



CIRES

COOPERATIVE INSTITUTE FOR RESEARCH
IN ENVIRONMENTAL SCIENCES

2020 Annual Report to NOAA Executive Summary

agreement no. NA17OAR4320101

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 2019-2020...

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. Below, 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: Forecasters and hydrologists using the Extreme Precipitation Forecast Table, which CIRES scientists integrated into National Weather Service operations, reported that the tool helped them highlight extreme rainfall events in forecasts. Photo: Carrie Bell/CIRES

THIS PAGE: Scientists head out for a day on the ice near Rothera Research Station, Antarctica. Photo: Alison Banwell/CIRES

Science in Service to Society, 2019-2020



Lightning strikes Broomfield, Colorado, in July 2013. CIRES scientists in NOAA's Global Systems Laboratory compared the satellite-based Global Lightning Mapper to ground-based lightning detection networks, finding both necessary to detect storms and verify they exist. Photo: Benjamin Castellani/CIRES

WEATHER-READY NATION

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

- CIRES scientists in NOAA's Global Systems Laboratory developed tools to help aviation managers assess weather-related threats, including storm-detection methods using satellite- and ground-based lightning data.
- CIRES scientists in NOAA's National Weather Service (NWS) added a tool to the Advanced Weather Interactive Processing System that improves winter weather forecasts and updated the Excessive Rainfall Outlook product with tools to identify high-risk areas. CIRES scientists also improved Ensemble Situational Awareness Tools for NWS Weather Forecast Offices.
- CIRES scientists in NOAA's Space Weather Prediction Center processed space- and ground-based observations of solar storms, assimilated new satellite data into space weather models, and began developing ground stations and software to support a 2024 satellite launch.
- CIRES scientists in NOAA's Chemical Sciences Laboratory led and supported the NOAA-NASA FIREX-AQ field campaign, measuring aerosol properties in wildfire smoke plumes and black carbon to better understand climate and air quality impacts. They developed software for analyzing observations, compared HRRR-Smoke forecasts to FIREX data, and evaluated different configurations of the Weather Research and Forecasting model coupled with Chemistry model (WRF-Chem) to improve forecasts.
- CIRES scientists In NOAA's Chemical Sciences Laboratory

documented changes in volatile organic compound emissions and urban air quality during COVID-19 shutdowns; discovered evidence of wildfire-injected black carbon in the stratosphere; and studied biomass burning smoke and the formation of new particles during the NASA Atmospheric Tomography field campaign, a mission to examine the distribution, transport, and processing of aerosol particles in the remote atmosphere.

CLIMATE ADAPTATION AND MITIGATION

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

- CIRES scientists in NOAA's Global Monitoring Laboratory continued to make measurements during COVID-19 shutdowns, recording CO₂ levels at Mauna Loa Observatory; measuring trace gases that feed into NOAA's Annual Greenhouse Gas Index and Ozone Depleting Gas Index; and monitoring increased global emissions of CFC-11. They also collected global ozone data to track stratospheric ozone recovery.
- CIRES scientists in NOAA's Global Monitoring Laboratory calculated national fossil-fuel derived CO₂ emissions with atmospheric data, a first; established a monitoring site north of Boulder to provide aerosol data for weather forecasting; and provided observational data to improve solar energy forecasts.
- CIRES scientists measured in NOAA's Global Monitoring Laboratory water vapor, a greenhouse gas, in the upper atmosphere with balloon launches in Colorado, Hawaii, and New Zealand, coordinating measurements with overpasses of a NASA spectrometer on the International Space Station.

CONTINUED ON NEXT PAGE



Elizabeth Thompson of NOAA's Physical Sciences Laboratory installs equipment aboard the NOAA ship *Ronald H. Brown* at the beginning of the NASA Atmospheric Tomography field campaign. Photo: Chris Fairall/NOAA

- In NOAA's National Centers for Environmental Information, CIRES scientists contributed to a global, 12,000-year temperature record database that enables researchers to examine current warming within a long climate record.
- CIRES scientists in NOAA's Chemical Sciences Laboratory attributed recent Southern Hemisphere climate changes to reductions in emissions of ozone-depleting substances due to the Montreal Protocol.

