COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES
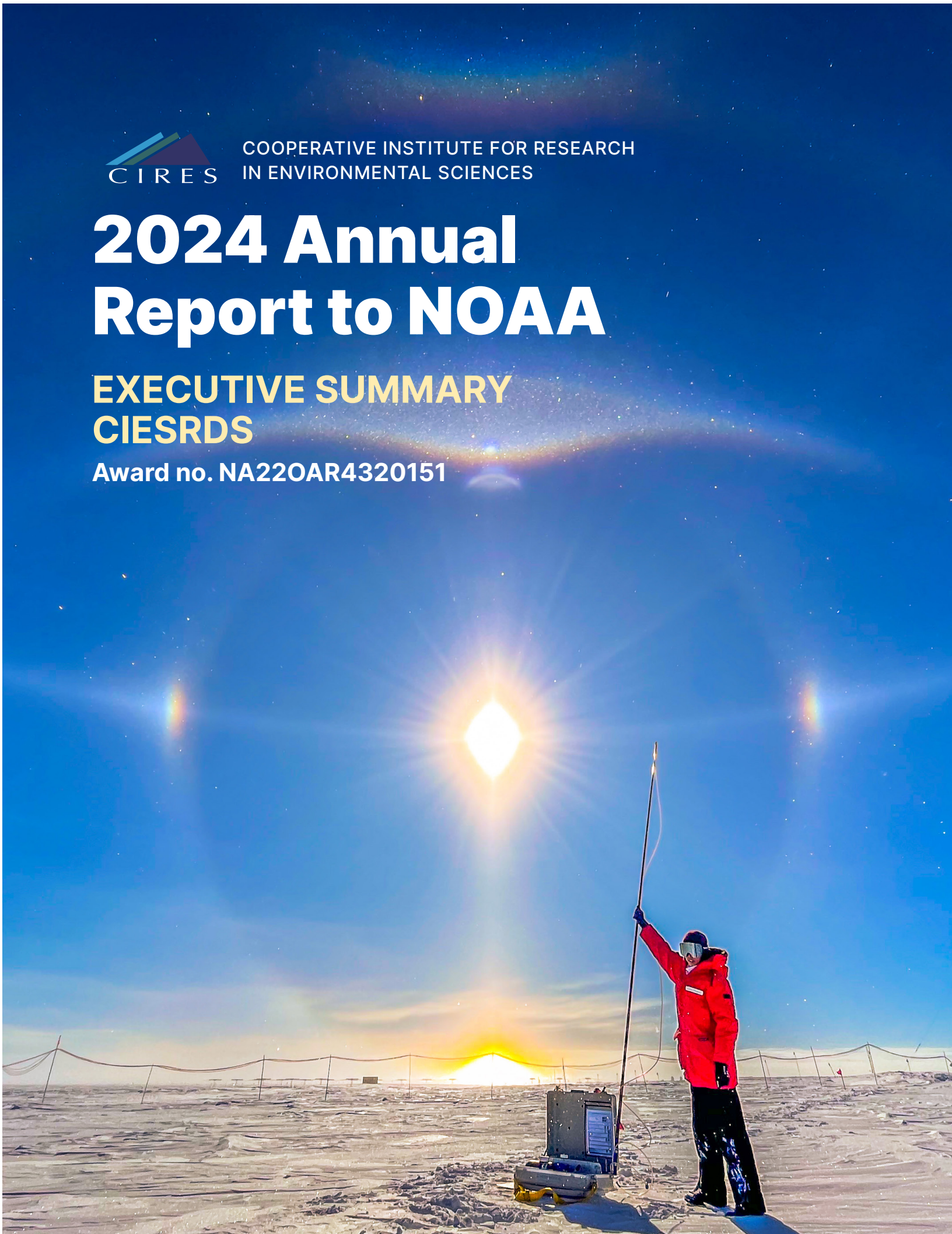
2024 Annual Report to NOAA

EXECUTIVE SUMMARY CIESRDS

Award no. NA22OAR4320151

About CIESRDS and CIRES

CIRES at CU Boulder has partnered with NOAA since 1967. In September 2022, we entered into a new cooperative agreement with NOAA: the Cooperative Institute for Earth Systems Research and Data Science (CIESRDS), which funds our research at NOAA labs for up to the next 10 years.

