

Climate and Environmental Sciences Division

A Division of the U.S. Department of Energy Office of Biological and Environmental Research

science.energy.gov/ber/research/cesd/

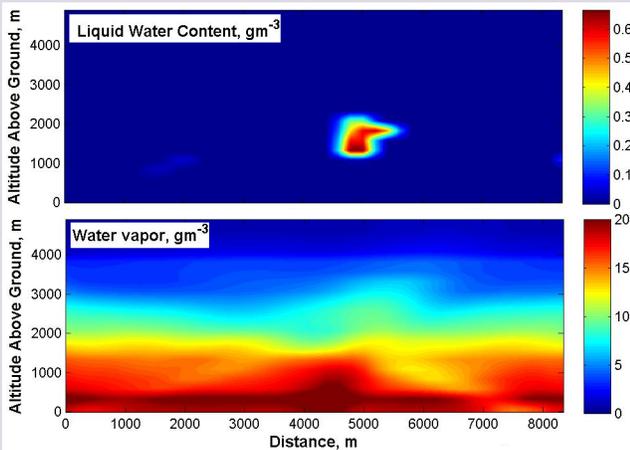
The Climate and Environmental Sciences Division (CESD) focuses on developing a predictive, systems-level scientific understanding of Earth systems to inform the nation's energy and environmental missions. As part of the Department of Energy's (DOE) Office of Biological and Environmental Research (BER) within the Office of Science, CESD supports an integrated, cross-cutting research portfolio ranging from molecular- to field- to global-scale studies. CESD emphasizes the use of advanced computer models and multidisciplinary experimentation in its research activities. The CESD portfolio includes Atmospheric System Research, Environmental System Science, and Climate and Earth System Modeling, as well as two national scientific user facilities—the Atmospheric Radiation Measurement Climate Research Facility and the Environmental Molecular Sciences Laboratory.

Atmospheric System Research

This research effort seeks to resolve two of the largest areas of uncertainty in climate model predictions—the role of clouds and the effects of aerosols on the atmospheric radiation balance. Research examines the relationships among aerosols, clouds, and precipitation and their role in the climate system. The program works to understand these processes in climatic regions with different cloud types, atmospheric conditions, and aerosol loadings. Results from

these studies are incorporated into next-generation climate models, improving representation of atmospheric processes and decadal climate predictions.

CESD's Atmospheric System Research is the only climate research program that seeks a holistic view of clouds, aerosols, precipitation, and the atmospheric radiation balance, as well as their interactions across a range of spatial and temporal scales. This program leads the advance in the treatment of clouds and radiation-transfer processes in climate models.



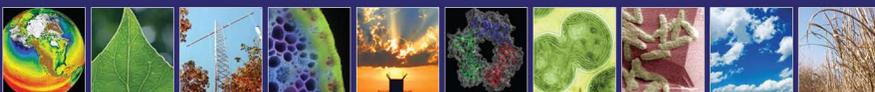
Cloud Tomography Measurements. Scanning microwave radiometers measure cloud microwave emissions from multiple directions to determine cloud water distribution. These plots show a snapshot of cloud liquid water and water vapor content retrieved during a 2009 field campaign over the Southern Great Plains. Such measurements are improving the accuracy of global climate models, which simulate the magnitude of regional and global fluctuations in climate. [Brookhaven National Laboratory]

Environmental System Science

This program's activities examine (1) the roles of terrestrial ecosystems in a changing climate and their representation in predictive models and (2) subsurface biogeochemistry to elucidate the processes involved in contaminant fate and transport. These research areas seek to understand and predict the impact of energy by-products on Earth systems extending from the bedrock to the top of the vegetative canopy.

Terrestrial Ecosystem Science focuses on developing unique, foundational scientific insights about the terrestrial biosphere's role in the global cycling of carbon, nutrients, and water, as well as feedbacks between terrestrial ecosystems and Earth's climate system. Research supported by this program ranges from fundamental, process-level studies to large-scale, long-term ecosystem manipulations. This effort is coordinated with BER's climate modeling program (and research activities of other federal agencies) so that experimental results can be incorporated into Earth system models. The overarching goal is to improve representation of terrestrial ecosystem processes in Earth system models, thereby increasing the quality of model projections to better inform DOE's energy decisions.

