CIRES

COOPERATIVE INSTITUTE FOR RESEARCH
IN ENVIRONMENTAL SCIENCES

2019 Annual Report to NOAA Executive Summary

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THE COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES (CIRES) has been facilitating collaboration between the University of Colorado Boulder and the National Oceanic and Atmospheric Administration (NOAA) since 1967. Our purpose is to support NOAA's mission by furthering research that crosscuts traditional scientific fields. CIRES brings together scientists from 10 CU Boulder departments (Atmospheric and Oceanic Sciences, Geological Sciences, Chemistry, Economics, etc.) and several NOAA line offices (Research, Satellites, Weather) to explore all aspects of the Earth system. These partnerships encourage innovation, rapid-response capabilities, and an interdisciplinary approach to complex environmental challenges. CIRES helps strengthen the scientific foundation upon which NOAA's environmental intelligence services depend, and our partnership with NOAA allows coordinated studies on a scale that could not be undertaken by university research units or NOAA alone.

IN 2018-2019...

CIRES total funding was nearly $100 million in FY19, thanks in part to proposal writing by CIRES scientists who achieved an astonishing 46 percent success rate the previous fiscal year. Our current NOAA Cooperative Agreement, a competitive award re-bid every 10 years, funds about half of the CIRES research enterprise; most of the rest is from the National Science Foundation, NASA, the U.S. Department of Energy, and other federal science sponsors. In the following pages, we highlight some of the many accomplishments achieved in support of NOAA's mission, through Cooperative Agreement funding.

CIRES DIVISIONS

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

CIRES CENTERS

- Center for Limnology
- Center for Microbial Exploration
- Center for Science and Technology Policy Research
- Earth Science and Observation Center
- National Snow and Ice Data Center
- North Central Climate Adaptation and Science Center

CIRES CORE PROGRAMS

- Earth Lab
- Education & Outreach
- International Global Atmospheric Chemistry Project
- Western Water Assessment

OTHER INSTITUTIONAL PROGRAMS

- Diversity and Inclusion
- Graduate Student Research Awards
- Innovative Research Program
- Integrated Instrument Development Facility
- Undergraduate Research Opportunities Program
- Visiting Fellows Program

COVER IMAGE: CIRES researchers were leaders in developing the NOAA High-Resolution Rapid Refresh-Smoke model (HRRR-Smoke), which simulates emissions and transport of smoke from wildfires. NOAA weather forecast offices rely on HRRR-Smoke for air quality and visibility forecasts. Image: NASA WorldView
ABOVE: A search and rescue coverage flight from Butchers Ridge, Anatarctica. Photo: Mike Willis/CIRES

Science in Service to Society, 2018-2019

WEATHER-READY NATION

CIRES science helps society better respond to weather-related events, reducing loss of life and property, improving transportation safety, and improving understanding of human health and air quality.

- CIRES scientists in NOAA's Global Systems Division (GSD) design and evaluate tools to help aviation managers assess weather-related threats to aviation—including icing, turbulence, and convection. They are part of a team working to improve the Hurricane Weather Research and Forecasting modeling system used to forecast tropical cyclones.
- CIRES scientists in the National Weather Service serve the needs of emergency managers and other decision makers by building and improving tools that improve forecasting and understanding of extreme events, such as extreme precipitation and flash flooding.
- CIRES scientists in NOAA's Space Weather Prediction Center (SWPC) operated, maintained, and enhanced several space weather observation systems including on the latest Geostationary Operational Environmental Satellite (GOES-R). They also supported the acquisition, monitoring, testing, and maintenance of data systems required for space weather research and forecasting.
- CIRES scientists in NOAA's Chemical Sciences Division (CSD) made field measurements in New York City to evaluate how emissions from personal care products and other sources contribute to urban air quality.
- CIRES researchers in CSD also contributed to three reports describing global air pollution and climate trends: 1) the Tropospheric Ozone Assessment Report; 2) NOAA's State of the Climate report; and 3) draft chapters in the Intergovernmental Panel on Climate Change Sixth Assessment Report, due out in 2021.
- CIRES scientists in the Physical Sciences Division (PSD) are working with NOAA colleagues to better understand the factors that drive heavy precipitation events.