The overarching goal of CIESRDS is to support NOAA with Earth system research and data science on topics of significant societal importance. CIESRDS is working to help society respond to meet the urgent needs of a changing world by:

- Conducting high-quality Earth system research and data science in collaboration with, and in service to, NOAA to support society's resilience to environmental change;
- Training and inspiring a diverse and skilled future Earth system and data science workforce for NOAA and beyond;
- Growing Earth system research and data science literacy in learners of all ages;
- Serving the general public and decision-makers with information that fosters resilience to changes in the Earth system; and
- Providing the robust scientific and administrative infrastructure to run a cooperative institute cost-effectively, to successfully fulfill NOAA's needs and objectives, and to support growth in other external funding.

CIRES' vision is to be an international leader in conducting cross-cutting environmental research of the highest quality while bridging fundamental science and service to society. We support and build leaders, scientists, communicators, and teams dedicated to developing sound and trusted information to address environmental challenges. We embrace a positive and inclusive culture, recognizing that CIRES thrives when our people do.

CIRES BY THE NUMBERS FY2024

More than

$122M

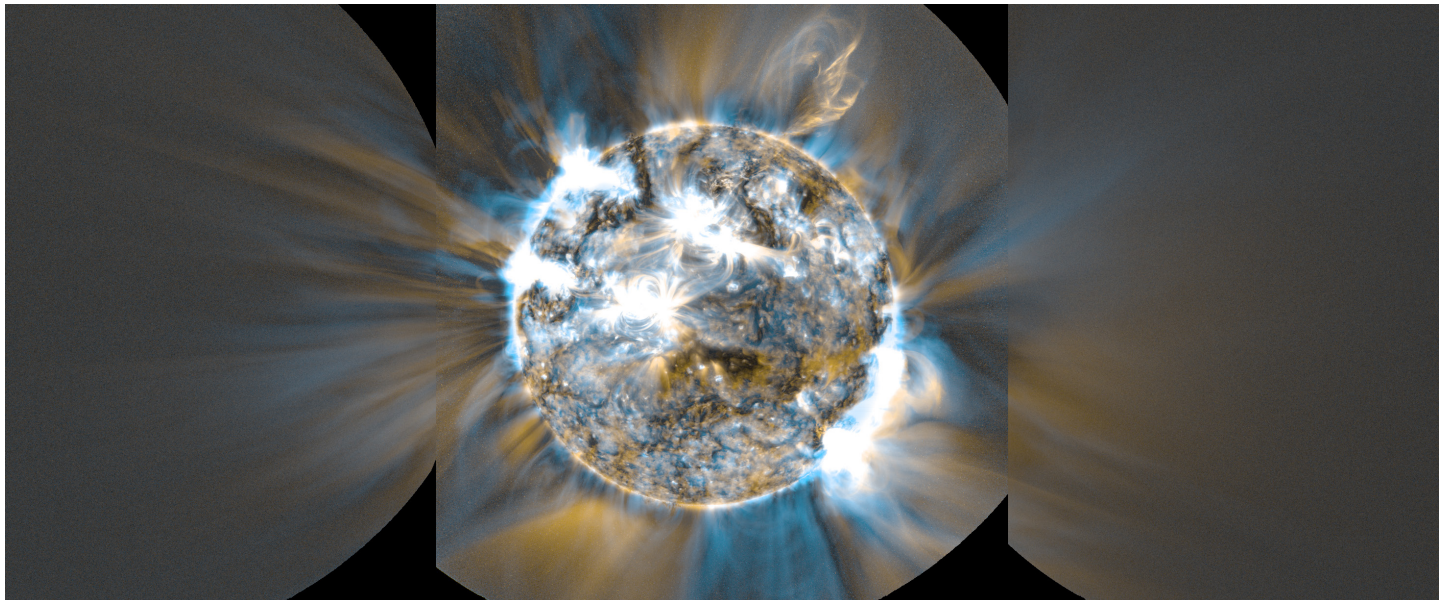in funding from NOAA, CU Boulder, contracts, and grants

908

researchers, faculty, students, and staff

624

papers published in academic journals; 65% of these had CIESRDS-funded authors

Cover image: Dr. Julianne Fernandez prepares to collect an air sample at the South Pole in support of the NOAA Global Monitoring Laboratory. Photo: Ian Crocker/CIRES and NOAA

Our NOAA partnerships

Chemical Sciences Laboratory
Advancing scientific understanding of the chemical and physical processes that affect Earth's atmospheric composition and climate.

