CIRES

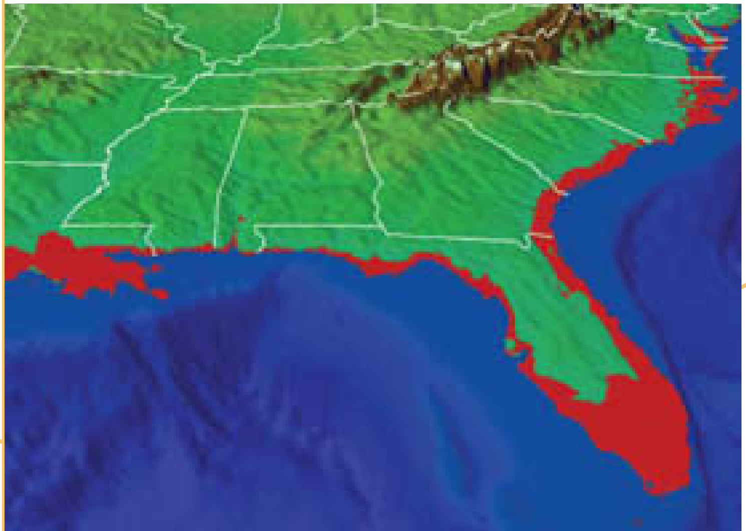
Cooperative Institute for Research in Environmental Sciences

At CIRES—

We study Earth in the field,

and we study Earth in the lab.

We study Earth using models . . .




. . . and we study Earth from space.

"Science in service to society is the overarching mantra for CIRES. We are proud to host a very dynamic and interdisciplinary environmental research program with the top leaders in innovative earth systems science research and education."

–Konrad Steffen,
CIRES Director

We look at how best to apply our research to serve society's needs.

CIRES researchers explore all aspects of the earth system and search for ways to better understand how natural and human-made disturbances impact our dynamic planet. Our focus on innovation and collaboration has made us a world leader in interdisciplinary research and teaching. We're committed to communicating our research in ways that help inform decision-makers and the public about how we can best ensure a sustainable future environment.

CIRES is . . .

- The Cooperative Institute for Research in Environmental Sciences
- A joint institute of the National Oceanic and Atmospheric Administration (NOAA) and the University of Colorado at Boulder
- Engaged in earth system research that spans six major divisions
- Home to five research centers on the CU-Boulder campus
- Inspired and directed by a diverse Council of Fellows
- Committed to education and outreach at all levels
- Host to more than 220 visiting research scientists since 1967
- A research and learning environment like no other

Boulder, Colorado—an unmatched research environment

In addition to providing a beautiful natural setting where CIRES researchers live and work, Boulder is home to many scientific agencies and research facilities. These include the National Center for Atmospheric Research (NCAR), the National Institute for Standards and Technology (NIST), and, nearby, the National Renewable Energy Laboratory (NREL). This robust scientific network provides rich opportunities for collaboration in the environmental sciences.

University-wide collaborations

Through partnerships with a dozen university departments, CIRES is an integral part of campus life at CU-Boulder. CIRES faculty teach normal course loads in their respective academic departments and offer subjects as wide-ranging as global climate modeling and cryospheric and polar processes. Our faculty provide students with unique opportunities to explore subjects that span multiple disciplines and to gain hands-on research experience. CIRES faculty have supervised the research of hundreds of graduate students who have gone on to successful careers in engineering and environmental sciences.

Our campus setting facilitates collaboration between CIRES and numerous CU-Boulder academic departments and programs. These include the College of Engineering and Applied Science, the College of Arts and Sciences, and the Graduate School, as well as university-based institutes such as JILA, the Laboratory for Atmospheric and Space Physics (LASP), and the Institute of Arctic and Alpine Research (INSTAAR), which oversees the Niwot Ridge long-term ecological research station near the Continental Divide.

Our NOAA partnership

More than half of CIRES' researchers work just down the street from the CU-Boulder campus at NOAA's prestigious Earth System Research Laboratory (ESRL). With the benefit of state-of-the-art research facilities and equipment, our researchers there participate in all aspects of ESRL's work. They study chemical and physical sciences, as well as analyze and monitor global systems. Other CIRES researchers collaborate with NOAA's Space Environment Center and the National Geophysical Data Center.

CIRES divisions

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

CIRES centers

Center for Limnology
Center for Science and Technology Policy Research
Center for the Study of Earth from Space
Climate Diagnostics Center
National Snow and Ice Data Center

Ice sheets and glaciers

Ice sheets and glaciers advance and retreat in response to the climate. By studying the rate of growth or loss in ice mass, CIRES scientists can better quantify the nature of present day climate variations. Our scientists also study the movement of ice sheets and glaciers in order to construct valuable climatological records of the past. From Antarctica to Greenland, we conduct field campaigns in many remote places and also monitor glaciers closer to home. The CIRES National Snow and Ice Data Center (NSIDC) maintains photographic records of the retreat of mountain glaciers in the U.S. and other mid-latitude regions.

Arctic climate

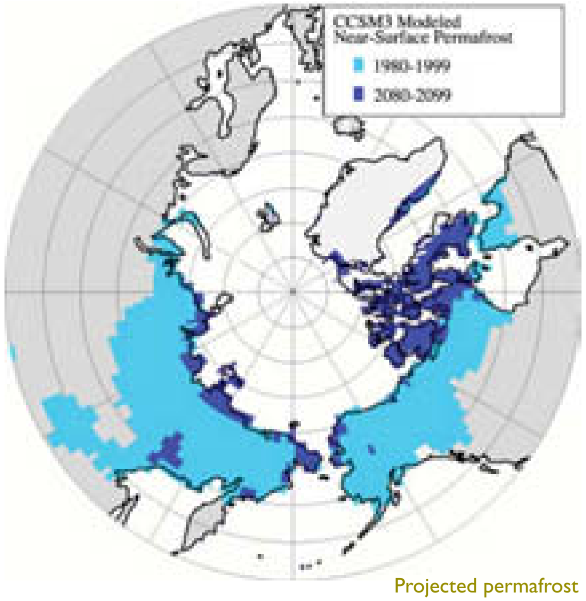
Arctic climate is rapidly changing, and this corresponds with what scientists expect from global warming. However, because of the Arctic's high latitude and seasonal exposure to sunlight, this polar region also experiences substantial natural climate variability. CIRES researchers are working to discern the causes of Arctic climate change, while also assessing the impact Arctic warming will have on global climate systems. We monitor variations in temperature and precipitation by sampling snow and ice, tracking sea ice and permafrost coverage, and measuring glacial melt.