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.

- CIRES scientists in NOAA's Global Systems Laboratory improved products that help weather forecasters and emergency managers provide decision support and hazard advisories. They upgraded the Meteorological Assimilation Data Ingest System, which runs operationally in the National Weather Service, to include new data providers and mesonet sites. They also added capabilities to Hazard Services and FACETS (Forecasting a Continuum of Environmental Threats), to help forecasters provide more lead time for tornadoes and thunderstorms.
- CIRES scientists in NOAA's Global System's Laboratory bringing powerful visualizations of NOAA data to the public with the release of the new Science On a Sphere® Mobile app.
- The National Snow and Ice Data Center's Sea Ice Index datasets were critical to polar ice condition reports in the *Bulletin of the American Meteorological Society's* annual State of the Climate assessment and NOAA's Arctic Report Card. NSIDC is part of CIRES.

SCIENCE AND TECHNOLOGY ENTERPRISE

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

- To improve forecasts, CIRES scientists in NOAA's Global Systems Laboratory developed and transferred to NOAA's National Centers for Environmental Prediction Rapid Refresh (RAP) and High Resolution Rapid Refresh (HRRR) model upgrades, including a new data assimilation system and smoke prediction capabilities. They improved the RAP/HRRR-Smoke model, which will go operational in 2020 to predict smoke, visibility, and smoke-weather interactions, and improved solar and wind forecasts by better representing clouds, better assimilating real-time atmospheric data, and forecasting smoke transport during wildfires.
- CIRES scientists in NOAA's Global Systems Laboratory also studied the forecast accuracy impact of reduced aircraft-based weather observations within the Rapid Refresh weather forecast model because of fewer flights during the COVID-19 pandemic, and supported the Hurricane Forecast Improvement Project's real-time hurricane season experiments.
- CIRES scientists in NOAA's National Centers for Environmental Information improved access to NOAA OneStop, a web portal for NOAA's environmental data; produced map products for and released the World Magnetic Model 2020, which supports safe navigation by the U.S. Department of Defense, NATO, smartphone users, airlines, and others; and updated the High Definition Geomagnetic Model used by researchers and the oil and gas industry.

CONTINUED ON NEXT PAGE

Publications and Media

PUBLICATIONS: CIRES scientists and faculty published nearly 700 peer-reviewed papers during calendar year 2019, 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 2019, including datasets, magazine articles, white papers, reports, and a book: *Creative (Climate) Communications* by CIRES Fellow Max Boykoff.

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 *The Atlantic*, *The Denver Post*, *Nature World News*, *National Geographic*, NPR, *The Washington Post*, *Smithsonian*, Fox News, BBC, *USA Today*, CNN, CBS, *The Wall Street Journal*, and many other local, national, and international media outlets. Below are a few news stories that attracted enough online attention between June 1, 2019 and May 31, 2020 that the highlighted research paper scored in the top five percent of all research outputs scored by Altmetric, a measure of online attention to papers.

- **Climate Change Already Damaging Health of World's Children, Threatens Lifelong Impact:** CU Boulder was one of 35 institutions to contribute to the 2019 *Lancet Countdown* report. <https://cires.colorado.edu/news/climate-change-already-damaging-health-world%E2%80%99s-children-threatens-lifelong-impact>
- **Continued CO₂ Emissions Will Impair Cognition:** Rising CO₂ causes more than a climate crisis—it may directly harm our ability to think. <https://cires.colorado.edu/news/continued-co2-emissions-will-impair-cognition>