CLIMATE ADAPTATION AND MITIGATION

CIRES research improves critical understanding of Earth's changing climate and its impacts, informing society and allowing decision makers to anticipate and respond.

- CIRES scientists are foundational to NOAA's efforts to track and understand global greenhouse gas distributions and trends. This year, and for the first time in millions of years, daily average CO_2 dry air mole fraction at NOAA's Mauna Loa Observatory surpassed 415 ppm.
- CIRES scientists in NOAA's Global Monitoring Division (GMD) contributed to an analysis that drew international attention from media, scientists, and decision makers: The discovery of substantial unreported emissions of CFC-11, an ozone-depleting substance restricted under the Montreal Protocol.
- CIRES researchers in the National Centers for Environmental Information (NCEI) converted all tree-ring datasets housed by the World Data Service for Paleoclimatology into more accessible formats and developed a new method of reconstructing past water availability using lake level information and hydrological models.
- The sustainability of marine ecosystems depends on future climate. CIRES scientists in PSD used coupled climate system modeling to help identify ecological "tipping points," specifically exploring how climate change may affect the circulation of the northwest Atlantic Ocean.

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A graduate student at the University of the South Pacific in Fiji launches a weather balloon carrying an instrument to measure ozone. CIRES scientists were critical in helping NOAA measure stratospheric ozone and surface ozone at 17 locations around the world. Photo: Irina Petropavlovskikh/CIRES

CIRES and NOAA researchers from the Chemical Sciences Division with the NOAA Twin Otter flight crew during the January 2018 FireWinds experiment in Florida. The team developed a state-of-the-art MicroDoppler lidar to measure complex wind flows around wildfires. It's part of a broader effort to study atmospheric processes in the boundary layer, the troposphere, and ocean ecosystems using innovative techniques. Photo: NOAA

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- CIRES scientists in CSD helped lead and support the multi-agency FIREX-AQ mission, to better understand the impact of wildfire smoke on air quality and weather. One team developed an unmanned aircraft system for measuring CO, CO_2, and aerosol in wildfire smoke plumes at night.
- CIRES scientists in several NOAA groups contributed to the United Nations Environment Programme and World Meteorological Organization's *2018 Scientific Assessment of Ozone Depletion,* released in 2019. The report noted that actions taken under the Montreal Protocol have led to decreases in ozone-depleting substances and the beginning of the recovery of stratospheric ozone.

NOAA ENGAGEMENT ENTERPRISE

CIRES helps NOAA meet the increasingly complex needs of its stakeholders by delivering data and knowledge to those who need it, and by engaging with users to better understand research needs.

- The Meteorological Assimilation Data Ingest System (MADIS) runs operationally at the National Weather Service (NWS) and provides global meteorological observations to forecasters and emergency managers. CIRES scientists in GSD supported MADIS by incorporating new observations from NOAA stations and international partners.
- CIRES scientists develop visual displays of NOAA's Earth science data to engage audiences and increase understanding of scientific topics. The team completed nine Science On a Sphere® (SOS) installations last year. The SOS Explorer team created SOS Explorer Mobile™ that runs on tablets and phones.
- More than 20,000 users download the National Snow and Ice Data Center's (NSIDC) Sea Ice Index annually, using it to learn about trends in sea ice extent or feed reports such as NOAA's Arctic Report Card and content on Climate.gov.
- In broader service to NOAA, though not directly funded through the cooperative institute program, CIRES' Western Water Assessment (WWA) is a national leader in co-produced science, focusing on how communities in the Rocky Mountain West can best produce and use science to manage climate impacts. WWA is part of the NOAA Regional Integrated Sciences and Assessments program.