Snow cover and snow hydrology

Seasonal snow covers up to 33 percent of the earth's total land surface and plays several important roles in the earth system. Snow's whiteness, for example, reflects incoming solar radiation, affecting the temperature of the planet. CIRES researchers are interested in knowing how dust and other pollutants alter the reflective properties of snow. Snow also stores a great deal of fresh water in certain parts of the world, such as in the Rocky Mountain states and California, where snowmelt is a large source of drinking and irrigation water. Our researchers look at how increasing global temperatures may impact Western U.S. water supplies.

Permafrost

In the cold regions of the earth, organic material is often frozen into the soil before it has a chance to fully decay. Observations show that this frozen soil layer, known as permafrost, is beginning to thaw in many high-latitude regions. CIRES is interested in learning more about how permafrost thaw will affect local hydrology and soil stability, as well as increase emissions of methane and other trace gases.



Projected permafrost loss by end of 21st century shown in light blue.

Arctic sea ice minimum

Arctic sea ice is shrinking, according to CIRES scientists, who have been monitoring the minimum sea ice coverage now for several years. This has significant implications for climate change, because melting ice exposes dark ocean, causing the planet to absorb additional solar radiation and warm further. Over the years, our researchers at the National Snow and Ice Data Center (NSIDC) have used remote sensing technology to follow this downward trend in ice coverage. Their observations suggest that the rate of September sea ice decline has steepened, since 2002, to 8.6 percent per decade, or 60,421 square kilometers per year, an area more than twice the size of the state of Massachusetts.

Water quality

Through the Center for Limnology, CIRES scientists research nutrient dynamics and food webs in lakes, rivers, and wetlands. Our work assists water managers in preserving natural aquatic ecosystems and maintaining safe drinking water supplies for Colorado communities. From estimating the effects of fertilizers on watershed nitrogen yield to identifying the processes involved in denitrification—the removal of nitrogen compounds from a system—our research is helping build a greater understanding of biogeochemical cycles in freshwater environments.

Regional and global disturbances

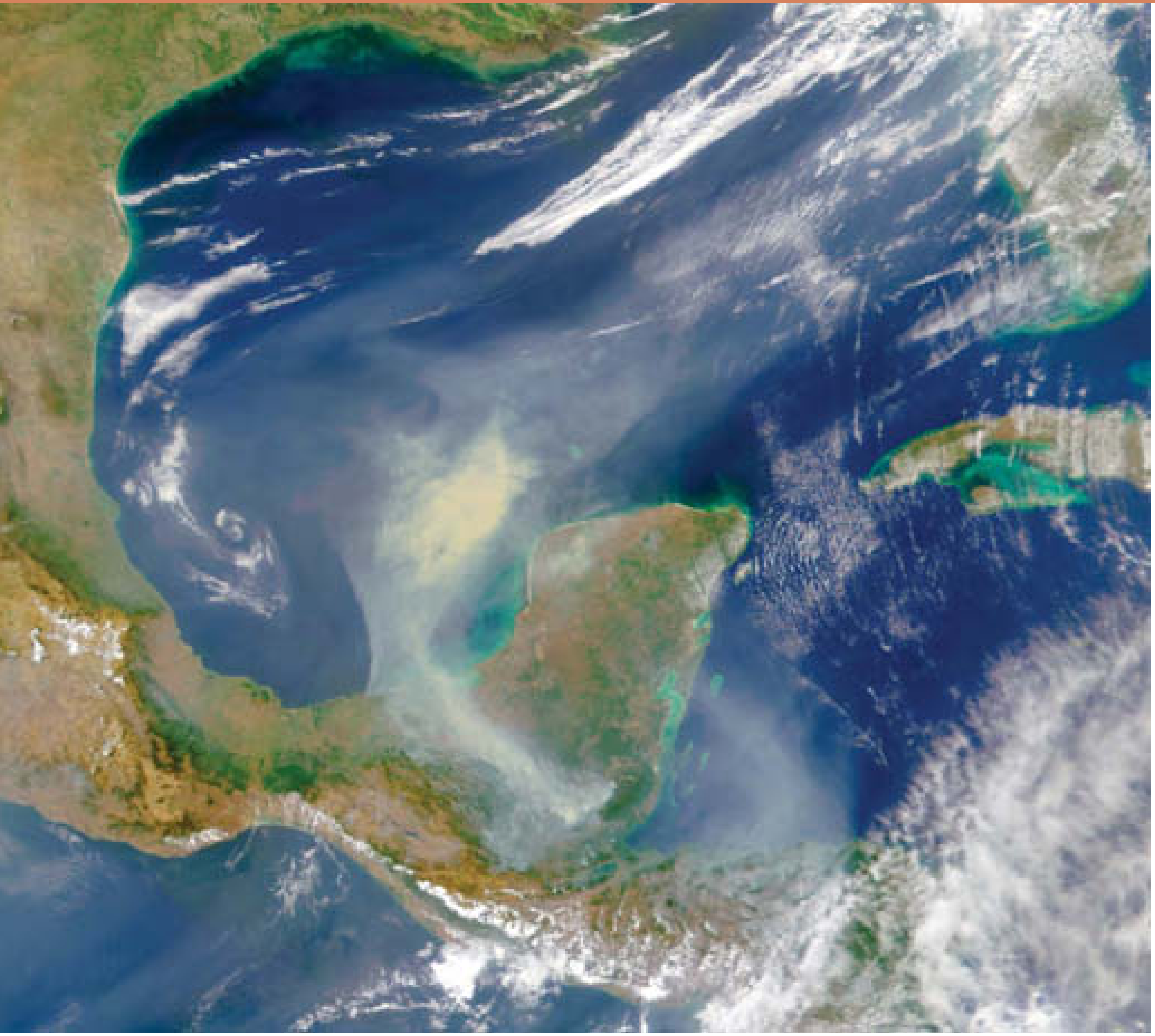
Natural processes, such as wildfires and windstorms, and human activities, such as deforestation and changes in land use, alter ecosystems and landscapes. At CIRES, we explore the effects these disturbances have on the structure and function of ecosystems. Toward this goal, we're developing quantitative methods that link spatial patterns and ecological processes over time. Our investigations have spanned the biogeochemical dynamics of woody plant encroachment in the U.S. Southwest, the ecological effects of habitat fragmentation due to urbanization, and ecological response to multiple disturbances in forest ecosystems. We're working to understand the scale and pace of these changes in terms of their influence on ecosystem health and sustainability.