- **Invasive Grasses Promote Wildfire:** Continent-wide analysis finds invasive grasses increase fire risk about as much as climate change does. <https://cires.colorado.edu/news/invasive-grasses-promote-wildfire>
- **Persistent Plume:** Analysis of a massive 2017 cloud of wildfire smoke will help calibrate climate models, including modeling of nuclear winter, geoengineering. <https://cires.colorado.edu/news/persistent-plume>
- **Solving the Space Junk Problem:** Internationally agreed upon fees to put satellites in orbit could boost value of the space industry. <https://cires.colorado.edu/news/solving-space-junk-problem>
- **Greenland's Growing "Ice Slabs" Intensify Meltwater Runoff into Ocean:** CU Boulder-led study: Warming climate could expand Arctic ice slabs substantially by 2100, accelerating sea-level rise. <https://cires.colorado.edu/news/greenland%E2%80%99s-growing-%E2%80%9Cice-slabs%E2%80%9D-intensify-meltwater-runoff-ocean>
- **Global Warming to Increase Violent Crime in the United States:** CU Boulder-led study predicts millions of additional violent crimes in coming decades. <https://cires.colorado.edu/news/global-warming-increase-violent-crime-united-states>

CIRES communicators, educators, and researchers worked to spread the word about the historic MOSAiC expedition, making major headlines around the globe. Outlets including *National Geographic*, *The New York Times*, NPR, *Scientific American*, and many others covered the *RV Polarstern's* epic yearlong drift through the frozen Arctic.

SCIENCE AND TECHNOLOGY ENTERPRISE CONTINUED FROM PREVIOUS PAGE

- CIRES scientists in NOAA's National Centers for Environmental Information processed data for products including nighttime lights maps, gas flare locations, sea ice extent, auroral boundaries, nighttime fire, and boat detection, and completed a report describing how NCEI supports the U.S. Tsunami Warning System.
- CIRES scientists in the National Snow and Ice Data Center maintained and published polar datasets for icebergs in shipping routes, ice in the Great Lakes, and historical glacier photos, and helped improve the accuracy of sea ice forecasts for NOAA and the U.S. Navy.
- CIRES scientists in NOAA's Physical Sciences Laboratory improved wind forecast models for the second Wind Forecast Improvement Project; supported the Year of Polar Prediction's Sea Ice Drift Forecast Experiment; provided forecast products to the MOSAiC campaign; released the longest atmospheric subdaily dataset to date: the NOAA-CIRES-DOE 20th Century Reanalysis v3, to fuel research on the frequency and severity of extreme events; and developed an extended-range probabilistic fire-weather forecast and a method of generating probabilistic subseasonal precipitation forecasts for California with artificial neural networks.



CU Boulder researcher Chad Wolak prepares NOAA air samples for carbon-14 measurement by colleagues at the University of California Irvine. Photo: Scott Lehman/University of Colorado Boulder



CIRES scientist Duane Kitzis approaches the air sampling station on Niwot Ridge, Colorado, part of NOAA's Global Greenhouse Gas Reference Network, in this 2017 photo. The first air sample analyzed for carbon-14 as part of research into a new method of estimating fossil fuel emissions from ambient air was collected here in 2003. Credit: James Murnan/NOAA National Severe Storms Laboratory

Selected Awards FY2020

HIGHLY CITED

This year, Clarivate Analytics named four CIRES scientists “highly cited researchers,” those among the one percent most cited in their fields: **Jose Jimenez**, **Noah Fierer**, **Julienne Stroeve**, and former Ph.D. student **Jonathan Leff**.

CIRES OUTSTANDING PERFORMANCE: SCIENCE AND ENGINEERING

- **Carsten Warneke** for exceptional leadership in advancing atmospheric fire science in FireLab, FIREX-AQ, and beyond
- The CIRES CarbonTracker Team of **Andy Jacobson** and **Ken Schuldt** for substantially improving NOAA's CarbonTracker data assimilation system and assembling the most comprehensive set of in situ CO₂ observations ever produced
- **Kai-Lan Chang**, **Owen Cooper**, **Audrey Gaudel**, and **Irina Petropavlovskikh** for generating global, accessible data on tropospheric ozone and advancing research on its temporal change and impact on climate, agriculture, and human health

CIRES OUTSTANDING PERFORMANCE: SERVICE

- **Hilary Peddicord**, **Beth Wehe**, and **Jonathan Joyce** for creating a mobile application that brings the innovative Science On a Sphere® experience to a worldwide audience
- **Hazel Bain**, **Carrie Wall Bell**, **Ryan Cassotto**, **Jonathan Kofler**, **Kathy Lantz** and **Hilary Peddicord** for creating a mentorship program at CIRES to boost workplace satisfaction and foster a more creative and productive research atmosphere
- **Hazel Bain**, **Ratina Dodani**, **Mariangel Fedrizzi**, **Dominic Fuller-Rowell**, **Kiley Gray**, **Jeff Johnson**, and **Ben Rowells** for building a critical system that serves the international com-

mercial airline industry with enhanced space weather predictions and communications.

OTHER AWARDS

- CIRES Fellow **Veronica Vaida** was elected to the National Academy of Sciences.
- **Veronica Vaida** was also honored with an ACS/APS Irving Langmuir Award in Chemical Physics for outstanding interdisciplinary research in chemistry and physics.
- CIRES Director **Waleed Abdalati** was elected a Fellow of the American Association for the Advancement of Science.
- CIRES Fellow **Rainer Volkamer** was honored with the Atmospheric Sciences Ascent Award by the American Geophysical Union.
- CIRES Fellow **Eleanor Brown** won an American Society for Mass Spectrometry Research Award.
- CIRES researchers **Kelly Carignan**, **Matt Love**, **Chris Aman-te**, and **Nic Arcos** were critical to the work of an NCEI team awarded a Department of Commerce Silver Medal for producing high-resolution topographic-bathymetric Digital Elevation Models, informing coastal inundation models for tsunami and hurricane hazards.
- CO-LABS announced the winners of the 2019 Governor's Award for High-Impact Research, and University of Colorado Boulder researchers contributed to all three winning projects.
- CIRES Fellow **Max Boykoff** is the 2020 faculty recipient of the University of Colorado's Thomas Jefferson Award.
- CIRES Visiting Fellow **Fabian Hoffmann** was awarded CU's Outstanding Postdoc Award, reserved for postdocs excelling in research productivity and innovation, communication, and leadership.
- **Carrie Wall Bell** was one of 25 CU Boulder researchers awarded seed funding from CU Boulder's Research & Innovation Office.



How do you demonstrate climate change to kids? With thermal cameras! CIRES and International Thwaites Glacier Collaboration researcher Tasha Snow led a workshop for 118 middle schoolers in Bradenton, FL in the fall of 2019. In a live demo, Snow showed how the greenhouse gas effect works, how useful satellites can be for understanding the world, and why glaciers and ice sheets are important. Images show the classroom, captured with a thermal camera on the right, compared with a regular optical one. Photo: Tasha Snow/CIRES

CIRES Education & Outreach Program

The CIRES Education & Outreach program provides programming and opportunities across the spectrum of geosciences and environmental education, including professional development for teachers, digital learning resources, student programs, workforce development, and program evaluation, mentoring opportunities and support for early career scientists, and more. Some projects from 2019-2020 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.
- **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, 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. RECCS has served dozens of community college students from across Colorado. Students are diverse along many dimensions, including first-generation college attendees, people of color, and veterans.

CIRES' Education & Outreach group has also led many efforts to support the unprecedented MOSAiC Arctic expedition, including launching Massive Open Online Courses and collecting video for a planetarium show and 360-degree Google Expeditions experiences, teacher workshops, and more.



A participant in the Lens on Climate Change program examines materials during an introductory lesson. Photo: Kathy Bogan/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 form the core of our institute. The 41 Fellows below were active between June 1, 2019 and May 31, 2020.

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 Laboratory

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 Laboratory

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

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 Laboratory

William D. Neff

CIRES Senior Research Scientist, NOAA Physical Sciences Laboratory

R. Steven Nerem

Professor of Aerospace Engineering Sciences

Judith Perlwitz

Management and Program Analyst at NOAA Physical Sciences Laboratory

Balaji Rajagopalan

Professor of Civil, Environmental, and Architectural Engineering

Prashant Sardeshmukh

CIRES Senior Research Scientist, NOAA Physical Sciences Laboratory

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

Photo above: Intern Dylan Murphy takes measurements in a post-wildfire plant community in Nevada.

Photo: Adam Mahood/CIRES