SCIENCE AND TECHNOLOGY ENTERPRISE

CIRES develops innovative and holistic research approaches to understand the connection between human prosperity and changes in the Earth system.

- A CIRES-led team in GSD developed and improved the RAP and HRRR-Smoke experimental forecasting systems, which provide critical, real-time wind and solar radiation information and simulations of emissions and transport of wildfire smoke to National Weather Service forecasters and air quality managers.
- CIRES scientists worked with several NOAA and international groups to verify satellite measurements and make them accessible and useful. One team, for example, compared new satellite-based sea ice thickness and concentration estimates with data from buoys and aircraft. And a CIRES scientist coordinated a multi-agency team that calibrated and validated the European Space Agency's Aeolus satellite lidar—the first space-deployed lidar for global wind measurements.
- CIRES researchers in GSD worked with federal, state, and local

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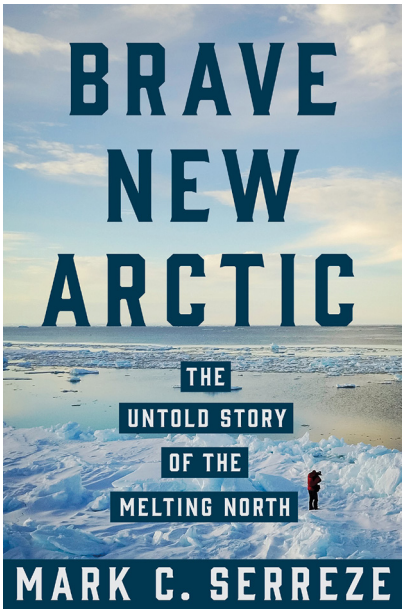
agencies to improve precipitation and hydrological forecasts to better meet the needs of water agencies in the San Francisco Bay area, where previous observations didn't accurately predict big storms and their impacts, like dangerous flooding.

- CIRES researchers in NCEI work to improve environmental data usability: the team released the award-winning version 2.0 of the NOAA OneStop website, dramatically improving NOAA's ability to deliver environmental data to the public.
- CIRES scientists in NCEI also completed an unplanned, out-of-cycle release to the World Magnetic Model more than a year ahead of schedule, ensuring unexpected shifts in Earth's magnetic field didn't compromise the navigation needs of the U.S. military, NATO, commercial aviation, search and rescuers, and others.
- CIRES researchers in NCEI are working with NOAA and the U.S. State Department to document the extent of the seafloor to which the nation may claim sovereign rights to manage natural resources, under international law.
- NOAA's NSIDC liaison office works directly with the National Ice Center (Navy, U.S. Coast Guard, NOAA) and NWS on projects that serve NOAA priorities such as marine safety, and environmental change.
- CIRES scientists in PSD developed a real-time, hourly-updated, online data product that helps forecasters at the Portland Weather Forecast Office monitor cool season easterly gap flow events to guide warnings to the public about potential weather-related hazards like snow, freezing rain, and strong winds.
- Space weather prediction depends on a number of technologies to provide and improve reliable forecasts, alerts, and warnings about the arrival and magnitude of solar, radiation and geomagnetic storms before they strike Earth. To support these services, CIRES scientists in SWPC created a new IT service architecture and deployed new forecaster tools.

Publications and Media



CIRES Fellow and National Snow and Ice Data Center director Mark Serreze published *Brave New Arctic: The Untold Story of the Melting North* in late 2018, with Princeton University Press.

PUBLICATIONS

CIRES scientists and faculty published nearly 800 peer-reviewed papers during calendar year 2018, in journals such as *Nature, Science, Geophysical Research Letters, Bulletin of the American Meteorological Society, Proceedings of the National Academy of Sciences*, and many others. CIRES scientists and faculty also authored hundreds of other types of publications in 2018, including datasets, magazine articles, white papers, reports, and a popular book (left).