Land-atmosphere exchanges

The biosphere, which extends from the bedrock of our planet up to the last breathable layer of air, determines the chemical makeup of Earth's atmosphere. Living organisms, for instance, regulate atmospheric concentrations of oxygen and trace gases. Vegetation and soils, which are rich in microbes, are a reservoir for carbon. And plants also emit reactive volatile organic compounds, which contribute to ground-level ozone pollution. Through field campaigns, remote sensing, and laboratory experiments, CIRES scientists research global biogeochemical cycling and ecosystem controls over biophysical fluxes. We're especially interested in understanding the nutrient balance of ecosystems and the influence of trace gas emissions from vegetation on global climate.

Biodegradation of toxic pollutants

Bacteria can play a major role in cleaning up pollution by breaking down toxic chemicals. CIRES scientists study how bacteria assemble new metabolic pathways that allow for degradation of pentachlorophenol (PCP), a toxic and persistent chemical used widely as a wood preservative. Experiments have revealed that although the bacteria are capable of metabolizing PCP, the enzymes they use to do so are relatively inefficient. CIRES researchers are looking at how directed evolution methods could generate improved enzyme function, enhancing the performance of the bacteria in degrading PCP.



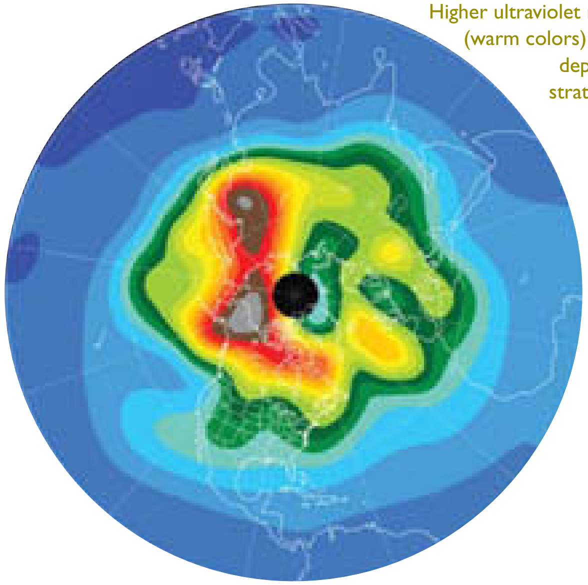
Climate forcing

Greenhouse gases—such as water vapor, carbon dioxide, methane, chlorofluorocarbons (CFCs), and nitrous oxide—trap heat radiating from our planet's surface. To better understand just how human activities are changing our planet's radiative energy balance, CIRES scientists measure the heat-absorbing properties and lifetimes of greenhouse gases and ozone. Ozone plays a particularly important role in controlling the overall chemistry of the atmosphere and the lifetimes of chemically active gases like methane.

We also investigate how the chemical composition of aerosols may influence the earth's temperature. By examining how different aerosols reflect the sun's radiation, we're able to estimate how they affect the heat balance of the atmosphere. In addition, aerosols appear to affect the planet's temperature indirectly by acting as nuclei for water condensation, facilitating cloud formation. Clouds, depending on their height and thickness, can either deflect radiation or trap it. Improving our understanding of the role of aerosols in influencing cloud formation and cloud radiative properties will vastly improve global climate modeling forecasts.

Air quality

Ground-level ozone and aerosols are two major contributors to air quality problems. Through regional field campaigns, laboratory studies, and modeling investigations, CIRES researchers study the production, transformation, and transport of these air pollutants, enabling us to provide essential guidance to decision-makers on effective air quality management. Our research has helped demonstrate that air pollution must be understood on local to regional levels and that flexible management strategies are critical. For instance, the most effective approach to improving air quality on a regional basis is often dependent on the balance between the natural and human-made sources of the oxides of nitrogen and volatile organic compounds in that particular area. This type of information has spurred new strategies for managing large industrial point sources of pollution and controlling multiple-source pollution in cities like Houston, Texas.



Higher ultraviolet radiation (warm colors) showing depletion of stratospheric ozone.

Stratospheric ozone

When the ozone hole was first discovered over Antarctica, CIRES researchers played a key role in illuminating the chemical nature of the problem. Since then, we have continued to monitor stratospheric ozone around the globe, to investigate the processes that can alter it, and to help develop safer chemical alternatives to CFCs—the main chemical culprit behind ozone depletion. A particularly active area of CIRES research concerns the connection between aerosols and the CFC-related chemical depletion of ozone. Ongoing laboratory measurements, field studies, and modeling allow us to improve the accuracy of our predictions concerning ozone layer recovery.