Global Monitoring Laboratory
Collecting, maintaining, and understanding long-term records of atmospheric greenhouse gases, aerosol particles, clouds, and surface radiation.

Global Systems Laboratory
A research and development lab for improving weather data, forecasts, and computing techniques used by industry, decision-makers, and stakeholders.

National Centers for Environmental Information
Stewardship and archiving of environmental data from the depths of the ocean to the surface of the Sun.

Office of Education
Providing opportunities for undergraduate students to gain hands-on experience in STEM while pursuing research and educational training in NOAA-mission sciences.

Physical Sciences Laboratory
Research to better observe, understand, model, and predict weather, water, and climate extremes and their related impacts.

Space Weather Prediction Center
Real-time monitoring of Earth's space environment and forecasting of space weather, including geomagnetic storms.

Weather Prediction Center
Synthesizing the nation's daily weather story and championing the operational prediction of rain, winter storms, and extreme temperature events for the protection of life and property.

The Sun shows a coronal mass ejection (orange loops in the upper right) as observed on 22 March 2024 by the Solar Ultraviolet Imager on the GOES-18 satellite during a special observing mode to increase the field of view. Space weather instruments on board GOES satellites allow NOAA to provide accurate forecasts of solar events that may affect Earth. Image: Chris Bethge/NOAA/CIRES

CIESRDS accomplishments

During this reporting period, CIESRDS scientists accelerated Earth and environmental research; mentored and trained the next generation of Earth system scientists; promoted diversity, equity, and inclusion at CIRES; and supported public understanding of environmental science. CIESRDS scientists co-authored 404 peer-reviewed papers over the last year, improving scientific understanding of weather, climate, and humans' ability to adapt to a changing planet.

Supporting satellite observations of space weather

CIESRDS scientists completed the validation of space weather instruments on board the GOES-18 satellite and transitioned operations from GOES-17 to GOES-18. The instruments on GOES-18 provide better-quality real-time space weather observations, enhancing the ability of NOAA's Space Weather Prediction Center to provide accurate space weather warnings and forecasts.

CIESRDS scientists continue to develop telemetry processing and product generation systems for the GOES-19 satellite and Space Weather Follow On-Lagrange 1 spacecraft. Instruments on board these satellites will provide more accurate and detailed observations of the Sun than are available today, once both spacecraft have launched and become operational.

Contributing to wind energy development

CIESRDS researchers embedded in three NOAA laboratories helped launch the third Wind Forecast Improvement Project (WFIP-3), which will play a significant role in the development of wind energy off the New England coast. The project began in November 2023, when CIESRDS scientists and federal partners installed meteorological instruments off the southern New England coast to better characterize the wind environment in the area.

CIESRDS scientists are also contributing to wind energy development by participating in the American WAKE experiment project, a study to understand the interaction between wind farms and their surrounding environment in the U.S. Midwest. They deployed a mobile Doppler lidar

instrument in 2023 to measure wake behavior downwind of the King Plains wind farm in central Oklahoma.

Advancing atmospheric observations

CIESRDS scientists co-authored several publications relating to the January 2022 Hunga Tonga–Hunga Ha'apai eruption. Their results show the eruption sent so much water vapor into the stratosphere that it caused an unexpectedly large loss of ozone and a rapid formation of aerosols.

CIESRDS scientists continue to support operations at NOAA's Mauna Loa Observatory (MLO). In collaboration with federal colleagues, they added to existing solar power systems at MLO during the power outage caused by lava flows in 2022 and helped the observatory win a grant to convert itself to a net-zero, off-grid power source. The long-term data collected by MLO supports researchers in understanding atmospheric composition and is used to make informed decisions at local and global levels.

Understanding severe weather

CIESRDS scientists contribute to the VORTEX Southeast, PERiLs, and DELTA field campaigns, which aim to better understand how tornadoes form in squall lines and supercell thunderstorms. Over the past year, CIESRDS scientists operated and maintained wind profilers, radio acoustic sounding systems, and surface meteorology stations in Alabama, Louisiana, and Mississippi.

CIESRDS scientists began a new project in 2024 that will air-drop wave buoys in the paths of hurricanes to provide real-time data for ocean wave forecast systems. Their work will provide new insights into wave dynamics in storm environments, improving our understanding of storm impacts on coastal communities.
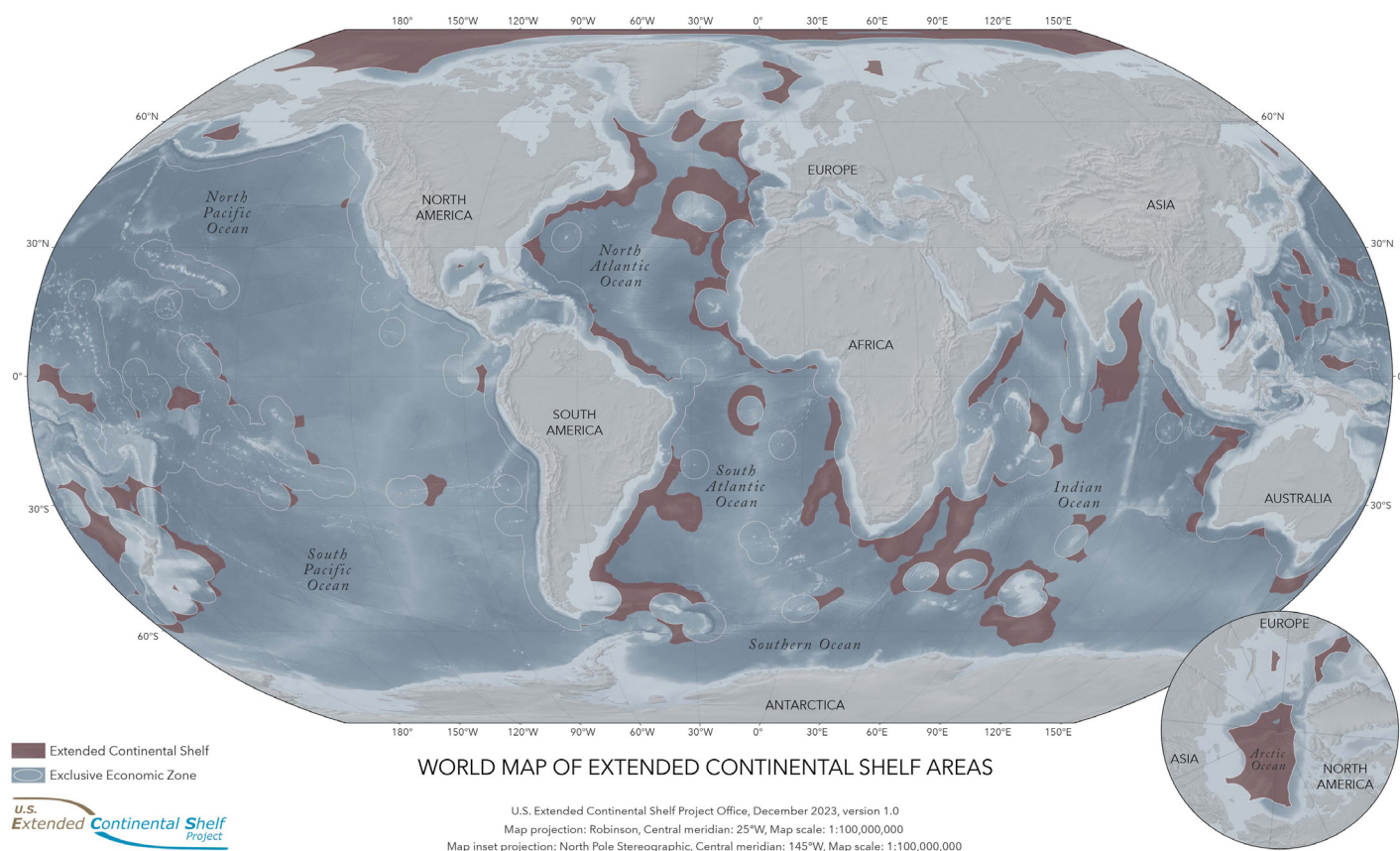
Probing wildfires

In early 2024, CIESRDS scientists published the first results from 2022's California Fire Dynamics Experiment. Their work shows it's possible to collect measurements of fire and smoke chemistry, weather conditions, and smoke plume dynamics in real time around an active wildfire. The preliminary results also shed light on how pollutants like ozone are made and dispersed in a wildfire plume.

Wind Forecast Improvement Project (WFIP-3) researchers raise a tower on Block Island for this collaborative project, which aims to improve weather forecasting in the area, especially for offshore wind farms. Photo: Laura Bianco/CIESRDS

Analyzing greenhouse gas trends

In spring 2024, CIESRDS scientists provided NOAA with updated levels of global greenhouse gases in Earth's atmosphere and assessed their direct radiative forcing. Their analysis found atmospheric levels of the three most important human-made greenhouse gases — carbon dioxide, methane, and nitrous oxide — continued to climb in 2023. Specifically, levels of carbon dioxide measured at NOAA's Mauna Loa Observatory peaked at just under 427 parts per million in May 2024. In addition, CIESRDS scientists found nitrous oxide emissions grew 40 percent from 1980 to 2020 and current concentrations of this potent greenhouse gas are higher than all major model projections for this point in time.

WORLD MAP OF EXTENDED CONTINENTAL SHELF AREAS

Extended Continental Shelf
Exclusive Economic Zone

U.S. Extended Continental Shelf Project Office, December 2023, version 1.0
Map projection: Robinson, Central meridian: 25°W, Map scale: 1:100,000,000
Map inset projection: North Pole Stereographic, Central meridian: 145°W, Map scale: 1:100,000,000

U.S. Extended Continental Shelf Project: CIESRDS scientists gathered marine geophysics data that the the the U.S. Department of State used to define the outer limits of the U.S. Extended Continental Shelf. Their work helped add one million square kilometers of seafloor to U.S. territory global maritime zones and limits, shown in this world map of extended continental shelf areas. Credit: U.S. Extended Continental Shelf Project

Impacts of CIESRDS research

CIESRDS scientists are world leaders in Earth and environmental research, but the impact of our work goes beyond basic science. In the past year, CIESRDS research and researchers have supported decision-making at local, state, and national levels and protected lives and property through improved weather monitoring and forecasting.

Providing new opportunities for scientific exploration

In 2023, the U.S. Department of State used marine geophysics data analyzed by CIESRDS scientists to define the outer limits of the U.S. Extended Continental Shelf: areas of the seafloor the United States now has sovereign rights to conserve, manage, and explore. Their work helped add one million square kilometers of seafloor to U.S. territory and resulted in discoveries of new undersea features that can be studied, such as a 1,400-meter-high methane plume off the California coast and pockmarks made by exploding gas on the Arctic Ocean floor.

Supporting decision-making with actionable information

CIESRDS scientists were instrumental in collecting data for the multi-pronged AGES+ field campaign, the largest coordinated air quality research campaign to date. Results from their work will be incorporated into future climate, air quality, and ozone assessments that benefit the public.

The Air (Ine)quality in NYC project: Isabella Vicenza, student at Barnard College (left), Yoshira Ornelas Van Horne (center), an environmental health scientist at Columbia University who wears monitoring equipment, and CIESRDS scientist Audrey Gaudel measure air pollutants in the South Bronx in August 2023. Photo: Lauren Lipuma/CIRES

The Air (Ine)quality in NYC project, conducted by a CIESRDS scientist in 2023, measured air pollutants at street level for various neighborhoods throughout New York City. This project aims to provide residents of New York neighborhoods with actionable information they need to advocate for better air quality.

CIESRDS scientists partnered with federal colleagues to publish new findings on air quality in Las Vegas, Nevada, and found pollutants from cooking can account for nearly a quarter of human-made volatile organic compounds in cities. Their work helps residents and decision-makers better understand the sources of air pollution in large cities.

Protecting lives and property

CIESRDS scientists helped dissect the forecasting challenges posed by the mountain wave windstorm that contributed to Colorado's 2021 Marshall Fire. Their work could change how Red Flag Warnings are issued to inform residents of dangerous fire-starting conditions and improve communication of risk levels and the severity of the risk once a wildfire is burning.

CIESRDS scientists produced a climatological dataset of the frequency and duration of low cloud ceiling and visibility events. Their work can serve as a foundation for improving forecasts for the aviation industry. Better aviation forecasts lead to safer and more comfortable flights (fewer turbulence encounters), shorter flights (minimizing routing around storms), and consequently, lower costs and emissions.

The work of CIESRDS scientists on the Famine Early Warning Systems Network provides benefits to people in food-insecure countries by providing early warnings of drought conditions and improved forecast reliability, which enables better decision-making processes for managing water and food resources in food-insecure countries.

Minimizing the cost and environmental impact of Earth system research

CIESRDS scientists have developed frost-point hygrometers using alternative cryogens that have more than 14,000 times less greenhouse-warming potential than traditional instruments that use Freon. Their work ensures long-term

robust records of upper atmospheric water vapor will continue at a reduced cost to the environment.

Bridging science and art to enhance climate literacy

Artist Beatie Wolfe used greenhouse gas data provided by CIESRDS scientists to create an animation called Smoke and Mirrors that increases climate awareness and literacy. The project uses art to communicate six decades of climate data, with a specific focus on rising methane levels. The project won the 2024 Golden Nica award of Prix Ars Electronica.

CIESRDS staff working with NOAA's Science On a Sphere® (SOS) and SOS Explorer technology co-hosted the first Environmental Literacy Program and SOS Network in-person workshop at The Wild Center located in the Adirondack Mountains; they also created new resources for outreach, including programs and movies for SOS based on the Fifth National Climate Assessment (that was released in 2023) and for the two exciting solar eclipses that occurred this reporting year.

CIESRDS staff demonstrate Science On a Sphere® projection during a joint workshop on environmental literacy hosted by The Wild Center in New York. Photo: The Wild Center

Media highlights

CIESRDS researchers, along with federal partners, participated in the AGES+ field campaign, the largest coordinated air quality research campaign in the U.S. to date, in July and August 2023. NBC Chicago and other media outlets covered the research, which took a deep dive into air quality over several major U.S. cities using instruments aboard aircraft and satellites.

CIESRDS scientist Monica Madronich analyzes the greenhouse gas concentrations in air samples from around the world.

The Colorado Sun and *Down to Earth* reported on 2023 greenhouse gas trends analyzed by CIESRDS scientists. Their analysis found carbon dioxide, methane, and nitrous oxide continued to rise in 2023.

Evidence of a 14,000-year-old ferocious space weather storm, known as a Miyake event, was recently discovered in a forest in France. CIESRDS scientist Mark Miesch commented on the study in *Scientific American*, saying the event appears to have happened during what was otherwise a regular quiet period for the Sun, which is a new and surprising finding.

Research by CIESRDS scientists and federal partners on cooking emissions in Las Vegas, Nevada, was covered by *The Los Angeles Times*, Tasting Table, and KTLA.

Awards and honors

Stan Benjamin, Jeffrey Duda, Jason English, Guoqing Ge, Jeff Hamilton, Joan Hart, Craig Hartsough, Jaymes Kenyon, Ruifang Li, Laura Melling, William Moninger, Shawn Murdzek, Gopa Padmanabhan, Sijie Pan, Michael Rabellino, Julia Simonson, Molly Smith, Sam Trahan, Hongli Wang, and Chunhua Zhou received a CIRES Gold Medal for scientific and engineering excellence in developing a revolutionary prediction tool that provides short-term probabilistic thunderstorm guidance.
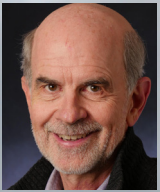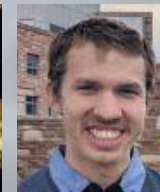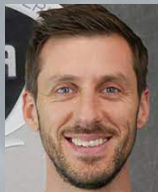
Benjamin **Duda** **English** **Ge** **Hamilton**
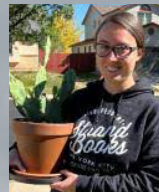
Hartsough **Li** **Melling** **Moninger** **Murdzek**

Photo unavailable: Hart, Kenyon, Padmanabhan, Pan, Simonson, Zhou

Rabellino **Smith** **Wang**

Asher **Cullis** **Hall** **Hurst**

Elizabeth Asher, Patrick Cullis, Emrys Hall, Dale Hurst, Allen Jordan, and Yunqian Zhu received a CIRES Silver Medal for successfully executing a rapid response campaign to study the atmospheric impact of the unprecedented Hunga Tonga-Hunga Ha'apai volcano eruption.

Jordan **Zhu**

Matthew Shupe received the International Arctic Science Committee Award for Service.

Shupe

de Boer **Hamilton**

Gijs de Boer and Jonathan Hamilton received a CIRES Silver Medal for the first deployment of a fully autonomous system for the measurement of vertical profiles of aerosol, cloud, and meteorological properties.

Ahmadov **James**

Ravan Ahmadov, Eric James, and Sam Trahan received a CIRES Silver Medal for the operational value of predictions of wildfire smoke transport and its impact on weather to support air quality alerts and visibility forecasts.

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