MEDIA

CIRES makes a robust effort to share the institute's research findings and implications with the scientific community, decision makers, and the public. During the reporting period, CIRES scientists' work earned coverage in BBC, Buzzfeed, CNN, *Forbes*, Fox News, *The Guardian*, National Public Radio, Newsweek, *New York Times, Popular Science, Scientific American, Washington Post,* and many other local, national, and international outlets. The research papers listed below were published between June 1, 2018 and May 31, 2019 and ranked in the top five percent of all research outputs scored by Altmetric, which measures online attention.

- **2018 Lancet Countdown on Health and Climate Change Released**
  Research from 27 global institutions including CU Boulder show extreme heat damages health and livelihood and may overwhelm hospitals. http://bit.ly/2018lancet
- **Who's the Source of a Banned Ozone-Destroying Chemical?**
  Nature study reveals increase in CFC-11 emissions from eastern China. http://bit.ly/bannedozone
- **Your Showerhead Slime is Alive and Mostly Harmless**
  CU Boulder citizen-science study reveals lung-disease causing strains of bacteria especially common in certain environments. http://bit.ly/slimealive
- **Ice Shelves Buckle Under the Weight of Meltwater Lakes**
  Researchers record first field measurements of Antarctic ice shelf flexure, which can lead to ice shelf break up. http://bit.ly/icebuckle
- **China is Hot Spot of Ground-Level Ozone Pollution**
  New study: Ozone levels higher across China than in other countries tracking the air pollutant. http://bit.ly/chinahotspot
- **New Study Finds U.S. Oil & Gas Methane Emissions 60% Higher than Estimated**
  High emissions findings undercut the case that gas offers substantial climate advantage over coal. http://bit.ly/oilgasmethane
- **Violent Crime Rates Rise in Warmer Winters**
  CU Boulder study uncovers surprisingly strong link between climate and U.S. crime rates. http://bit.ly/climatecrime
- **Unprecedented Ice Loss in Russian Ice Cap**
  New CU Boulder-led study shows just how quickly cold glaciers can change speed, lose mass. http://bit.ly/icecaploss

Awards

CIRES BRONZE MEDAL

Martin Aubrey, Elizabeth Delk, Christopher Esterlein, Richard Fozzard, Semere Ghebrechristos, Arianna Jakositz, Evan McQuinn, David Neufeld, and **Elliott Richerson** were part of a NOAA team honored with a Department of Commerce Bronze Medal for implementing the NOAA OneStop data discovery system, dramatically improving NOAA's ability to deliver environmental data to the public.

Highly Cited: Jose Jimenez, Joost de Gouw, Julienne Stroeve, Noah Fierer, and the late **John Wahr** were named 2018 Highly Cited Researchers in their fields by Clarivate Analytics. These researchers were selected for their exceptional research performance, demonstrated by production of multiple highly cited papers that rank in the top 1 percent by citations for field and year.

CIRES OUTSTANDING PERFORMANCE / SCIENCE AND ENGINEERING

- **Caroline Womack,** for pioneering innovations in measurement and modeling of aerosol pollution.
- **Geoff Dutton, Lei Hu, Ben Miller, Debra Mondeel, Fred Moore, David Nance, Eric Ray, Carolina Siso,** and **Pengfei Yu**, for the significant discovery of substantial unexpected emissions of ozone-depleting trichlorofluoromethane (CFC-11).
- **Christina Williamson**, for developing unique aerosol sizing instruments and flying them around the world to improve understanding of climate.

CIRES OUTSTANDING PERFORMANCE / SERVICE

- **Patrick Alken, Nir Boneh, Arnaud Chulliat, Brian Meyer, Manoj Nair, Jesse Varner,** and **Adam Woods**, for exemplary professionalism and efficiency when updating the critical World Magnetic Model in an unexpected, out-of-cycle release.
- **Charles Anderson**, for taking initiative to develop, enhance, and expand custom-built software tools to enable superior preservation of marine geophysical data critical to the scientific community and the nation.
- **Amanda Morton**, for tirelessly coordinating the first-ever landlocked National Ocean Sciences Bowl final competition and accommodating teams displaced by natural disaster.