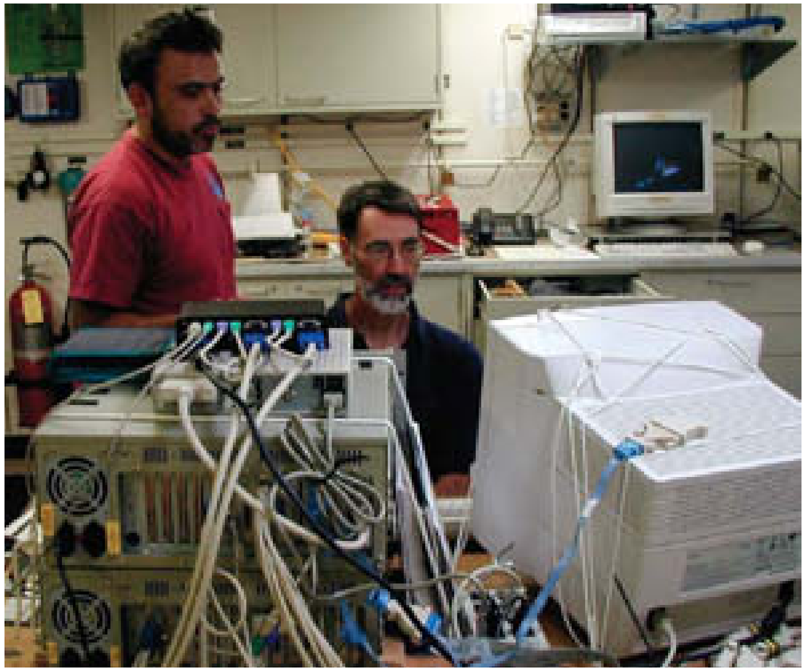
Applications to biomedical science and global health

The development of new tools to study the sources and processes that determine the distribution and composition of atmospheric aerosols has opened important new areas of investigation and application for human health. At CIRES, we've looked at using biologically active aerosols as an effective delivery system for medication. Our scientists have patented methods that create micro-particles of antibiotics, antivirals, and vaccines that can be inhaled rather than injected. These methods are particularly valuable for improving public health in developing countries.

Environmental observations, modeling, and forecasting

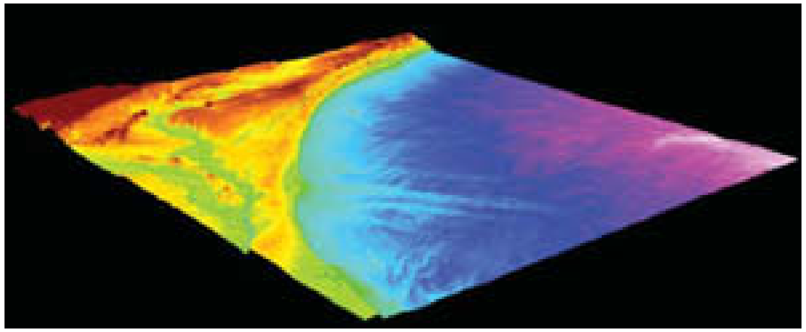
Measuring carbon and greenhouse gases

Models and forecasts are only as good as the quality of the initial data input. That's why CIRES scientists participate in global monitoring networks for carbon, greenhouse gases, ozone, and other atmospheric compounds. Through these networks we collect information at the site (*in situ*) and also remotely. Measurements aboard unmanned aircraft systems, for instance, have greatly enhanced our ability to monitor difficult-to-reach places like the Arctic Ocean.



Remote sensing

Remote sensing allows us to study earth system processes over large areas and in hard-to-access places. When it comes to measuring properties of the atmosphere, for example, remote sensing enables us to capture information about an entire column of air nearly instantaneously. This is invaluable for tracking trace gases and pollutants, as well as for modeling temperature changes in the atmospheric column. Using this technology, CIRES researchers investigate the thermal structure of the middle and upper atmosphere and cloud formation at different heights. In other disciplines, we use remote sensing to monitor ice melt, seismic activity, and land use changes.

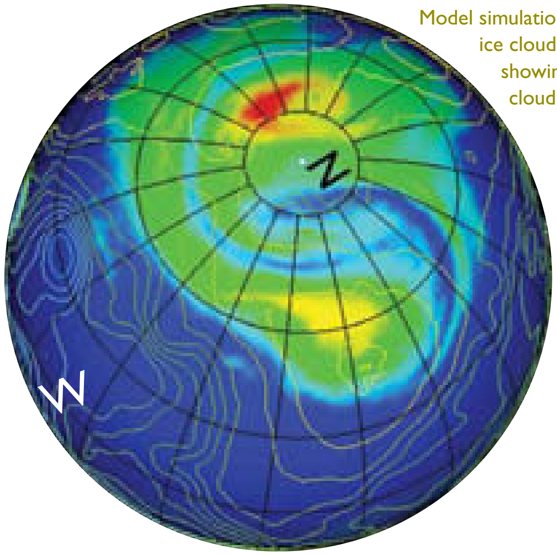


Geophysical data stewardship

CIRES scientists work with their NOAA counterparts to maintain the world's largest collection of seafloor data, space environment data, and historical tsunami data. We also manage and store geophysical observations taken from the Defense Meteorological Satellite Program. CIRES scientists are especially knowledgeable in building and maintaining long-term archives for data acquired by NOAA observing systems. Our robust data sets are used by scientists worldwide, and they will provide invaluable historical information for future generations of earth scientists.

Global climate modeling

Models are exceptionally powerful tools for investigating complicated earth system processes, such as the sensitivity of the global climate to natural and human-made disturbances. One aspect of our modeling work focuses on understanding the sensitivity of large-scale Arctic weather patterns to increases in atmospheric carbon dioxide. We also look to understand what the likelihood is that these different synoptic weather patterns will actually occur. In other research, our scientists use models to improve the representation of clouds and land-surface processes and to investigate the response of regional hydrology to global climate change.



Model simulation of water ice clouds, with red showing greatest cloud thickness.

Texas air quality study

Increasingly, air quality is influenced by more than just local pollution. In Texas, CIRES researchers have worked to evaluate how regional, continental, and even global factors influence urban air quality. We've taken measurements of pollution from air, sea, and land, and modeled the meteorology and chemistry involved in controlling atmospheric conditions. These studies have allowed us to better understand the formation and transport of key urban pollutants, like ozone and particulate matter, and will aid decision-makers in improving pollution reduction programs.

