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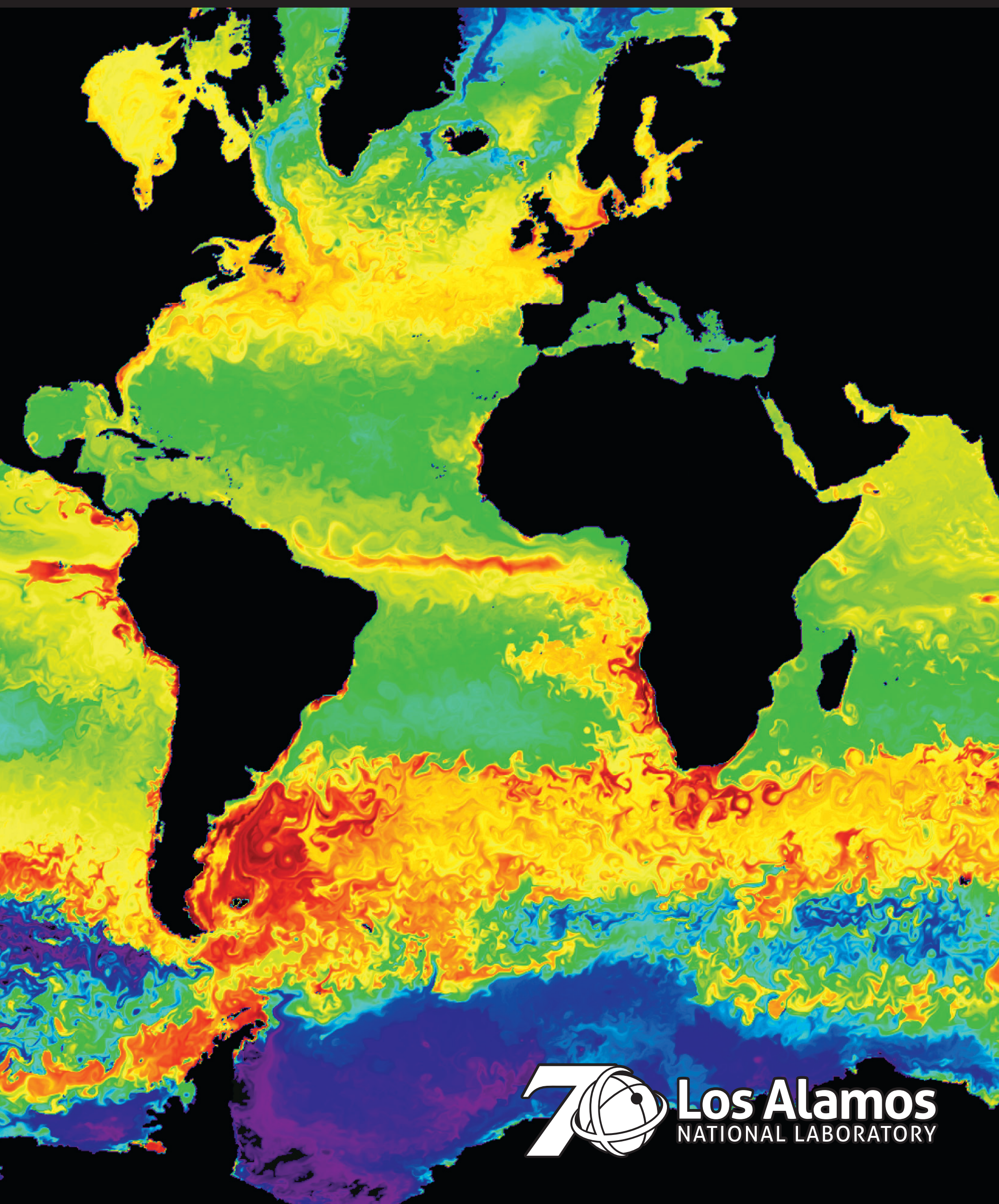
CLIMATE
AND IMPACT RESEARCH
at Los Alamos National Laboratory



Climate Research and National Security

Los Alamos National Laboratory is truly a national security science laboratory, tackling some of the world's most challenging science and engineering issues. We are interested in the potential future impacts of climate change on global security, such as the coastal effects of sea level rise, increased number of extreme storms, and the consequences of extensive regional tree mortality.

Gaining a better understanding of the forces behind global climate change—how these forces operate, how they may affect us, and how we might mitigate their negative impacts—brings together biologists, physicists, mathematicians, geologists, electrical engineers, computer programmers, and chemists.

The Laboratory has more than 300 formal collaborations with other research institutions across the globe. Our geographic reach is equally broad—extending from the piñon and juniper forests on Laboratory property to the high Southwest desert, to the tundra of Alaska, and above the Arctic Circle in Norway.

I welcome the opportunity to share with you the span of our cutting-edge global research, from our work in theory and modeling with high-powered computing to our detailed fieldwork and analysis.

I hope you enjoy this survey of our state-of-the-art climate work, and I encourage you to contact any of our researchers to learn more.

Sincerely,

Charles F. McMillan
Director
Los Alamos National Labortory

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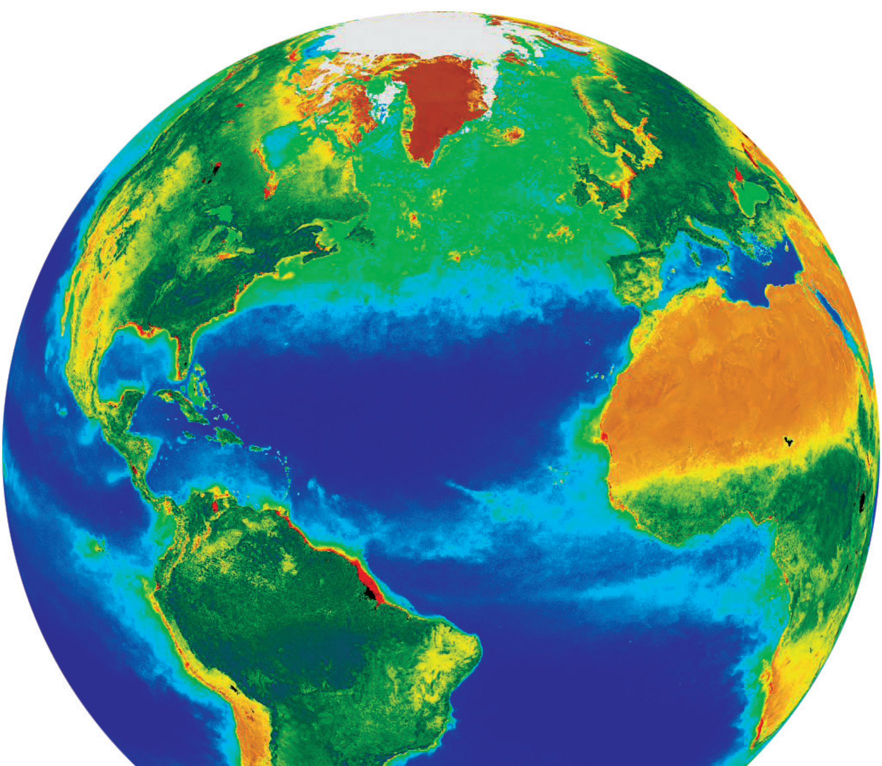


Climate, Ocean, and Sea Ice Modeling

Developing high-performance computer models for climate change research

THE CAPABILITY

With our ocean and sea ice models, we can better understand, predict, and respond to effects of worldwide climate change.

At Los Alamos National Laboratory, the Climate, Ocean, and Sea Ice Modeling (COSIM) project researchers develop high-performance models of the ocean, sea ice, and ice sheets to understand and predict climate change.

