aboard a United Launch Alliance Atlas V rocket November 19, 2016 at 6:42 p.m. EST from Cape Canaveral Air Force Station in Florida. Image: NOAA

NCEI-08: Development of Space Environment Data Algorithms and Products

■ CIRES Lead: Juan Rodriguez ■ NOAA Lead: William Denig

NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project will develop the algorithms and products necessary to support use of the GOES-R satellite data for describing space weather with particular attention to damaging solar storms.

Accomplishments

We crossed an important divide this year in our work: the Geostationary Operational Environmental Satellite (GOES)-R was launched on November 19, 2016, and earned its new number, 16, after successfully reaching geostationary orbit. Since then, with real data from NOAA's new space weather instruments on GOES-16, we have put to the test the data processing algorithms and on-orbit calibration-and-validation software that we developed during the last eight years. We have also started to develop mitigation methods for issues with the data that have been identified post-launch. Finally, we have started developing user community interfaces for making the new GOES-16 data conveniently available to the public from NCEI.

We are responsible for four space weather instruments: the Solar Ultraviolet Imager (SUVI), the Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS), the Space Environment In-Situ Suite (SEISS), and the Magnetometer (MAG). Our team had the exciting responsibility of creating first light images that the GOES-R program released to the public in the first few months after launch. For each of the space weather instruments, our instrument scientists successfully briefed a review committee on the status of the instrument and the data processed by the GOES-R ground segment, prior to the data formally being accorded "beta" status. As part of this process, we identified the major data quality issues that need to be resolved before the data can be considered of "provisional" quality suitable for operational use. By May 31, we had submitted nearly 60 formal Algorithm Discrepancy Reports to the GOES-R program identifying data quality issues that need to be fixed, and this process continues.

In parallel with our preparations for evaluating the instruments and their data, we have been developing science algorithms for creating higher-level data products that the NOAA Space Weather Prediction Center (SWPC) will use directly for their real-time operations, as well as the Satellite Product Analysis & Distribution Enterprise System (SPADES) for demonstrating the production of the higher-level data products. This year, we successfully integrated into SPADES the science algorithms that provide continuity of operations for SWPC and delivered this integrated software package to the National Weather Service. These algorithms are currently running on GOES-16 data that NCEI receives in real time, and we are evaluating their outputs.

As part of our development of user community interfaces for the GOES-16 data, we have met with representatives from the Virtual Solar Observatory (VSO) and Helioviewer to discuss collaborative partnerships with these organizations. VSO and Helioviewer are popular data dissemination platforms within the solar physics community that are essential for handling the huge data volume produced by the high-resolution and multi-spectral-channel SUVI imager.

GOES-16 is definitely a work-in-progress, and we will be busy in 2017-18 with the continuation of the above activities, as well as with preparations for the launch and post-launch testing of GOES-S!

NCEI-09: Enhanced Ionosonde Data Access and Stewardship

■ CIRES Lead: Terry Bullett ■ NOAA Lead: Rob Redmon

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

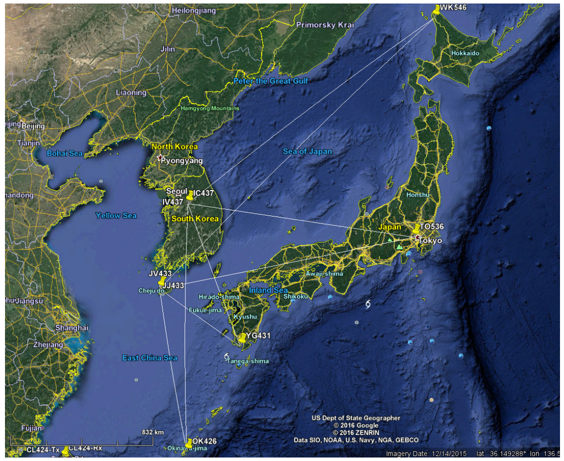
Accomplishments

A key accomplishment of our group was the installation of two oblique ionosonde receivers at South Korean Space Weather Center (KSWC) facilities in Jeju and Icheon. CIRES' Terry Bullet and Justin Mabie installed receivers and operated them in coordination with Japan's National Institute for Communications Technology to make observations between Japan and the Korean Peninsula. These are over-water paths, used where ground based vertical incidence techniques are not possible. We hosted Ph.D. student Dario Sabbagh from from Università degli Studi Roma Tre in Rome, Italy, at NCEI for four months to apply his technique of analyzing oblique propagation data into vertical electron density profiles of the ionosphere. We applied this technique to the data obtained from Korea and Japan.

Mabie and Bullett published a paper on the findings of acoustic waves from an orbital rocket launch which create an ionosphere plasma displacement around 200 km altitude. We used the high-resolution data from the Vertical Incidence Pulsed Ionosphere Radar (VIPIR) at NASA Wallops Flight Facility to detect and measure the acoustic waves.

Our project has provided ionosonde data required to study energy transport from the oceans into space. CIRES principal investigator Nikolay Zabotin has lead the effort to publish these convincing results, with three journal articles on the topic, and one Ph.D. thesis by Catalin Negrea, of CIRES and CU Boulder. We have obtained direct evidence of the correlation of deep ocean wave activity with atmospheric gravity waves in the ionosphere-thermosphere system.

The U.S. Naval Research Laboratory has loaned our project a transportable VIPIR for



NCEI-09: Receiver systems for the Vertical Incidence Pulsed Ionosphere Radar were installed at the Korean Space Weather Center field sites on Jeju Island and Icheon, South Korea. In cooperation with National Institute for Communications Technology in Japan, four Japanese transmitters allow observation of the ionosphere on eight over-water oblique paths connecting the six facilities. Credit: Terry Bullet/CIRES

measuring the solar eclipse of August 2017. This instrument is valued at over $300,000.

We operated a receiver for six months at the Table Mountain Radio Quiet Zone to measure the effects of lightning on the Medium Frequency High Frequency portions of the radio spectrum, and to monitor the ionosphere by changes in long-range radio propagation.

In an increasingly challenging information technology security environment, we were able to obtain and keep 60 real time ionosonde data streams from across the globe and maintain minimal real-time public access to the data archive. Public access has greatly diminished because of security-driven changes and a lack of resources to address these changes. Data access tools such as the Space Physics Interactive Data Resource were hosted off-site, but they are no longer supported and the data are no longer being updated. Changes in internal NCEI computers and policies have produced great stress on this project through loss of computer resources and increasing difficulty to use the remaining resources.

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

■ CIRES Lead: Carrie Morrill ■ NOAA Lead: Eugene Wahl

NOAA Theme: Climate Adaptation and Mitigation

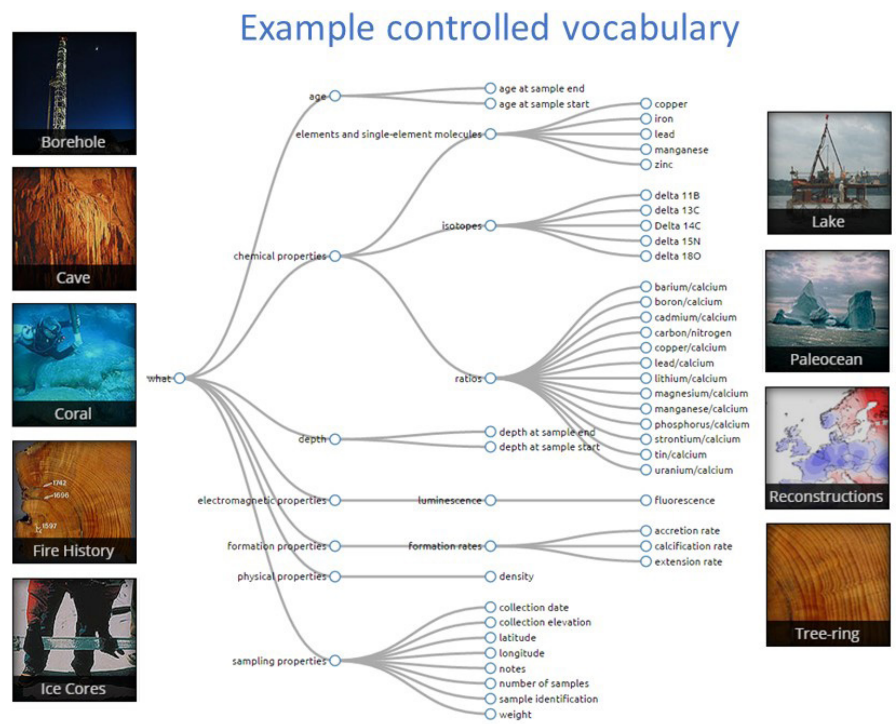
Goals & Objective

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

Accomplishments

We completed version 1 of the Living Blended Drought Product. This product seamlessly blends hydroclimate information inferred from the width of the annual tree rings over the past two millennia with the shorter, but continuously-updated instrumental record. This year, we completed Palmer Modified Drought Index (PMDI) reconstructions for the last two millennia (0 CE – 1978 CE). We contributed this product to NOAA's National Integrated Drought Information Service (NIDIS); integration of the paleoclimate data with the instrumental record will place recent droughts into a longer-term perspective and will enable researchers to understand and predict hydroclimate changes in the continental United States.

We continued progress on a two-year project to create and apply comprehensive controlled vocabularies for describing the measurements we archive as part of the World Data Service for Paleoclimatology. The heterogeneity of paleoclimate variables is one of the



NCEI-11: A subset of the controlled vocabulary terms we are developing, together with the nine data types that will have controlled terms as part of our vocabulary project. Image: CIRES/NOAA

biggest barriers to the development of accumulated data products and access capabilities, and to the use of paleo data beyond the community of paleoclimate specialists. We have now formulated comprehensive vocabularies for the remaining five of nine archive types and are working with subject matter experts to revise and improve them. We have also developed the database structures that will house the vocabulary information. This project will conclude at the end of calendar year 2017, with implementation of a new search-by-variable feature.

Lastly, we submitted two research projects for publication that compare past lake level changes and climate model output to understand the causes of hydroclimate variability. We learned that, for western North America, the same factors that caused past extreme wet periods are projected to cause regional drying under increased greenhouse gas concentrations, indicating continuity from past to future in the mechanisms altering hydroclimate. We also found that the paleoclimate record generally supports hypotheses describing future hydrologic change throughout the Americas.

Project NCEI-12 closed in 2016 due to NOAA reorganization.

NCEI-13: U.S. Extended Continental Shelf Project

■ CIRES Lead: Barry Eakins ■ NOAA Lead: Robin Warnken
NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project will determine and define the extent of the seafloor to which the U.S. has sovereign rights for the purpose of exploring, managing, conserving and/or exploiting the natural resources of the seabed and subsoil.

Accomplishments

The team members of the U.S. Extended Continental Shelf (ECS) Project Office had several major accomplishments this year: we refined geospatial analysis methods, developed a GIS database and workflow for cartographic production, and finalized cartographic-element stylesheets. We used these procedures to compile the ECS scientific documentation for the Western Gulf of Mexico and Arctic regions, which were reviewed by a panel of international experts. We also refined the overall Table of Contents for the U.S. Submission, and contributed to ECS overview documentation on: (1) methods and approaches to continental shelf delineation; and (2) U.S. legal interpretations of Article 76 of the United Nations Convention on the Law of the Sea.

Specifically, our group refined the geospatial analysis methods that we had developed in previous years, including identifying the base of the slope of the continental margin, and determining the location of the maximum change in gradient at its base. We also developed robust methods for establishing sediment thickness point pairs, developing depth constraint lines, and determining ECS outer limits. Our team developed and implemented an integrated geospatial/cartographic database and schema, as well as a workflow process for creating these cartographic products. The database and workflow processes ensure that ECS cartographic data are handled consistently and efficiently, and that changes are updated on all affected cartographic products. We also developed stylesheets for cartographic elements and templates for cartographic products. The result of this work is common, standardized, and consistent symbology and layouts on maps and figures used in ECS documents.

NCEI-13: Map showing the outer limits of the U.S. continental shelf in the Western Gulf of Mexico region. The 16 points connected by straight lines that comprise the outer limit line are the same as those that form the line of delimitation agreed between the United States and Mexico in the June 9, 2000 treaty. Image: NOAA

NSIDC-03: Approximate September 1850 sea ice extent is illustrated with the blue line, from the data product Gridded Monthly Sea Ice Extent and Concentration, 1850 Onward. Image: Where Ice Once Crushed Ships, Open Water Beckons, by Andrew C. Revkin

We implemented the geospatial analysis methods, database, workflow, stylesheets, and map templates for the Western Gulf of Mexico and Arctic regions. Our group embedded the cartographic outputs into the ECS scientific documentation for these regions, in close collaboration with ECS project colleagues in NOAA, USGS, and the Department of State. A panel of international experts, including current and former members of the Commission on the Limits of the Continental Shelf, reviewed these regional ECS documents.

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

■ CIRES Lead: Florence Fetterer ■ NOAA Lead: Eric Kihn
NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

Accomplishments

Over the reporting period, we made 16 posts to the NOAA@NSIDC data news page (http://nsidc.org/the-drift/data-set/noaa/) informing users about new products or additions or changes to the existing collection of polar region data sets. Because the NOAA program at NSIDC serves about 80 percent of the users that visit NSIDC's site and download data, it is important for us to keep users informed. Some of the year's highlights follow.

Updated NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration: We extended the record through 2016, and completed development work on a parallel data set that will be updated daily.

International Data Rescue Award for Glacier Photograph Collection work: A Council on Library & Information Resources funded project entitled "Revealing Our Melting Past: Rescuing Historical Snow and Ice Data," is allowing us to complete digitization of the archive's store of glacier photographs. This project, lead by CU Libraries archivist Athea Merredyth, won the 2016 International Data Rescue Award in the Geosciences, presented at the AGU Fall Meeting. When digitization is complete, we will add scanned images to the popular online Glacier Photograph Collection. We recently added 1,173 photographs of glaciers in and around the Lake Clark National Park and Preserve in Alaska to this collection.

Satellite data rescue for NOAA: Garrett Campbell, with help from undergraduate students, has rescued early NOAA satellite data from the Environmental Science Services Administration series. Three talks at the 2016 Fall AGU meeting featured this work, leveraging NASA funding: https://nsidc.org/the-drift/data-update/nsidc-working-to-rescue-essa-1-data-as-the-satellite-celebrates-its-50-year-anniversary/. We are now seeking funding to extend the work to include visible and IR band imagery from 1974-1978.

Sea Ice Mass Balance in the Antarctic: This new product uses observations we made t in the fall of 2007 and the spring of 2009 during a drift program of the Nathaniel B. Palmer icebreaker along with a buoy network established on the Antarctic sea ice. We made measurements of ice thickness, temperature profiles, large-scale deformation, and other sea ice characteristics.

Gridded Monthly Sea Ice Extent and Concentration, 1850 Onward: A New York Times article comparing Canadian Archipelago ice conditions during the time of Franklin's expedition with those encountered by the recent Crystal Serenity cruise included a graphic that used of our data from this product: http://www.nytimes.com/2016/09/25/opinion/sunday/where-ice-once-crushed-ships-open-water-beckons.html?_r=0.s

NSIDC-04: Support the activities of the NCEI Arctic Team

■ CIRES Lead: Florence Fetterer ■ NOAA Lead: Eric Kihn
NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project will support NCEI and NOAA's mission in the Arctic by coordinating NCEI broad Arctic observational, modeling, and research data products, and online data services.

Accomplishments

Florence Fetterer participated in numerous NOAA National Centers for Environmental Arctic Team activities, and represented the NCEI Arctic team in ongoing work on climate indicators led by Diane Stanitski at NOAA Earth Systems Research Laboratory.

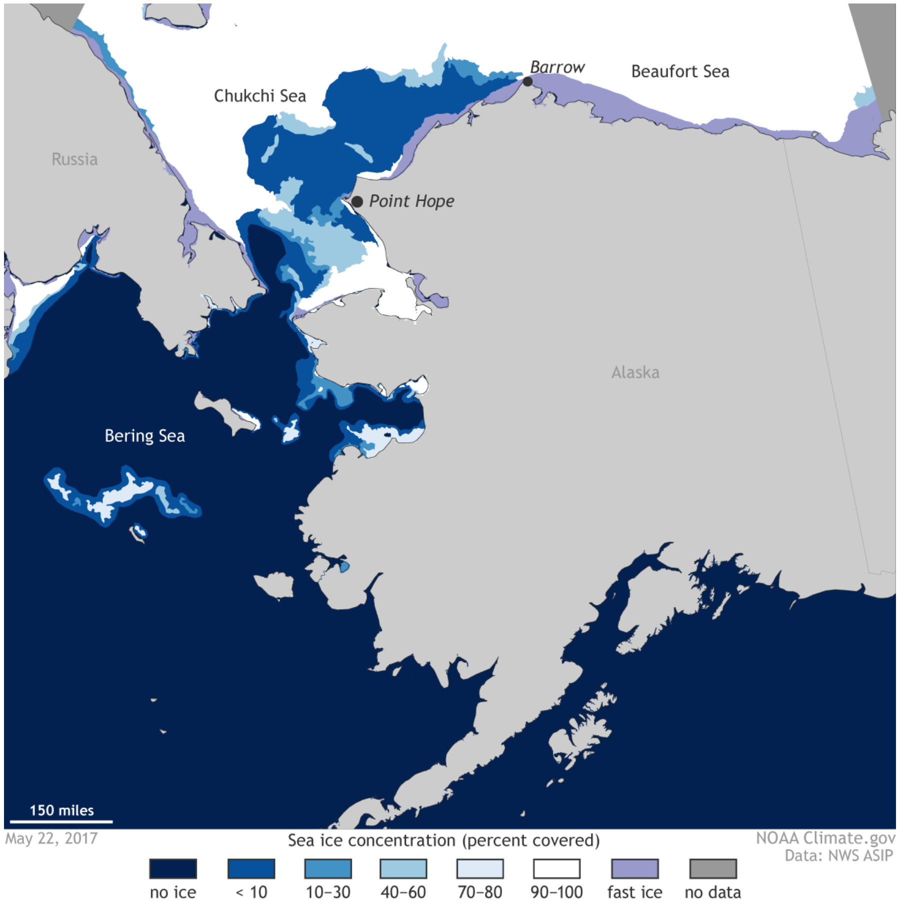
Ann Windnagel met with the NCEI Information Communications and Outreach Branch Chief along with the NCEI Center for Coasts and Ocean Geophysics Information Services Branch, to describe key products like the Sea Ice Index.

Florence Fetterer briefed NOAA Arctic Research Program lead Jeremy Mathis and Sandy Starkweather from the NOAA Climate Program Office, on how we use NOAA support and work with NCEI to build key data products.

We maintain the International Ice Charting Working Group pages (https://nsidc.org/noaa/iicwg/), and have direct ties with the NOAA/Navy/Coast Guard National Ice Center (NIC) and the NOAA National Weather Service Sea Ice Program operational groups. We publish and archive several products in collaboration with NIC.

We provided a custom version of a 4 km sea ice concentration product to the NOAA ESRL experimental sea ice forecasting group focusing on improving short-term predictions.

With NOAA Big Earth Data Initiative support, we provided web services for the Sea Ice Index. One major accomplishment was making the Index map products available in GeoTIFF format. NOAA NCEI collaborators Jennifer Jencks and John Cartwright are assisting with NCEI data portal integration.



NSIDC-04: This NOAA National Weather Service Alaska Sea Ice Program map shows sea ice concentration in percent coverage. It appears in an Arctic Sea Ice News and Analysis post. We are working with the Alaska Sea Ice Program to archive their products. Image: NOAA Climate.gov

Regional Sciences and Applications

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

■ CIRES Lead: Christoph Senff ■ NOAA Lead: Alan Brewer
NOAA Theme: Weather-Ready Nation

CSD-08: CIRES researcher Guillaume Kirgis adjusts the TOPAZ laser system during the California Baseline Ozone Transport Study. Photo: Will VonDauster/NOAA

Goals & Objective

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, our work under this project included studies to investigate transport processes of ozone in California, observe the wind and turbulence structure in the vicinity of wind farms, and improve the performance of the plankton-sensing NOAA Oceanographic Lidar.

We deployed the Tunable Optical Profiler for Aerosol and Ozone (TOPAZ) ozone lidar in late spring and summer 2016 to the San Joaquin Valley as part of the California Baseline Ozone Transport Study (CABOTS) to investigate the influence of trans-boundary ozone on surface air quality in the San Joaquin Valley, one of two "extreme" ozone non-attainment areas remaining in the United States. TOPAZ was located at the Visalia, California, airport and measured the vertical distribution of ozone during two, three-week intensive operating periods in May/June and July/August. We chose the two periods to contrast different ozone photochemical production and transport regimes.

We observed a complex, layered ozone structure above the San Joaquin Valley on most days of the study. These ozone layers aloft were attributed to regional, trans-Pacific, and stratosphere-to-troposphere transport. During the July/August intensive the primary source of ozone aloft was the Soberanes Fire that burned near Monterey, California. In most cases, these ozone layers were located above the top of the shallow (<1 km deep) boundary layer in the San Joaquin Valley and did not get mixed down to the surface. During CABOTS, transported ozone had only a limited impact on San Joaquin Valley surface air quality.