Geochemistry of mountains

Not all mountain ranges are created equal. In fact, the processes that build and erode mountains are surprisingly diverse, and they're not always triggered by the collision or divergence of tectonic plates. At CIRES, our researchers are involved in a major effort to discern the separate effects of the crust and upper mantle on western U.S. topography. We're finding that many of the observed differences in western geology are a result of variations in the density or composition of the mantle. Mountain uplift and extension in the Sierra Nevada, for example, appear to be driven by the "drip" of hot and dense rock from the foundation of the mountain range.

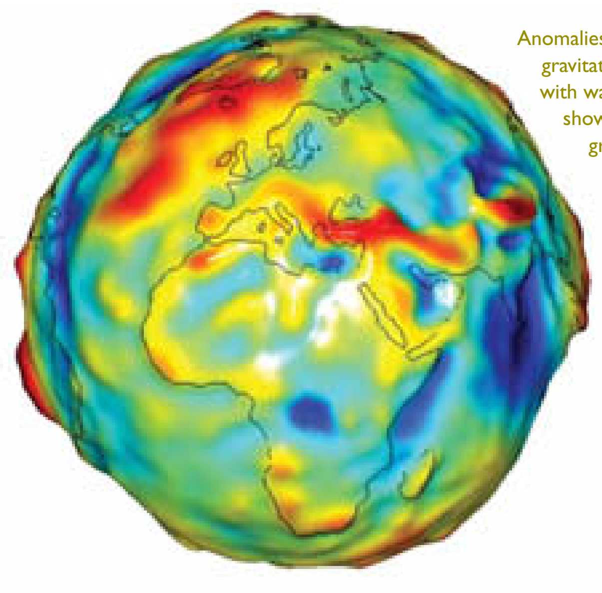
Crustal deformation and mantle dynamics

Earth's mantle extends from the top of our planet's liquid core to the crust of its surface. CIRES scientists study this dynamic layer and its influence on plate tectonics and crustal deformation. Convection within the mantle is thought to occur at just a few centimeters per year, yet this motion causes continental plates to drift and collide, triggering earthquakes and fueling volcanic activity. Our researchers use seismology and geodesy to measure ground motion in places as far away as the Himalaya and as close as the Rocky Mountains. These tools allow us to map the deep structure of the earth and estimate future seismic hazards at plate boundaries.

Earthquakes Extension faults Soil erosion Mountain formation Geodesy

Landscape evolution and climate

Earth's surface is in constant motion. Processes ranging from catastrophic landslides to the gradual accumulation of sediment in floodplains shape the landscape and have multiple feedbacks with the atmosphere, lithosphere, and geosphere. CIRES scientists study the physics and chemistry of these surface processes to better understand their contribution to sculpting the earth's varied topography. We also study the relationship between surface processes and regional climate. One area of CIRES research has focused on the uplift of the Himalaya and its impact on the initiation of the Asian monsoon cycle.



Anomalies in Earth's gravitational field, with warm colors showing higher gravitational pull.

Gravity from space

Earth's gravitational field changes in strength according to minor differences in surface topography and mass. Even water runoff after a rainstorm can temporarily alter Earth's gravitational pull by changing the surface characteristics over a particular area. By taking precise measurements of gravity from space, CIRES scientists are able to monitor changes in the distribution of Earth's mass. We can apply this technology to track melting of continental ice sheets and follow the depletion of underground aquifers.

Tools of the trade

CIRES scientists apply several techniques to monitor earthquake-associated crustal deformation. Creepmeters on the San Andreas fault in California record surface slips smaller than the diameter of a human hair. This creep can reduce strain near fault zones and reduce the elastic energy available for earthquakes.

In Washington state, 500 meter-long, water-filled tiltmeters monitor surface bending caused by the descent of the Juan de Fuca plate beneath the North American plate. Every 20 seconds the tilt of the earth's surface is recorded and transmitted to a central site where the data are being used to forecast the approach of the next magnitude nine earthquake near Seattle.

In Bhutan, Baluchistan, Pakistan, Tibet, India, and Nepal, CIRES scientists have installed GPS tracking systems to monitor Himalayan collision zone complexities and to characterize the seismic hazard caused by the movement of the Indian plate.

Atmosphere-ocean interactions

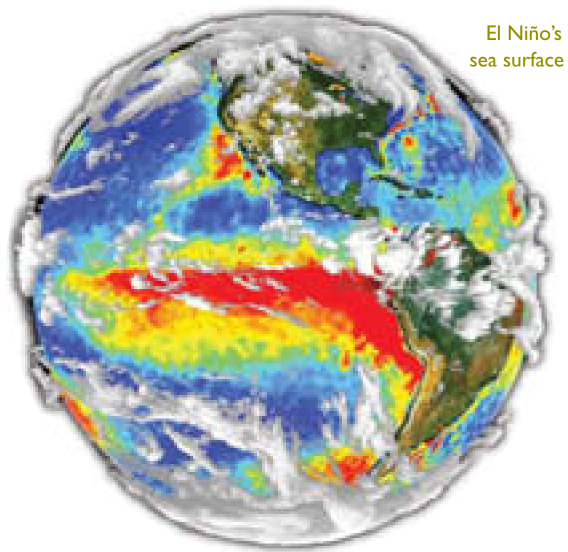
Oceans play a key role in regulating the earth's climate. This is partly because of inertia; oceans take longer to heat and cool than land. But scientists at CIRES are also interested in studying how sea surface temperature changes affect weather phenomena and longer-term climate variability. In one area of research, CIRES scientists look at how variations in the temperature anomaly and location of El Niño events impact precipitation in different parts of the world.