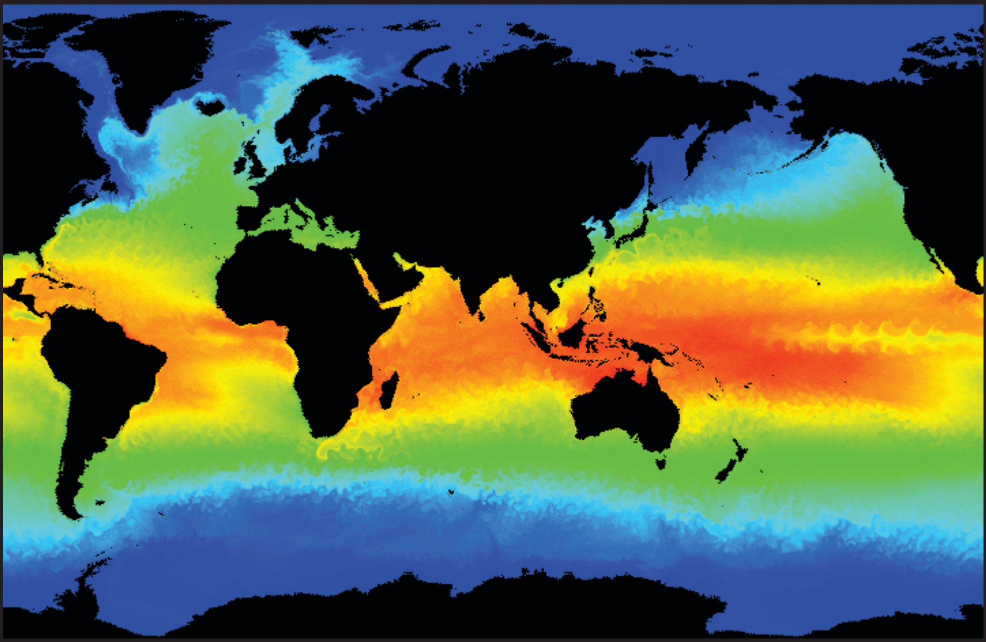
Oceans, sea ice, and land ice sheets are critical elements of the climate system. Melting of glaciers and ice sheets contributes to large changes in sea level, and understanding their role in the rate of rising sea levels will be important as we respond to climate change.

The ocean transports heat, water, and other quantities around the globe and contributes to longer time scales of climate variability, from decades to centuries and longer.

Sea ice provides strong feedbacks to the climate system through albedo changes. Rapid decreases in Arctic ice could significantly impact human activities in the Arctic and beyond.

In particular, COSIM researchers apply these models of the ocean, sea ice, and ice sheets as part of coupled climate models, analyzing the results to understand the role of ocean and ice systems in high-latitude climate change and its impacts throughout the globe.

We use our COSIM models as part of the Community Earth System Model contributions to national and international climate assessments and inter-comparisons, including the scientific assessments of the Intergovernmental Panel on Climate Change (IPCC).



Surface temperature from a Climate, Ocean, and Sea Ice Modeling ocean simulation

Partners/Collaborators
The Community Earth System Model is a collaboration that includes the National Center for Atmospheric Research, several DOE laboratories, and many academic researchers.

Sponsors
This work is supported by the Department of Energy's Office of Science Climate Modeling Programs.

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Sea Ice and Climate Change

Simulating polar ice levels and predicting their effects on climate systems

THE CAPABILITY

Our model captures the key role of sea ice in enhancing and accelerating change within the climate system.

As Earth warms due to climate change, the pace of Arctic warming amplifies at two to three times faster than the rest of the globe. This rapid decrease in Arctic ice significantly impacts local communities, Arctic ecosystems, and Earth's climate.

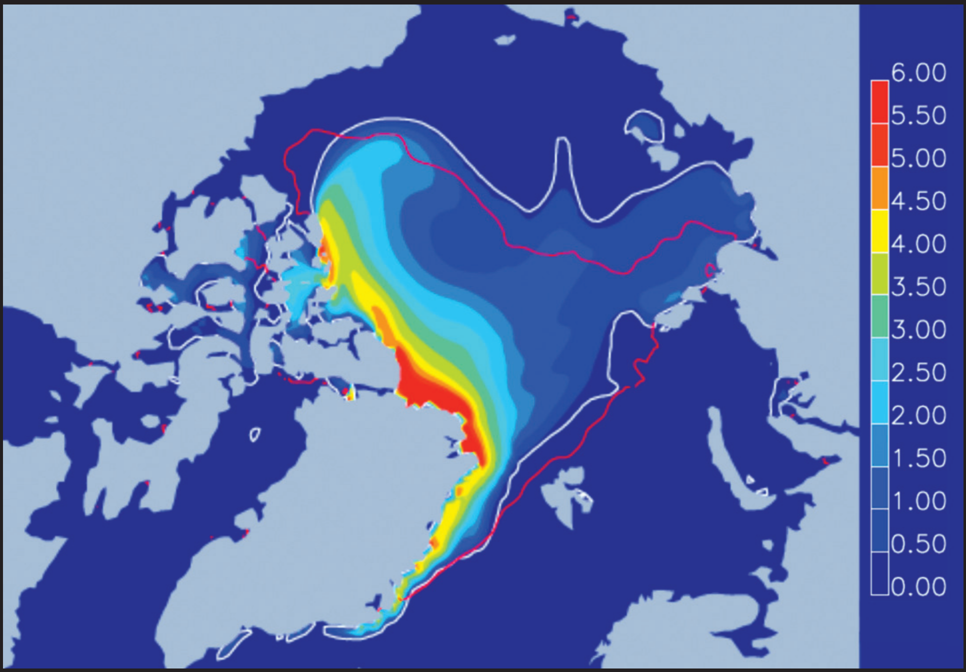
We develop the Los Alamos Sea Ice model (CICE) as part of the Climate, Ocean, and Sea Ice Modeling (COSIM) project. CICE accurately describes how the sea ice evolves and interacts with the ocean and atmosphere.

As the ice continues to thin under a warming climate, sea ice will become more variable and highly sensitive to local weather and ocean conditions. Continued melting of ice results in warmer oceans and further melting, a positive feedback cycle known as the ice–ocean albedo feedback. Polar warming can impact the behavior of the jet stream, potentially increasing the severity and length of extreme weather events throughout the world. Melting ice opens the Arctic to increased commercial activity like shipping and resource extraction.

In 2012, the Arctic sea ice September minimum extent reached a new record low of 3.41 million square kilometers, 49 percent below the 1979–2000 average and 18 percent below the previous record in 2007. The last six years (2007–2012) have seen the six lowest minimum extents in the satellite record (since 1979).

Many climate modeling groups and operational forecasters throughout the world use CICE to study and predict changes in the atmosphere-ice-ocean system. We continue to improve our model, for instance, by representing the flow of brine through channels created during the freezing of seawater.

Continued improvement of this model helps researchers better understand and predict future polar and climate change.



Over the last 30 years, the area of thick multiyear Arctic sea ice in winter has declined by two-thirds as a result of climate change. The decline of Arctic sea ice has impacts on Northern Hemisphere weather and climate patterns, shipping, fossil energy resource exploration, naval operations, and global security. This image shows sea ice thickness (in meters), which simulates the minimum ice event of September 2007 (red line).

Partners/Collaborators

Sea ice model development benefits from collaboration with the National Center for Atmospheric Research and the U.K. Met Office, as well as a large number of researchers worldwide.

Sponsors

This work is supported by the Department of Energy's Office of Science Climate Modeling Programs.

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Ice Sheets and Sea Level Rise

Mapping atmosphere and ocean interactions that lead to ice melt

THE CAPABILITY

LANL's new ice sheet models can project the decades-long evolution of rising sea levels from rapidly melting Greenland and Antarctic ice sheets.