CIRES OUTSTANDING PERFORMANCE / DISTINGUISHED CAREER AWARD

- **Ted De Maria**, for a 26-year (so far) career at CIRES, tirelessly supporting CIRES PIs and others with extraordinary dedication and financial expertise.

OTHER AWARDS

- **Magali Barba** received the CIRES George C. and Joan A. Reid Award, awarded to PhD students, for her innovative, intelligent exploration of natural hazards and outstanding support of diversity and inclusion in geosciences.
- **John Cassano** was awarded a 2019 Boulder Faculty Assembly Excellence Award in research, scholarly, and creative work
- **Climate Literacy and Energy Awareness Network** run by the CIRES Education & Outreach program was named an Exemplary Project by the Goldin Foundation for Excellence in Education.
- **Craig Jones** received Geological Society of America's Structural Geology and Tectonics Division's outstanding publication award.
- **Jaymes Kenyon, Joe Olson, Laura Bianco, Kathy Lantz, Chuck Long, Yelena Pichugina, Terra Ladwig, Eric James, Katie McCaffrey, Irina Djalalova, Aditya Choukulkar, Tim Bonin**, and **Brandi McCarty** were among those who received a Federal Laboratory Consortium for Technology Transfer Far West Region Award for Outstanding Partnership for the Wind Forecast Improvement Project-2, a Department of Energy and NOAA-led project.
- **Peter Molnar** received Geological Society of America's International Distinguished Career Award.
- CIRES Fellows **Steve Montzka** and **Balaji Rajagopalan** were named 2018 AGU Fellows.

Liquid nitrogen calibration for the Radiometric Microwave Radiometer in Troutdale, Oregon. CIRES scientists in PSD developed a real-time, hourly-updated, online data product that helps forecasters at the Portland NWS Forecast Office monitor cool season easterly gap flow events to guide warnings to the public about potential weather-related hazards such as snow, freezing rain, and strong winds. Photo: Laura Bianco/CIRES

Outreach

CIRES EDUCATION & OUTREACH PROGRAMS

The CIRES Education & Outreach program provides programming and opportunities across the spectrum of geosciences and environmental education, including teacher professional development, digital learning resources, student programs, workforce development, and program evaluation, as well as mentoring opportunities and support for early career scientists, and more. Some projects from last year include:

- **Climate Literacy & Energy Awareness Network (CLEAN):** The CLEAN collection (cleanet.org) is a peer-reviewed digital repository of climate and energy learning resources, syndicated through NOAA's Climate.gov and the National Science Teachers Association. CLEAN was named an Exemplary Project by the Goldin Foundation for Excellence in Education in 2018.
- **Lens On Climate Change (LOCC):** Dozens of middle and high school students from rural Colorado produced short films featuring climate change impacts on their local communities, implemented with the support of science researchers, CIRES graduate students, and Colorado Film School students.
- **Research Experiences for Community College Students (RECCS):** Community college students conducted research at CIRES and NOAA after the program was awarded a renewal for another three years of funding. To date, RECCS has served 49 community college students from across Colorado—students are diverse along many dimensions, including first-generation college attendees, people of color, and veterans.

OTHER OUTREACH EVENTS

- **Flight Week:** CIRES and NOAA hosted a public community day in Colorado's San Luis Valley in the summer of 2018, to highlight an international project using unmanned aircraft systems making intensive atmospheric measurements. Alamosa's mayor and other elected officials attended, as did farmers, ranchers and area residents.
- **TEDx Salon:** In October 2018 CIRES and the CU Museum of Natural History organized and ran, collaboratively with TEDx Boulder, a community event focused on the changing Arctic. Experts from across the university engaged with community members at posters and then in a panel emceed by CIRES Director Waleed Abdalati.
- **Science on Tap:** CIRES/NOAA researchers organized a series of monthly gatherings at Gunbarrel Brewing in Boulder, bringing together scientists and science enthusiasts to discuss the latest and greatest research happening on the Front Range. CIRES and NOAA scientists in the Chemical Science Division talked about the pollutants in our deodorant, CIRES Fellow Jennifer Kay talked about the world of the vanishing polar bear, and CIRES/NOAA educator Hilary Peddicord talked about data visualization.

Ty Coleman (at right), mayor of Alamosa, Colorado, watches a team get several Unmanned Aircraft Systems ready for Flight Week in Colorado's San Luis Valley in 2018. CIRES' Gijs de Boer organized the week, in which international participants flew unmanned systems to study the atmosphere. Photo: CIRES

CIRES COUNCIL OF FELLOWS

The Council of Fellows 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. The 42 Fellows below were active between June 1, 2018 and May 31, 2019.

Waleed Abdalati
CIRES Director, Professor of Geography

Richard Armstrong
CIRES Senior Research Scientist, National Snow and Ice Data Center

Jennifer Balch
Director, Earth Lab and the North Central Climate Adaptation Science Center; Associate Professor of Geography

Stanley G. Benjamin
Senior Scientist for Advanced Modeling Systems, NOAA Global Systems Division

Roger Bilham
Professor Emeritus of Geological Sciences

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

Eleanor C. Browne
Assistant Professor of Chemistry

Matthew Burgess
Assistant Professor of Environmental Studies

John Cassano
Associate Professor of Atmospheric and Oceanic Sciences

Xinzhao Chu
Professor of Aerospace Engineering Sciences

Shelley D. Copley
Professor of Molecular, Cellular, and Developmental Biology

Joost de Gouw
Professor of Chemistry

Lisa Dilling
Director, Western Water Assessment; Associate Professor of Environmental Studies

G. Lang Farmer
Associate Dean for Natural Sciences; Professor of Geological Sciences

Graham Feingold
NOAA Research Scientist, Chemical Sciences Division

Noah Fierer
Professor of Ecology and Evolutionary Biology

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

R. Michael Hardesty
CIRES Senior Research Scientist, NOAA Chemical Sciences Division

Jose-Luis Jimenez
Professor of Chemistry

Craig H. Jones
Professor of Geological Sciences

Kris Karnauskas
Associate Professor of Atmospheric and Oceanic Sciences

Jennifer Kay
Associate Professor of Atmospheric and Oceanic Sciences

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

Ben Livneh
Assistant Professor of Civil, Environmental, and Architectural Engineering

Peter Molnar
Distinguished Professor of Geological Sciences

Stephen A. Montzka
Research Chemist, NOAA Global Monitoring Dvision

William D. Neff
CIRES Senior Research Scientist, NOAA Physical Sciences Division

R. Steven Nerem
Professor of Aerospace Engineering Sciences

Judith Perlwitz
Management and Program Analyst at NOAA Physical Sciences Division

Balaji Rajagopalan
Professor of Civil, Environmental, and Architectural Engineering

Prashant Sardeshmukh
CIRES Senior Research Scientist, NOAA Physical Sciences Division

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

Anne F. Sheehan
Professor of Geological Sciences

Robert E. Sievers
Professor of Chemistry

Kristy Tiampo
Director of the Earth Science and Observation Center; Professor of Geological Sciences

Margaret A. Tolbert
Distinguished Professor of Chemistry

Gregory Tucker
Professor of Geological Sciences

Veronica Vaida
Professor of Chemistry

Rainer Volkamer
Professor of Chemistry

Carol A. Wessman
Director of the CU Boulder Environmental Studies Program; Associate Director, CIRES Ecosystem Science Division; Professor of Ecology and Evolutionary Biology

Michael Willis
Assistant Professor of Geological Sciences

Paul Ziemann
Professor of Chemistry