Tropical convection

Atmospheric convection in the tropical regions is one of the main mechanisms of transporting solar energy from the equator to the polar regions of our planet. This pattern of warm air rising, cool air sinking is responsible for both the daily rainstorms typical of equatorial regions and heat transport away from the equator toward higher latitudes. CIRES researchers look at whether improving our understanding of tropical convection will shed light on weather-climate connections. They also continually work to improve models that explain poleward transport of heat.

Connecting climate and weather

Traditionally, the atmospheric sciences have treated weather and climate separately. At CIRES, we're moving toward a more unified study of these processes. We want to know how climate variations influence weather events and how weather patterns affect climate. We've already observed that weather events can shift the path of the jet stream and that changes in sea-surface temperatures influence hurricane intensity. By further studying these connections across time scales, our researchers hope to improve long-term weather-climate forecasting abilities, especially for extreme events like droughts, floods, wildfires, and hurricanes.



El Niño's above-normal sea surface temperatures shown in red.

El Niño

For years, scientists have tracked the intensity of the El Niño Southern Oscillation by measuring the strength of the sea surface temperature anomaly. El Niños occur when warmer ocean water wells up toward the eastern equatorial Pacific. But the strength of the temperature anomaly may not be the only important factor in predicting El Niño-related weather events. Our researchers found that the location of sea-surface warming appears to be just as critical. For instance, El Niños that develop near the central equatorial Pacific appear to cause drought during the Indian Monsoon, whereas warm waters near the eastern equatorial Pacific may have no impact on monsoon rains.

Water resource management

Working directly with water resource managers at federal, state, and local levels, CIRES researchers aim to reduce societal vulnerabilities to climate variability. Through the Western Water Assessment, which is one of eight similar programs around the country, our experts in climate, water, law, and economics collaborate to improve long-term water planning in the Intermountain West. The assessment provides key information concerning climatic effects on water supply and demand, as well as regional modeling tools that help predict the relationships between shifts in climate, population growth, and water allocation.

"The hands-on experience I've gained through CIRES while working toward my master's degree in geography at CU-Boulder is invaluable. I spent my first spring doing fieldwork on the Greenland ice sheet with some of the world's top cryospheric researchers. I don't know where else I would get this kind of opportunity."

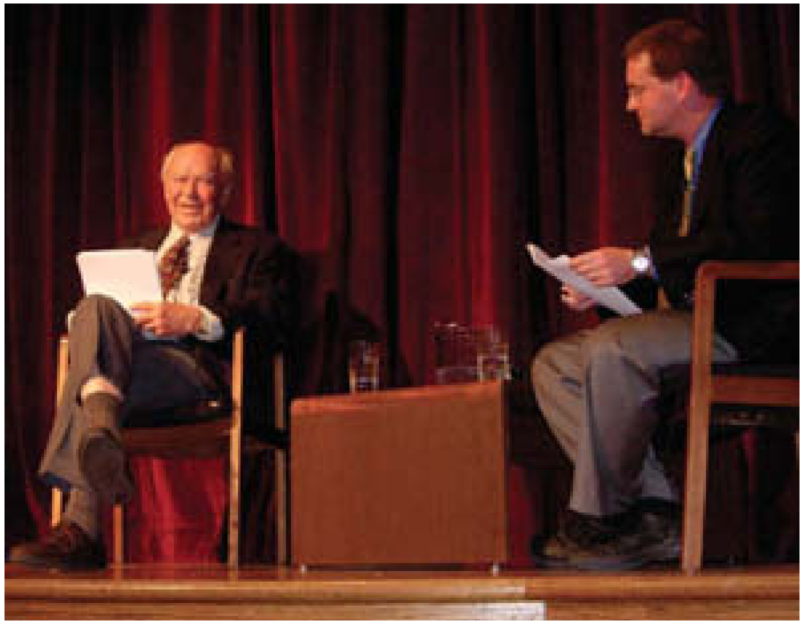
—Master's candidate, geography

Graduate education

Commitment to education is an integral part of our mission at CIRES. Every year our faculty and scientists supervise the research of more than 60 graduate-level students. We provide our students with a unique opportunity to experience professional-level research while they complete their degrees. We also offer a graduate research fellowship, which helps recruit top students to CU-Boulder's academic programs, as well as a certificate program in science and technology policy. CIRES also employs about 50 undergraduate students in research and administration.

Education Outreach Program

CIRES strongly supports education at all levels, not just the graduate level. Our Education Outreach Program staff collaborate with CIRES researchers to help meet educational needs in Colorado communities and beyond. These contributions include professional development work with K–12 educators from Colorado and around the country, long-term partnerships with local school districts, and development of teaching materials. All of our projects, whether in the classroom or in the field, benefit from our rigorous attention to science and inquiry-based teaching.