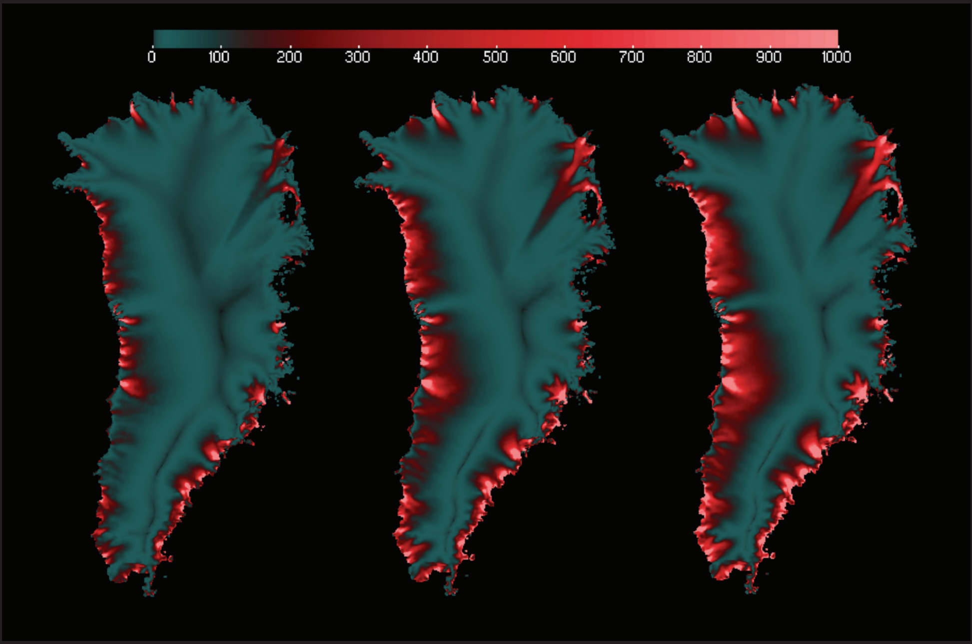
As Earth's climate warms, melting of the Greenland and Antarctic ice sheets accelerates. The resulting fresh water input into the oceans will be the dominant contribution to future sea level rise.

Members of the Climate, Ocean, and Sea Ice Modeling (COSIM) project at LANL develop computer models of large ice sheets to represent how ice flows in response to changes in atmosphere and ocean conditions (climate change), as well as the complex interaction with the land surface beneath the ice.

The most rapid changes occur at the ice sheet margins or at the grounding line where land ice flows out over the surface of the ocean. As warm ocean water flows under ice shelves, the shelves melt rapidly and the ice upstream of the shelves flows more quickly into the ocean. On land, meltwater that reaches the base of the ice sheet can lubricate the bottom of the ice, increasing basal sliding and accelerating ice flow and subsequent melting.

COSIM researchers are developing robust, comprehensive computer models of ice sheet dynamics that can represent these processes and thus simulate the evolution of continent-scale ice sheets like Greenland and Antarctica.

To understand how ice sheets respond to climate change, we integrate ice sheet models into complete models of Earth's climate system. Using this coupled system, researchers simulate decade-to-century-scale evolution of the Greenland and Antarctic ice sheets and the subsequent changes in sea level across the globe.



Simulated changes to Greenland ice sheets resulting from increased basal sliding

Partners/Collaborators

Ice sheet model development is a collaboration among Los Alamos and several other DOE laboratories, as well as researchers at Florida State University, the University of South Carolina, the Massachusetts Institute of Technology (MIT), the University of Montana, the University of Bristol, and the National Center for Atmospheric Research.

Sponsors

This work is supported by the Department of Energy's Office of Science Climate Modeling Programs.

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Ocean Circulation and Ocean Eddies

Accurately modeling the ocean's role in climate systems

THE CAPABILITY

Our models of ocean eddies—key to ocean circulation—will lead to better simulations of future climate change.

Eddies—small rotating features in ocean flow—are an important part of ocean circulation and form the equivalent of weather systems in the ocean. Eddies are also important for mixing heat, salt, and chemical species around the world.

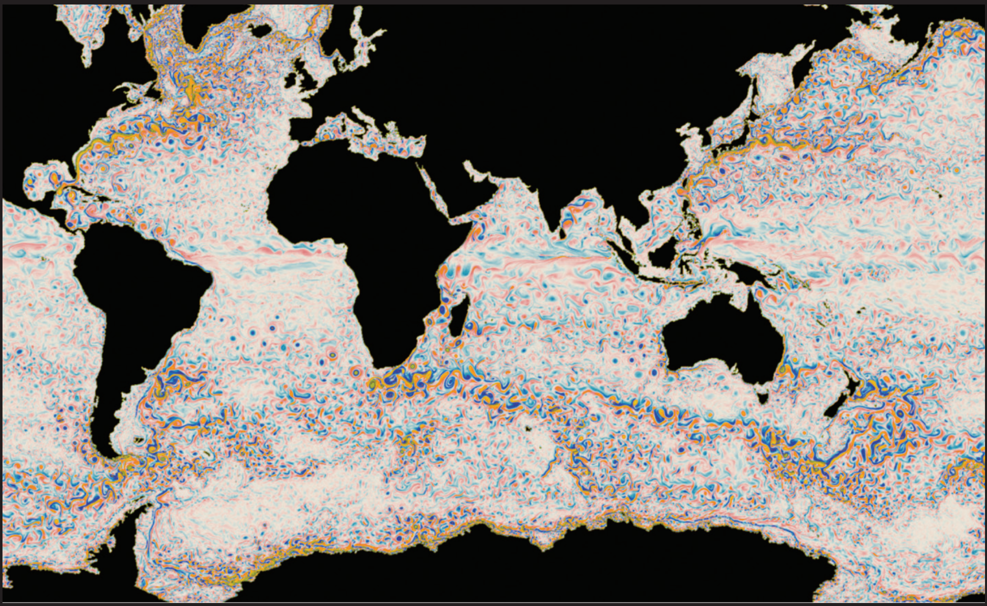
Computer models of the global ocean must capture these eddies and their impact on ocean circulation in order to accurately represent the climate system and future climate change. This is difficult because the small size (10–100 km) of eddies requires high spatial resolution and substantial computing power.

Researchers in the Climate, Ocean, and Sea Ice Modeling (COSIM) project at LANL have developed high-performance ocean models and used these models for long simulations of ocean circulation that include ocean eddies.

Early simulations used only the ocean component model to investigate the role of eddies. As computers have become more powerful, COSIM researchers now perform high-resolution simulations of the entire climate system, with ocean grids cells at 3–10 kilometer size and atmospheric cells representing 25-kilometer scales.

COSIM has also created a new ocean model in which computational power can be focused on particular geographical regions or where eddy activity is highest, a more cost-effective way to simulate the ocean.

These models are continuing to provide important information on the role of ocean eddies in the climate system and will lead to better simulations of future climate change and its impacts.



Ocean eddies from a high-resolution simulation of the global ocean

Partners/Collaborators

Ocean model development and eddy-resolving simulations benefit from collaborations with the National Center for Atmospheric Research and the Scripps Institution of Oceanography.

Sponsors

This work is supported by the Department of Energy's Office of Science Climate Modeling Programs.

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Ocean Biogeochemistry

Illustrating fundamental changes in ocean biology and chemistry

THE CAPABILITY

LANL models are determining how increasing temperatures hurt crucial carbon dioxide and methane absorption systems in the oceans.

Some biological and chemical feedbacks are possibly more important than temperature rise and related climate impacts.

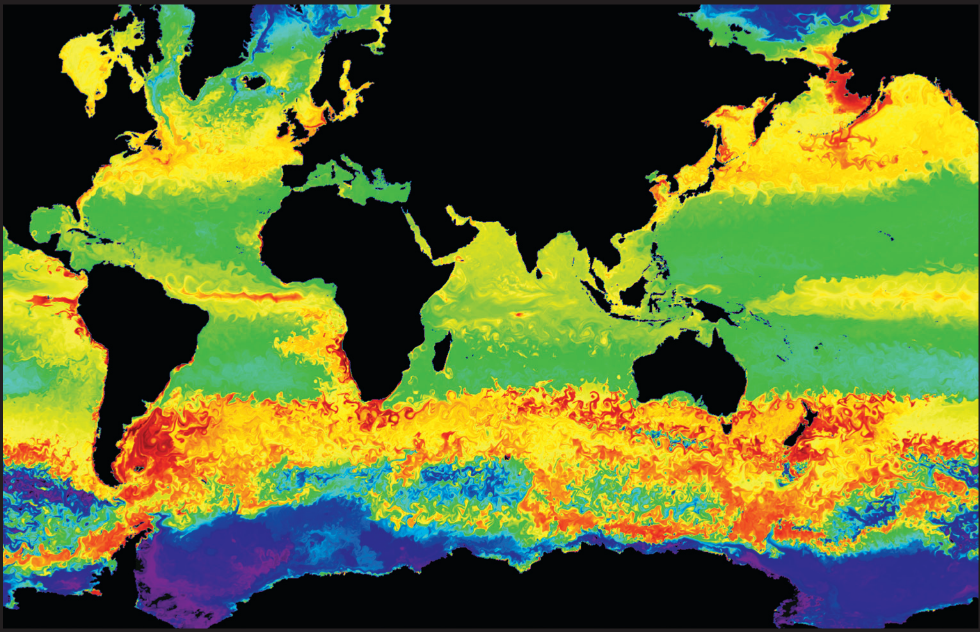
Ecosystem processes and chemical exchange with the land and ocean are currently responsible for absorbing a significant fraction of the carbon dioxide emitted by human activity. As the climate changes and the surface ocean warms, the ocean will not be able to continue this level of carbon sequestration.

Other biogeochemical exchanges are also important. As the ocean absorbs carbon, it becomes more acidic with a subsequent harmful impact to many ocean ecosystems, a process that is not easy to mitigate and is a serious consequence of climate change.

Methane hydrates in shallow Arctic shelf regions may be unstable in future warming climates, potentially leading to accelerated warming. Ocean organisms also emit chemicals that become atmospheric aerosol particles and contribute to the reflectivity and behavior of clouds, another strong feedback in the climate system.

To understand these processes and how they will change in future climate regimes, members of the Climate, Ocean, and Sea Ice Modeling (COSIM) project at LANL have included ecosystem and chemical cycling components into their ocean and ice models. These are coupled with atmosphere and land components to simulate carbon, sulfur, and other cycling throughout the complete climate system.

These comprehensive models are used to determine the likelihood of rapid methane release and the impacts of ocean and ice biogeochemical changes on ocean acidification, cloud feedbacks, and carbon uptake.



Chlorophyll concentration from a high-resolution ocean simulation with an ocean ecosystem model

Partners/Collaborators

Biogeochemical components of COSIM models benefit from collaborators at Lawrence Berkeley National Laboratory, as well as researchers at the University of Alaska–Fairbanks and the National Center for Atmospheric Research.

Sponsors

This work is supported by the Department of Energy's Office of Science Climate Modeling Programs and the Department of Energy's Fossil Energy Hydrates Program.

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Arctic Landscape Evolution and Impacts

Modeling effects of a warming climate on Arctic carbon stores

THE CAPABILITY

By combining field observations with novel computational methods, we are developing the most advanced models to predict climate impacts and feedbacks in Arctic landscapes.

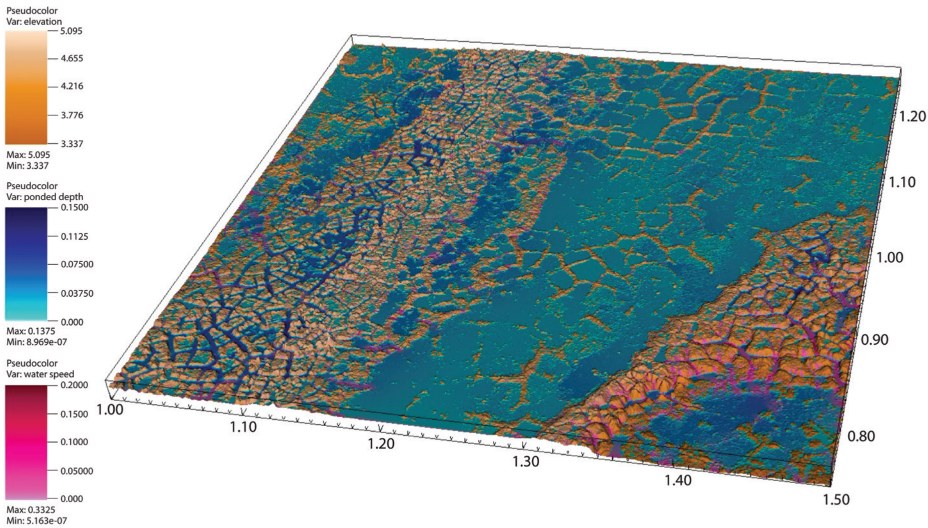
At LANL, Arctic landscape researchers are focused on answering one of the most critical questions in contemporary climate science: Will a warming Arctic landscape provide a net positive or negative feedback to the climate system?

The Arctic region has been a global carbon sink for thousands of years, and it is currently the largest land-based store of carbon on Earth. This carbon has been locked away, frozen in permafrost. However, the scientific community cannot currently predict how much of this vast store of Arctic carbon will thaw, decompose into CO_2 and CH_4, and be released to the atmosphere, or how fast it will happen (IPCC, 2007).

At Los Alamos, we are addressing this problem by carrying out tightly coupled observations, experiments, and model development to predict for the first time the complex coupled interactions between warming permafrost; thaw-induced reorganization of topography and drainage pathways; and the resulting redistribution of soil moisture that drives the Arctic carbon cycle and energy balance.

LANL is a key partner in the DOE Office of Science, Next Generation Ecosystem Experiment (NGEE-Arctic), and we lead the hydrology and landscape evolution components of this multi-institution project. We are applying our expertise in isotope geochemistry and in water and carbon cycle monitoring to quantify water and carbon pathways through and from the land surface and subsurface to the atmosphere, lakes, rivers, and oceans.

LANL is also providing the global community with critical new computational capabilities to improve predictions of hydrology, vegetation dynamics, and



The Arctic Terrestrial Simulator (ATS) model was used to predict snowmelt depth (blues) and runoff velocity (pinks) into and through a drained thaw lake basin using high resolution laser altimetry topographic data to define the computational grid. The polygon shaped topographic features in the landscape are caused by the formation and degradation of ice wedges below the ground surface.

greenhouse gas (GHG) releases from the Arctic landscape. Our new Arctic Terrestrial Simulator (ATS) is the first model to fully couple thermal, soil mechanical, and hydrologic permafrost processes that control GHG production and sequestration in a thawing and topographically evolving landscape.

These LANL observational and computational capabilities also provide new tools to assess impacts of permafrost thaw on our critical Arctic energy pipelines and infrastructure.

Partners/Collaborators

Our partners include Oak Ridge National Laboratory (NGEE-Arctic lead organization), Lawrence Berkeley National Laboratory, University of Alaska–Fairbanks, and Brookhaven National Laboratory. Our collaborators include Idaho State University, Stockholm University, and the University of Texas at El Paso.

Sponsors

This research is supported by the DOE Office of Biological and Environmental Research (BER) Next Generation Ecosystem Experiment, the NGEE-Arctic project, and LANL's Laboratory Directed Research and Development (LDRD) program.

Contact

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Greenhouse Gases and Pollutants

Monitoring the ground, air, and space for climate and energy security

THE CAPABILITY

By observing human-emitted greenhouse gases and pollutants, we can detect areas vulnerable to climate change, predict natural responses, and plan protection efforts.

LANL scientists are leaders in integrating multiscale observations of greenhouse gases and pollutants from ground, air, and space with models to verify fluxes.

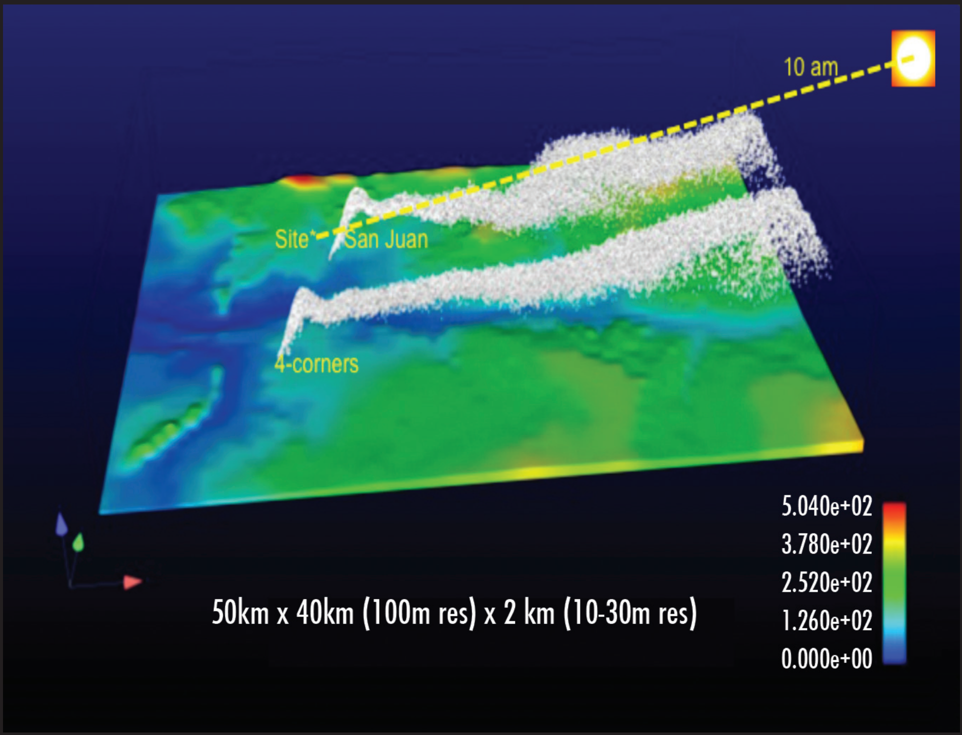
Quantification of regional carbon dioxide (CO_2) emissions is key to predicting the response of the natural carbon cycle to warming and the verification of national inventories.

Furthermore, responsible harnessing of natural gas by hydraulic fracturing to achieve energy independence demands measurements of fugitive methane (CH_4) and hydrocarbon leaks.

We have collected three years of data using a remote and robotic field laboratory in the Four Corners area of New Mexico to demonstrate that greenhouse gas emissions from coal power plants can be verified remotely. We also have detected large-scale CH_4 enhancement from coal and gas mining.

The instrumentation we use includes solar spectrometers, in situ laser sensors, and satellites. We have unique expertise in using chemical and isotopic signatures to discriminate natural and anthropogenic greenhouse gas sources, and we use customized high-resolution plume-to-regional atmospheric transport models for analysis.

LANL is working with DOE's climate field programs in the Amazon and the Arctic to understand the fate of the tropical and tundra soil and vegetation carbon reservoirs to warming. Our regional scale greenhouse gas observations will enable early detection of CO_2 and CH_4 release in these regions that are sensitive and vulnerable to warming. This early warning capability of climate tipping points will be crucial to protect our people and planet from a runaway greenhouse.



Plume transport model

Our data will enrich DOE's Next Generation Ecosystem Experiments by enabling the development of validated parameterizations of new carbon-climate feedbacks for Earth System Models.

LANL is also working with Chevron and DOE Fossil Energy on measuring CH_4 seepage from tight gas exploration to enable energy security in United States.

Partners/Collaborators

Our partners include Caltech, NASA's Jet Propulsion Laboratory, the Environmental Protection Agency, the New Mexico Environment Department, the Bureau of Land Management, and Harvard University. We collaborate with NASA, Japan, and Europe to validate their satellite greenhouse gas retrievals.

Sponsors

The climate research is supported by the DOE Office of Biological and Environmental Research (BER) Climate Observations. The verification research is supported by LANL's Laboratory Directed Research and Development program. The EPA supports the air pollution observations. The methane detection research is supported by Chevron.

Contact

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Institute of Geophysics, Planetary Physics, and Signatures

Expanding the frontiers of astrophysical, space, Earth, and climate sciences and their signatures

THE CAPABILITY

In collaboration with university and community partners, Los Alamos supports creative scientific research on the environmental and economic impacts of climate change.

At Los Alamos National Laboratory, the Institute of Geophysics, Planetary Physics, and Signatures (IGPPS) sponsors high-quality, cutting-edge research in climate science.

Specific research topics are selected based on their breadth of scientific challenges facing the international scientific community, as well as relevance to the strategic objective to extend Laboratory scientific excellence.

IGPPS-sponsored research emphasizes the nonlinear dynamics and multiequilibria of the coupled atmosphere, hydrosphere, biosphere of Earth, and liquid and ice-covered ocean, on scales ranging from urban canopies to basin and global extent.

Of general interest are studies that extend our understanding of the causes of temporal variations of ocean and atmospheric basin scale oscillations; rapid climate change on both global and regional scales; and the physics and chemistry governing storms, hydrology, geomorphic processes, and land use within a region experiencing climate change.

For example, one collaboration with Harvard involves the development of a hardened, field-ready methane gas detector system for conducting high sensitivity measurements of greenhouse gases. Initial field measurements will be conducted in the coal-fired, power-generating Four Corners Power Plant prior to deployment of the instruments in Arctic regions such as Norway and Alaska.

Methane is 25 times more potent a greenhouse gas than carbon dioxide, and it has increased by 150 percent in the anthropocene, the period from the beginning of the industrial era, making it the second most important contributor to heat retention and climate forcing. The atmospheric

Four Corners Coal-Fired Power Plant used for sensor test beds

methane growth rate that had slowed between 1999 and 2007 has accelerated again beginning in 2008; the causes are not known. Methane is released from the seas as well as from melting permafrost as ambient temperatures rise.

Partners/Collaborators

Our partners include numerous U.S. universities, including Idaho State, Texas A&M, the University of Colorado–Boulder, the University of New Mexico, Harvard University, and others.

Sponsors

The research is supported by LANL's Laboratory Directed Research and Development program.

Contact

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Using Metagenomics to Understand the Role of Soil Microorganisms in Terrestrial Ecosystems

Contributions of soil to carbon sequestration

THE CAPABILITY

Our climate researchers analyze and predict how climate change influences soil's ability to process and store carbon.

The activities of the soil microbial community, an extremely abundant and diverse assemblage of bacteria, fungi, archaea, and microscopic animals, control an important balance in soil ecosystems.

Soil serves as a huge carbon reservoir, containing approximately three times as much carbon as terrestrial vegetation. Microscopic bacteria, fungi, and other organisms are responsible for cycling of this carbon, and microbial respiration and decomposition of plant matter accounts for about half of the carbon flux in the terrestrial biosphere.

Each thimbleful of soil can contain tens of thousands of species and representatives of all major branches of life. The vast majority of these organisms has not yet been identified, cultured, or studied. Because it has been so difficult to identify and study the collective activities of this complex community, an understanding of carbon cycling and mass balance in terrestrial ecosystems has not yet been achieved.

Assessment of the process (or flux) alone does not provide mechanistic information that allows interpretation or prediction. One must understand the soil process and biological functions in context with the identities and lifestyles of the organisms responsible for those processes.

Consequently, the net flux of carbon in soils under climate change conditions over the next 100 years is uncertain. Indeed, a variety of predictive models have projected very different and sometimes contradictory outcomes, with soils serving either as a carbon source or sink.

Our research aims to understand the carbon cycling roles of the complex soil microbial communities in temperate forest and arid land ecosystem under changing nitrogen conditions, warming temperatures, and altered

In arid landscapes worldwide, the top few centimeters of soil are colonized by cyanobacteria and other microorganisms that fix carbon and nitrogen and stabilize the soil surface from erosion.

precipitation patterns and to identify processes that influence below-ground carbon storage and release.

Advancing fundamental knowledge of soil microbial communities within the context of altered environmental regimens will improve our ability to predict and possibly manage ecosystem contributions to global climate.

Partners/Collaborators

Our partners include the United States Geological Survey, Michigan State University, the University of New Mexico, and the University of Michigan.

Sponsors

This work is supported by the DOE Office of Biological and Environmental Research, Biological System Science Division, and LANL Laboratory Directed Research and Development (LDRD).

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Where, When, and How Does Vegetation Die During Drought?

Developing accurate models of forest mortality

THE CAPABILITY

We are investigating how future heat and drought will affect vegetation mortality—and thus, environmental, agricultural, and economic policies.

Climate warming is currently driving a global acceleration of vegetation mortality. This increased mortality is impacting agriculture and economics and feeds back upon climate by increasing the amount of carbon dioxide (CO_2) in the atmosphere through loss of photosynthesis and increases in decomposition.

Models of vegetation mortality are essential for forecasting future impacts of climate on the land and making associated policy decisions. However, models of forest mortality are in their infancy because scientists have not discovered how plants die during drought or how to quantify the global patterns of mortality.

At LANL, our team is focused on answering these questions through theory, observations, experiments, and models, with the ultimate goal of developing more mechanistic and accurate models of forest mortality.

We begin our science with developing theory based on the first principles of plant physiology to allow prediction of where, when, and how mortality may occur. These theories are then tested via observations of mortality globally, via forest inventory or remote sensing, or via experiments.

We manipulate ecosystem precipitation amounts and temperature. Measurements are often taken at the scale of leaves to whole trees and focus on the key processes of carbon uptake, storage, starvation, and water use. We frequently use our local piñon pine–juniper woodlands as a model system to study the physiological mechanisms that enable a plant to survive heat and drought mortality drivers.

Left: Open-topped chamber placed around piñon pine and juniper trees allows continuous heating of the trees to ~5°C above ambient temperatures measured outside the chamber. Right: Measurements of foliar exchange of carbon dioxide, water, and their isotopes allow examination of the response of photosynthesis, water use, and their controls in relation to severe drought and heat extremes.

Ultimately, all of the knowledge we gain is distilled, tested, and applied to models of regional and global vegetation dynamics. The objective is to enhance the accuracy of these models so that they can most effectively aid in prediction of future ecosystem impacts from climate change and subsequent feedbacks upon climate.

Partners/Collaborators

Collaborators include researchers from the United States Geological Survey, the Forest Service, Lawrence Berkely National Laborartory, University of California Santa Cruz, Tulane University, and Colorado State University, Decagon, Inc., and the universities of New Mexico, Idaho, and Montana.

Sponsors

This research is supported by DOE Biological and Environmental Research, Biological System Science Division, and LANL Laboratory Directed Research and Design (LDRD).

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How Do Trees Die?

Nuclear magnetic resonance and magnetic resonance imaging of tree mortality

THE CAPABILITY

By detecting fatal changes in plant physiology, our instruments help determine when and what kinds of trees will die.

Summertime droughts are predicted to increase in frequency and severity around the globe with a warming climate. To predict how these changes will affect vegetation, it is important to understand how trees die.

Generally, all plants close their stomata and stop photosynthesis during drought to avoid excessive water loss and wilting. Stomatal closure may prolong survival only temporarily because it leaves plants without an energy source and may lead to death via starvation.

It has been hypothesized that plants that close stomata early would survive severe but short droughts while plants that close stomata late would survive if the drought were less severe but longer. Testing these hypotheses is difficult because all existing measurement systems interfere with plant function and may cause mortality in trees suffering from drought.

At Los Alamos, we have developed Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) systems that can be placed around tree trunks and do not require cooling. We can measure changes in water content (wilting), and we are testing systems for detecting movement of sugars in trees.

Our goal is to develop a system that could have detectors at different parts of the tree. We will use this system to detect the progression of tissue mortality during drought and identify what kind of physiological changes occur at the point when trees cannot recover from drought anymore. This will enable us to predict when and what kinds of trees die under different climates.

Instruments that measure water content in tree trunks can help predict tree mortality in different climates.

Partners/Collaborators

Michele Espy and Jacob Yoder of LANL's Physics Division collaborate on this project.

Sponsors

This work is supported by Laboratory Directed Research and Design Exploratory Research (LDRD-ER) at LANL.

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Effects of Wintertime Warming on Arctic Vegetation

Understanding and evaluating plant mortality

THE CAPABILITY

Our research is studying how increasingly warm temperatures could damage the Arctic's vegetation, the carbon balance, and its overall ecosystem.

Global warming is expected to increase temperatures, especially in the far north.

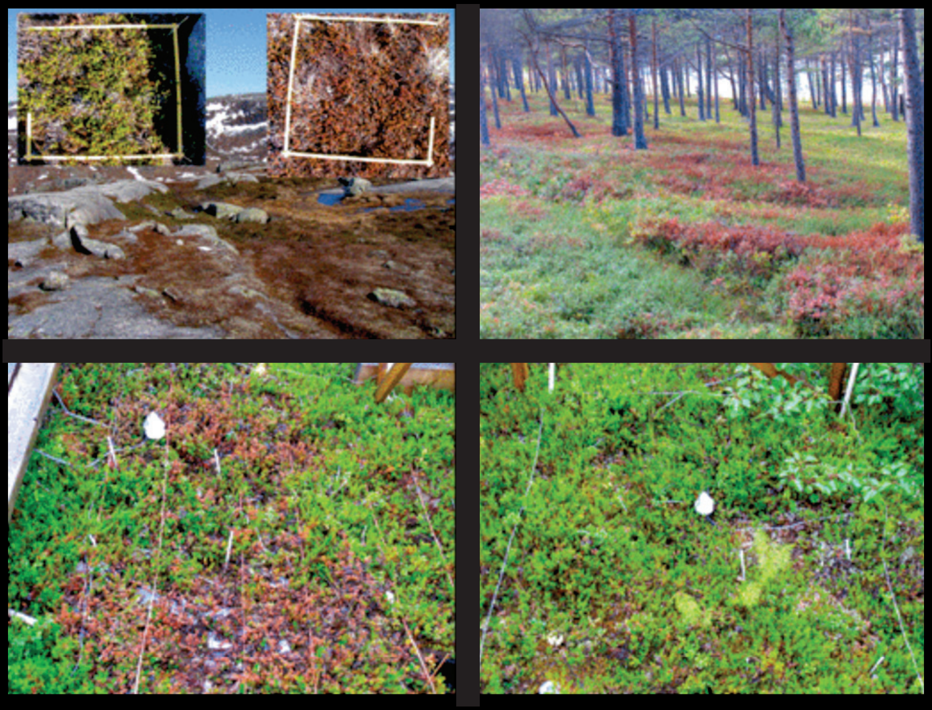
Spring and summertime warming should make plants more productive and allow new species to move in, leading to a greening of the Arctic.

Wintertime warming may have very different effects on the vegetation because removal of the protective snow cover might expose plant tissues to frost damage, leading to plant mortality the following spring.

Loss of vegetation in the Arctic would not only affect the carbon balance of the ecosystems and influence the local climate, but it would also lead to altered hydrology and leaching of nutrients from the soil. These effects might completely change the habitat both for plants and animals and result in a drier and more desert-like Arctic.

In this LANL project, we are performing artificial snow removal on selected areas in Northern Norway and Sweden. We will compare the effects of snow removal at different times during winter on evergreen and deciduous woody plants.

Our goal is to understand which plant types are more susceptible to damage during wintertime warm spells and evaluate whether mid-winter warm spells are more damaging to the vegetation than late winter warm spells.



Wintertime warm spells leading to melting of snow cover in the middle of winter have been observed to damage vegetation in Northern Scandinavia, as shown in these images (Bokhorst et al. [2009] Journal of Ecology 91:1408-1415).

Partners/Collaborators

With LANL, collaborators on this project include Dr. Annika Hofgaard of the Norwegian Nature Institute and the Abisko Scientific Research Station, Abisko, Sweden.

Sponsors

This research is supported by the Institute of Geophysics, Planetary Physics, and Signatures.

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A Greenhouse Gas Information System

Monitoring and validating emission reporting and mitigation

THE CAPABILITY

With our collaborative work on a greenhouse gas information system, we can independently assess and respond to rising global greenhouse gas levels, supporting multipurpose climate agreements.

Los Alamos National Laboratory joined with three other laboratories to define for the DOE Office of Science an initial design framework of a greenhouse gas (GHG) information system (GHGIS) that would achieve the following:

1. Support monitoring national emissions-reduction and the efficacy of renewable-energy programs
2. Provide information on compliance with existing emissions agreements
3. Assist in the negotiation of and provide actionable information on compliance with possible future emissions and climate agreements
4. Provide Earth-science data presently not available at adequate space and time scales on a sustained and traceable basis
5. Provide multipurpose monitoring, data, and analysis

The product of the GHGIS would be reliable estimates of anthropogenic GHG emissions, reconciling top-down (GHG measurement) data with bottom-up (fossil-fuel inventory) data on a regional, national, or global basis.

A functioning GHGIS would provide the basis for reasoned choices on how best to respond to rising GHG levels, especially if proposed U.S. actions were compared with or conditioned on the actions of other nations.

GHGIS would also allow for the independent assessment of the claims of others so that the United States could participate fairly and equitably in any process aimed at reducing GHG emissions.

A greenhouse gas information system would estimate emissions on a regional, national, or global basis.

Partners

Our partners include the Jet Propulsion Laboratory, Sandia National Laboratories, and Lawrence Livermore National Laboratory.

Collaborators

We collaborate with multiple entities, including Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, and National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory.

Sponsor

This work is supported by the DOE Office of Science.

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Climate–Infrastructure Impacts

Using integrated assessment models for simulation and assessment

THE CAPABILITY

To better model climate change scenarios, we plan to add infrastructure simulations and so determine economic and societal vulnerabilities of climate change.

Integrated assessment models (IAMs) are used extensively to evaluate climate change scenarios, but their application currently focuses mainly on greenhouse gas emissions and mitigation in the context of economic growth.

Adding infrastructure simulation capabilities allows us to assess how economies and societies adapt to climate change and what the quantifying risk would be. Existing infrastructure modeling is focused on detailed U.S. concerns.

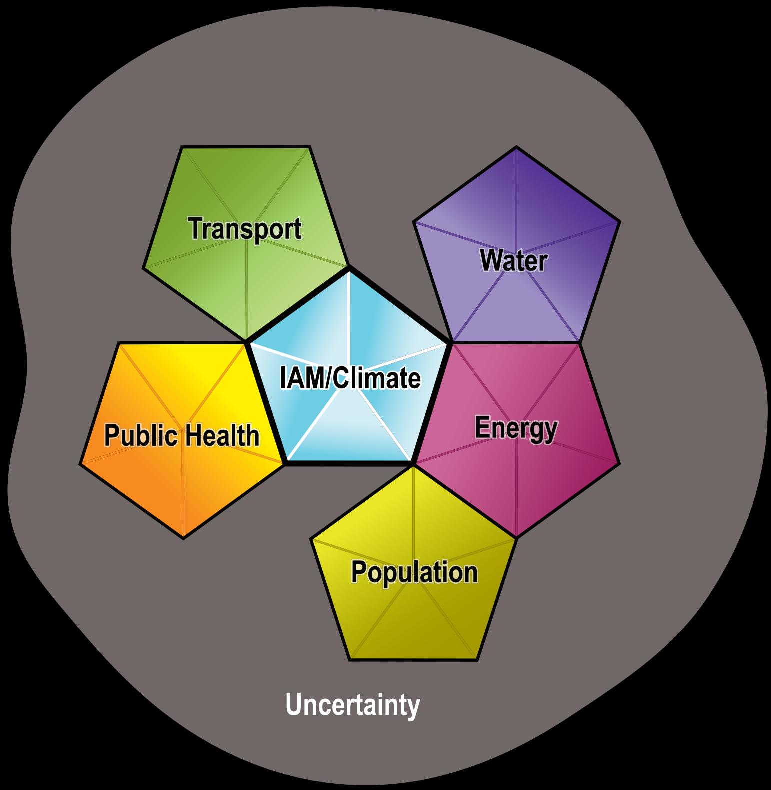
Further, the level of Critical Infrastructure Protection (CIP) geographic and facility detail exceeds requirements for many climate change assessments. Recent National Climate Assessment (NCA) efforts suggest a need to include infrastructure dynamics within IAMs to quantify risk, determine impacts, and evaluate adaptation options.

In this effort, Los Alamos National Laboratory supports the development of a longer-term climate research program to include analysis of impacts on built and planned infrastructure.

The development of infrastructure simulation modules for IAM use will start with U.S. (regional or state) resolved simulations. Once created and tested, the jointly developed infrastructure modules will use specific parameters that represent the same global coverage as many IAMs. Based on detailed models, such parameterizations will eventually recognize critical local vulnerabilities of the regions without fully simulating impacts at detailed spatial resolution.

The following are key questions to be addressed through this research:

- Can multiscale infrastructure impacts be addressed with IAM?
- Can social behavior be introduced into IAM through asset-level modeling?



Notional view of a complex interoperable integrated assessment model (IAM)/ Critical Infrastructure Protection (CIP) modeling system

- What are the key feedbacks at the asset level that must be represented?
- How does climate rate of change affect the selection of appropriate models?

Partners/Collaborators

This project relies on the collaboration of Oak Ridge National Laboratory, Joint Global Change Research Institute, Pacific Northwest National Laboratory, and the University of Maryland.

Sponsors

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Uncertainty Quantification Capabilities

Refining computational model accuracy and sensitivity

THE CAPABILITY

Los Alamos researchers are addressing challenges in climate modeling by improving calibration techniques that reduce uncertainty.

Uncertainty quantification (UQ) is concerned with learning about computational model accuracy and sensitivity. It is also concerned with combining models with physical measurements to make inferences.

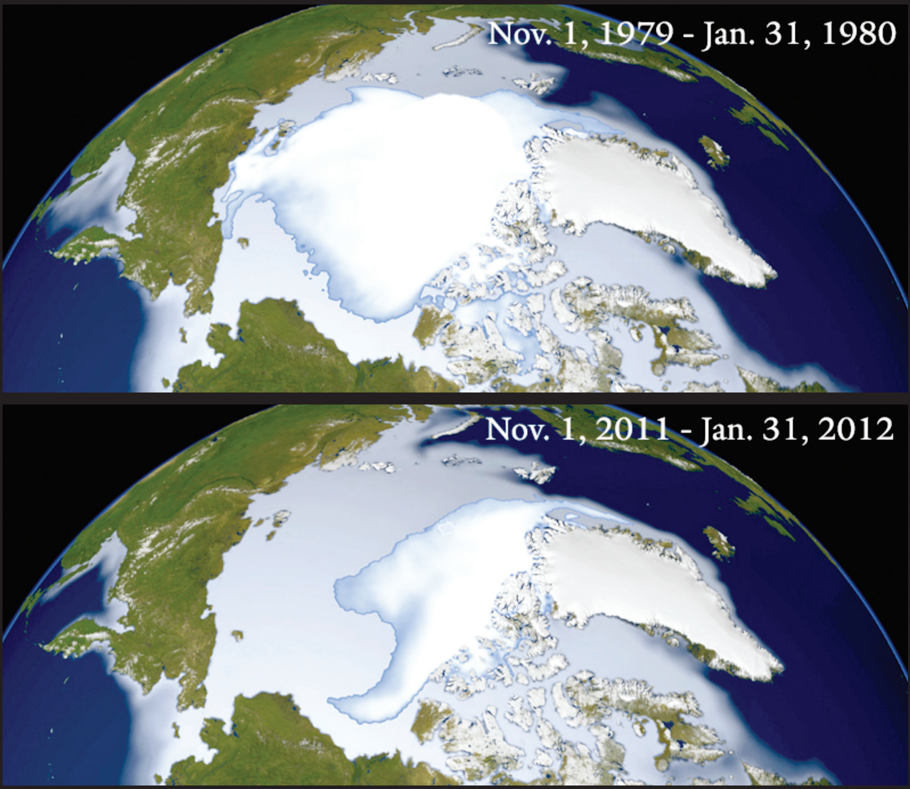
LANL's UQ capabilities were motivated by stockpile stewardship, which combines large-scale computational models with experiments to assess reliability and performance of the nation's nuclear stockpile. More recently, these capabilities have been adapted and extended to a variety of applications in the engineering, physical, and biological sciences.

Uncertainty quantification for climate has a number of challenges. The climate system itself is highly complex. The computational models that simulate climate are very computationally demanding, limiting the number of model runs that can be carried out.

As complicated as these models are, they must still omit processes, and important processes that are modeled may be approximate or not fully resolved. Also, physical observations of Earth's climate are quite limited in both observation density and the length of the observation record. Climate UQ at Los Alamos is tailored to these challenges.

One key focus is on understanding the input–output map induced by these complex computational models using a limited number of model runs. This supports traditional sensitivity analysis of model response to parameters and fitting statistical response surfaces to predict the model's response at untried input settings, allowing advanced analyses.

Key to such studies is the effective parameterization of inputs and the summarization of outputs as targeted quantities of interest, capturing emergent features of the weather and climate in huge, evolving spatial fields.



Over the last 30 years, the area of thick multiyear Arctic sea ice in winter has declined by two-thirds as a result of climate change. The decline of Arctic sea ice has impacts on Northern Hemisphere weather and climate patterns, shipping, fossil energy resource exploration, naval operations, and global security. (Images courtesy of NASA)

Another focus is model calibration—determining model parameter settings that are most consistent with physical observations.

In addition to the challenges posed when computational constraints limit the survey of model behavior, uncertainties associated with physical observations as well as some understanding of how a climate model differs from reality even as the best parameter settings must be assessed.

Partners/Collaborators

This research benefits from the collaboration of the National Center for Atmospheric Research, Princeton University, the Institute for Geophysics, and the University of Texas.

Sponsors

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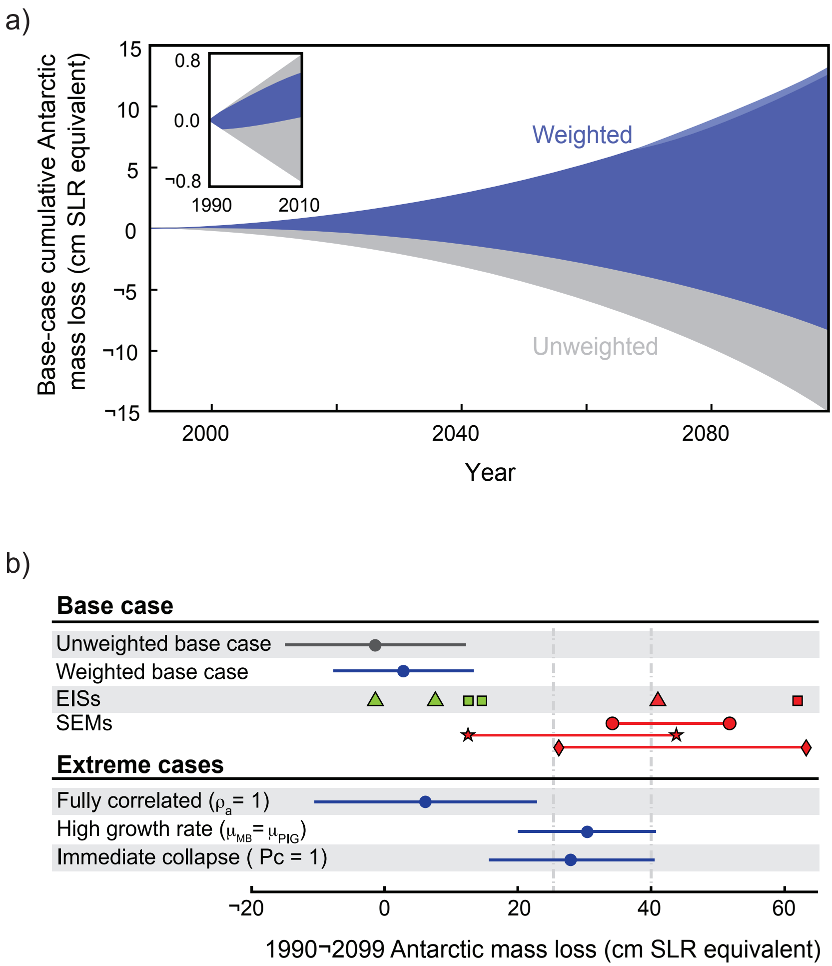
Accurately describing these uncertainties are crucial for model-based projections, as well as for linking such analyses to policy-relevant decision-making under uncertainty.

Recent and ongoing LANL activity in climate UQ includes the following:

- Calibration and prediction using a medium complexity global climate model
- Calibration of atmospheric parameters in a large-scale global circulation model
- Developing lower-resolution ocean model parameterizations that account for mixing effects present in high-resolution models
- Hierarchical modeling approaches that account for multiple types of model outputs and physical measurements
- Determining optimal ice-sheet measurement locations for assessing mass loss
- Empirical modeling approaches for assessing impact of Antarctic ice-sheet mass loss on sea level rise

Estimation of greenhouse gas emissions from the Four Corners Power Plant using integrated column and point measurements of CO_2 over time

- Data assimilation for a global ocean model
- Assessing the impact of data collection on climate uncertainty to help determine the tradeoff between "wait-and-see" and "precautionary" policy options



Quantifying uncertainty in sea level rise due to mass loss in the Antarctic ice sheet: *(a) Uncertainty in future sea level rise over time due to ice loss from Antarctica in a warming climate. The analysis estimates the uncertainty in the acceleration of ice discharge to the ocean across different regions of the ice sheet. (b) Uncertainties calculated from an alternate set of assumptions and compared to other analyses.*

CLIMATE

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