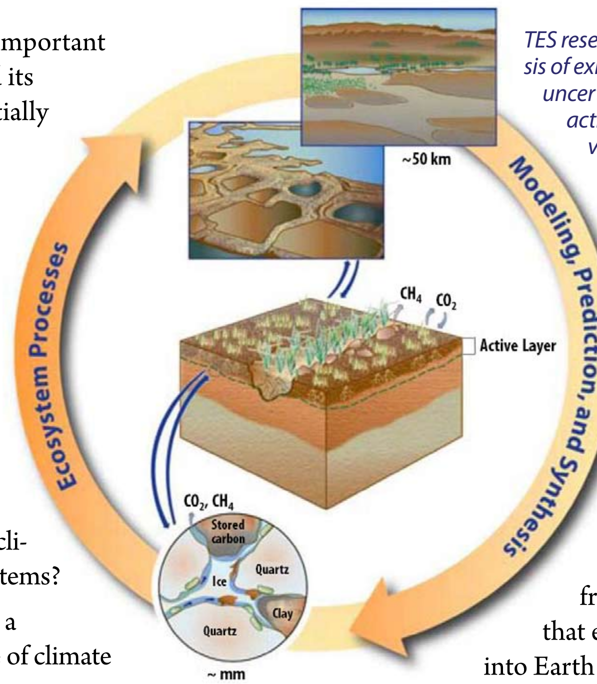
Terrestrial Ecosystem Science

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

Improving the representation of terrestrial ecosystem processes in Earth system models to increase the quality of climate model projections and inform DOE's energy decisions

Terrestrial ecosystems play important roles in Earth's climate and its response to change, potentially enhancing or lessening the effects of that change. Among these roles is the ability to absorb and store carbon from the atmosphere, which reduces greenhouse effect impacts. Carbon also can be released back to the atmosphere or stored as ecosystems alter their biological properties in response to disturbances such as climate change. Key questions include:

- What are the potential effects of climate change on terrestrial ecosystems?
- How will ecological responses to a changing climate modify the rate of climate change itself?



TES research uses modeling, prediction, and synthesis of existing data to identify knowledge gaps and uncertainties in predictive capabilities. These activities in turn inspire the field experiments that validate models and provide crucial data for their improvement. This cyclical, integrative approach is applied at multiple scales—from the molecular to pore to ecosystem level. [Lawrence Berkeley National Laboratory]

Understanding and predicting terrestrial ecosystem responses to climate change are crucial for managing and informing U.S. energy challenges and improving confidence in climate model projections. Decision makers and the public require this fundamental scientific understanding to plan for, mitigate, and adapt to a changing climate.

Research Approach

The Terrestrial Ecosystem Science (TES) program within the Department of Energy's (DOE) Office of Biological and Environmental Research (BER) develops unique, foundational scientific insights about the terrestrial biosphere's role in the global cycling of carbon, nutrients, and water. The program also supports research examining the feedbacks between the terrestrial biosphere and Earth's climate system. As part of the Climate and Environmental Sciences Division, TES is coordinated with BER's climate modeling program (and research from other federal agencies), ensuring that experimental results are incorporated into Earth system models to improve climate projections. The overarching goal of TES is to improve the representation of terrestrial ecosystem processes in Earth system models, thereby increasing the quality of model projections and informing DOE's energy decisions.

BER's TES activity:

- discovers the ecological implications of climate change and
- quantifies critical feedbacks between the terrestrial biosphere and the global climate system, with a focus on the terrestrial carbon cycle.

Building on BER's Legacy of Experimental Innovation

Terrestrial ecosystems respond to changes at varying scales of time and space, with some long-term effects emerging slowly over many years. Understanding these responses often requires observation or manipulation over extended time periods.

The FACE experiment in Wisconsin quantifies the effects of elevated concentrations of CO_2 and ozone on the ecology and productivity of northern hardwood ecosystems.

BER has a distinguished history of designing, testing, and implementing leading-edge experimental approaches to study long-term effects of climate and atmospheric composition on the structure and functioning of terrestrial ecosystems. The Free-Air CO_2 Enrichment (FACE) method of controlling elevated CO_2 (and ozone) concentrations within ecosystems is one such success story;

SPRUCE, an ecosystem-scale manipulation study in northern Minnesota, will reveal new insights about climate change effects on the structure and functioning of spruce and peatland areas. The experiment (partially visible here) increases CO_2 to more than twice the amount of current levels and increases air and soil temperatures as much as 9°C to discover ecosystem responses to predicted changes in climate. [Both images, Oak Ridge National Laboratory]

Leaf gas exchange is measured as part of the Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) study.

FACE is now used throughout the world in a wide range of ecosystems. Results of the FACE experiments are invaluable in forecasting both future atmospheric CO_2 concentrations and the role of terrestrial ecosystems in future climates.

Large-scale, long-term experimental precipitation and temperature manipulation experiments also were pioneered by BER. These studies provide vital knowledge about the effects of changing precipitation on the structure and functioning of terrestrial ecosystems, as well as the regional-scale regulation of weather and climate carried out by ecosystems. Future investments—including BER's innovative concept for coupling models with experimental and observational campaigns in the Next Generation Ecosystem Experiment (NGEE) in the Arctic—will build on this legacy and reshape the approach to long-term ecosystem studies through model-inspired research activities.

Unraveling Carbon Cycle Mysteries

A significant fraction of the CO_2 released to the atmosphere during energy production is taken up by terrestrial ecosystems, but the effects of climate variability and change on that uptake remain a mystery. Uncertainties about how terrestrial ecosystems will function in a changing climate hamper efforts to determine long-term impacts and stability of carbon in the biosphere. This limitation makes resolving the role of the terrestrial biosphere in the global carbon cycle a high priority. BER investments also provide management and support infrastructure for AmeriFlux, the interagency activity coordinating long-term CO_2 (and energy) flux measurements across North America. TES research will continue to navigate the forefront of interactions between terrestrial ecosystems and a changing climate.

Permafrost stores massive quantities of carbon in frozen soil. Release of this carbon as permafrost melts in a warming Arctic represents a potential tipping point for climate change. [University of Alaska, Fairbanks]

TES focuses on ecosystems and ecological processes that:

- are globally or regionally significant
- are expected to be sensitive to climate change, and
- are presently understudied and thus poorly understood.

Program Priorities

The need to understand ecosystem responses to warming, as well as increasing atmospheric CO_2 concentration and altered precipitation timing and amount, is essential to improving forecasts of both the ecological effects of climate change and the feedbacks between the biosphere and atmosphere. Through hypothesis-driven observations; experimental manipulations; and large-scale, long-term field studies, TES focuses on foundational research, including studies in critical and potentially sensitive ecosystems. The goals are to understand and explain mechanisms and processes controlling primary production and carbon cycling, biogeochemistry, and the impacts of disturbance on terrestrial ecosystems. This information is required to improve model-based projections of climate change.

Research Funding

TES supports BER mission-oriented ecosystem research at universities, national laboratories, and other research institutions through regular peer-reviewed, hypothesis-driven, and proposal-based competitions. Funding opportunities are posted at **www.grants.gov**.

Climate and Environmental Sciences Division

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

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Office of Biological and Environmental Research
U.S. Department of Energy Office of Science

October 2011