Policy research: science and decision-making

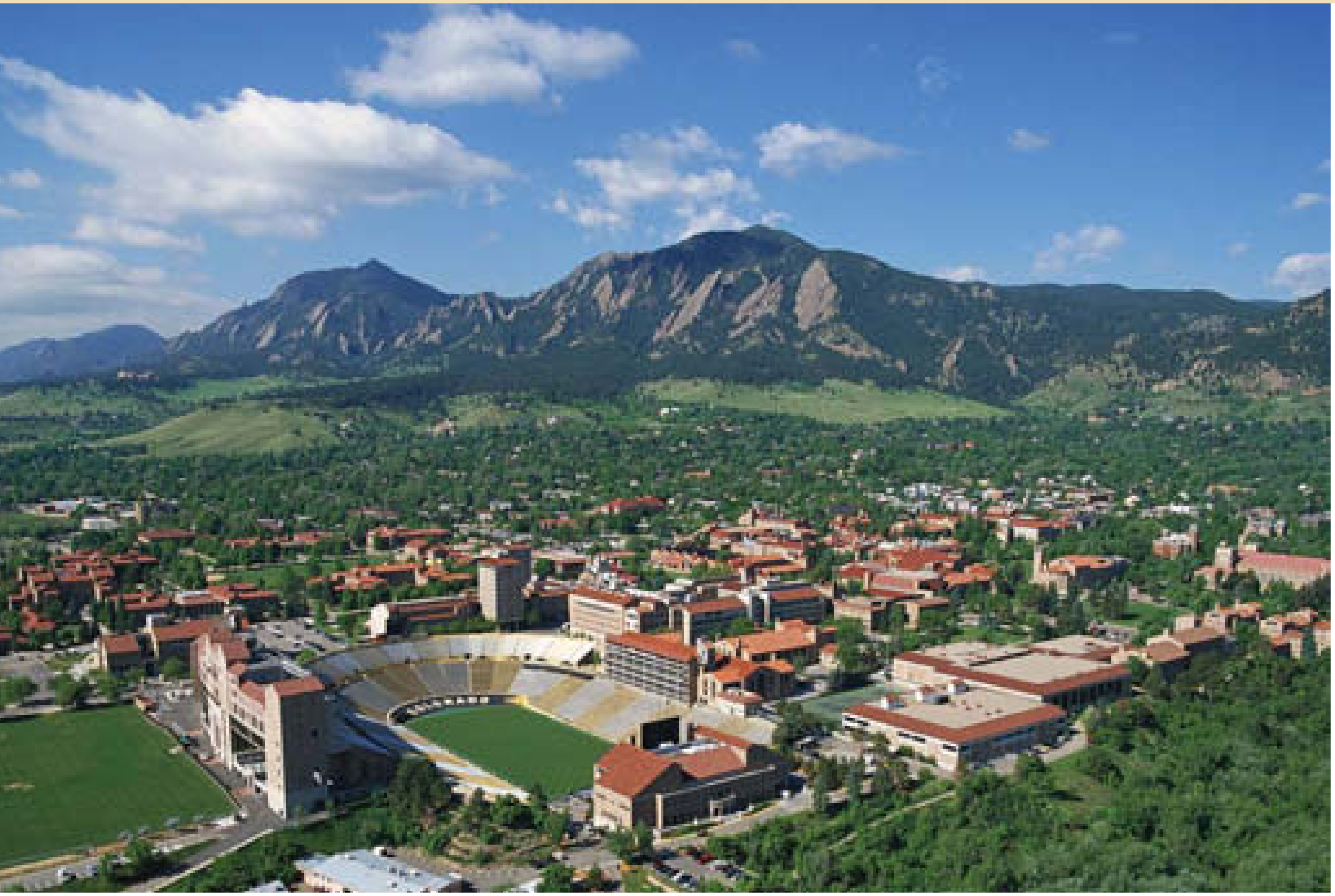
The CIRES Center for Science and Technology Policy Research was established to conduct research, education, and outreach in response to an increased demand for "usable" scientific information. The center focuses on analyzing problems and decisions that have a scientific component or that deal with the structures and priorities of science itself. Center research has run the gamut, from the interpretation of global climate models to understanding decision-making in a nanotechnology lab. Center staff communicate their research to decision-makers through several important avenues. These include an online clearinghouse of climate science information, an active and widely read website, and a bi-monthly briefing of current activities that has a readership of more than 2,300 people around the world. The center also hosts various workshops, public lectures, and forums at CU-Boulder and beyond.

"I know I will be a more effective teacher because of this institute."

"Instruction was geared toward the needs of teachers. The instructors constantly asked what we needed to be more successful teachers and they did their best to give it to us."

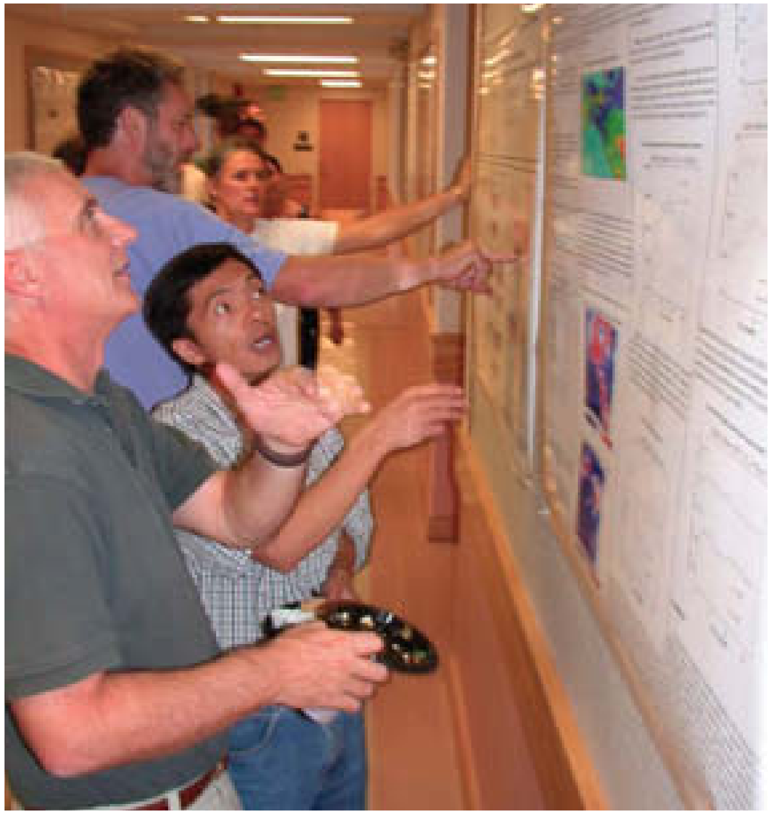
—Education Outreach Program summer institute participants

Opportunities for earth system researchers



Innovative Research Program

The Innovative Research Program stimulates a creative research environment within CIRES by providing funding for novel or unconventional research projects. Funded projects are often inventive and sometimes opportunistic, without necessarily having an immediate practical application or guarantee of success. Past projects include quantifying the production of volatile organic compounds by microbial communities, investigating the impact of phytoplankton on sea surface temperatures and ocean circulation, and assessing the possibility of abrupt climate change in the next few decades.