We continued around-the-clock observations of the wind field near wind farms in the Columbia River Gorge using two unattended NOAA Doppler lidars as part of the Second Wind Forecast Improvement Project, WFIP2. To help improve NOAA's wind forecasts, we created two new data products: (1) a measurement uncertainty quantification framework, which was tested using data from previous experiments and was implemented in WFIP2 data processing, and (2) a new method to process the Doppler lidar data to retrieve wind profiles at a 1-km horizontal spacing along the scan direction of the lidar. The latter provides a powerful tool to study the evolution of the wind flow in complex terrain and to validate model forecasts of wind farm wakes.

We updated the NOAA Oceanographic Lidar with new amplifiers and tested a new detector. The new amplifiers have greatly improved the lidar's performance, including better system calibration to allow quantification of chlorophyll concentrations in the Arctic Ocean.

PSD-19: Improving Wind and Extreme Precipitation Forecasting

■ CIRES Lead: Laura Bianco ■ NOAA Lead: Kelly Mahoney

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

Accomplishments

The Wind Forecast Improvement Project 2 (WFIP2) is a multi-institutional program to improve NOAA's short-term weather forecast models and increase understanding of physical processes that affect wind energy generation in regions of complex terrain (Pacific Northwest with a focus on the Columbia River Gorge).

Our project builds on WFIP2 to:

(1) Enhance WFIP2 observations with a focus on moisture:

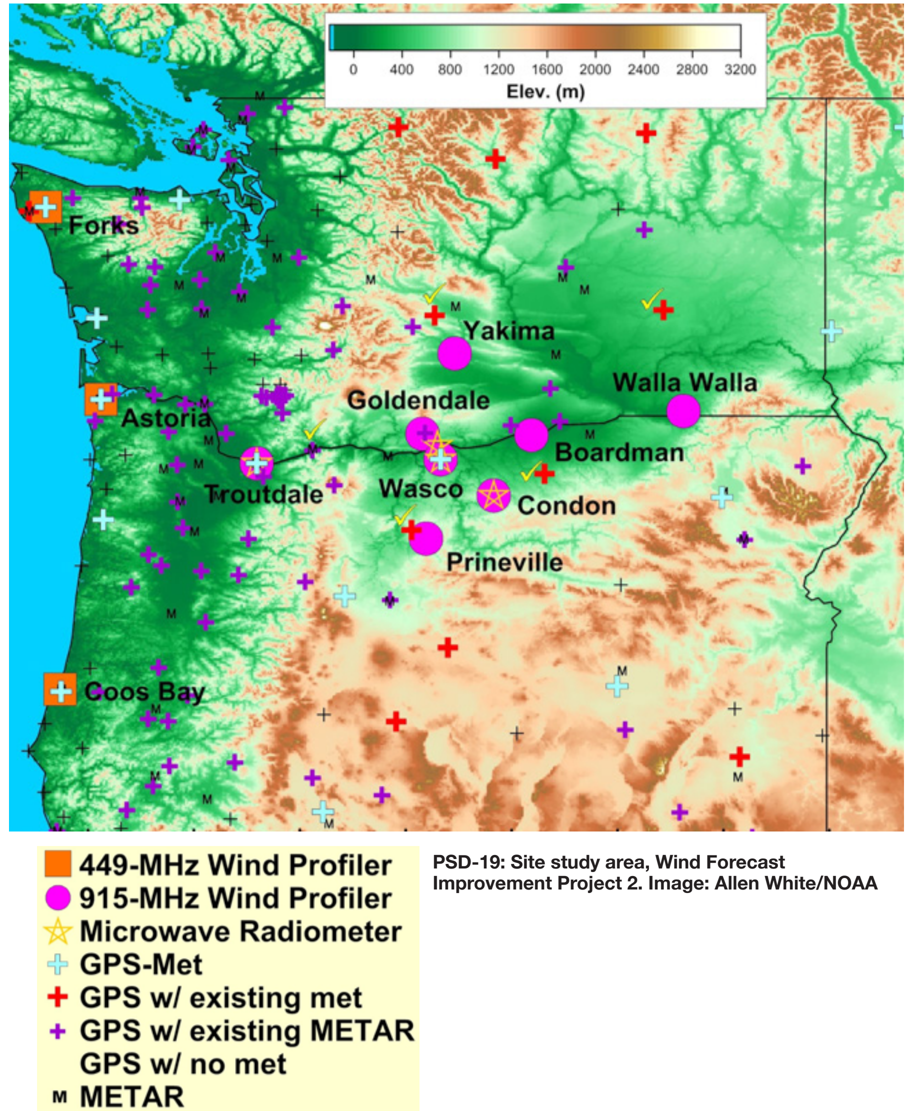
We investigate techniques for measuring humidity using wind profiling radars (WPRs) and microwave radiometers (MWRs). MWRs are passive instruments measuring integrated contents from atmospheric emissions. They retrieve profiles based on climatology (from nearby soundings) and neural network algorithms. These retrieval techniques work well for pressure and temperature, but less so for humidity. Clear-air radars (WPRs) are active instruments that emit signal that reflects off irregularities in the refractive index in the atmosphere. We can use the combination of MWR and WPR to calculate profiles of humidity. We are testing the technique on the data collected at the Boulder Atmospheric Observatory (BAO) in 2015. Testing is in progress and will be evaluated versus radiosonde launches available at the same site.

(2) Compute surface energy and moisture budgets:

We are evaluating soil moisture, local energy and moisture budgets at the Physics Site (5 km N-E from Wasco, OR). We have deployed the following observations especially for this project: soil moisture/temperature (in-situ measurements at 5, 10, 20, 50, 100 cm into the ground); GPS interferometric reflectometry (to derive near surface soil moisture with a new technique); near-surface meteorology; radiative fluxes; turbulent fluxes including evaporation and precipitation. Our approach is to compare observations with various models and investigate model improvements. We are investigating preliminary comparisons between the various observations to identify the behaviors of air temperature, soil temperature, soil moisture, and precipitation at this site.

(3) Improve quantitative precipitation estimation and quantitative precipitation forecasts:

To understand large-scale dynamics and moisture transport upstream and downstream of the Gorge, we have created a directory of storm-relevant quantities from the



PSD-19: Site study area, Wind Forecast Improvement Project 2. Image: Allen White/NOAA

High Resolution Rapid Refresh model (HRRR, 3-km grid spacing). Eighteen storms with precipitation greater than about 1.5 inches over the mountains in Idaho have been found and carefully documented at http://www.esrl.noaa.gov/psd/people/dustin.swales/TheGorge/synoptics/ (including maps of integrated horizontal water vapor transport (IVT) and moisture convergence cross sections of moisture transport).

(4) Better understand moisture transport (atmospheric rivers, AR) throughout the Pacific:

To answer the question "how representative are Columbia Gorge AR extreme moisture flux cases?" we plan to place the extreme AR events in the context of past 150 years using 20th Century Reanalysis (20CR). Preliminary analysis on what better 20CR resolution has to be used for this purpose (20CR ver 2c at 2ox2o, or 20CR ver 3 at 0.5ox0.5o) are being conducted.

(5) Examine the influence of climate variability, especially tropical sea surface temperature (SST) on precipitation in this area:

We investigate the tropical influence on northwest U.S. precipitation. Our goal is to examine whether we can link variability in the precipitation field to the tropical climate (SST, subsurface ocean conditions) at different timescales, and identify the SST pattern(s) that are more conducive to precipitation variations in the northwestern United States ("sensitivity patterns").

PSD-21: Develop and Prototype Experimental Regional Arctic Sea Ice Forecasting Capabilities

■ CIRES Lead: Amy Solomon ■ NOAA Lead: Janet Intrieri

NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project will improve predictions of Arctic sea ice on an extended weather scale by identifying critical physical processes, characterizing process-level model deficiencies, and improving model representation of key processes.

Accomplishments

This year, the NOAA-CIRES Sea Ice Forecasting team made daily quasi-operational 10-day forecasts of the 2016 Arctic Ocean freeze-up season (July-November) with an improved version of the Regional Arctic System Model (RASM-ESRL). We made the following model improvements for the 2016 freeze-up season: updating the sea ice model, updating the land surface model, and replacing the mixed-layer ocean with a full dynamical ocean model to allow for the mixing of subsurface waters into the ocean mixed layer. We posted figures and animations of the daily forecasts on the NOAA/ESRL/PSD Experimental Sea Ice Forecast webpage (https://www.esrl.noaa.gov/psd/forecasts/seaice/) in real time, to allow users such as the NWS Alaska Sea Ice Program and the Arctic Testbed to assess the forecasts for use in their operations.

In addition, we ran a suite of hindcasts with a variety of initialization fields to identify the impact of ocean initial conditions on 10-day forecasts, and we completed studies to assess the performance of forecasts made during the 2015 freeze-up period. Diagnostics from these studies are posted on the NOAA/ESRL/PSD Experimental Sea Ice Forecast webpage.

In the off-season, the our team completed process-oriented diagnostics of observations from the 2015 ONR SeaState campaign (http://www.apl.washington.edu/project/project.php?id=arctic_sea_state) to be used for model verification. This work includes developing a novel approach to estimating sea ice thickness. We are using these observations to evaluate model simulations of ocean, sea ice, and atmospheric variability.

One objective we are completing in collaboration with the NOAA National Center for Environmental Prediction is determining to what extent a dynamical ocean model is required for subseasonal sea ice forecasts. Our preliminary results indicate that it is necessary to include the mixing of subsurface ocean water into the mixed layer for accurate forecasts, even on these short time scales. Our team is also working with the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) in Bologna, Italy to develop a state-of-the-art Arctic Ocean analysis for model validation and to forecast initial ocean conditions. This ocean analysis has horizontal resolution similar to the forecasts (10km). However, comparisons with the SeaState measurements indicate that the mixing of subsurface Pacific Ocean water into the mixed layer is underestimated in the analysis. This finding led to an additional collaboration with CMCC, where our team is compiling all available Arctic Ocean measurements for 2015 to be assimilated into the ocean analysis. We will determine if using the assimilated ocean analysis will improve the skill of the subseasonal forecasts.

Our team will also focus on simulating the impact of lower-level atmospheric jets. These jets may be playing an important role in the evolution of the sea ice by forcing strong winds and fluxes across the ice edge. We are using observations from the SeaState campaign to assess the model skill in simulating these jets and the RASM-ESRL model to determine the impact of these jets on the sea ice evolution.

PSD-25: Linking Weather, Climate and Environmental Tipping Points

■ CIRES Lead: James Scott ■ NOAA Lead: Michael Alexander

NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

This project will provide guidance for assessing impacts on short term and long-term changes to large marine ecosystem environments in the United States.

Accomplishments

We published two papers in *Climate Dynamics* in March 2017 on sea surface temperature (SST) predictability in coastal regions, which included significant contributions from CIRES' Gaelle Hervieux:

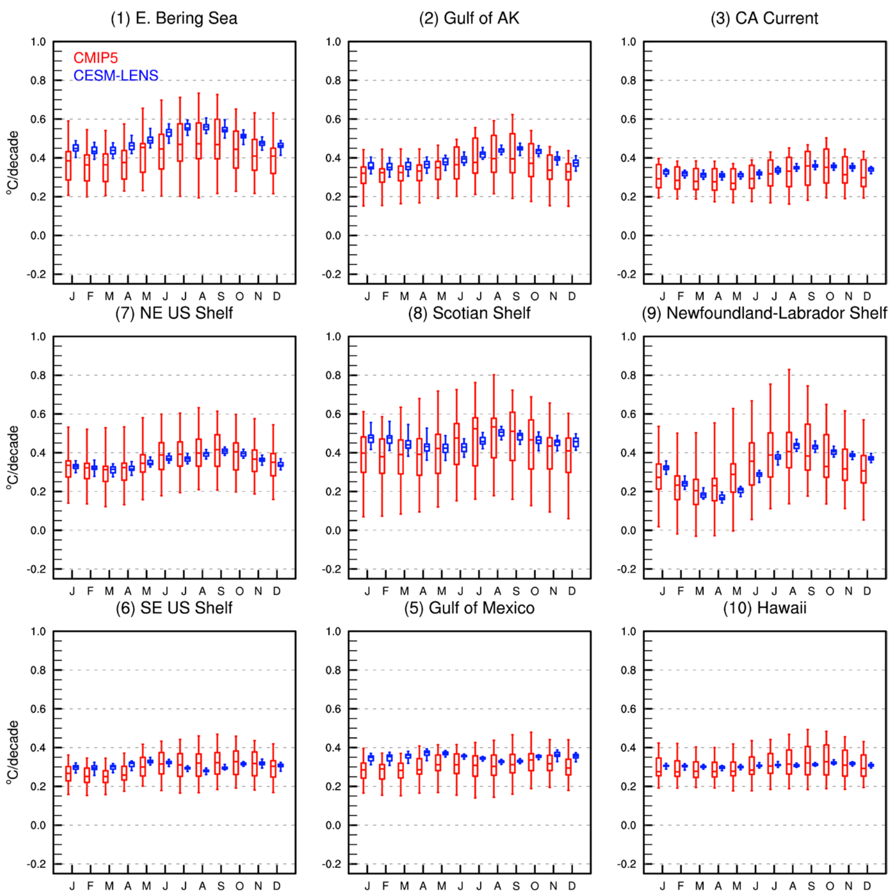
Hervieux, G., M. A. Alexander, C. A. Stock, M. G. Jacox, K. Pegion, E. Becker, F. Castruccio, and D. Tommasi (2017), More reliable coastal SST forecasts from the North American Multimodel Ensemble, *Climate Dynamics*, doi:10.1007/s00382-017-3652-7.

We analyzed the forecast skill of the North American Multimodel Ensemble (NMME) using three different metrics: anomaly correlation, root mean square error, and the Brier score. Our results indicate that current global climate forecast systems with relatively coarse oceanic and atmospheric resolution have skill in forecasting SST anomalies in many coastal Large Marine Ecosystems (LME). Forecast skill is highly dependent on the month being predicted, with certain months producing higher or lower seasonal predictability regardless of the initialization time and duration of the forecast. This forecast skill varied widely by region, with relatively high skill in the Pacific, especially in the Bering Sea and Gulf of Alaska, and in the vicinity of Newfoundland, but limited skill in regions along the U.S. East Coast.

Jacox, M. G., M. A. Alexander, C. A. Stock, and G. Hervieux (2017), On the skill of seasonal sea surface temperature forecasts in the California Current System and its connection to ENSO variability, *Climate Dynamics*, doi:10.1007/s00382-017-3608-y.

Each of our coupled climate models in the NMME exhibits significant SST forecast skill in the California Current System (CCS). At short lead times (0-4 months), much of that skill can be attributed to persistence, while at longer leads skill above persistence emerges and in some cases extends for the full length of the forecast. Individual models, as well as the NMME multi-model mean, are particularly skillful for forecasts of February-April, regardless of initialization month. These late winter/spring forecasts also generate the greatest skill above persistence, as they coincide with times of low skill from persistence forecasts. In the case of Canadian Climate Model (CanCM4), we attribute the observed skill above persistence primarily to a predictable evolution of the CCS wind (and resultant upwelling) anomalies during moderate to strong El Niño Southern Oscillation (ENSO) events.

Two other papers are still in preparation with significant contributions from CIRES scientists Antonietta Capotond, James Scott, and Matt Newman.



PSD-25: Monthly SST trends during 1976-2099 for LMEs around North America. Trends computed for each model from the CMIP5 (red) and CESM-LENS (blue) experiments are shown in box and whiskers format, where the end points indicate the maximum and minimum values, the box boundaries are the inter-quartile (25% and 75%) range and the median is the central line. Image: Alexander et al. 2017

Scientific Outreach and Education

GSD-02: Science Education and Outreach, Science On a Sphere®

■ CIRES Lead: Elizabeth Russell ■ NOAA Lead: John Schneider

NOAA Theme: NOAA Engagement Enterprise

Goals & Objective

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

Accomplishments

We reached many significant milestones for Science On a Sphere (SOS), SOS Explorer (SOSx), and the NOAA Earth Information System (NEIS). A constant goal for our team is continual innovation, which we achieved through regular software releases that include improvements and new features. We released software updates for SOS in August 2016 and April 2017. These updates included an upgraded operating system, major improvements and new additions to the Visual Playlist Editor, better translation support, more robust automated alignment, and improvements to the kiosk and SOS Remote app.

We completed five SOS installations, bringing the number of worldwide installations to 145. In order to keep sites up to date and provide collaboration and networking opportunities, we held the SOS Users Collaborative Network Workshop at the Detroit Zoo in April 2017. At the workshop, which also featured SOSx, our team gave presentations on SOS software and best outreach and education practices.

We released new updates for SOSx in September 2016, February 2017, and May 2017. Our latest release introduced support for virtual reality with the Oculus Rift goggles, improved touch interaction, a fully featured TourBuilder, and new 3D models. In 2017, there were five public installations of SOSx. This is a major accomplishment as it expands the group's outreach and exposes more people to work of NOAA and CIRES. Our free version of SOSx, SOSx Lite, continues to be regularly used and downloaded, further expanding our outreach.

To provide exposure for SOS and SOSx, our team attended many professional conferences. In addition, SOSx was set up in the exhibit halls at the following meetings: the Association of Science and Technology Centers Conference, the American Geophysical Union Fall Meeting, the American Meteorological Society Annual Meeting, and the National Space Symposium. In addition, SOSx was the primary exhibit at community outreach events at the Denver Museum of Nature and Science. We created additional exposure through social media, including Facebook and a new Instagram account. We added presentations by CIRES educators using SOSx on Facebook Live Stream as a new outreach tool in 2017.

Our team overhauled several important NOAA Earth Information System (NEIS) features this year to update the technology and improve stability. We significantly improved support for multi-display, mixed resolutions, and touch input for a better user experience.

On the web service side, we implemented continuous integration to add automated testing and deployment. We improved the NEIS presentation capabilities with the addition of TourBuilder, which allows users to create custom content for presentations and was used by several speakers at the AGU and AMS conferences. Our team also added product licensing and registration capabilities.

GSD-02: A student selects a dataset to view in SOS Explorer in an immersive, virtual reality setting. Photo: Theo Stein/NOAA

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

■ CIRES Lead: Florence Fetterer ■ NOAA Lead: Eric Kihn
NOAA Theme: NOAA Engagement Enterprise

Goals & Objective

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

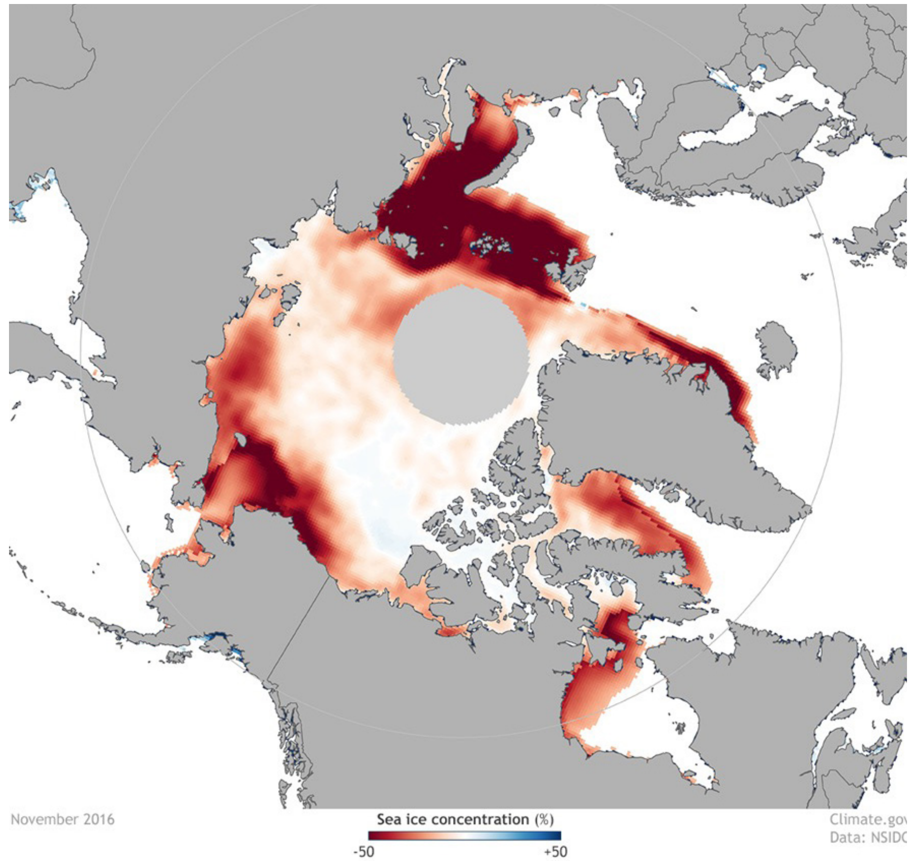
Accomplishments

About 3,000 users download data each month from the Sea Ice Index, and significantly more view the data online. Arctic Sea Ice News and Analysis (https://nsidc.org/arctic-seaicenews/), NOAA's Arctic Report Card (http://arctic.noaa.gov/Report-Card/Report-Card-2016), and NOAA's Climate.gov (https://www.climate.gov) all rely on the Sea Ice Index to track ice. Ann Windnagel highlighted the product, its users and uses, and its development goals in a presentation for the NOAA-CIRES Cooperative Agreement review board in September 2016. For the winter of 2016-2017, we saw extraordinarily low ice extents, as tracked by the Sea Ice Index and described in an article for Climate.gov.

We published Version 2 of the Sea Ice Index in July 2016, with updated production code and other changes outlined in the documentation. After porting code to Python was completed in January 2017, we published Version 2.1. Prior to V2.1, we processed the Sea Ice Index with code written mainly in IDL with some Perl, Ruby, and C. Major improvements including a new color scheme for the daily and monthly images and graphs, reorganized FTP site, daily images and blue marble images now archived on FTP, minor adjustments to monthly computations, and interdecile and interquartile columns now supplied in the daily climatology file to complement the standard deviation value in that file.

In May 2017, we added the median sea ice extent line (the pink line) to the daily and monthly Sea Ice Index concentration images. Previously, this line only appeared on the sea ice extent images. The addition of the median extent line to the concentration images helps us inform users of how sea ice extent and concentration relate to one another, and continues our work to make the Sea Ice Index a user friendly, go-to source for sea ice information.

We also added the web service described in the NSIDC-04 report.



NOAA NSIDC-01: This map shows Arctic sea ice concentration anomalies in November 2016, based on data from the Sea Ice Index. Areas with unusually high concentration are blue, and areas with unusually low concentration are red. Image: Climate.gov

Space Weather Understanding and Prediction

NCEI-06: Satellite Anomaly Information Support

■ CIRES Lead: Juan Rodriguez ■ NOAA Lead: Bill Denig
NOAA Theme: Science and Technology Enterprise

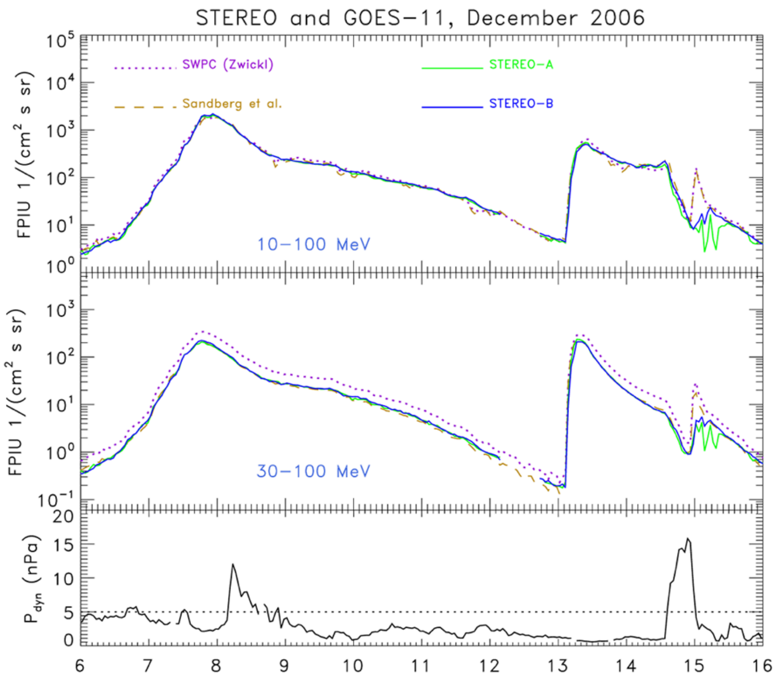
Goals & Objective

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

Accomplishments

This year, we contributed to the Satellite Anomaly Information Support project primarily through the publication of two peer-reviewed publications.

In the first publication (Rodriguez et al., 2017), we led an international team in the validation of a previously-published cross-calibration of the Geostationary Operational Environmental Satellite (GOES) solar proton data. This validation effort took advantage of a serendipitous series of solar proton events that occurred days after the launch of the two NASA Solar Terrestrial Relations Observatory (STEREO) spacecraft, while they were orbiting around the Earth just prior to the lunar swing-by that sent them into their separate orbits around the Sun. With their fine energy resolution, the STEREO solar proton measurements could be used to validate the cross-calibrations performed against the earlier NASA Interplanetary Monitoring Platform (IMP)-8 measurements of comparably fine energy resolution. We found that the STEREO observations agreed well with the cross-calibrated GOES observations, thereby establishing the accuracy of the earlier cross-calibrations. An important consequence of this result is that current GOES integral fluxes used by the NOAA Space Weather Prediction Center (SWPC) in their solar radiation storm alerts are too high by up to a factor of 3 (at >100 MeV). This paper received an Editors' Highlight from the journal in which it was published.



NCEI-06: Comparison of (top) 10–100 MeV and (middle) 30–100 MeV integral fluxes observed by STEREO and GOES 11 during the December 2006 solar proton events. The GOES 11 integral fluxes are calculated by using the NOAA SWPC method and by using the cross-calibrated effective energies validated by this paper. (bottom) The solar wind dynamic pressure (Pdyn) from the NASA OMNI data set. All data here are 1 h averages. Image: Rodriguez et al. 2017.

Our team contributed to an NCEI publication (Redmon et al., 2017) in which a parametric charge accumulation model was used to determine whether a series of anomalies on the NOAA Polar Orbiting Environmental Satellites could be attributed to internal charging by >800 keV electron fluxes as originally proposed by NOAA. We found that internal charging now appears to be an unlikely root cause for this particular series of anomalies in the absence of an additional, enabling physical mechanism.

References:

Rodriguez, J. V., I. Sandberg, R. A. Mewaldt, I. A. Daglis, and P. Jiggens (2017), Validation of the effect of cross-calibrated GOES solar proton effective energies on derived integral fluxes by comparison with STEREO observations, *Space Weather*, 15, 290–309, doi:10.1002/2016SW001533.

Redmon, R. J., J. V. Rodriguez. C. Gliniak, and W. F. Denig (2017), Internal charge estimates for satellites in low earth orbit and space environment attribution, *IEEE Transactions on Plasma Science*, in press.

SWPC-01: Space Weather Information Technology and Data Systems

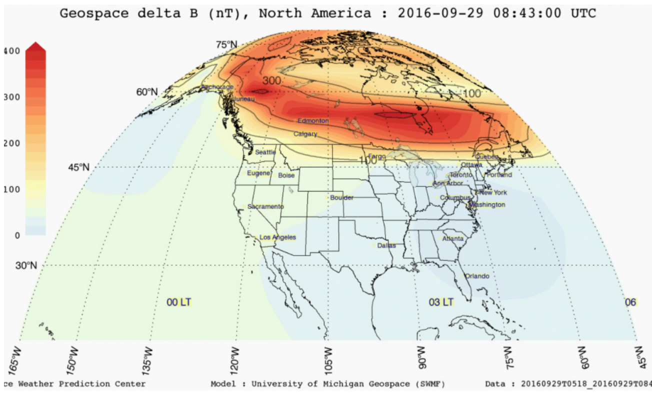
■ CIRES Lead: David Stone ■ NOAA Lead: Steven Hill
NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project will modernize data storage and retrieval relevant to space weather.

Accomplishments

Our team successfully transitioned the University of Michigan's Geospace Model into operations to serve NOAA's Space Weather Prediction Center (SWPC) forecasters as well as power grid operators throughout the world. While the Geospace Model has diverse ca-



SWPC-01: Example of the North American product on a five- by five-degree grid from 9/29/2016 at 08:43 UT created automatically and served on the Space Weather Prediction Center's public website. Image: NOAA

pabilities for specifying conditions in the near Earth space environment, the initial operational application is to specify regional geomagnetic activity at Earth's surface (see image).

We transitioned the new North American total electron content (NATEC) U.S. and North America products to operations in order to serve single and dual frequency GPS applications. The model products are designed to specify vertical and slant TEC using a Kalman Filter data assimilation model in near real-time. These new changes include a larger assimilation grid and the addition of new GPS data in Alaska, Hawaii, Canada, and Mexico.

Our group assisted in the operational adaptation of a new real-time solar wind (RTSW) database schema that gives us the ability to easily switch between the aging Advanced Composition Explorer (ACE) satellite and the new DSCOVR satellite as sources for RTSW data. This work included retrofitting the remaining operational products which use RTSW data: Relativistic Electron Forecast Model (REFM), Aurora 30 minute forecast and Auroral 3-day forecast.

We deployed the Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) Model total electron content (TEC) forecast product to our experimental website. This model illustrates the height of integrated electron density from the CTIPe model and aids the forecasters in nowcasting effects on GPS systems, satellite drag and electric power transmission.

We finished the last Red Hat Enterprise Linux (RHEL) 5 to RHEL 6 transition, which was for the ACE processor and its web products. This highly complex migration allowed SWPC to continue to operate under the tightening security requirements of the National Weather Service (NWS).

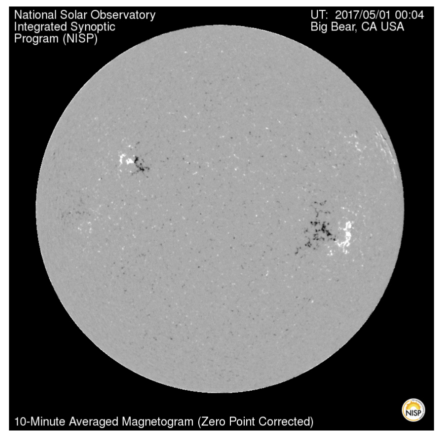
Our team provided timely operational support for the following critical systems and maintained a high customer satisfaction:

- SWPC's public website
- Advanced Composition Explorer (ACE) processor
- Deep Space Climate Observatory (DSCOVR) ground data system
- Geostationary Environmental Satellite (GOES) processor and preprocessor
- WSA-Enlil model
- D Region absorption predictions (D-RAP)
- Air Force and Institute for Science and Engineering Simulation (ISES) message decoder (AIMED) processor
- Microsoft SQL server space weather data store (SWDS)

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

■ CIRES Lead: Alysha Reinard ■ NOAA Lead: Vic Pizzo

NOAA Theme: Weather Ready Nation



SWPC-02: High resolution image of a GONG magnetogram. These images are compiled into monthly plots of the solar magnetic field which are used as inputs to the WSA-Enlil model of the solar wind. This model predicts the timing and effects of solar storms.

Goals & Objective

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

Accomplishments

We have transfered the existing Global Oscillation Network Group (GONG) processing software to the Integrated Dissemination Program (IDP) and the software is working on their system. We are currently generating real-time magnetograms and H-alpha images. We have also been testing two methods for transfering data from the six GONG sites to the IDP. We have talked to the IDP about setting up an ftp webpage to provide the processed images and carrington maps to the Space Weather Prediction Center (SWPC) and other customers, in particular the National Center for Environmental Information (NCEI), the Air Force and the National Solar Observatory (NSO). These tasks have been delayed on the IDP side due to a backlog of projects that they are working through—this delay has affected our schedule. However, we now have the permissions needed to do our testing and we are working through validating the data products and determining which method of data transfer best meets our needs. We have been validating the data products by comparing the outputs produced by the IDP with the outputs produced at NSO. We have brought Jeff Johnson, a CIRES software engineer, onto the project to begin evaluating the software to (1) provide detailed knowledge of the processing software within SWPC and (2) identify potential improvements to the software. He has been getting up to speed on the project and will be traveling to Tuscon in June to get a detailed walkthrough of the software with the experts at the NSO.

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

■ CIRES Lead: Timothy Fuller-Rowell ■ NOAA Lead: Rodney Viereck

NOAA Theme: Science and Technology Enterprise

Goals & Objective

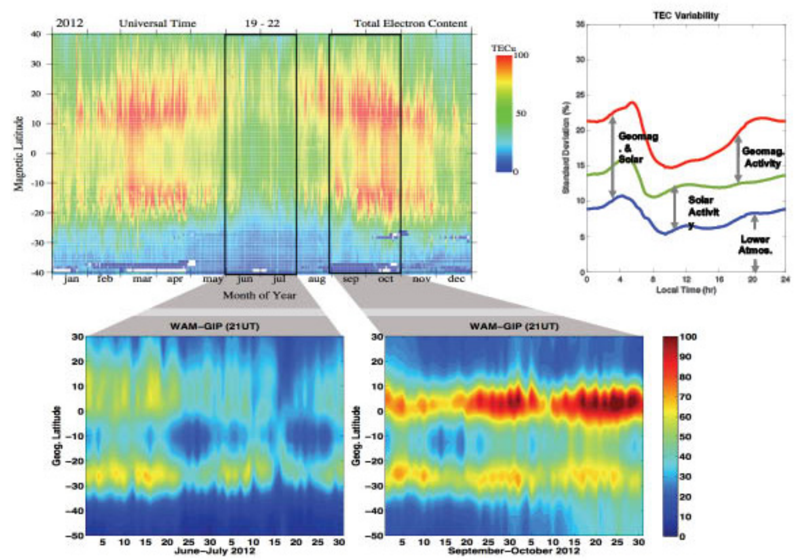
This project will use models to determine causes for variation in space weather, with implications for infrastructure protection.

Accomplishments

In an effort to model the space weather system from the Sun to Earth, NOAA is transitioning three separate physical model components. These include the WSA-Enlil solar wind propagation model, the Michigan Geospace model of the magnetosphere (see SWPC-01), and a coupled model of the whole atmosphere and the ionosphere-plasmasphere-electrodynamics (WAM-IPE). We have already transitioned the first two of these components to operations at NOAA, and we will test the third component in an operational real-time setting in September 2017.

WAM is a whole atmosphere extension of the National Weather Service (NWS) Global Forecast System (GFS) operational weather model, which extends the top boundary from 60 km to ~600 km. WAM can also be run with the NWS data assimilation scheme for WAM to follow real changes in tropospheric weather. The WAM model is coupled to a new Ionosphere-Plasmasphere-Electrodynamics (IPE) model, using the Earth System Modeling Framework (ESMF), under the NOAA Environmental Modeling System. IPE is a time dependent, three-dimensional model of the ionosphere and plasmasphere. WAM provides us with the thermospheric properties of wind, composition, and temperature to the IPE, so it can respond to changes in terrestrial weather propagating upward and influencing the thermosphere. IPE will in turn provides time dependent, global, three-dimensional plasma densities for nine ion species, electron and ion temperatures, and both parallel and perpendicular velocities of the ionosphere and plasmasphere. IPE reproduces not only the climatology of global TEC observations, but the model also responds to changes in solar wind conditions during geomagnetic storms, and to terrestrial lower atmosphere changes, such as sudden stratospheric warmings (SSW). Our model follows the storm-time redistribution of plasma in the ionosphere and plasmasphere during an SSW, and the evolution of storm enhanced densities (SEDs) during a geomagnetic storm.

We have tested and validated the coupled WAM-IPE model with one-way coupling, where the winds, temperature, and composition from the neutral WAM code drive the IPE ionosphere. We have simulated several months with the one-way coupled model configuration to quantify the contribution of the three major sources of variability in the thermosphere-ionosphere system. These simulations demonstrated that during quiet-to-moderate geomagnetic activity, the three major sources—solar EUV radiation, geomagnetic, and lower atmosphere forcing—all contribute roughly equal amounts to the variability of thermosphere-ionosphere dynamics, electrodynamic, and plasma density.



SWPC-03: Comparison of observed variability of total electron content (TEC) in 2012 (upper panel), derived from ground-based GNSS receivers, with results from WAM-IPE for June-July solstice (lower left panel) and for September-October equinox conditions. The peak values of TEC either side of the magnetic equator are associated with the equatorial ionospheric anomaly. The figure shows the seasonal change in variability, which is well represented by the model. The upper right panel illustrates that solar, geomagnetic, and lower atmosphere forcing contribute roughly equally to the variability. Image: CIRES/NOAA

SWPC-04: Geospace Modeling Effort

■ CIRES Lead: Howard Singer ■ NOAA Lead: George Millward
NOAA Theme: Weather Ready Nation

Goals & Objective

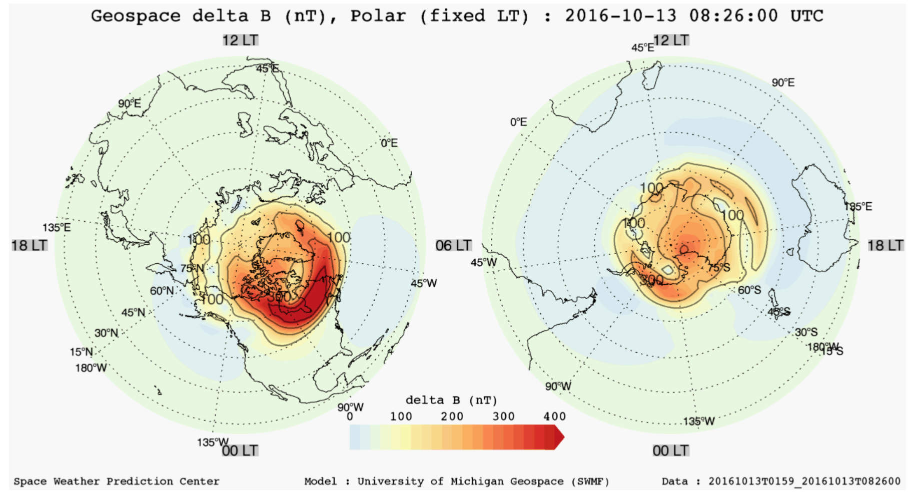
This project will use first-principles physics-based models to predict variations of space weather conditions in Earth's near-space environment that affect critical infrastructure in space and on the ground.

Accomplishments

Our aim has been to take the Space Weather Modeling Framework (SWMF) Geospace model, developed at the University of Michigan (UMICH), and transition it into full operations at the National Weather Service (NWS). The project has involved working closely with the model developers at UMICH to implement code and script changes needed for real-time, weather forecasting model usage. We have also worked with technical staff at the National Centers for Environmental Prediction Central Operation's Production Management Branch (NCEP/NCO/PMB) on all aspects of the real-time system, including the ingestion of real-time satellite data used as model input and the dissemination of output products to the Space Weather Prediction Center and, for public consumption, to the web.

The 2016 NWS milestone for the project was to have an end-to-end system, fully operational, on the NWS supercomputers. We achieved this by the milestone date of October 1, 2016. Initial products included global maps of ground magnetic perturbations and estimations of global geomagetic indexes such as the planetary K value (Kp) and the Disturbance Storm Time Index (DST).

In May 2017 Millward was awarded a CIRES Science and Engineering Outstanding Performance Award "For Scientific creativity and resoursefulness in transitioning an academic-based geospace model into NOAA operations, serving space weather forecasters and power grid operators."



SWPC-04: North and south polar views of ground magnetic perturbations (dB) during a moderate Geomagnetic storm, as predicted by the University of Michigan Space Weather Modeling Framework (SWMF) model of the geospace environment. The model was transitioned at the Space Weather Prediction Center to full operations at the National Weather Service on October 1st 2016. Image: NOAA SWPC

Stratospheric Processes and Trends

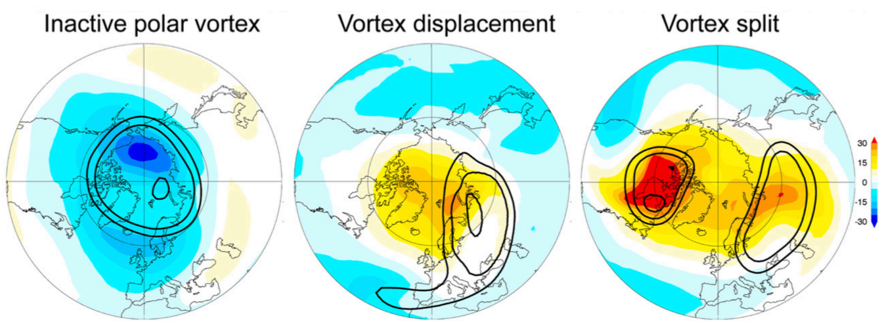
CSD-09: Stratospheric Radiative and Chemical Processes That Affect Climate

■ CIRES Lead: Sean Davis ■ NOAA Lead: Karen Rosenlof
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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 stratospheric ozone layer, in that region of the atmosphere.

Accomplishments



CSD-09: Temperature anomalies at 10 hPa (shading, (K)) and the potential vorticity at 550 K (contours shown for 75, 100, and 125 PV units) during three types of polar vortex states: (left) an inactive (or strong) phase of the polar vortex (9 January 2009), (center) a vortex displacement following the 23 January 1987 event, and (right) a vortex split following the 24 January 2009 event. Image: Butler et al. 2016

One prominent theme of our project is improving past estimates of variability in stratospheric water vapor and ozone levels. 2016-2017 marked a major milestone for the Stratospheric Water Vapor and OzOne Satellite Homogenized (SWOOSH) data set, a CIRES/CSD-led data record of ozone and water vapor. In 2016, SWOOSH was officially released concurrently with the publication of the SWOOSH methodology paper (Davis et al., 2016). SWOOSH ozone data were used to quantify past variability in the width of the so-called tropical belt edge (Davis et al., 2017), and to estimate ozone depletion and recovery rates (Steinbrecht et al., 2017). In a paper published in Nature Geoscience, CIRES researchers used SWOOSH water vapor data, in conjunction with a model and other observations, to document and explain highly unusual water vapor and cloud ice conditions in the stratosphere caused by overshooting convection associated with the 2015-2016 El Niño (Avery et al., 2017).

Our group also led a number of studies aimed at improving understanding of radiative and dynamical processes that can impact chemistry and transport in the stratosphere. In 2017, we produced a new database of stratospheric polar vortex breakdowns (Butler et al., 2017), publicly archived the data (doi:10.7289/V5NS0RWP), and began examining the vortex evolution in the context of El Niño-Southern Oscillation. We also calculated improved estimates of Earth's past and future energy budget for a suite of climate model simulations, and presented this material at international conferences (Larson et al., 2016; Larson et al., in preparation). We also used in situ measurements and model output to produce an improved estimate of the sulfur hexafluoride (SF6) stratospheric lifetime (Ray et al., 2017). This lifetime reduction, from 3200 years to 850 years, has major implications for the use of SF6 as an indicator of transport in the stratosphere as well as for the Global Warming Potential of SF6 for time horizons beyond ~500 years.

In addition to these studies, we made significant advances in understanding radiative and transport properties related to stratospheric aerosols. In one study using a state-of-the-art aerosol model (Community Aerosol and Radiation Model for Atmospheres or CARMA) and airborne in-situ measurements, we found that stratospheric aerosols contributed a surprisingly large 20 percent of radiative forcing since 1850 (Yu et al., 2016). In addition, we found that Asian summer monsoon can efficiently transport surface pollutants to the stratosphere, and contributes 15 percent of the global stratospheric aerosol budget (Yu et al., 2017).

References:

Yu et al. (2017). Efficient transport of troposhperic aerosol into the stratosphere via the Asian summer monsoon anticyclone. *Proceedings of the National Academy of Sciences*, doi: 10.1073/pnas.1701170114

GMD-02: Analysis of the Causes of Ozone Depletion

■ CIRES Lead: Irina Petropavlovskikh ■ NOAA Lead: Russ Schnell
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

This project addresses changes in the chemistry of the stratosphere that affect ozone depletion, which supports estimates of the types of adaptation and mitigation that will be necessary to stabilize ozone in the stratosphere.

Accomplishments

Ozonesonde

We have finished reprocessing the vertical ozone profile measurements from nine sites for the ozonesonde data homogenization project. This includes over 7,000 individual flights and spans over 50 years for the Boulder, Colorado, (figure 1) and South Pole stations.

Reprocessing of historical data has resulted in a robust data set that now includes individual and unique uncertainties for each sounding. This improves the usefulness and value of the ozonesonde data sets for use in trend analysis and comparison with satellite data sets. We have replaced the homogenized ozonesonde records with data files that are formatted identically and homogenized for instrument version and solution type and include uncertainty calculations for every ozone profile. We have re-submitted data to the Network for the Detection of Atmospheric Composition Change (NDACC) archive at: http://www.ndsc.ncep.noaa.gov/data/ and updated on the NOAA data archive ftp site ftp://aftp.cmdl.noaa.gov/data/ozwv/Ozonesonde/. The updated uncertainties for the ozonesonde profiles in the entire NOAA record are important for assessment of ozone trends in stratosphere and troposphere.

NEUBrew (NOAA Environmental UV-ozone Brewer Network)

We continued to operate the six-station NEUBrew network during 2016. There were problems with Brewer 144 at the Bondville, Illinois, station, which reduced the amount of total column ozone and ozone profile data. The rest of the stations operated relatively trouble-free during the year. Both the total column ozone and ozone profiles are available at the NEUBrew website (esrl.noaa.gov/gmd/grad/neubrew) with one-day latency.

We shipped the Bondville Brewer # 96-144 to Boulder for repairs after many attempts to correct the problem in the field failed. Upon receipt of the Brewer we determined that there had been a mechanical failure in a coupling in the wavelength drive. We replaced the coupling and put the Brewer through a series of operational tests. We also performed an absolute spectral UV calibration, and returned the unit to Bondville after it successfully passed the operational tests. We compared the total column ozone measurements made by the Brewer to the OMI satellite values. Their difference was less than 1.2%, which is very good for this particular comparison.

To continue testing the Brewers with their new UVC-7 solar blocking filters and comparing them to instruments with the older nickel-sulfate ($NiSO_4$) filters, we tested three Brewers for changes in their temperature dependence. The three ozone-triad Brewers at Table Mountain, Colorado, numbers 96-134, 96-139, and 96-141, were sequentially removed from Table Mountain and brought to NOAA's David Skaggs Research Center. We tested each for temperature-dependent changes in both ozone and spectral UV responsivity. We placed the Brewers in an environmental chamber and aligned to an external quartz-tungsten-halogen light source. Our team made multiple measurements of spectral UV and total column ozone against the lamp over typical temperatures that the Brewer might experience in the field. The temperature range was from -10 to +40 degrees Centigrade. From these measurements we will calculate new temperature coefficients and compare them to the original values. Depending on the outcome, post processing of past data may be required.

Dobson

The impact of a seasonal biases in the Dobson spectrophotometer total ozone data record is related to the use of static temperature for determining the ozone absorption cross sections in the UV Solar spectrum. A correction is therefore required to post-process Dobson data to account for daily changes in stratospheric temperature. To calculate the ozone-weighted (effective) temperatures we use: the hourly ozone profiles from the NASA GMI (Global Model Initiative) model and temperature profiles from the NASA MERRA reanalysis (Modern-Era Retrospective analysis for Research and Applications), which are available for years 1992-2014 for most of the NOAA Dobson stations locations. As the result of the applied corrections we observe some improvements in comparisons between Dobson and satellite data, as shown in figure 3, comparing the Dobson and the Ozone Mapping Profiler Suite (OMPS) instrument on the JPSS-Suomi satellite over the South Pole station.

We also investigated the applicability of using global chemistry and transport models (CTMs) hourly output as compared to the monthly mean climatology to correct the Dobson historical record for stratospheric temperature variability, and its impacts on long-term trends in corrected Dobson records. We used ozonesonde and satellite profile data (i.e., Microwave Limb Sounder, MLS, Aura satellite) to validate the temporal variability in hourly outputs of the ozone and temperature vertical profiles derived from the GMI and

GMD-02: Figure 1: CIRES scientist Patrick Cullis releases an ozone research balloon on the 50th anniversary of ozone research at Marshall Mesa south of Boulder. Photo: Theo Stein/NOAA

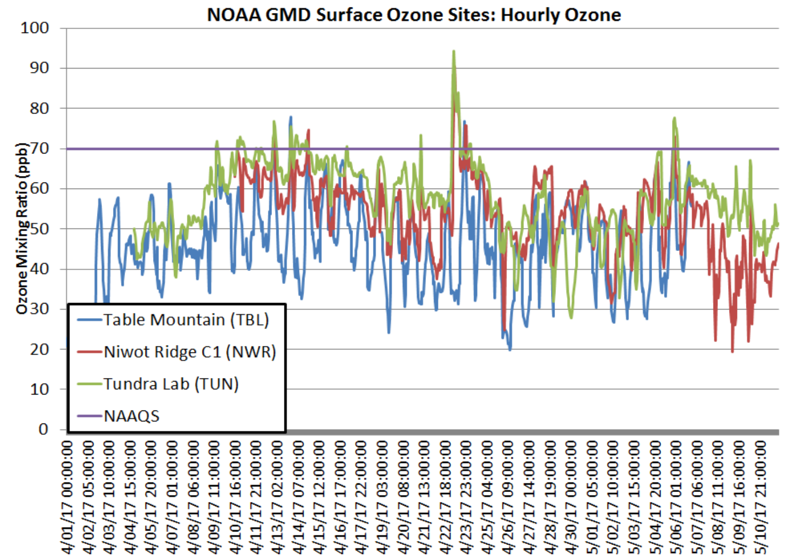
MERRA databases. We found that observations strongly correlate with model output. Our team compared Dobson operational ozone cross-section data to other spectroscopic datasets to determine the proper selection of absorption cross-section data sets and its respective temperature sensitivity for Dobson total ozone data processing (i.e. Bass and Paur, 1984; Daumont et al., 1992; and Serdyuchenko et al., 2014).

Total Ozone Column (TCO) measurements made with Dobson spectrophotometers continued at the 14 locations operated by NOAA's Global Monitoring Division (GMD) with the exception of our station in Perth, Australia, which malfunctioned in early July of 2016. Due to its outdated automation, remote location, and sparse funding we have been unable to repair it, and all plans for servicing it have been deferred until fiscal year 2018. NOAA GMD has continued to process and archive data from all other stations, and the data sets archived with the World Ozone and Ultraviolet Radiation Data Centre and Network for the Detection of Atmospheric Composition Change have been reprocessed using Windobson software. We will re-submit the reprocessed data from each of those data sets upon acceptance of a peer-reviewed paper describing the process.

NOAA is responsible for maintenance and calibration of the World Meteorological Organization Global Atmosphere Watch standard Dobson D083 instrument and provides calibration services to the Dobson regional calibration centers around the world. We shipped Dobson 083 to NOAA Mauna Loa Observatory in May of 2016 for its biannual calibration check. Although much of the data collected between May and July 2016 was of marginal quality due to various technical issues, subsequent checks made in Tenerife, Spain during an international intercomparisons campaign in September 2016 and comparisons to other instruments have verified that its calibration is within the tolerance. We made 11 Langley measurements over a 14-day period and the results were compared to other Dobson spectrophotometers and other spectrometers used to measure total ozone column (TCO). In addition, Dobson D083 participated in the WMO region V intercomparison in Broadmeadows Australia in February 2016. The Asian regional standard (D116), and the Australian regional standard (D105) were both calibrated during this event.

Surface ozone

The baseline levels of ozone in the boundary layer are often influenced by stratospheric intrusions. In Colorado, levels of the surface ozone are often increased for a short periods of time during spring and early summer, when the subtropical jets are often located near 40 degrees N and influence stratospheric intrusion processes in the Front Range. The location of three NOAA stations at different altitude levels in Colorado Front Range is designed to capture these events and understand the frequency and contribution to the baseline ozone levels (figure 2). Since these locations do not have measurements of other atmospheric composition that can be used to identify the origin of increased ozone air masses, we use regional chemistry models, (i.e. NCAR MOZART, NOAA RAQMS and WRF CHEM) to help analyze hourly ozone variability in continuous surface ozone measurements. Recent changes we have made to the location of spatial distribution of NOAA stations include moving surface ozone measurements from the Boulder Atmospheric Observatory near Erie, Colorado, to the NOAA Table Mountain facility, closer to the mountains.



GMD-02: Figure 2: Time series of ozone measurements at three NOAA sites organized by altitude of the station (Table Mountain is in the Foothills, Niwot Ridge is at 3000 m, Tundra Lab is at 3500 m above sea level). National air quality standard (NAAQS) is shown for reference to indicate the enhanced ozone observed by three stations on April 23, 2017. The enhancement is related to the stratospheric intrusion event. Image: CIRES and NOAA

Data archiving

In support of the previous Administration's Big Earth Data Initiative (BEDI), we concentrated on preparing NOAA-acquired historical records (i.e. Dobson spectrophotometer total ozone, ozone-sonde profiles, and surface ozone time series for archival at the NOAA Center for Environmental Information, NCEI). The data sets incorporate records from 14 NOAA Dobson stations and 15 surface ozone stations set to be produced in a new data format known as netCDF. The netCDF is the Network Common Data File created by the University Corporation for Atmospheric Research and is "a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data."

GMD-05: Understanding the Behavior of Ozone Depleting Substances

■ CIRES Lead: Fred Moore ■ NOAA Lead: James W. Elkins

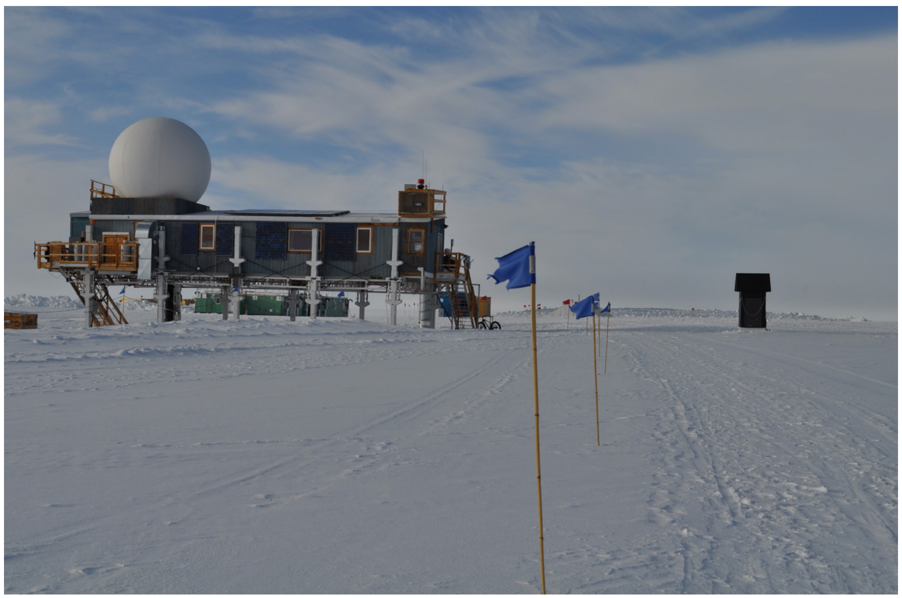
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

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

Our work and accomplishments are tied to our long-term global observations derived from the two surface networks and small aircraft profiles conducted at ~20 locations, mostly over North America. Highlights from this program include documenting the surprisingly large global increase in dichloromethane, an ozone-depleting gas not controlled by the Montreal Protocol; improving our understanding of atmospheric loss processes from an analysis of methyl chloroform data; and providing atmosphere-based constraints on 20th-century changes in global gross primary productivity (affecting CO_2 concentrations). Our results from these programs feed into annual updates tracking global changes in climate warming from long-lived greenhouses gases (NOAA's Annual Greenhouse Gas Index or AGGI) and global changes in ozone-depleting gases (NOAA's Ozone Depleting Gas Index or ODGI); the AGGI was updated in May 2017 and the ODGI will be updated in Summer of 2017. We also incorporated these data into a projection of greenhouse gas concentrations that will be used throughout the global modeling community to simulate climate change in the 21st Century). We now use the Gas Chromatograph Mass Spectrometer (GCMS) named Perseus for routing analysis of flasks obtained from all programs within the group. The increased throughput, higher precision and accuracy, and the additional measurements of new and more volatile compounds add to our flask program.



GMD-05: Flag line leading from the clean air sector to the Summit, Greenland, station (known as the "Big House") and the outhouse. Summit is one of the ground sites slated for work reduction. Photo: Geoff Dutton/CIRES

Regular low-altitude airborne flask measurements and periodic higher-altitude, mission-oriented measurements complement these surface observations. Our airborne program helps define the processes that connect the surface network measurements to the atmosphere as a whole. By themselves, each set of results addresses specific aspects of atmospheric chemistry (source and sinks), transport, feedback mechanisms, etc. However, because these data sets are referenced to a common in-house standards program, they represent a much more powerful tool when combined with the surface observations and are especially well suited to analysis by 3-D models. Our in-house standards and calibration capabilities allow us to test instruments and methods in ways that would be much more difficult if such capabilities did not exist. A major focus of our airborne programs this past year were the two NASA funded projects: Atmospheric Tomography Mission (ATom) and the Pacific Oxidants, Sulfur, Ice, Dehydration, and Convection Experiment (POSIDON). We have obtained data from the first and Second deployment of ATom and are in the process of being appropriately reviewed. With ATom we are using the NASA DC-8 to generate a chemistry-oriented extension of the global-scale tropospheric HIPPO observations from 2009 to 2011, with a focus on OH. With this extensive payload, we will be tracking the interplay between transport and chemistry in the free troposphere and will ultimately have full seasonal coverage. The data are already showing a temporal and spatial structure in the interhemispheric exchange process that controls much of the mass flux through the tropics where OH chemistry dominates.

Our work on stratospheric transport continued, resulting in the submission of a publication that substantially reduced the lifetime estimate for SF_6, a potent greenhouse gas. We accomplished this through measurements of loss seen in the Arctic vortex. Our publication was also successful in quantitatively connecting 3-D mesospheric transport models with measured data. We have also started a study to quantify how circulation asymmetry between the northern and southern stratosphere produce measurable tropospheric gradients with correlated temporal and spatial structure. Our team's work not only identifies a new potential measurement tool for stratospheric circulation studies but also modifies the interpretation of tropospheric gradients, particularly when used to determine tropospheric sources and sinks.

GMD-06: Monitor Water Vapor in the Upper Troposphere and Lower Stratosphere

■ CIRES Lead: Dale Hurst ■ NOAA Lead: Russ Schnell
NOAA Theme: Climate adaptation and mitigation

Goals & Objective

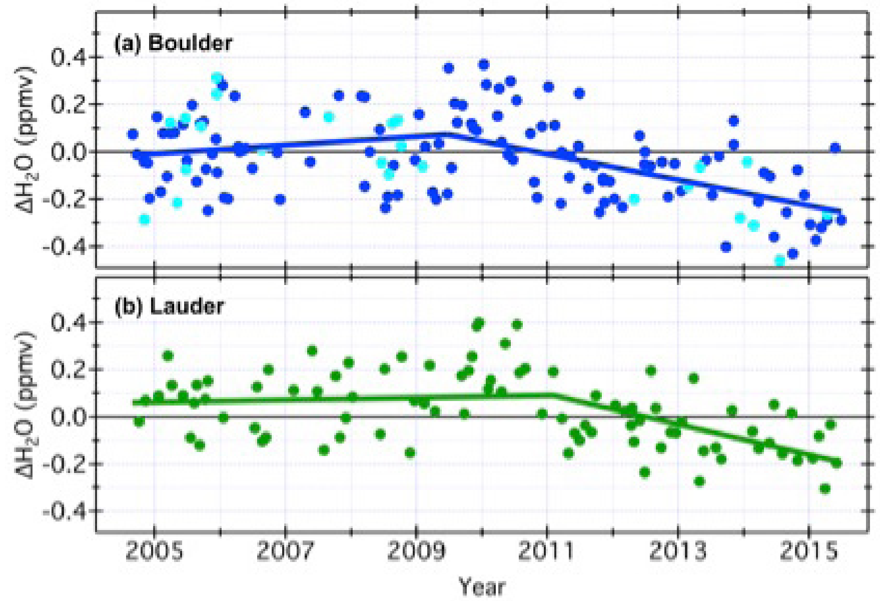
This project will make use of long-term UTLS water vapor measurements by balloon-borne frost point hygrometers to measure inter-annual changes and longer-term trends at three monitoring sites.

Accomplishments

We made monthly balloon soundings with the NOAA frost point hygrometer (FPH) at Boulder, Colorado, Hilo, Hawaii, and Lauder, New Zealand, to measure water vapor in the upper troposphere and lower stratosphere (UTLS). These measurements extended the long-term records at these sites to 37, 7 and 13 years, respectively. Each sounding produced vertical profiles of water vapor, ozone, temperature, pressure and horizontal winds from the surface to an altitude of approximately 28 km. We used these data for the calibration and validation of satellite-based water vapor sensors and as critical checks of climate models.

We published a paper that exposes the recent divergences in stratospheric water vapor measurements by the Aura Microwave Limb Sounder (MLS) and FPHs over five different sites. The Figure shows the downward trends in FPH-MLS differences at Boulder and Lauder, starting between mid-2009 and early 2011 and continuing through mid-2015. In many cases, these trends have caused FPH-MLS differences to now exceed the combined measurements accuracies of the two instruments. We attribute these divergences to MLS measurements drifting high (wet) in recent years, primarily because it is very unlikely that two different types of FPHs, independently manufactured and calibrated, would be drifting at the same rates at several sites (Hurst et al. 2016).

We also published a paper (Hall et al. 2016) that documents the history of the NOAA frost point hygrometer, including instrumental changes and upgrades made over the years. This paper also describes the current design of the FPH and quantitatively assesses its measurement uncertainties using laboratory-based tests and performance metrics from actual soundings.



GMD-06: Differences between coincident water vapor measurements at 68 hPa by frost point hygrometers and the Aura Microwave Limb Sounder over (a) Boulder, Colorado, and (b) Lauder, New Zealand. Dark and light blue markers for Boulder denote measurements by two different types of frost point hygrometer: the NOAA FPH and the CFH, respectively. Piecewise continuous linear regression fits to the two time series of differences indicate substantial negative trends starting in (a) mid-2009 and (b) early 2011. Image: CIRES and NOAA.

Systems and Prediction Models Development

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

■ CIRES Lead: Gary Hodges ■ NOAA Lead: Joseph Michalsky
NOAA Theme: Climate Adaptation and Mitigation

Goals & Objective

This project provides long term data for a network of sites on the amount of solar irradiation that reaches the Earth's surface, including potentially harmful ultraviolet radiation. These measurements will indicate the mitigation strategies that might be necessary to maintain acceptable UV exposure and total irradiation exposure that is not excessively perturbed by human activity.

Accomplishments

Since the last project update, we have completed the installation of new Multi-Filter Rotating Shadowband Radiometers (MFRSRs) and Multi-Filter Radiometers (MFRs) at all the fixed NOAA Global Monitoring Division Radiation Group surface radiation (SURFRAD) stations. These spectral instruments include a 1625 nm channel that will provide better accuracy in the retrieval of aerosol optical properties, along with improvements in the measurement of other atmospheric variables. With paired units (MFRSR and MFR) at each site, we can now calculate spectral surface albedo. Effort is now underway to work through the data corrections and calibrations necessary to produce high-quality albedo data sets.

Along with the new spectral instruments, all SURFRAD stations now have an improved instrument for measuring direct normal broadband solar radiation. The new instrument will improve the uncertainty of that measurement by 50 percent, which is particularly significant as direct normal shortwave is about 90 percent of the of the total shortwave reaching Earth's surface. To further improve our broadband shortwave and longwave measurements, we have replaced AC fans with DC units for all the ventilated instruments. The new DC fans produce less heat and move more air, which improves an intrinsic problem in these types of measurements known as the nighttime offset error.

Motivated by, and in conjunction with the new instrumentation, we made substantial site infrastructure improvements in the prior year. The SURFRAD program is a long-term measurement network, and it is crucial it operates with very little downtime. The effort put into the infrastructure is foundational to the success of the program, so the materials used and careful planning is in consideration of decades into the future, and not just "years."

About five years ago, our Global Monitoring Division Radiation Group assembled two mobile SURFRAD stations to be used in focused field campaigns in support of a wide variety of scientific research. In the past year, one station was operating in eastern Oregon in support of an experiment to improve wind forecasting in complex terrain. This short-term experiment has concluded and the station was removed in May. The other mobile station was removed from a location near Alamosa, Colorado. This station had provided valuable data to help improve short-term cloud forecasts in support of photovoltaic power generation. Now, it has been set up on a dry lake bed in northern Arizona to provide surface data for a validation study of the new GOES-16 satellite that was launched November 19, 2016.

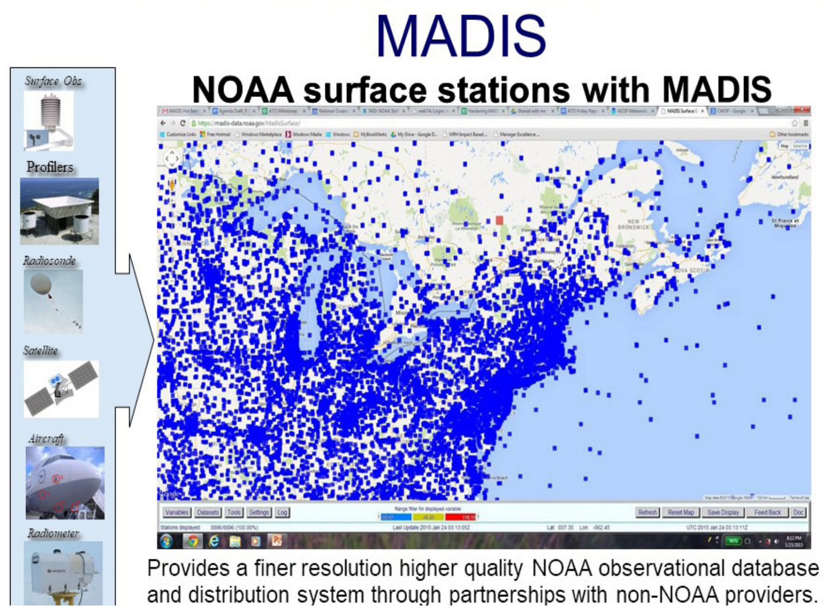
With few exceptions, the mobile SURFRAD stations are identical in capability as the seven fixed sites. The data provided by these stations are core measurements for the science pursued, and in particular as input to the variety of computer models we employed in these studies.

GSD-01: Innovative Weather Data Delivery Systems

■ CIRES Lead: Leon Benjamin ■ NOAA Lead: Gregory Pratt
NOAA Theme: NOAA Engagement Enterprise

Goals & Objective

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



GSD-01: This graphic shows the increasing density of weather data sources provided by MADIS to NOAA weather forecasters and the global weather forecasting community. The number of data sources has increased from about 20,000 to 64,000 during the development of this new data tool. Image: CIRES and NOAA

GMD-01: Mobile surface radiation (SURFRAD) site operated by NOAA's Global Monitoring Division Radiation Group located on the dry bed of northern Arizona's Red Lake. Instrumentation is measuring the surface radiation budget. Photo: Gary Hodges/CIRES and NOAA

Accomplishments

Our group's Meteorological Assimilation Data Ingest System (MADIS) ingests data from NOAA data sources and non-NOAA providers, decodes the data, adds quality control, then encodes all of the observational data into a common format with uniform observational units and time stamps. It is also a conduct to transition observational projects from research to National Weather Service (NWS) operations. Our accomplishments in the last year include:

- Transitioning the NWS's Hydrometeorological Automated Data System (HADS) system into a high security system from a medium system and incorporated it into MADIS. This included adding automated processing updates, verification, and back-out system to update sites changes. This process followed the security rules to allow HADS to add and change sites during critical weather conditions when all changes normally are frozen. It is during those critical weather times that HADS has the greatest need to add new observations for life and safety reasons.
- Running Clarus quality control in MADIS at operations. It is being beta tested and is slated for official release in late 2017.
- Transitioning amdar.noaa.gov into MADIS, in which much work was done. MADIS was officially assigned the gate keeper role in vetting aircraft data access. We are still in the process of moving the amdar.noaa.gov websites.
- Quality controlling providers and sites that are constantly being added to MADIS. MADIS currently quality controls more than 3,000,000 observations per hour.
- Transitioning the creation of the Snow Telemetry (SNOTEL) NOAAport message. It is currently in beta testing and slated for operationalization in summer 2017.
- Transitioning the aircraft Eddy Dissipation Rate observations into NWS operations.
- Acting as the conduit to transition the GPS precipitable water (PWV) raw data from a private provider to NOAA and NWS forecasters.

GSD-03: Improving Numerical Weather Prediction

■ CIRES Lead: Ming Hu ■ NOAA Lead: Georg Grell

NOAA Theme: Science and Technology Enterprise

Goals & Objective

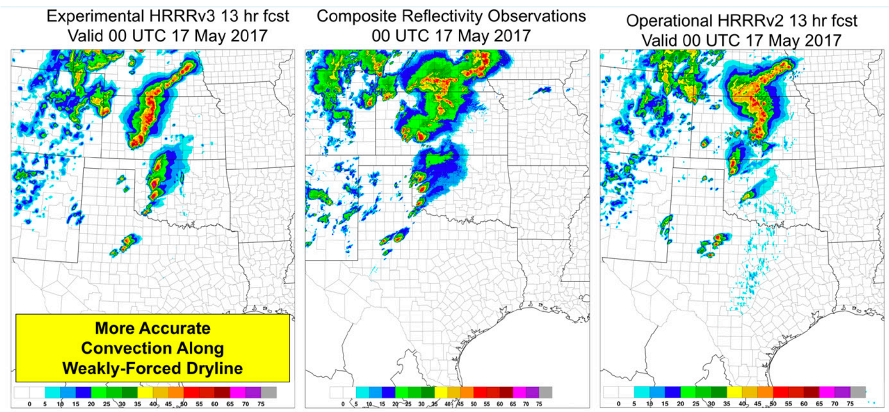
This project focuses on improvements in numerical weather prediction by use of models through improved model design and implementation and optimal use of new and existing observations.

Accomplishments

On August 23, 2016, we made the third version of Rapid Refresh (RAPv3) and the second version of the High-Resolution Rapid Refresh (HRRRv2) operational at the National Centers for Environmental Prediction of the National Weather Service.

Since then, we have made improvements for the next round of code updates in RAP and HRRR, including:

- adaption of a new hybrid vertical coordinate option in the Weather Research and Forecasting (WRF) Model,
- better representation of boundary-layer processes and sub-grid stratiform clouds in model physics,
- further increase in the ensemble weight in the Gridpoint Statistical Interpolation (GSI) hybrid analysis,
- addition of several new satellite radiance datasets,
- reduction of latent heating strength for RAP radar reflectivity assimilation,
- enhancements for Global Systems Division cloud analysis, and
- surface observation assimilation near coast-lines.



GSD-03: The HRRR3 has improved convective forecasts from the operational version, HRRRv2. The figure shows the 13-h forecast for a storm system along a weak forced dryline from HRRRv3 (left panel) and HRRRv2 (right panel). Observed reflectivity (middle panel) shows the new HRRRv3 forecast has improved both storm structure and location. Image: CIRES and NOAA

The updated code had been well tested and showed improvement over RAPv3/HRRRv2 in prediction of temperature, relative humidity, winds aloft, and precipitation. The HRRR also showed substantial improvement in forecasts of conviction during the first six hours of the forecast.

In the summer and fall of 2016, we initiated experimental HRRR forecasts over Alaska, Hawaii, and Caribbean domains, with a 3-hour update frequency and 36-hour forecast length. Since early 2017, we have run a formal HRRR ensemble (HRRRE) in real time, providing probabilistic hazard guidance for heavy precipitation, intense snowfall, and severe thunderstorms. We evaluated HRRRE real-time ensemble forecasts during the Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) field project, and the National Severe Storm Laboratory/ Storm Prediction Center (SPC) Spring Experiment.

Our work continued with development and refinement of a variational cloud analysis, a cloud assimilation procedure for camera data, and with Real-time Mesoscale Analysis and Rapidly Updating Analysis packages.

The team continued to improve reliability of probabilistic forecasts from the HRRR time-lagged ensemble (HRRR-TLE), notably through dynamic bias correction of precipitation forecasts. The HRRR-TLE product suite has been expanded to include aviation and fire weather concerns.

We have started working with the global Finite Volume Cubed-Sphere Dynamical Core (FV3) model in many aspects including physics package, software engineering, and more. Some of our team members are participating the sub-seasonal forecast project at the Climate Prediction Center of the National Centers for Environmental Prediction. We have delivered a set of multi-year hindcast model outputs, and the real time experiments will start soon.

Our verification team has augmented the modeling development verification system to add new regions for Alaska and Hawaii, to add new models new projections and new forecast hours, to implement verification for HRRR ensembles, and to implement a new algorithm for radius-categorical verification.

GSD-05: 2017 xJet Compute System Expansion. Photo: Eric Schnepp/CIRES and NOAA

GSD-05: Development of High-Performance Computing Systems

■ CIRES Lead: Eric Schnepp ■ NOAA Lead: Forrest Hobbs

NOAA Theme: Science and Technology Enterprise

Goals & Objective

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

Accomplishments

Over the past year, our researchers have helped support NOAA's High Performance Computing (HPC) team in the Global Systems Division (GSD). Work spanned several areas, including new system acquisition and planning, application optimization, software development, and user management and support.

In 2016, NOAA acquired an expansion to an existing HPC system to support the computational needs of Hurricane Forecast Improvement Project (HFIP) users. Our role in this acquisition included defining requirements, performing trade-off studies, system validation, and performance testing. The expansion increased xJet from 8,064 to 19,584 compute cores and represents a 23 percent increase in overall computational performance at GSD. In addition to the compute system expansion, NOAA acquired a 1-petabyte capacity expansion to one of three existing High Performance File Systems (HPFS), representing a 22 percent increase in overall HPFS storage at GSD.

Rocoto, a software system designed to help NOAA scientists improve the reliability of their computational experiments on NOAA's HPC systems, saw important bug fixes and performance enhancements. An increasing number of NOAA's GSD and HFIP scientists rely on Rocoto to help them construct complex job workflows that reliably complete. Also, other NOAA labs, including NCEP's Environmental Modeling Center, have adopted Rocoto as a viable alternative to ecFlow for critical projects.

One of the more important experiments that we support on the HPC systems at GSD is the annual real-time hurricane season experiments for HFIP. The goal of this experiment is to demonstrate their ability to deliver improved hurricane forecasts. Our responsibility is to develop the tools and techniques for HFIP scientists to use so that their experiments can run reliably and on-time. Rocoto is a big part of this process. Well before the peak of hurricane season, we implemented a complex system based on reservations that guaranteed system resources to HFIP projects when needed. We closely monitored system utilization and reservation usage during the real-time hurricane season. During periods of low storm activity, we provided tools to HFIP projects to allow them to release unneeded resources, thereby letting the rest of the research and development community to execute as resources became available.

GSD-06: Verification Techniques for Evaluation of Aviation Weather Forecasts

■ CIRES Lead: Matthew Wandishin ■ NOAA Lead: Mike Kraus

NOAA Theme: Weather-Ready Nation

Goals & Objective

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

Accomplishments

Our evaluation of the global Graphical Turbulence Guidance (GTG-G) was delayed due to miscommunication between the product developer and the National Centers for Environmental Prediction (NCEP), who will be incorporating the algorithm into their global model post-processing suite. We held several coordination meetings with the United Kingdom Met Office (UKMO), NCEP, and the Aviation Weather Center (AWC) to establish an agreed upon plan for evaluating the new product in the context of the World Area Forecast System (WAFS) turbulence forecasts. We also began implementation of the GTG-G verification plan.

We completed the assessment of the Icing Product Alaska-Forecast (IPA-F) and reported it to the Federal Aviation Administration and the Alaska Aviation Weather Unit. Overall IPA-F provides an improved forecast over the current operational product, but some issues with IPA-F were noted and are being addressed by the product developers.

We nearly completed an assessment of the follow-on Icing Product Alaska-Diagnostic (IPA-D) nowcast during the reporting period, with the final reporting to be given in June. We found IPA-D provided little value above that which is available from IPA-F.

Our team completed an evaluation of the automated version of the Collaborative Convective Forecast Product (CCFP); the forecasts were found to perform better during the 2016 convective season than it did in the previous year, likely due to upgrades in the underlying models. Despite this improvement, the performance was still below the level that the human forecasters used to achieve (there were no human CCFP forecasts in 2015 and 2016).

We completed the Terminal Radar Approach Control (TRACON) Facilities Gate Forecast Verification Tool expansion to additional airports. A planned further expansion to include human forecaster adjustments to the automated forecast was delayed because of a delay in the implementation at AWC of the human component of the forecast and a lack of forecaster involvement.

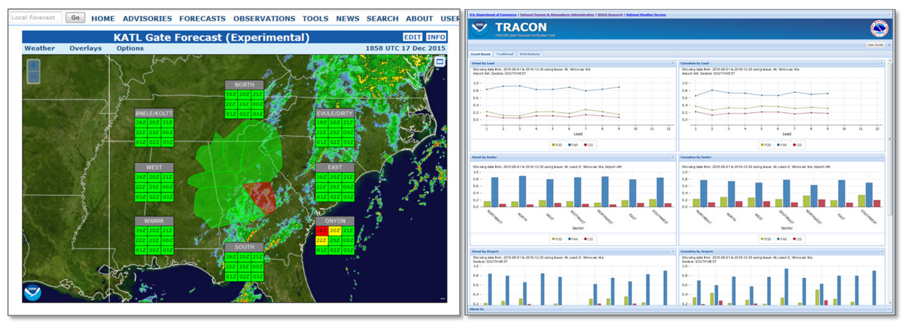
The verification tool for wind-shift forecasts at airports is still in development. We held many consultations with National Weather Service management to establish agreed upon definitions of significant wind-shift events.

Our team conducted extensive research into suitable observations against which to verify the Ensemble Prediction of Oceanic Convective Hazards (EPOCH) forecast product. There is no single product that provides a reliable observation of convection at a global scale. As a result, we will need to combine several observation sets to assess the performance of the EPOCH forecasts.

Similar to with the GTG-G product, meetings were held with NCEP, the UKMO, and AWC to establish a verification plan for the EPOCH product in the context of the WAFS thunderstorm forecast product.

We are incorporating three web-based verification tools developed by the Forecast Impact and Quality Assessment Section—the Central Weather Service Unit Briefing and Verification Tool, the TRACON Gate Forecast Verification Tool, and the Event-based Verification and Evaluation of NWS gridded products Tool—into a common system knows as the Verification Services for Aviation Forecast Evaluation (VSAFE). VSAFE is planned for transition to the NWS to support verification of aviation forecasts supporting traffic flow management.

Our group completed core research projects on an object-oriented approach to verifying forecasts of convective initiation and on the application of a cluster-based presentation of forecast scenarios to a convective-allowing ensemble, as well as an investigation into observation platforms that can serve as truth sets for global convection.



GSD-06: Example of a Terminal Radar Approach Control Gate Forecast of the impact of thunderstorms on arrival and departure route sectors for Atlanta (left image: Aviation Weather Center) and the corresponding TRACON Gate Forecast Verification Tool (right image: CIRES and NOAA)

GSD-07: Numerical Prediction Developmental Testbed Center

■ CIRES Lead: Ligia Bernardet ■ NOAA Lead: Stan Benjamin
NOAA Theme: Weather-Ready Nation

Goals & Objective

This project aims broadly to improve numerical weather prediction for research and operations by building, sharing and maintaining code and techniques for data assimilation, forecast, verification and more.

Accomplishments

CIRES and collaborators continued to act as a bridge between research and NOAA operations in the field of numerical weather prediction. Our activities focused on two fronts: O2R (transition of operational capabilities to the research community) and R2O (test, evaluation, and transition of new research and developments to operations).

Our accomplishments included:

- Public release and support of the HWRF (Hurricane Weather Research and Forecasting) model and GSI (Gridpoint Statistical Interpolation) data assimilation system. This involved testing code for public releases, creating and updating documentation and instructional materials, conducting tutorials, and answering questions from users.
- Support to the developers of the HWRF and GSI codes, by chairing developers' committees, conducting code management, and providing assistance in adding new capabilities to the software.
- Advancement of the CCPP (Common Community Physics Package), a library of physical parameterizations for use in NWP systems, by collecting requirements, formulating a design, and creating a beta version which includes an IPD (Interoperable Physics Driver) that can be used to connect the physics to a variety of models.
- Establishment of a hierarchical "test harness" for assessment of global models. This includes capability to run the GFS (Global Forecast System) in cycled data assimilation mode and produce diagnostics (water and energy budget, tropical cyclogenesis etc.) to inform model development.
- Development of a draft protocol for innovations in physical parameterizations to be transitioned from the research community to the NOAA operational global forecast system.
- Assessment of new capabilities for R2O, including
- Regional 4D-EnVar (four-dimensional ensemble-variational data assimilation).
- Alternate cumulus parameterization for HWRF and GFS.
- Updates to the HWRF partial cloud parameterization and cloud overlap algorithm.
- Publishing a newsletter to inform the community of the activities undertaken by DTC.

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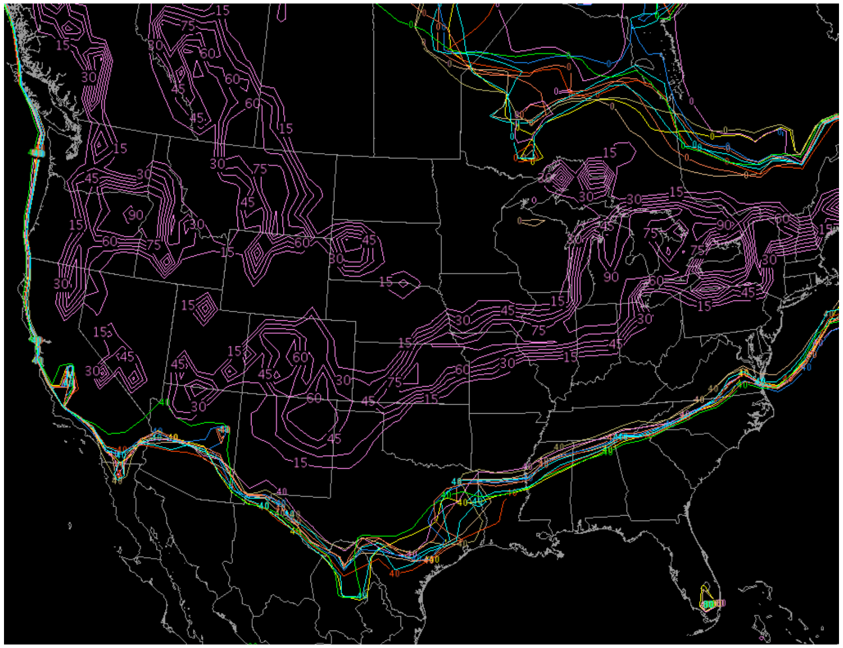


GSD-09: The Ensemble Tool in the Advanced Weather Information Processing System. Image: CIRES and NOAA

GSD-09: Improve the AWIPS Weather Information System

■ CIRES Lead: Paul Schultz ■ NOAA Lead: Mike Kraus
NOAA Theme: NOAA Engagement Enterprise

Goals & Objective

This project focuses on developing forecast tools for NWS forecasters using the AWIPS-2 system.

Accomplishments

We made substantial improvement to the usability, performance, and stability of the Matrix Navigator, an AWIPS tool that allows forecasters to make quick comparisons between alternative forecast scenarios. We also refactored the entire Ensemble Tool for readability, and to ensure the contractor, Raytheon, could efficiently maintain it. We added two new features. The first makes images from contour products, which is expected to improve the utility of the spaghetti tool as the basis for user-custom decision support graphics. The second allows forecasters to efficiently mine the ensemble solution space for details not seen in default contour values; it allows the user to choose a specific contour, then change and redraw it one small increment at a time. These tasks were given highest priority by National Weather Service (NWS) forecasters who attended NOAA's Forecaster Decision Support Environment workshop in September 2016, in Boulder, Colorado. A progress report was given to the annual convention of the American Meteorological Society in Seattle, Washington.

Project NCEI-12 closed in 2016 due to NOAA reorganization.

GSD-11: Improve RAP/HRRR for Wind and Solar Forecasts

■ CIRES Lead: Joe Olson ■ NOAA Lead: Melinda Marquis
NOAA Theme: Science and Technology Enterprise

Goals & Objective

This project focuses on improving the skill of Rapid Refresh and High-Resolution Rapid Refresh forecasts of low-level winds and downward shortwave radiation, which are both useful for the electric power system.

Accomplishments

We developed the boundary layer scheme used in the Rapid Refresh (RAP) and the High-Resolution Rapid Refresh (HRRR) including improvements to the local mixing in stable conditions and the addition of non-local mixing for unstable conditions. We accomplished the former by redesigning the formulation of the mixing length scales to better control the magnitude throughout a wide range of atmospheric conditions. And we accomplished the latter by the addition of a new mass-flux scheme. Both components demonstrated improvement over the previous version of the RAP and HRRR and were included in the code transfer to the National Center for Environmental Prediction for the next generation operational versions of the two models.

Another major accomplishment of our team was the addition of a hybrid vertical coordinate (HVC) to the RAP and HRRR. Our purpose was to reduce artificial numerical mixing caused by the traditional terrain-following vertical coordinate. The HVC code, originally written by colleagues at the National Center for Atmospheric Research (NCAR), was integrated into the RAP/HRRR code repository. Further code required the data assimilation, boundary condition updating, and post-processing software. We tested the code in both the RAP and HRRR for a set of retrospective simulation sampling all four seasons. Our results show that the majority of the improvement is in the upper-tropospheric temperature and relative humidity, with little or no impact in over variables or at other levels of the atmosphere. Although we found no improvement for low-level winds, the improvements to the upper-level humidity can translate into improved cloud forecasts over complex terrain, resulting in small positive improvements in forecasts of downward shortwave radiation.

Stochastic physics is a promising approach to help improve the spread and skill of ensemble forecast systems, providing forecasters with probabilistic information along with traditional deterministic forecasts. The implementation of stochastic parameter perturbations (SPP) into the RAP/HRRR physics, geared specifically for improving the spread of low-level winds and downward shortwave radiation, may provide valuable probabilistic information for the renewable energy industry. We made code changes in MYNN PBL (Mellor-Yamada-Nakanishi-Niino level 2.5 planetary boundary layer), surface layer scheme and RUC LSM (Rapid Update Cycle land surface model) to include SPP. Our team performed ensemble tests to determine optimal spatial and temporal decorrelation length scales. Our results from HRRR-based ensemble shows that SPP helps to improve the ensemble spread. With the addition of other traditional stochastic approaches, it is likely that the HRRR ensemble will be able to attain similar spread as other multi-physics ensembles but maintain better skill. We have outlined future work to achieve this goal.

GSD-12: NOAA Environmental Software Infrastructure and Interoperability Project

■ CIRES Lead: Cecelia DeLuca ■ NOAA Lead: Dave Zezula
NOAA Theme: Science and Technology Enterprise

Goals & Objective

The project advances understanding and improves predictions of the Earth system by delivering infrastructure software that enables new scientific discoveries, fosters inter-agency collaborations, and promotes resource efficiency.

Accomplishments

Our Environmental Software Infrastructure and Interoperability (NESII) project continued to develop and deploy community model infrastructure software, working toward the goal of coordinating modeling activities across agencies.

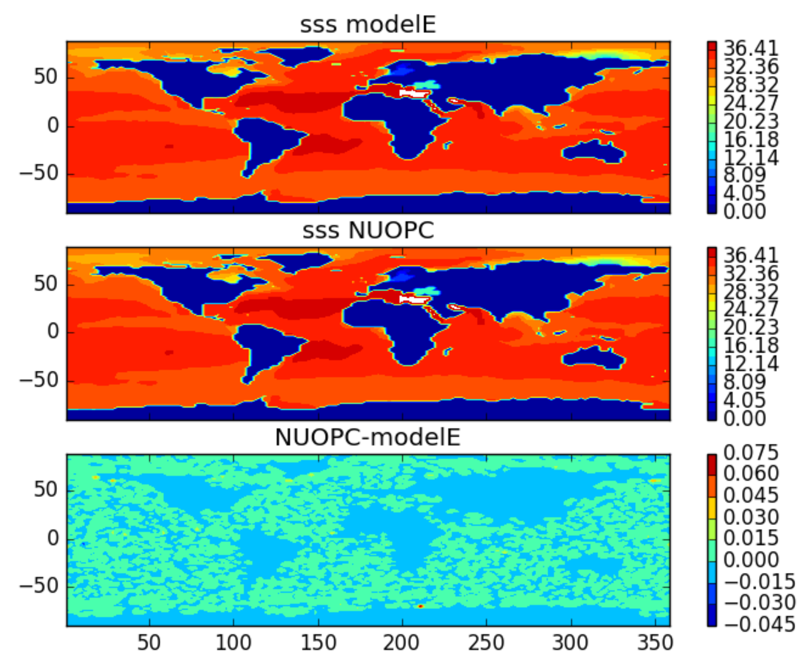
During the last year, we made improvements in NESII products including the Earth System Modeling Framework (ESMF) software for building and coupling models and the National Unified Operational Prediction Capability (NUOPC) Layer, an extension to ESMF that increases the interoperability of model components across centers. Our team worked closely with teams at NOAA, NASA, Navy, the National Center for Atmospheric Research (NCAR), other federal centers, and universities to implement and update ESMF and NUOPC Layer software interfaces in their coupled modeling systems.

One of our goals for this year was to expand the collection of model components that conform to ESMF and NUOPC Layer interfaces, called the Earth System Prediction Suite (ESPS). An important addition to the ESPS this year was a new atmospheric model called the Finite Volume 3 Global Forecast System (FV3GFS). This atmospheric model will be included in numerous NOAA applications (for example, weather forecast, hurricane, seasonal) that are connected by a new unified modeling system for National Weather Service operations. The unified modeling system, or NEMS (NOAA Environmental Modeling System) is based on ESMF and NUOPC Layer coupling tools. Our first release of the FV3GFS under NEMS was in May 2017.

We collaborated with the NOAA Environmental Modeling Center (EMC) and other partners to deliver milestones for other applications running under NEMS. Our deliveries included improvements to a coupled atmosphere-ocean-ice seasonal prediction system, a coupled atmosphere-ionosphere system, a coupled atmosphere-ocean hurricane forecast system with moving nests, and a coupled atmosphere-wave system. These new milestones reflect additional feedbacks and greater physical fidelity.

Other milestones we achieved included a coupled atmosphere-ocean code based on NASA's ModelE using the NUOPC Layer infrastructure, and a coupled regional atmosphere-land-ocean-hydrology code for the Navy. We collaborated with the Navy, NCAR, and university partners to complete a 20-year run of the Community Earth System Model (CESM) coupled to a high-resolution ocean. For a new project with CESM, EMC, and the Geophysical Fluid Dynamics Laboratory (GFDL), we will develop a multi-scale community NUOPC Layer-based coupler that these centers can share.

In addition to developing modeling infrastructure and the ESPS, we also continued to support data infrastructure for the Coupled Model Intercomparison Project 6 (CMIP6), an international effort that is the basis for climate assessments like the Intergovernmental Panel on Climate Change (IPCC). The CoG collaboration environment, developed by NESII, has become the primary U.S. interface for downloading data from the preceding experiment, CMIP5, and will be used for CMIP6. CoG is part of a federated data distribution environment managed by the Earth System Grid Federation, an international consortium. The main CoG installation is at CU Boulder, but there are separate CoG installations in France, Sweden, Germany, the U.K, U.S. federal labs, and other countries. Our team also delivered an extensive model metadata questionnaire for collecting information about the CMIP6 models.



GSD-12: Sea surface salinity computed in two coupled atmosphere-ocean configurations of NASA ModelE, developed at the NASA Goddard Institute for Space Studies. The top image shows the original ModelE code. The middle image shows the code after it was modularized and components were fitted with standard interfaces based on the Earth System Modeling Framework (ESMF). This standardization will enable modelers working with ModelE to exchange components more easily with other models at NASA and in the broader community. The bottom image shows the difference in values between the two configurations. Image: Carlos Cruz/NASA Goddard

Appendices

Contents

Publications

CIRES scientists and faculty published at least 805 peer-reviewed papers during calendar year 2016. Below, we tabulate publications by first author affiliation, per NOAA request. CIRES scientists and faculty published additional non-refereed publications in 2016, many of them listed in the pages that follow. These citations represent a subset of all CIRES publications; our tracking process misses some, although improved tracking methods may be responsible for some increases over recent years. Moreover, 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 "CIRES: Science in Service to Society" (page 3) and detailed throughout this report.

Journal articles

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CIRES Lead Author	141	130	110	158	137	238	186	189	141	158	194
NOAA Lead Author	81	73	99	79	63	41	30	44	65	64	64
Other Lead Author	289	264	385	342	312	293	312	370	490	496	547
Total	**511**	**467**	**594**	**579**	**512**	**572**	**528**	**603**	**696**	**718**	**805**

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Commonly used abbreviations

CSD	NOAA ESRL Chemical Sciences Division
CU Boulder	University of Colorado Boulder
ESRL	NOAA Earth System Research Laboratory
GMD	NOAA ESRL Global Monitoring Division
GSD	NOAA ESRL Global Systems Division
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
OAR	NOAA Office of Oceanic and Atmospheric Research
PSD	NOAA ESRL Physical Sciences Division
SWPC	Space Weather Prediction Center

Active NOAA Awards (June 1, 2016, to May 31, 2017)

Record number	Description	Start date	End Date	Amount in $
NA10OAR4310214	Western Water Assessment	9/1/10	8/31/16	$4,150,933
NA13OAR4310063	Collaborative Research: Influence of NOx and NO3 on SOA Formation: Analysis of Real-Time Field Observations	8/1/13	7/31/16	$382,151
NA13OAR4310074	Quantification of Fossil Fuel CO2 by Surface Sector Using Multi-Species Trace Gas Measurements in the Influx Experiment	9/1/13	8/31/17	$111,786
NA13OAR4310079	Improving Carbontracker by Incorporating Constraints from Atmospheric O_2 and Ocean Biogeochemical Tracer Data	8/1/13	7/31/17	$125,415
NA13OAR4310082	Improving Carbontracker Flux Estimates for North America using Carbonyl Sulfide	8/1/13	7/31/17	$307,488
NA13OAR4310083	Towards Assimilation of Satellite, Aircraft, and other Upper-air CO_2 Data into Carbontracker	8/1/13	7/31/16	$151,754
NA13OAR4310085	Quantifying Observational Variability and Inverse Model Biases of Planetary Boundary Layer Depths and their Impact on the Calculation of Carbon Fluxes in Carbontracker	8/1/13	7/31/17	$79,476
NA14OAR0110120	Climate Literacy and Energy Awareness Network (Clean) Core Activities	6/1/14	7/31/17	$280,313
NA14OAR4310140	Basin-wide Top-down Estimates for CH_4 Emissions from Oil and Gas Extraction Using Aircraft Observations	8/1/14	7/31/17	$273,691
NA14OAR4310142	Ground-based Measurements to Study Fossil Fuels Production Operations Emissions of Methane and Non-Methane Hydrocarbons and their Atmospheric Impacts	8/1/14	7/31/17	$496,327
NA14OAR4310251	Balancing Severe Decision Conflicts Under Climate Extremes in Water Resource Management	8/1/14	7/31/17	$261,689
NA14OAR4830115	NOAA's High Impact Weather Prediction Project (HIWPP) Test Program	6/1/14	5/30/17	$1,651,754
NA14OAR4830123	HIWPP Assimilation, Ensemble Stochastic Physics and Parameterization Development	7/1/14	6/30/17	$1,236,200
NA14OAR4830161	Mission Support and Analysis Associated with the Sensing Hazards with Operational Unmanned Technology (SHOUT) Project	7/1/14	6/30/17	$2,128,163
NA14OAR4830169	CIRES' Contribution to the SHOUT Project Data Management and Visualization	7/1/14	6/30/17	$235,987
NA14OAR4830170	CIRES' Contribution to the Observing System Experiments and Obs. System Sim. Experiments in Support of SHOUT Program	7/1/14	6/30/17	$744,512
NA14OAR4830294	Cog Support for High Impact Weather Prediction Project	9/1/14	8/31/16	$24,880
NA15NWS4680009	Integrating Unified Gravity Wave Physics into the Next Generation Global Prediction System	5/1/15	4/30/18	$468,629
NA15OAR4310103	Modeling and Data Infrastructure in Support of NOAA's Global Models	8/1/15	7/31/18	$2,519,941
NA15OAR4310144	Western Water Assessment: Building Climate Resilience by Design	9/1/15	8/31/20	$1,640,426
NA15OAR4310171	Snow-Atmosphere-Ice Interactions to Advance Sea Ice Predictability	8/1/15	7/31/18	$549,362
NA15OAR4590160	Validation and Improvement of Microphysical Parameterizations for Better Orographic Precipitation Forecasts	9/1/15	8/31/17	$249,702
NA16NWS4680016	Critical Comparison and Evaluation of Skill Scores in Support of NGGPS	9/1/16	8/31/18	$400,000
NA16NWS4680021	Data Assimilation in the Vertically Extended Global Atmosphere Models of NEMS	9/1/16	8/31/18	$386,820
NA16OAR4310132	Advancing the Use of Drought Early Warning Systems in the Upper Colorado River Basin	7/1/16	6/30/18	$286,367
OCG6128B	Intergovernmental Personnel Act Agreement	6/1/14	8/15/18	$750,715
OCG6378B	Deheza NOAA IPA Intergovernmental Personnel Agreement	8/4/16	9/30/17	$140,000

Personnel Demographics

CIRES Personnel Breakdown 2016–2017[1]

	Total Count of CIRES employees	≥50% NOAA[2]	Highest Degree Earned for those ≥50% NOAA[2]			
			BS	MS	PhD	no degree info.
Faculty	21	0				
Research Scientist	244	148	0	0	148	
Visiting Scientist	12	0				
Postdoctoral Researcher	25	5	0	0	5	
Associate Scientist	294	173	76	79	14	4
Administrative	36	31	20	7	2	2
TOTAL	**632**	**357**	**96**	**86**	**169**	
Hourly/Undergr	107	45				
Grad Students	104	8	8	0	0	
GRAND TOTAL	**843**	**410**	**104**	**86**	**169**	

[1]Counted July 15, 2017
[2]CIRES personnel receiving 50% of more of their pay from our NOAA Cooperative Agreement (CA)

CIRES personnel in NOAA Boulder Laboratories receiving any funding from NOAA CA

CSD	77
GMD	63
GSD	71
PSD	79
TOTAL OAR	**290**
NCEI (NESDIS)	55
SWPC	22
NWS	3
GRAND TOTAL	**370**

During the period June 2016 to May 2017, ***two*** *CIRES employees obtained federal employment with NOAA groups in Boulder.*

Project Goals for 2017–2018

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

■ NOAA Lead: Tom Ryerson ■ CIRES Lead: Andy Neuman
CIRES Theme: Air Quality in a Changing Climate
NOAA Theme: Weather-Ready Nation

- Several intensive regional field studies will be conducted to study climate-air quality interdependencies.
- The Fires, Asian, and Stratospheric Transport - Las Vegas Ozone Study (FAST-LVOS) seeks to understand the major sources of unhealthy levels of surface ozone in Clark County, Nevada. Measurements of ozone, carbon dioxide, methane, and carbon monoxide from a ground site and an instrumented van will be performed from May-June, 2017, with an emphasis on characterizing the roles of emissions from regional wildfires and pollution from southern California in addition to transport from the stratosphere and from Asia.
- Measurements will be performed aboard the NASA DC-8 aircraft in Fall 2017 and Spring 2018, as part of the NASA Atmospheric Tomography mission. Measurements of reactive nitrogen, ozone, halogens, particle concentrations, and black carbon will be made over the Atlantic and Pacific Oceans, nearly pole to pole.
- The analysis of measurements from recent intensive field studies will continue (for example, SONGNEX, WINTER, ATom, UWFPS, FIREX, and CABOTS), and results will be presented at conferences and meetings, and published in peer-reviewed journals.

CSD-02: Chemistry, Emissions, and Transport Modeling Research

■ NOAA Lead: Michael Trainer ■ CIRES Lead: Stu McKeen
CIRES Theme: Air Quality in a Changing Climate
NOAA Theme: Climate Adaptation and Mitigation

- Compare the Fourier based method for variance scaling determination with simpler approaches published within the satellite community.
- The satellite retrievals for CO were based on low spectral resolution retrievals that were available before spring of 2015. Since then, the CO retrievals have been upgraded using higher spectral resolution capabilities within the Cross Track Infrafred Sounder (CrIS) aboard the VIIRS platform. A similar variance scale analysis of these newer retrievals is necessary to determine if true improvement was obtained.
- Recent release of NASA DC-8 measurements from the 2016 Atmospheric Tomography Mission (ATom1) global field campaign provide a more comprehensive data set for satellite evaluation work, including variance scale analysis, compared to the SENEX-2013 field study used to date.

CSD-03: Scientific Assessments for Decision Makers (IPCC, MP, U.S. Climate, U.S. AQ)

■ NOAA Lead: David Fahey ■ CIRES Lead: Owen Cooper
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

TOAR will reach its completion by the end of 2017. From June 1 through September 30 the remaining five TOAR papers will be completed and submitted to the journal Elementa for peer review. As the papers are accepted for publication they will be made available immediately through the journal's webpage. All papers will be open-access. Once TOAR is complete, the TOAR chairperson, Owen Cooper (CIRES) will communicate the results to the IGAC (International Global Atmospheric Chemistry Project) Scientific Steering Committee and ask them to consider supporting TOAR-II, which will begin towards the end of 2018.

CSD-04: Effects of Emissions on Atmospheric Composition

■ NOAA Lead: Tom Ryerson ■ CIRES Lead: Carsten Warneke
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

- This project will continue to provide and test new and improved quantifications of surface emissions of important trace gases, aerosols and greenhouse gases to determine their relevance for pollution, air quality and climate.
- The analysis of emission measurements from recent intensive field studies including SONGNEX and FIREX will continue and results will be presented at conferences and meetings, and published in peer-reviewed journals.
- The FIREX experiment to study biomass burning emissions with the NOAA WP-3D aircraft will take place in summer 2019 in collaboration with NASA's FIREChem (Fire Impacts on Regional Emissions And Chemistry) and the Joint Fire Science Program's FASMEE project (Fire and Smoke Model Evaluation Experiment), but laboratory experiments together with instrument and model development in preparation for the mission will be conducted in 2017 and 2018.
- Methane and VOC emissions from oil and natural gas production using the SONGNEX measurements and inverse modeling will be derived from several production areas that combined have more than 70% of the natural gas production in the US.

CSD-05: Laboratory Studies of Fundamental Chemical and Physical Processes

■ NOAA Lead: Jim Burkholder ■ CIRES Lead: Dimitris Papanastasiou
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

- The evaluation of the atmospheric fate and climate metrics for potential replacement compounds will continue. The initial emphasis is to study the reactivity of cyclic unsaturated hydrofluorocarbons.
- A comprehensive set of climate metrics (lifetimes, ozone-depletion and global warming potentials) for a large set of hydrochlorofluorocarbons (HCFCs) that are currently controlled by the Montreal Protocol, but which lack laboratory data, will be evaluated using theoretical methods. The methodology established will be expanded to a series of HFCs in a separate task.
- Calibration methods for aerosol mass spectrometers (AMS) and particle-into-liquid samplers (PiLS) will be developed. Research will be undertaken on the production and calibration of aerosol particle streams containing carbon, nitrogen, and sulfur compounds of atmospheric interest. Sample streams will be calibrated for C/N/S content by catalytic conversion to and detection of CO_2, NO, and SO_2.
- A project to develop a total atmospheric OH reactivity apparatus and methodology will be initiated. Here, we will develop and extensively characterize a comparative reactivity method with the goal of providing a robust method to be applied in a range of environments.
- Manuscripts describing the results from completed experimental work will be prepared and submitted to peer-review journals.

CSD-06: Aerosol Formation, Composition, Properties, and Interactions with Clouds

■ NOAA Lead: Dan Murphy ■ CIRES Lead: Barbara Ervens
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

- Aerosol formation, composition, properties: Aerosol mass formation in clouds: We will improve current descriptions of sulfate and secondary organic aerosol formation in clouds. In addition, we will explore based on field and model data, if there is a 'signature' of aqueous phase processing of aerosols in various air masses that may allow us to determine the role of aqueous phase processes for total atmospheric aerosol loading.
- Characterization of the abundance and transport of climate-relevant aerosol: We will continue to make fast response in situ measurements of mineral dust, biomass burning paritcles, and particle nuclei during the final two deployments of the NASA ATom (Atmospheric Tomography) field campaign. These measurements will be compared to global aerosol models in a series of publications to investigate aerosol loses, transport, and cloud forming properties.
- Representation of clouds in models: We will refine the cellular network approach, in order to explore further the extent to which such a framework can be used to explain and predict the structure and arrangement of cloud systems. Furthermore, we will explore the role and effects of the improved radiation scheme for various cloud systems.
- Aerosol-Cloud Interaction Observations and Modeling: We will continue the development of the Lagrangian LES approach. The system will be used in conjunction with large-scale reanalysis data and observations from ongoing field campaigns to investigate the effect of (anthropogenic) biomass burning aerosol on cloud properties in the South-East Atlantic region, and the role of meteorological and ocean properties on the susceptibility of clouds to aerosol.

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

■ NOAA Lead: Ru-Shan Gao ■ CIRES Lead: Troy Thornberry
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

- Deploy a Wideband Integrated Bioaerosol Sensor (WIBS) instrument on a NOAA Twin Otter during July 2017 flights in the Arctic to study the potential role of bioaerosol in cloud formation at high latitudes.
- Deploy the NOAA CSD SO_2, O_3 and POPS (Printed Optical Particle Spectrometer) instruments on board the NASA Global Hawk during a NASA mission to observe cyclogenesis in the eastern Pacific Ocean in August 2017.
- Operate a Single Particle Soot Photometer (SP2) instrument on the NASA DC-8 to measure black carbon (BC) aerosol mass loadings in the remote atmosphere during the third and fourth deployments of the Atmospheric Tomography (ATom) mission in October 2017 and April 2018.
- Complete analysis of BC aerosol data from the NASA KORUS-AQ mission and submit a manuscript on sources and distribution of BC in South Korea
- Complete analysis of BC data from the first ATom deployment and submit a manuscript describing the observed vertical distribution of BC compared to previous observations and models.
- Complete analysis of water vapor and ice water content measurements made during the Pacific Oxidants, Sulfur, Ice, Dehydration and cONvection (POSIDON) mission and prepare a manuscript describing high altitude cirrus formation processes over the tropical western Pacific.
- Complete analysis of SO_2 measurements made during the POSIDON mission and prepare a manuscript describing factors controlling the transport and distribution of SO_2 in the upper troposphere and lower stratosphere over the western Pacific Ocean.

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

■ NOAA Lead: Alan Brewer ■ CIRES Lead: Christoph Senff
CIRES Theme: Regional Sciences and Applications
NOAA Theme: Weather-Ready Nation

- Deploy the TOPAZ ozone lidar to Las Vegas as part of the Fires, Asian, and Stratospheric Transport - Las Vegas Ozone Study (FAST-LVOS) to investigate the different sources and transport processes that contribute to elevated ground-level ozone concentrations observed in the Las Vegas area.
- Use the autonomous NOAA wind lidar observations to evaluate wind forecasts for different seasons and under various flow regimes and to study the effect of terrain on wind flow.
- Deploy the Oceanographic Lidar to the Arctic Ocean on a NOAA Twin Otter aircraft in summer 2017. Continue the evaluation of the new detectors and participate in engineering flights in spring 2018 during which the Oceanographic Lidar will be co-deployed with a Doppler wind lidar.

CSD-09: Stratospheric Radiative and Chemical Processes that Affect Climate

■ NOAA Lead: Karen Rosenlof ■ CIRES Lead: Sean Davis
CIRES Theme: Stratospheric Processes and Trends
NOAA Theme: Climate Adaptation and Mitigation

- Compare changes in tracer-tracer relationships in satellite and aircraft measurements with chemistry-climate model simulations.
- Evaluate surface impacts of Northern hemisphere stratospheric final warmings.
- Improve nitrate-ammonia representation in a state-of-the-art aerosol model (CARMA) to better simulate stratospheric chemistry.
- Improve understanding of aerosol processes and their relation to cirrus clouds using Atmospheric Tomography airborne field experiment data.
- Calculate observationally based estimates of Earth's globally average radiative forcing using novel methods that were developed at CIRES.
- Study the influence of interannual stratospheric circulation variability on emission estimates of trace gases important for ozone depletion and climate, such as CFC-11 and N2O.
- Quantify atmospheric reanalysis representations of dynamical variables, water vapor, and ozone in the stratosphere to evaluate their use in constraining past atmospheric variability and trends.
- Use satellite data, models, and reanalyses to better understand changes in the edge of the tropics and potential linkages between tropospheric and stratospheric circulation changes.

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

■ NOAA Lead: Joseph Michalsky ■ CIRES Lead: Gary Hodges
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Climate Adaptation and Mitigation

In the coming year site visits will continue to focus on infrastructure refresh and updating. It is hoped the bulk of this effort will be completed by the end of 2017. Now that spectral albedo data is being collected, work will be directed at producing high quality spectral albedo data datasets for all the SURFRAD stations. This will involve careful error correction and instrument characterization.

GMD-02: Analysis of the Causes of Ozone Depletion

■ NOAA Lead: Russ Schnell ■ CIRES Lead: Irina Petropavlovskikh
CIRES Theme: Stratospheric Processes and Trends
NOAA Theme: Climate Adaptation and Mitigation

- **Ozone-Sonde:** Routine observations at all NOAA ozonesonde sites will continue with regular flight schedules. Validation of the changes in homogenized ozone profiles will be accomplished through comparisons between ozonesondes and Umkehr profiles at several NOAA stations where both types of measurements have been routinely performed since the 1980's. The long-term time series of ozone-sondes will be assessed for trends under the SPARC Long-term Ozone Trends and Uncertainties in the Stratosphere (LOTUS) project. The project aims to assess propagation of measurement uncertainties in trend regression analyses . The assessment of ozone variability in the Upper Troposphere and Lower Stratosphere (UTLS) region will be performed using records from the NOAA ozonesonde stations. This is part of SPARC emerging activity "Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere" (OCTAV-UTLS), which focuses on improving the quantitative understanding of the UTLS's role in climate and the impacts of stratosphere-troposphere exchange (STE) processes on air quality. Achieving this goal requires a detailed characterization of existing measurements (from aircraft, ground-based, balloon, and satellite platforms) in the UTLS, including understanding how their quality and sampling characteristics (spatial and temporal coverage, resolution) affect the representativeness of these observations.
- **NEUBrew:** Further analysis of the past data taken by Brewer network for studying the new UVC-7 solar blind filters will be performed. Additional test may also be performed to determine any long-term changes to the transmittance of the filters. It is also hoped that we can update the ozone calibration on some of the NEUBrew network Brewers in 2018. NEUBrewer instruments have not been compared to the WMO Toronto Brewer triad since 2014 and it will be of importance to track the degradation of the measurement system against the reference.

- **Dobson:** Dobson Reprocessing with Seasonal Correction will continue after the new GMI/MERRA2 data has been released in June 2017. With these new datasets, the correction period has been extended to the years 1985-2016 for most of the NOAA Dobson stations, with additional stations (i.e. Arosa, Arrival Heights, De Bilt, Hohenpeissenberg, Izana, Midi-Pyrenees, Paramaribo, etc.). This will be an ongoing evaluation and likely data archival for the seasonally-corrected Dobson historical record. The plan is to continue with making Dobson observations and processing data from NOAA fourteen sites. Barring funding shortages we plan to repair the Dobson at Perth, swap instruments at the American Samoa observatory and perform significant repairs to its shelter including total replacement of the door. We will bring the instruments from Hanford, CA; Caribou, ME; and Wallops Island, VA to Boulder for calibration.
- **Surface ozone:** Data collection and analyses of surface ozone variability will continue at 15 NOAA stations. Analyses of surface ozone variability at multiple stations will continue with help of the SOCOL and CESM model data. To expand analysis to Colorado state region (in collaboration with Gabriele Pfister form NCAR) regional NCAR model will be used to assess transport patterns of stratospheric ozone intrusions and anthropogenic and biomass burning airmasses that influence baseline levels of surface ozone observed at three NOAA stations. The work will be done in collaboration with PIs of multiple stations in State of Colorado (University Colorado in Boulder) and by CDHE (Colorado Department of Health and Environment, private communications with Barkley Sive).
- **Data archiving:** Archival project for Dobson total ozone, ozonesonde profiles and surface ozone data will remain ongoing for as long as the Big Earth Data Initiative (BEDI) project is active. The next step is to go through the archival of the dataset. The work will involve assessment of the quality of the datasets for archival, including conformities to the required NCEI standards and policies of the data formatting.

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

■ NOAA Lead: Patrick Sheridan ■ CIRES Lead: Betsy Andrews
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

Our primary goal is, as always, to continue to maintain high quality in-situ optical measurements at all the sites in the federated aerosol network. This includes decommissioning a site on the northern coast of California and moving into a new measurement building at a site in Illinois. There may be some sites added to the network (potential locations include Utah and Siberia). We plan to finish rolling out the new data acquistion system by the end of 2017, though depending on site access, that deadline may slip.

Research-wise, the primary focus will continue to be the model/measurement evaluation project. There are also multiple manuscripts in the works that we hope will be submitted to peer-reviewed journals in the next reporting period. There are several manuscripts currently circulating amongst co-authors (typically the last stage before submissiont to a journal). These cover the following topics: (i) Arctic aerosol climatology, (ii) influence of topography on aerosol measurements at mountain sites, and (iii) evaluation of the NOAA-built continuous light absorption photometer (CLAP) instrument. Papers in progress (but not quite ready to circulate!) include a manuscript draft on the measurement/model comparison at low RH conditions and several papers related to aerosol climatology and/or aerosol events at aerosol network sites.

GMD-04: Studies of Greenhouse Gas Trends and Distributions

■ NOAA Lead: Pieter P. Tans ■ CIRES Lead: Gabrielle Petron
CIRES Theme: Climate Forcing, Feedbacks, and Analysis
NOAA Theme: Climate Adaptation and Mitigation

Goals for 2017-2018 will focus on timely and public updates of existing products, and continuation of data collection in the field and laboratory.

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

■ NOAA Lead: James W. Elkins ■ CIRES Lead: Fred Moore
CIRES Theme: Stratospheric Processes and Trends
NOAA Theme: Climate Adaptation and Mitigation

This is primarily a long-term monitoring project, so the goals remain essentially unchanged. Unfortunately, this coming year's work at several remote surface sites will be curtailed, mainly due to budgetary constraints. Fortunately, we have been able to retain the flask collection programs at these locations. There will be publications focused on unusual observations obtained over the past few years for important ozone-depleting gases this coming year. The high altitude mission oriented studies do evolve and as such we will be part of the NASA Atmospheric Tomography Mission (ATom, 3rd and 4th deployment) and will be working up the data from the NASA Pacific Oxidants, Sulfur, Ice, Dehydration, and cONvection Experiment (POSIDON).

GMD-06: Monitor Water Vapor in the Upper Troposphere and Lower Stratosphere

■ NOAA Lead: Russell Schnell ■ CIRES Lead: Dale Hurst
CIRES Theme: Stratospheric Processes and Trends
NOAA Theme: Climate Adaptation and Mitigation

Continue monthly water vapor soundings with the balloon-borne NOAA Frost Point Hygrometer (FPH) at Boulder, Colorado, Hilo, Hawaii, and Lauder, New Zealand.

Perform nighttime balloon launches at Boulder and Lauder in coordination with over-passes of the International Space Station to validate stratospheric water vapor and ozone measurements by the Stratospheric Aerosol and Gases Experiment (SAGE-III).

Publish a peer-reviewed journal paper describing the precipitous drop in tropical lower stratospheric water vapor during 2016 that was driven by the anomalous behavior of the 2015-16 quasi-biennial oscillation (QBO) and the concurrent transition of the El Niño Southern Oscillation (ENSO) from strong El Niño to weak La Niña conditions.

GSD-01: Innovative Weather Data Delivery Systems

■ NOAA Lead: Gregory Pratt ■ CIRES Lead: Leon Benjamin
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Engagement Enterprise

Support the MADIS system by software upgrades, adding providers, improved efficiency, and improving capabilities:

- Add providers
- Complete the Sensing Hazards with Operational Unmanned Technology (SHOUT) transition to operations
- Complete the amdar.noaa.gov tranistion including the gate-keeper for private aircraft data
- Complete the SNOTEL transition

GSD-02: Science Education and Outreach (SOS)

■ NOAA Lead: John Schneider ■ CIRES Lead: Beth Russell
CIRES Theme: Scientific Outreach and Education
NOAA Theme: Engagement Enterprise

New software releases are planned for SOS and SOSx. For SOS, the release includes support for higher resolution videos for use with 4k projectors, better highlighting of new datasets, improved collaboration tools, and improved software security. For SOSx, the release will include better virtual reality interfaces, interactive new content, and improved tools for creating content.

A yearly goal is to grow the SOS Users Collaborative Network through new SOS installations, new content creators, and other partners. Another goal is to increase the SOSx installations. News about SOS and SOSx will be spread by attending workshops and conferences, and enhancing our online presence. Quarterly education webinars and SOS training webinars will continue in order to support users.

For NEIS, CIRES and collaborators will continue to research solutions for efficiently displaying and animating high-resolution data. As model and satellite data continues to grow the scientific community will need tools that are capable of using that data. We will also continue to expand presentation capabilities to make it easy for presenters to display their data along with other custom content.

GSD-03: Improving Numerical Weather Prediction

■ NOAA Lead: Georg Grell ■ CIRES Lead: Ming Hu
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Science and Technology Enterprise

Complete evaluation and testing of code for the next version of the RAP (RAPv4) and HRRR (HRRRv3). The RAPv4/HRRRv3 system will be transferred to the NCEP in late June 2017 for further testing, and become operational in early 2018, including the Alaska HRRR. Work will continue on refinements to data assimilation procedures, focusing radar and satellite data assimilation, and the variational cloud analysis. Work will be expanded in the RTMA/RUA package with production of 15-min analysis using CONUS and Alaska HRRR grids as background. Begin building and testing of capability to produce high resolution, short-term forecasts of hazardous weather using the FV3 model, chosen by NWS to succeed WRF-ARW. Work will begin to evaluate data assimilation for regional/storm-scale FV3 applications. HRRRE will be developed through additional retrospective and real-time testing. A full-CONUS forecasting capability will be added. Prototype HRRRE forecasts will be produced for evaluation at the National Weather Service (NWS) SPC in spring 2018. Other development will focus on improved ensemble spread through methods such as stochastic physics and on improved post-processing through methods currently being developed in the HRRR-TLE. Further refinement of probabilistic forecast algorithms in HRRR-TLE through testing and evaluation at Weather Prediction Center (WPC), SPC, and Aviation Weather Center (AWC) testbeds, in preparation for a possible future implementation of this system at NCEP. Will work closely with partners at NCEP and the Geophysical Fluid Dynamics Laboratory (GFDL) on the FV3 development and implementation towards the operational the Next Generation Global Prediction System project (NGGPS). Start running real-time sub-seasonal forecast using the coupled Flow-following Icosahedral Model (FIM) and the icosahedral Hybrid Coordinate Ocean Model (i-HYCOM). Verification group will work to migrate existing applications from java applet-based system into new JavaScript-based system and develop process-base metrics based on more detailed observations.

GSD-04: Improve Regional Air Quality Prediciton

■ NOAA Lead: Georg Grell ■ CIRES Lead: Ravan Ahmadov
CIRES Theme: Air Quality in a Changing Climate
NOAA Theme: Science and Technology Enterprise

- Finish the HRRR-Smoke paper
- Update parameterization of biomass burning emissions (emission factors and diurnal cycle) in HRRR-Smoke
- Study impact of smoke on numerical weather prediction using the HRRR-Smoke model

GSD-05: Development of High-Performance Computing Systems

■ NOAA Lead: Forrest Hobbs ■ CIRES Lead: Eric Schnepp
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Science and Technology Enterprise

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

GSD-06: Verification Techniques for Evaluation of Aviation Weather Forecasts

■ NOAA Lead: Jennifer Mohoney ■ CIRES Lead: Matthew Wandishin
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Weather Ready Nation

- Complete Part 1 of the evaluation of the global version of the Graphical Turbulence Guidance (GTG-G) product in coordination with the US and UK World Area Forecast Centers.
- Begin Part 2 of the GTG-G evaluation. Complete evaluation of the Icing Product Alaska-Diagnostic Product.
- Complete evaluation of the Ensemble Prediciton of Oceanic Convective Hazards forecasts for the Northern Hemisphere summer season and being evaluation for the Southern Hemisphere summer season.
- Begin evalution of an analysis product for ceilings and visibility.
- Transition one of the verification tools to the National Weather Service (which tool is still to be determined by NWS management).
- Complete the first phase of transition of the Integrated Support for Impacted air-Traffic Environments (INSITE) decision support tool to a data services model--fields of forecast constraint will be provided to the Aviation Weather Center for display within their forecast viewers (AWIPS).
- Core research projects include an exploration of data-denial approaches to minimize resource costs, the construction of a Flow Constraint Mitigation tool that models the flow of air traffic in the presence of weather hazards, an exploration into techniques for verifying forecasts of convectively-induced turbulence, an investigation supporting the verification of probabilistic forecasts of turbulence.

GSD-07: Numerical Prediction Developmental Testbed Center

■ NOAA Lead: Stan Benjamin ■ CIRES Lead: Ligia Bernardet
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Weather Ready Nation

- Keep the GSI, HWRF codes used in operations and in the research and development community synchronized.
- Assist GSI and HWRF community users by providing new code releases, tutorials, updated documentation and datasets, and answering questions.
- Support GSI and HWRF community developers in adding their innovations to the centralized code repository.
- Enhance the Global Model Test Bed with additional tools to diagnose the strengths and weaknesses of physical parameterizations.
- Implement and test promising NWP developments to evaluate them for potential operational implementation.
- Conduct initial experiments with the new NWS atmospheric dynamic core (FV3) and propose mechanisms to foster community engagement with it.
- Publish a newsletter to inform the community of the activities undertaken by DTC.

GSD-09: Improve the AWIPS Weather Information System

■ NOAA Lead: Mike Kraus ■ CIRES Lead: Paul Schultz
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Engagement Enterprise

We will continue to add new features (and fix bugs) under the guidance of NWS field forecasters. There will probably be no workshop, but we expect to test and collect feeback by distributing the software to select forecasters to test on their workstations in various Warning and Forecast Offices.

GSD-11: Improve RAP/HRRR for Wind and Solar Forecasts

■ NOAA Lead: Melinda Marquis ■ CIRES Lead: Joe Olson
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Science and Technology Enterprise

- Add additional non-local mixing in the PBL scheme to represent turbulence produced by cloud-top cooling. This is an important souce of turbulence that can help regulate the cloud cover over the subtropical oceans, which can have a big impact on long-term forecasts.
- Add additional parameters to be perturbed stochastically in order to further help improve the spread in the HRRR ensemble.
- Make improvements to the data assimilation of clouds, winds, and temperatures in complex terrain.

GSD-12: NOAA Environmental Software Infrastructure and Interoperability Project

■ NOAA Lead: Dave Zezula ■ CIRES Lead: Cecelia DeLuca
CIRES Theme: Systems and Prediction Models Development
NOAA Theme: Science and Technology Enterprise

- Deliver improvements to NESII infrastructure packages requested by development partners and customers.
- Deliver coupled modeling system milestones for federal agencies including Navy, NASA, NOAA, and NSF.
- For NOAA, migrate the new NOAA atmosphere model slated for operations, Finite Volume 3 Global Forecast System (FV3GFS) into coupled applications running under the NOAA Environmental Modeling System (NEMS). This supports NOAA's move to a unified operational production suite that shares infrastructure and uses the same model components for multiple purposes (e.g. seasonal prediction, weather forecasting).
- Under new NOAA funding, develop guidelines for repositories, verification tests, and model metadata for components in the Earth System Prediction Suite (ESPS), a collection of codes with standard component interfaces. Improve the tools and website used to disseminate information about ESPS.
- Continue to support the international Coupled Model Intercomparison Project 6 (CMIP6) with the CoG environment and metadata questionnaire, as CMIP6 enters its data collection and dissemination phase.

NCEI-01: Enhancing Data Management Systems and Web-Based Data Access

■ NOAA Lead: Drew Saunders ■ CIRES Lead: David Neufeld
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

During the 2017-18 year, agile teams will focus on continuing to support our CCOG, ESRA, and OneStop projects. CCOG goals will encompass additional subset capabilities for crowd-sourced bathymetry data during data extraction as well as increased integration of ECS Catalog metadata into core Common Ingest capabilities. ESRA will focus on deploying updated Common Ingest software into the DMZ, and replacing some legacy archive software. Lastly OneStop will be adding community data access protocols like OpenSearch and Catalog Services for the Web to it's capabilities as well as allowing citizens to customize their search experience. EMMA team will focus on completing migration of EMMA applications to secure servers in North Carolina. Converting from an Oracle database to PostgreSQL, and implementing single-sign-on for all apps. Lastly, adding advanced metadata editing capabilities (e.g. controlled vocabularies, modular metadata components) to CEdit. Enhance geospatial services to improve discoverability and usability for NCEI's diverse datasets. Examples: Visible Infrared Imaging Radiometer Suite (VIIRS) satellite nighttime lights products, visualizations of historical tsunami data, Arctic and North Atlantic data portals, and managing/visualizing very large point collections using Esri's Spatiotemporal Big Data Store. Work towards consolidation and standardization of geospatial services across NCEIâ€™s locations. Increase use of cloud-based services (e.g. ArcGIS Online, Story Maps).

NCEI-02: Enhancing Marine Geophysical Data Stewardship

■ NOAA Lead: Jennifer Jencks ■ CIRES Lead: Carrie Wall
CIRES Theme: Manageme

NCEI and CIRES staff will continue to search, acquire, and provide access to new and historical marine geophysical data (e.g., bathymetry, gravity, seismic, magnetics, and water column sonar data) from the global oceanographic community. Metadata content and data discovery capabilities, specifically in support of IOCM projects, will continue to be improved.

CIRES staff will continue to collaborate with the software development team to expand beyond our initial crowdsourced bathymetry data providers. Over the next year, the data upload and download pipelines will continue to be refined and improved and a new point storage technology will be implemented to better handle the large volumes of point data that are expected.

CIRES staff at NCEI will expand on passive acoustic data steward by incorporating a broader range of data sources and types. The water column sonar data archive will incorporate data collected at all NOAA Fisheries Science Centers, which could double our current holdings.

NCEI-03: Improved Geomagnetic Data Integration and Earth Reference Models

■ NOAA Lead: Rob Redmon ■ CIRES Lead: Arnaud Chulliat
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

Our goals for next year are:

- To perform simulations aimed at determining the impact of various data collection methods and instrument performances on the final accuracy of the World Magnetic Model, the standard model for navigation, attitude and heading referencing systems of the U.S. Government.
- To produce the 2018 update of the HDGM; (3) to continue research aimed at better separating geomagnetic signals from internal and external sources, focusing on ionospheric, magnetospheric and oceanic sources.

NCEI-04: Enhanced Coastal Data Services, Integration, and Modeling

■ NOAA Lead: Emily Rose ■ CIRES Lead: Kelly Stroker
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

CIRES staff at the National Centers for Environmental Information (NCEI) will continue to make improvements to the Historical Natural Hazards Events Database. This database is continuously updated based on new references, newly found references (e.g. historical documents), and new field studies. In the coming year, we hope to make improvements to the hazard image search tool enabling users to more easily find what they are interested in. In cooperation with the International Tsunami Information Center (ITIC) and the University of Southern California and through funding from the NOAA Big Earth Data Initiative (BEDI), we hope to add several thousand images to the online database and archive. These long-term data, including photographs, can be used to establish the history of natural hazard occurrences and help mitigate against future events. Through continued funding received from a NOAA Big Earth Data Initiative grant, NCEI will reformat, document, archive, and make discoverable segments of historical marigram (tide gauge) records on which are recorded measurements of the 1854, 1883, 1896, 1968 and 1933 tsunamis.

CIRES staff will continue developing integrated bathymetric-topographic digital elevation models (DEMs) that will increase the accuracy of tsunami and hurricane storm-surge forecasts and warnings, and support more effective coastal and marine spatial planning, ecosystems management, habitat research, and coastal change studies. This work builds on the existing catalog of more than 200 DEMs covering the coastal US, Hawaii, Alaska, and Pacific Islands developed at NCEI.

In 2018, CIRES staff will build 4 DEMs to support the National Tsunami Hazard Mitigation Program (NTHMP) and 4 to support our NOAA Tsunami Warning Centers and research at the NOAA Center for Tsunami Research (NCTR). Through COASTAL (Consumer Option for an Alternative System to Allocate Losses) Act funding, CIRES staff at NCEI will follow the procedures developed and tested under the Disaster Relief Appropriation for Hurricane Sandy to build the suite of seamless topographic-bathymetric and bathymetric high-resolution telescoping DEMs in Houston/Galveston TX, New Orleans, LA, South Florida (Atlantic coast), and coastal North Carolina.

Through BEDI funding, NCEI CIRES staff will update the National Ocean Service (NOS) Estuarine Bathymetry Digital Elevation Models (DEMs) for various estuaries in the United States. These data were initially created in 1998 by the now defunct NOS Special Projects Office. Although these data still represent the "best available" gridded depictions of bathymetry in some locations, they are primarily based on antiquated historical data and do not include many modern survey data, in particular, high resolution BAG format hydrographic data. Only available data digitized before 1997 were used in the original project. New data will be incorporated and the products archived and made available online.

For the water level data archive, we are looking at ways to extract and show detected tsunami amplitudes from the time-series data and record these in our natural hazards database. We are working with the Pacific Tsunami Warning Center (PTWC) to add their water level data to the archive. We will also be working with the Center for Operational Oceanographic Products and Services (CO-OPS) to fill in gaps in archived water level data. During the next year, we hope to improve the presentation of tide gauge data as represented in the timeline plots by making the plots more interactive for the user. These improvements support the interests of the coastal hazard scientific community, state and federal agencies, and coastal hazard managers who research the history of natural hazard occurrences and can help mitigate future events.

NCEI-05: Enhanced Stewardship of Space Weather Data

■ NOAA Lead: William Denig ■ CIRES Lead: Justin Mabie
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

In the next year transition of data management duties to the appropriate branches of NCEI will continue. Implementation of a management plan for historical analog data records on both paper and film which are stored at the NCEI warehouse will be finalized. Management of ionosonde data will continue. New experiments will be conducted to observe the ionospheric disturbances associated with rocket launches. Field site maintenance will continue. The current goal is to submit two articles for peer review.

NCEI-06: Satellite Anomaly Information Support

■ NOAA Lead: William Denig ■ CIRES Lead: Juan Rodriguez
CIRES Theme: Space Weather Understanding and Prediction
NOAA Theme: Science and Technology Enterprise

Quality-controlled long-term space radiation data sets are essential for successful Satellite Anomaly Information Support. Therefore, we will continue to reprocess and validate the space environmental data that NCEI makes available to the public. We will also continue to support NCEI environmental assessments requested by satellite anomaly resolution teams.

NCEI-07: Remote Sensing of Anthropogenic Signals

■ NOAA Lead: Chris Elvidge ■ CIRES Lead: Kimberly Baugh
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

This scientist did not report goals for next year.

NCEI-08: Development of Space Environment Data Algorithms and Products

■ NOAA Lead: William Denig ■ CIRES Lead: Juan Rodriguez
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

- Formally evaluate Level 1b data for provisional quality; formal reviews are scheduled no earlier than November 2017.
- Deliver remainder of Level 2 algorithms integrated into SPADES, with a Final Operating Capability Review in 2QFY18.
- Prepare for launch of GOES-S and (if it launches on time) start post-launch test.

NCEI-09: Enhanced Ionosonde Data Access and Stewardship

■ NOAA Lead: Rob Redmon ■ CIRES Lead: Terry Bullett
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

- Finish migration of the real time ionosonde data collection system to fully supported NCEI computer systems.
- Deploy the Naval Research Laboratory VIPIR ionosonde to Wyoming to observe acoustic and gravity waves in the ionosphere-thremosphere system generated by the 21 August 2017 solar eclipse.
- Restore public access to the Space Physics Interactive Data Resource (SPIDR) ionosonde data archive by adding real time data ingest.
- If funded by NSF, begin to design and construct a VIPIR type ionosonde for Dome Concordia, Antarctica.
- If funded by NASA, fly a phase coherent radio beacon receiver on a sounding rocket to measure plasma densities in the D layer of the ionosphere from 70 to 100 km.
- Update Korean Space Weather Center VIPIR systems with transmit capability.

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

■ NOAA Lead: Eugene Wahl ■ CIRES Lead: Carrie Morrill
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Climate Adaptation and Mitigation

- Produce version 2 of the Living Blended Drought Product, including a half-degree gridded product.
- Complete ingest of controlled vocabularies into database and implement search by variable.
- Submit manuscript(s) on quantitative model-data comparisons of hydroclimate in the western United States.

NCEI-13: U.S. Extended Continental Shelf Project

■ NOAA Lead: Robin Warnken ■ CIRES Lead: Barry Eakins
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

- In the coming year, CIRES team members will finalize the U.S. Submission Table of Contents and organization for each U.S. ECS region. They will also finalize Western Gulf of Mexico and Arctic regional ECS documents, including cartographic products, based on feedback from international experts.
- The team will then focus on the Bering Sea and Eastern Gulf of Mexico regions. This will include conducting geospatial analyses to determine the base of the continental slope and foot of the slope, and ECS formula, constraint, and outer limit lines. They will create cartographic products depicting the ECS data in these two regions. The team will also develop, in close collaboration with NOAA, USGS and Department of State ECS project colleagues, the ECS scientific documentation for the Bering Sea and Eastern Gulf of Mexico regions, incorporating the cartographic products.
- Preliminary work will also be done on the Atlantic and Pacific regions, in preparation for developing ECS scientific documentation the following year.

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

■ NOAA Lead: Eric Kihn ■ CIRES Lead: Florence Fetterer
CIRES Theme: Scientific Outreach and Education
NOAA Theme: Engagement Enterprise

Compute the monthly extent differently than it is done now, averaging the daily ice concentration data and then using that average to get monthly extent, rather than using the daily extent maps to get the monthly extent. The way it is currently done, while not incorrect, is a carry over from when the product did not update daily. It causes considerable user confusion. This will be addressed.

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

■ NOAA Lead: Eric Kihn ■ CIRES Lead: Florence Fetterer
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

Emphasis will be on working with operational groups within NOAA to 1) Institute a program of archiving, documenting, and distributing National Weather Service Alaska Ice Desk products. This will support NWS Alaska by serving those users of their products who do not have immediate operational needs, but need to access an archive of well-documented data. 2) Develop a cost effective method of creating gridded ice chart products suitable for remote sensing algorithm and sea ice forecast model validation.

NSIDC-04: Support the Activities of the NCEI Arctic Team

■ NOAA Lead: Eric Kihn ■ CIRES Lead: Florence Fetterer
CIRES Theme: Management and Exploitation of Geophysical Data
NOAA Theme: Science and Technology Enterprise

Contribute to the NCEI Arctic Team via teleconferences and response to requests for reviews or input as the need arises. Carry an understanding of NCEIs capabilities in working with other groups both within and outside of NOAA (e.g., the Southern Ocean Observing System data committee).

PSD-19: Improving Wind and Extreme Precipitation Forecasting

■ NOAA Lead: Kelly Mahoney/ James Wilczak ■ CIRES Lead: Laura Bianco/Mimi Hughes
CIRES Theme: Regional Sciences and Applications
NOAA Theme: Science and Technology Enterprise

- Process all data after observation period is over (Spring 2017)
- Create user-friendly summary files
- Validate & continue development of moisture profile methodology
- Continue development of GPS-IR method
- Detailed model-data intercomparison
- Use model experiments to understand processes that influence moisture transport and precipitation
- Used WRF experiments to guide Reanalysis development

PSD-20: Develop Stochastic and Scale-Award Parameterizations Informed by Observations

■ NOAA Lead: Cecilia Penland ■ CIRES Lead: Prashant Sardeshmukh
CIRES Theme: Earth System Dynamics, Variability and Change
NOAA Theme: Science and Technology Enterprise

- Continue to investigate multi-scale physical and dynamical processes and their proper representation in weather and climate models through stochastic parameterizations.
- Prepare and submit a paper on a related topic of changes in extreme daily temperatures around the globe in observations and model simulations of the last 60 years.
- Prepare and submit a paper on a related topic of changes in the near-surface global atmospheric circulation and storminess over the period 1871-2012 in observational reanalysis datasets and uncoupled and coupled model simulations.
- Prepare and submit a paper on a related topic of changes in the atmospheric global overturning circulation.

PSD-21: Develop and Prototype Experimental Regional Arctic Sea Ice Forecasting Capabilities

■ NOAA Lead: Janet Intrieri ■ CIRES Lead: Amy Solomon
CIRES Theme: Regional Sciences and Applications
NOAA Theme: Science and Technology Enterprise

- In the next fiscal year we will be producing daily quasi-operational 10-day forecasts with a domain that includes the Bering Sea. We have been contacted by a number of stakeholders who need forecasts in this region for operations. We will also be experimenting with different ocean and sea ice initial conditions (for example, cryosat sea ice thickness) to identify potential improvements in skill.
- We will be completing a number of publications focused on the SeaState period, specifically, a publication on the impact of lower-level atmospheric jets on sea ice evolution, a publication on the improvement of forecast skill by including a dynamical ocean model, and a publication on assessing model simulations of near-surface atmospheric stratification in the marginal ice zone.
- We will be working with CMCC to develop a state-of-the-art ocean analysis for model verification and initial conditions.
- We will continue to work with NCEP and the NWS, to transition our findings to improve operations.
- We will be uploading our forecasts to the U.S. National Ice Center this next fiscal year.

PSD-22: Predictive Understanding of Tropical-Extratropical Coupling, Moisture Transport and Heavy Precipitation

■ NOAA Lead: Allen White/George Kiladis ■ CIRES Lead: Darren Jackson
CIRES Theme: Earth System Dynamics, Variability and Change
NOAA Theme: Science and Technology Enterprise

- Establish a climatology of atmospheric river landfalls and evaluate the impact ARs have on extreme precipitation along the Alaskan coast.
- Continue aerosol analysis of INPs in California and analyze their impacts on clouds and precipitation associated with ARs.
- Continue analysis of water vapor transport and forecast skill of precipitation from the El Niño Rapid Response (ENRR) data sets.
- Submit and publish the ENRR field campaign mission paper.
- Submit and publish journal article on aerosol analysis for special issue of Atmosphere called "Atmospheric Aerosol Composition and its Impact on Clouds".

PSD-23: Lead the Planning and Execution of Large-Scale National and International, Multi-Institutional Field Campaigns to Observe and Understand the Coupled Behavior of the Atmosphere over Land, Oceans, Ice, and Snow

■ NOAA Lead: Chris Fairall/Allen White ■ CIRES Lead: Matt Newman
CIRES Theme: Earth System Dynamics, Variability and Change
NOAA Theme: Science and Technology Enterprise

The main goals for the next year are analysis of the ENRR observations and collaboration with Australian scientists on publications from CAPRICORN. We will be beginning preparations for a major field and modeling study in the Maritime Continent called Propagation of IntraSeasonal Tropical Oscillations (PISTON). PISTON is a joinnt NOAA, ONR, NASA, and DOE project.

PSD-24: Interpret Weather and Climate Extremes to Explain and Improve the Prediction of High-Impact Weather and Climate Events

■ NOAA Lead: Martin Hoerling ■ CIRES Lead: Judith Perlwitz
CIRES Theme: Earth System Dynamics, Variability and Change
NOAA Theme: Climate Adaptation and Mitigation

- Complete the on-going project which examines changes in coupling strength between high temperature and soil moisture deficit, and submit a paper to summarize our findings and promote the involved framework as a nascent development to extreme event attribution.
- Submit an Attribution study on the 2016 Extreme Arctic Warmth using a hierarchy of NOAA ESRL historical climate simulations.

PSD-25: Linking Weather, Climate and Environmental Tipping Points

■ NOAA Lead: Michael Alexander ■ CIRES Lead: James Scott
CIRES Theme: Regional Sciences and Applications
NOAA Theme: Climate Adaptation and Mitigation

- Finish preparation and submit paper entitled: "Response of O2 and pH to ENSO in the California Current System in a high resolution global climate model." to a peer reviewed journal.
- Finish preparation and submit paper entitled: "Projected Sea surface temperatures over the 21st century: changes in the mean, variability and extremes" to a peer reviewed journal.
- Begin new work examining climate change impacts to the ocean ecosystems along the east coast of the United States using a high resolution regional ocean model (ROMS) the is forced with atmospheric conditions in 2070-2099 as predicted by 3 models in the Climate Model Intercomparison Project 5 (CMIP5). The ROMS model is much higher resolution (10km) than the ocean models used in CMIP5 and will give a better representation of climate change impacts to ecosystems very near the shoreline.
- Submit a paper for peer review in the Bulletin of the American Meteorology Association "Explaining Extreme Events of 2016" special volume. The paper is examine multiyear extreme ocean temperatures and their impact on living marine resources off the US West Coast during 2016.

PSD-26: Next Generation Global Prediction System

■ NOAA Lead: Jeff Whitker ■ CIRES Lead: Phil Pegion
CIRES Theme: Earth System Dynamics, Variability and Change
NOAA Theme: Science and Technology

- Have a tuned stochastic physics suite and the 4D incremental analysis update running in NCEP's real-time parallel runs.
- Develop and testing new, physically based stochastic parameter schemes.
- Start producing a reanalysis data set with the FV3GFS that will be used as initial conditions for the reforecast dataset needed for statistical post-processing.

SWPC-01: Space Weather Information Technology and Data Systems

■ NOAA Lead: Steven Hill ■ CIRES Lead: David Stone
CIRES Theme: Space Weather Understanding and Prediction
NOAA Theme: Science and Technology Enterprise

- Upgrade the Space Weather Prediction Center's (SWPC) Space Weather Data Store (SWDS) and implement a better separation for database development, staging for operations and operational environments.
- Transition the new Regional Geoelectric model and display products to the experimental website.
- Build the lab's first Continuous Integration environment using Jenkins to automate the test and build process of one or more of the lab's operational product systems.
- Continue to provide operational support for the following critical systems: SWPC's Public website, Advanced Composition Explorer (ACE) processor, Deep Space Climate Observatory (DSCOVR) ground data system, Geostationary Environmental Satellite (GOES) processor and preprocessor, WSA-Enlil, D Region Absorption Predictions (D-RAP), Air Force and Institute for Science and Engineering Simulation (ISES) Message Decoder (AIMED) processor, Microsoft SQL Server Space Weather Data Store (SWDS).

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

■ NOAA Lead: Vic Pizzo ■ CIRES Lead: Alysha Reinard
CIRES Theme: Space Weather Understanding and Prediction
NOAA Theme: Weather Ready Nation

- Complete the validation of GONG data products
- Determine the best method for transfering data from the six GONG sites to the IDP and implement that method
- Johnson will travel to Tuscon for a detailed code walkthrough with NSO experts
- Set up an ftp web server to provide processed data products to customers including SWPC
- Work on improving the processing software, in particular, customizing the results for SWPC needs

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

■ NOAA Lead: Rodney Viereck ■ CIRES Lead: Timothy Fuller-Rowell
CIRES Theme: Space Weather Understanding and Prediction
NOAA Theme: Science and Technology Enterprise

The WAM-IPE model will be run continuously in a real-time test operational mode on the NOAA development computers, with data assimilation in the lower atmosphere, from October 1st, 2017. Space weather products of total electron content, ionospheric gradients, and departures from the mean state, will be extracted from the real-time simulations and provided to SWPC Forecast Office for evaluation. The model specification and forecast fields will be extensively validated by comparing with ground-based GNSS and COSMIC satellite radio occultation observations. The IPE fields for ion drag and Joule heating will be passed back to WAM to test full two-way coupling.

Note: Improved quality figure will be provided later.

SWPC-04: Geospace Modeling Effort

■ NOAA Lead: Howard Singer ■ CIRES Lead: George Milward
CIRES Theme: Space Weather Understanding and Prediction
NOAA Theme: Weather Ready Nation

Following on from the successful transition of the Geospace model into operations, my efforts have then been focussed on working on the Whole Atmosphere Model - Ionosphere Plasmasphere Electrodynamics Model (WAM-IPE), and to get this running in an operational mode on the NWS operational supercomputers. The milestone for October 2017 is to demonstrate the model in pseudo-operations (though still in development mode) at the NWS, with an initial full operational implementation in 2018.

Shadow over Ross Ice Shelf in Antarctica. Photo: John Cassano/CIRES

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