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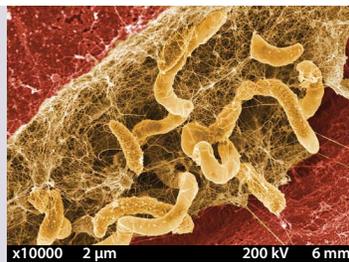
Measuring Carbon Fluxes. The AmeriFlux Network provides continuous observations of ecosystem-level exchanges of CO₂, water, energy, and momentum spanning diurnal, synoptic, seasonal, and interannual time scales.

Subsurface Biogeochemical Research advances a basic understanding of subsurface processes at the intersection of biology, chemistry, and physics. This activity supports interdisciplinary research in an iterative cycle of hypothesis generation, experimentation, and modeling between the laboratory and the field. The current focus is on understanding processes impacting the mobility of contaminant metals and radionuclides

found in the subsurface at DOE legacy waste sites, but the overall scientific approach is applicable to a wide range of DOE-relevant energy and environmental challenges. These challenges include the underground storage of spent nuclear fuel, carbon and nutrient cycling, carbon sequestration, and fossil fuel recovery.

Biofilm of Sulfate-Reducing, Anaerobic Bacteria *Desulfovibrio desulfuricans* Grown on a Hematite Surface.

This microbe is being studied for its ability to reduce toxic metals and radionuclides such as chromium and uranium in soils and groundwater. [Pacific Northwest National Laboratory]



Climate and Earth System Modeling

This program focuses on developing, evaluating, and analyzing large-scale and coupled climate, Earth system, and integrated assessment models to inform the nation’s energy decisions in the context of a changing climate. Major scientific goals are to capture and evaluate current scientific understanding through the use of world-class regional,

global, Earth system, and integrated assessment models, particularly the Community Earth System Model.

CESD’s Climate and Earth System Modeling efforts (climatemodeling.science.energy.gov) support some of the world’s most powerful and sophisticated climate models that contribute to reports by the Intergovernmental Panel on Climate Change.

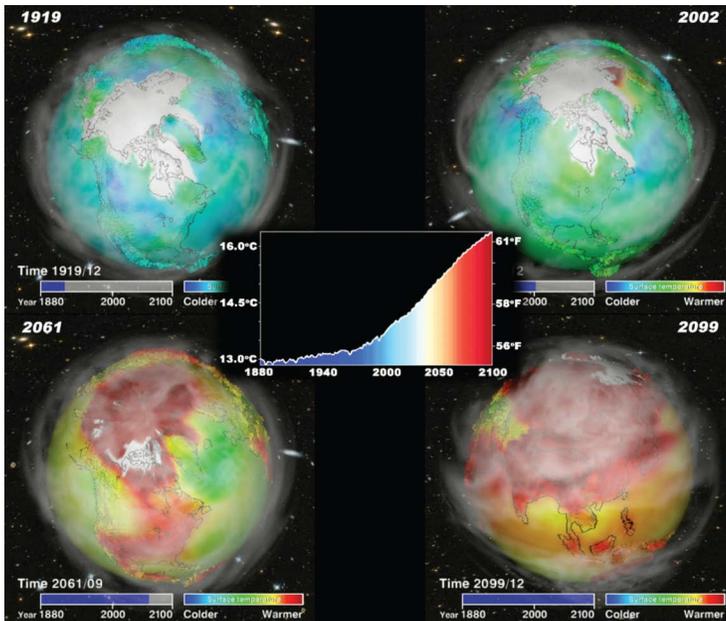
Regional and Global Climate Modeling focuses on the development, evaluation, and application of regional and global climate models with the objective of understanding high-resolution patterns and causes of climate change. Core research includes:

- Development of methods to produce reliable projections at regional scales.
- Climate model diagnosis and intercomparison through the use of appropriate metrics.
- Analysis of multimodel climate change simulations and projections.
- Understanding of natural and forced variability of the climate system.
- Development and use of new techniques for quantifying uncertainty of climate variability and change.

This activity also focuses on regions of vital interest to future climate assessments, including the tropics and the Arctic.

Earth System Modeling develops the components and mechanisms needed to model the atmosphere, ocean, land, and cryosphere to simulate climate variability and change, providing the scientific foundation underpinning CESD’s regional and global climate modeling activities. Research focuses on incorporating improved physical representations (e.g., atmospheric, biogeochemical, terrestrial, land and sea ice, ocean, aerosols, and clouds). The program also tests the models with innovative metrics, probes potential abrupt shifts to the climate system, increases model resolution, and exploits DOE’s leadership in world-class computing capabilities.

Integrated Assessment research provides scientific insights into options for mitigation and adaptation to climate change through multiscale models of the entire climate system. This research includes human processes responsible for greenhouse gas emissions, land use, and combined impacts on and feedbacks from changing human and natural systems such as the energy system. Importantly, integrated assessment activities develop advanced quantitative tools for exploring the implications of science and technology decisions and innovations on our energy, environmental, and economic futures.



Surface Warming Effects. Four maps of the Northern Hemisphere demonstrate the trend of average surface temperature and sea ice over a 200-year period. In the center, the global average temperature, as a function of time, is shown. Derived from the Coupled Model Intercomparison Project, phase 3 multimodel data archive, the computations were based on observed temperature (pre-2000) and a climate model assuming a continued high rate of greenhouse gas emissions. [DOE Program for Climate Model Diagnosis and Intercomparison]

National Scientific User Facilities

Atmospheric Radiation Measurement (ARM) Climate Research Facility. The ARM Facility sets the standard for long-term observations. Using stationary, mobile, and aerial platforms and instruments at fixed and varying locations worldwide, the ARM Climate Research Facility provides precise, long-term observations of radiative fluxes, cloud and aerosol properties, and related atmospheric characteristics. This unique collection of high-quality measurements is crucial for improving and validating climate model performance over a wide range of climatic and meteorological conditions. Data are made available in near real time in the Atmospheric Radiation Measurement Archive (www.archive.arm.gov). The ARM Facility serves nearly 1,200 users worldwide.

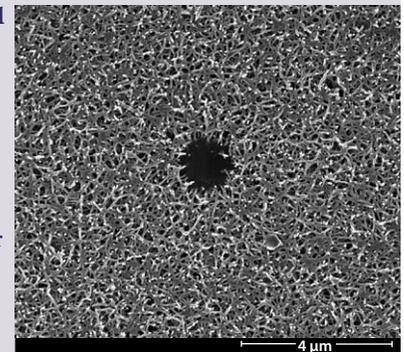
Environmental Molecular Sciences Laboratory. EMSL provides a wide range of premier capabilities for molecular-level experimentation, a high-performance computing platform and associated computational chemistry software and data storage, and an accomplished scientific staff. These features enable the investigation of molecular-level physical, chemical, and biological processes that underpin a broad spectrum of environmental and energy challenges facing DOE and the nation. EMSL's unique combination of experimental and computational capabilities facilitates iteration between theory and experiment. This process enables scientific breakthroughs that lead to alternative energy sources, improved catalysts and materials for industrial applications, tools for managing and predicting the movement of subsurface contaminants, approaches for mitigating climate change, and strategies for making carbon biosequestration and bioenergy sources a reality. EMSL serves more than 700 users annually.



Scanning Cloud Radar

Cloud Properties. Detailed measurements of cloud properties are significantly improving representations of mixed-phase (liquid and ice) clouds in climate models, resulting in better climate simulations. [DOE ARM Climate Research Facility]

Cellulose Nanocrystal Aerogel. Scientists worldwide use results from EMSL's focused ion beam/scanning electron microscope (FIB/SEM) to understand surfaces for geochemistry, biology, and energy research. This FIB/SEM image shows the inorganic material cellulose nanocrystal aerogel. [DOE Environmental Molecular Sciences Laboratory]



Data Management

This program facilitates full and open access to quality-assured data for climate change research by supporting data management for records maintained at two sites:

- **Carbon Dioxide Information Analysis Center** (cdiac.ornl.gov) houses data for major projects that examine the emissions, sinks, and trends of CO₂ and other greenhouse gases. These projects include the AmeriFlux Network, Free-Air CO₂ Enrichment (FACE) experiments, and Ocean CO₂ Data Program.

- **Program for Climate Model Diagnosis and Intercomparison (PCMDI; www.pcmdi.llnl.gov).** This program is a leader in implementing, maintaining, and facilitating access to the climate model output from over 20 international modeling groups for analysis by the broader community. This output includes frequently analyzed variables such as those used for the Intergovernmental Panel on Climate Change assessment reports. PCMDI supports the climate modeling and assessment community in coordination with the activities of the Earth System Grid Federation, which provides access to climate model and observational data (including those from PCMDI), data transfer, and software tools needed for climate data analysis.

Synergies for Higher-Impact Science

CESD collaborates with other programs both inside and outside BER to foster advances in fundamental research on relationships between climate and energy and energy-related subsurface processes.

BER. Within BER, CESD conducts collaborative and integrated research to address key research needs through programs such as GOAmazon2014 and the Next Generation Ecosystem Experiment (NGEE). These activities focus BER's investments and scientific resources on critical uncertainties in predictive capabilities and seek to explore and integrate research from the molecular, to ecosystem, to global scales.

Office of Science. Many of CESD's climate and subsurface modeling activities are carried out collaboratively with the Office of Science's Advanced Scientific Computing Research program (science.energy.gov/ascr/). These efforts include joint research projects involving the Scientific Discovery through Advanced Computing program (science.energy.gov/ascr/research/scidac/) and computational resources made available through the National Energy Research Scientific Computing Center (science.energy.gov/ascr/facilities/nersc/), an Office of Science user facility.

DOE. CESD's climate research activities are coordinated closely with DOE's offices of Energy Efficiency and Renewable Energy (www.eere.energy.gov) and Policy and International Affairs (energy.gov/pi). The goal of these interactions is to maintain information flow between DOE's program offices and its basic research program to support decisions on the nation's energy future. CESD's subsurface biogeochemical research activities are coordinated with DOE's Office of Environmental Management. This collaboration has resulted in an effective R&D integration approach for addressing DOE's soil and groundwater contamination.

Interagency Linkages. CESD represents the DOE contribution to the U.S. Global Change Research Program (USGCRP), a 13-agency group that coordinates and integrates federal research on changes in the global environment and their implications for society. CESD also represents DOE on numerous activities under the National Science and Technology Council's (NSTC) Committee on Environment, Natural Resources, and

For More Information

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Websites

DOE Climate and Environmental Sciences Division

- science.energy.gov/ber/research/cesd/

CESD Programs

Atmospheric System Research

- science.energy.gov/ber/research/cesd/atmospheric-system-research-program/

Environmental System Science

- **Terrestrial Ecosystem Science**
science.energy.gov/ber/research/cesd/terrestrial-ecosystem-science/
- **Subsurface Biogeochemical Research**
science.energy.gov/ber/research/cesd/subsurface-biogeochemical-research/

Climate and Earth System Modeling

climatemodeling.science.energy.gov

- **Regional and Global Climate Modeling**
science.energy.gov/ber/research/cesd/regional-and-global-modeling/
- **Earth System Modeling**
science.energy.gov/ber/research/cesd/earth-system-modeling-program/
- **Integrated Assessment**
science.energy.gov/ber/research/cesd/integrated-assessment-of-global-climate-change/

Data Management

- science.energy.gov/ber/research/cesd/data-management/

CESD User Facilities

DOE Atmospheric Radiation Measurement

Climate Research Facility

- science.energy.gov/ber/research/cesd/arm-climate-research-facility/

DOE Environmental Molecular Sciences Laboratory

- science.energy.gov/ber/research/cesd/environmental-molecular-sciences-laboratory/

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Sustainability (CENRS). CENRS supports the Department of Defense's environmental missions through participation in the Strategic Environmental Research and Development (SERDP) program.