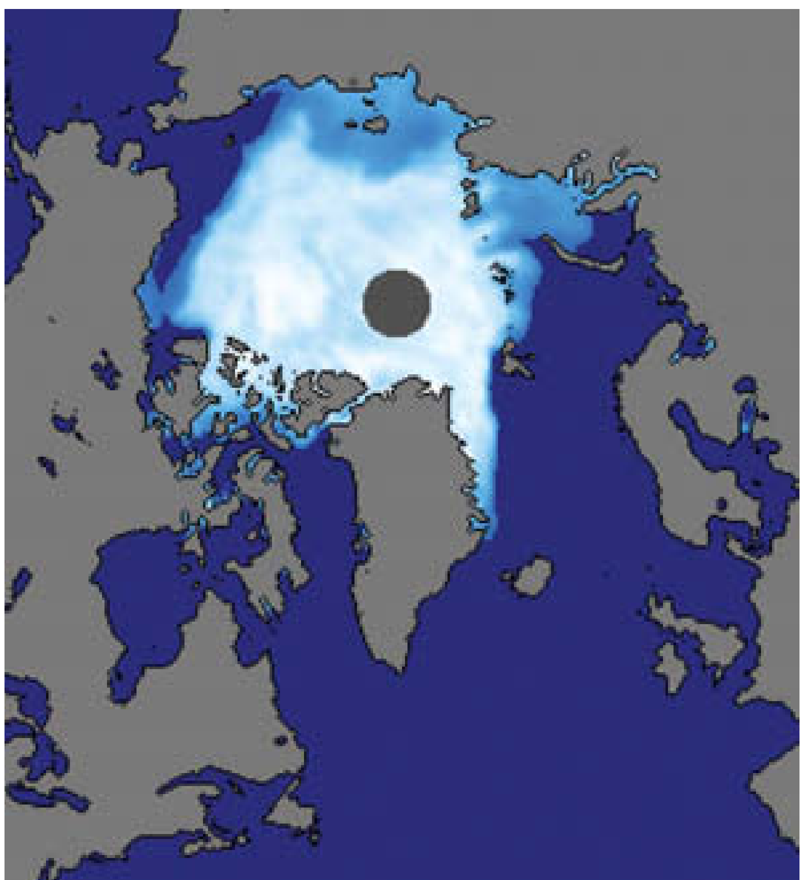


Visiting Fellows Program

Every year CIRES awards up to eight visiting fellowships to scientists from outside CU. This affords scientists an incredible opportunity to work collaboratively with CIRES researchers, both on campus and at NOAA. Since 1967, more than 220 visiting fellows have worked at CIRES, including current director Konrad Steffen and Susan Avery, dean of the CU Graduate School. Visiting fellows contribute to research in the following general areas: atmospheric chemistry, climate system variability, cryospheric processes, earth system modeling, earth system monitoring, geodynamics, and planetary metabolism.

Environmental data products

Scientific research produces large volumes of data. Whether from observations made in the field or measurements taken remotely by satellites above Earth, scientific data form the basis of the research that informs people about our planet and allow for continually improved understanding of our earth system. The National Snow and Ice Data Center (NSIDC), established in 1976, is a leading example of data management support at CIRES. Specialists at NSIDC process and manage cryospheric data by organizing, preserving, documenting, and distributing it, ensuring that data are reliably accessible to researchers both now and into the future.



Instrument development

CIRES' Integrated Instrument Development Facility designs and constructs scientific instruments for CIRES, NOAA, and CU-Boulder. The facility specializes in metal, electronic, and glass work, as well as software design for data acquisition. Examples of instruments made on site include a portable ozone monitor, a multi-channel electron energy analyzer, a high-altitude frost-point hygrometer, and a controlled atmosphere flow system.

CIRES centers

Center for Limnology

The Center for Limnology studies inland aquatic ecosystems such as lakes, streams, and wetlands. Research from this center helps water managers maintain natural ecosystems and monitor water quality for drinking supplies.

Center for Science and Technology Policy Research

CSTPR works to address the increased demand among public and private decision-makers for useful scientific information, analyzing problems and decisions with a scientific component and widely communicating such research.

Center for the Study of Earth from Space

CSES brings together a diverse set of disciplines to study the earth and its global systems through remote sensing. Center scientists are also dedicated to teaching these tools to the next generation of earth scientists.

Climate Diagnostics Center

The Climate Diagnostics Center develops and applies tools that help us understand the causes of climate variations. Center scientists also work to improve models used for climate assessments and predictions.

National Snow and Ice Data Center

NSIDC manages and distributes snow, ice, sea ice, glacier, and frozen-ground data to benefit scientists and the public today and into the future. NSIDC offers user support and data access tools, as well as the expertise of in-house cryospheric scientists.

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Image credits

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Sea level rise (inside front cover) courtesy of NOAA/GFDL, U.S. Department of Commerce.

Arctic sea ice minimum (page 5) courtesy of NASA Goddard Space Flight Center Scientific Visualization Studio.

Climate forcing (page 8); image provided by GeoEye and NASA SeaWiFs Project.

Stratospheric ozone (page 9) courtesy of NOAA, U.S. Department of Commerce.

Geophysical data stewardship (page 11) courtesy of NOAA, U.S. Department of Commerce.

Global climate modeling (page 11) courtesy of R. John Wilson, NOAA/GFDL, U.S. Department of Commerce.

Texas air quality study (page 11) courtesy of www.utexas.edu/research/ceer/texaqs.

Gravity from space (page 13) courtesy of the University of Texas Center for Space Research and NASA/JPL.

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Connecting climate and weather (page 15) courtesy of Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC (visibleearth.nasa.gov).

El Niño (page 15) courtesy of R. B. Husar, Washington University; the land layer from the SeaWiFS Project; fire maps from the European Space Agency; the sea surface temperature from the Naval Oceanographic Office's Visualization Laboratory; and cloud layer from SSEC, University of Wisconsin (visibleearth.nasa.gov).

Environmental data products (page 19); data from Sea Ice Index, NSIDC.

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Colorado
University of Colorado at Boulder

CIRES

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE