DEPARTMENT OF ENERGY

Principal Areas of Focus

Research supported by DOE's Office of Science is focused on the effects of energy production and use on the global climate system, primarily through studies of climate response to changes in greenhouse gas and aerosol concentrations. Research covers three program areas: 1) climate change modeling, 2) climate forcing, and 3) climate change response.

Program Highlights for FY 2008

DOE will continue support of climate change research at its National Laboratories and other public and private research institutions, including universities. In support of CCSP, the DOE Office of Science's Climate Change Research Program will continue to provide the data and predictive understanding that will enable objective, scientifically rigorous assessments of the potential for, and consequences of, human-induced climate change.

Climate Change Modeling

DOE continues to develop, improve, evaluate, and apply fully coupled atmosphere-ocean-sea ice-land surface general circulation models (GCMs) that simulate climatic variability and change over decadal to centennial time scales. As one of its contributions to the suite of synthesis and assessment products (SAPs) being prepared by CCSP, DOE is leading the effort on SAP 3.1, *Climate Models: An Assessment of Strengths and Limitations for User Applications*.

In FY 2008, DOE researchers will continue analysis of multi-model ensemble runs under various forcing scenarios. IPCC Fourth Assessment Report model simulations from major national and international high-end modeling centers are currently archived at Lawrence Livermore National Laboratory (LLNL) / Program for Climate Model Diagnosis and Intercomparison (PCMDI), and made accessible to the climate research community. Under the DOE-wide Scientific Discovery through Advanced Computing (SciDAC) initiative, DOE will continue to support model development of the Community Climate System Model (CCSM) to incorporate atmospheric chemistry and coupled biogeochemistry, in addition to improved physics and dynamics. DOE will also continue ongoing development of high-resolution comprehensive coupled GCMs that incorporate more accurate and verified representations of clouds and other important climatic processes. DOE will continue support of the development of a global cloud resolving model. New activity in the area of abrupt climate change will be initiated.

Climate Forcing

Collection and analysis of data from DOE's Atmospheric Radiation Measurement (ARM) Cloud and Radiation Test Bed (CART) sites will continue in FY 2008 to improve understanding of the radiative transfer processes in the atmosphere and to formulate better parameterizations of these processes, especially cloud and aerosol effects for use in climate models. DOE will also report on the results of two major campaigns: the Cloud and Land Surface Interaction Campaign (CLASIC) and the 9-month deployment of the ARM Mobile Facility (AMF) in the Black Forest region of Germany. The latter is part of a large international campaign, Convective and Orographically Induced Precipitation Study (COPS). The COPS region can be characterized by significant orographic precipitation with most of the

summertime precipitation being convective. The experiment is designed to improve the prediction of precipitation in this environment. CLASIC was designated as the core of a FY 2007 priority for the interagency Water Cycle Interagency Working Group of the CCSP. The goal of CLASIC is to advance understanding of how land surface processes influence cumulus convection and to produce improved parameterizations of cumulus convection and associated parameterizations of land surface processes. Cumulus convection is an important component in the atmospheric radiation budget and hydrologic cycle of the Southern Great Plains, particularly during the summertime growing season. In 2008, ARM will deploy the AMF to China and will conduct two experiments that contribute to the International Polar Year (IPY). The AMF deployment to China will study the aerosol indirect effect. Aerosols in China have exceptionally high loading and diverse properties whose influence has been detected across the Pacific Rim. The first IPY experiment, the Indirect and Semi-Direct Aerosol Campaign (ISDAC), is designed to determine the semi-direct effect of the aerosol on the clouds in the arctic. The second IPY experiment, Routine *In Situ* Cloud and Aerosol Measurements at the North Slope of Alaska, will conduct intensive cloud and aerosol observations that can be used to develop and evaluate new model parameterizations. In FY 2008, the ARM science program will also focus on the development of new cloud schemes and improvement of cloud-radiation parameterization schemes. Special measurements from the Tropical Warm Pool International Cloud Experiment (TWP-ICE), COPS, the aerosol study in China, and CLASIC will give scientists ample opportunities to validate and improve radiation-cloud-aerosol processes representations in climate models.

DOE's Atmospheric Science Program (ASP) will continue research in FY 2008 to reduce uncertainties in aerosol radiative forcing of climate. This research includes laboratory and field research on key processes individually and as encountered in "real world" environments. Acquired data are used to develop and test predictive parameterization schemes or models for aerosol properties and their effect on radiative transfer in the atmosphere. Field and laboratory observations are also used to interpret and extend the results of process model simulations. Current priority atmospheric processes under study include transformations and properties of carbonaceous aerosols, especially secondary organic aerosols, that are poorly predicted by current atmospheric models. Also important are processes controlling new particle formation and growth, as well as the properties that affect their activation as droplet and crystal nuclei. During FY 2008, technical planning and preparations will be finalized for ASP participation in a major collaborative interagency field campaign in October 2008 (VOCALS) aimed at measuring interactions of aerosols with clouds in a region that is impacted both by pristine and polluted air masses. One specific objective of ASP activity is to test new process models of drizzle formation that show promise for inclusion into global climate models. Analysis of data from prior field studies will continue, principally from the FY 2006 campaign conducted in and around Mexico City to examine the properties and processes of aerosols emanating from a large metropolitan area, and from the FY 2007 CHAPS campaign, that examined interactions of aerosols with fair-weather cumulus clouds.

DOE's carbon cycle research will continue to improve understanding of the role of terrestrial ecosystems in the global carbon cycle, with attention on processes that control the rate of CO_2 exchange with ecosystems and that affect the rate of atmospheric increase and climate forcing by this greenhouse gas. Research in FY 2008 will address the questions and elements described in Chapter 7 of the *CCSP Strategic Plan*. DOE's Terrestrial Carbon Processes (TCP) research will continue to contribute to the North American Carbon Program (NACP) through support of experiments, observations, and modeling of atmospheric CO_2 and the terrestrial carbon cycle. As recommended by the Biological and Environmental Research Advisory Committee (BERAC) review, research will continue to focus on the

AmeriFlux network of observations, experiments, modeling, and syntheses. Temporal and spatial observations of gross and net carbon dioxide fluxes, and real-time information on ecosystem carbon states and sinks, will be made available to researchers that are investigating regional CO_2 exchange, continental-scale carbon sinks and sources, and carbon cycle-climate relationships. DOE will also support the NACP strategy of a model-based comparison of "bottom-up" (distributed ecosystem models driven by land surface and meteorological information) and "top-down" (inferring spatially distributed surface fluxes from atmospheric measurements) approaches to estimating ecosystem carbon dioxide fluxes for different regions of the United States. DOE will provide information on biogeochemical, physiological responses and terrestrial ecosystem feedbacks related to climate change as part of joint carbon cycle-climate change research to improve simulation models.

Climate Change Response

DOE will continue to design, implement, and maintain large-scale and long-term experimental field manipulations of environmental factors affected by energy production in important North American ecosystems. This includes support of Free-Air CO_2 Enrichment (FACE) experimental facilities for study of the response of U.S. forests to elevated atmospheric concentrations of carbon dioxide and/or ozone. The goal is to understand, and be able to predict, effects of environmental changes associated with energy production on the structure and functioning of terrestrial ecosystems. The research focuses on the physiology, growth, and reproduction of plants, animals, and microbes; nutrient and water cycling in ecosystems; plant community dynamics; plant-insect and plant-microbe interactions; and acclimation and adaptation of plants, animals, microbes, and whole ecosystems to environmental change. As recommended by BERAC, DOE will begin to wind down the FACE experiments in FY 2008.

Ongoing experimental research will be continued in FY 2008, including field manipulations of temperature, precipitation and soil moisture, carbon dioxide concentration, and/or ozone concentration in a range of terrestrial ecosystems, including boreal forest, temperate shrublands, temperate grasslands, temperate woodlands, and temperate deciduous and evergreen forests. New warming experiments will be initiated in the ecotone separating the temperate and boreal forest biomes and at the alpine tree line. Warming experiments to evaluate potential effects of climatic change on important insect populations will also be initiated. Such experiments will provide the data and information needed to evaluate (test) the ability of ecological models to realistically predict effects of climatic change on terrestrial ecosystems; such models form the basis of most assessments of potential effects of climatic change on terrestrial ecosystems.

The DOE Integrated Assessment of Global Climate Change Research Program will continue to support research on the nature and magnitude of human-earth systems interactions, providing scientific insights into the integrated drivers of climate change and the impacts of and adaptations to those changes. With improvements to models of global economies and the corresponding energy-driven technologioes that emit greenhouse gases, and with similar improvements and stronger coupling to the underlying models of the natural earth systems, the program will deliver improved science-based tools for determining safe levels of greenhouse gas emissions and understanding of the relative efficiencies and impacts of potential mitigation strategies. In FY 2008 and in response to a FY 2007 review of the program by BERAC, the program will shift emphasis and take on the important and challenging task of strengthening representations of impacts and adaptations in integrated assessment models. There is a strong interagency dimension to this challenge and the program began in FY 2007, and will continue in FY 2008, efforts to build multi-agency collaborations to realize this objective. In FY 2008, the program will apply new

mathematical and computational approaches to integrated assessment in order to reveal deeper insights into complex human-earth systems interactions and process dynamics while taking advantage of the more detailed, underlying models of the natural systems. In FY 2008, work will continue on the two large integrated assessment models funded by the program to improve their representation of renewable energy derived from biological sources. The portrayal of uncertainty in emission scenarios will also be studied to help identify methods that represent important variability with a small number of alternative scenarios. Also in FY 2008, select scenarios will be developed and analyzed with the goal of delivering key emissions and land-use parameters to Earth systems modelers for calibration and bounding of emerging models and for use in climate research.

DOE will also continue support of its Global Change Education program in FY 2008, including support of undergraduate and graduate students through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREFs). Support will also be continued for the Carbon Dioxide Information and Analysis Center (CDIAC) to enable it to respond to data and information requests from users all over the world who have a need for data on, for example, greenhouse gas emissions and concentrations.

Related Research

DOE plays a major role in carbon sequestration research to reduce atmospheric concentrations of energy-related greenhouse gases, especially carbon dioxide, and their net emissions to the atmosphere. The research builds on, but is not part of, the CCSP. It focuses on both developing the scientific information needed to enhance the natural sequestration of excess atmospheric carbon dioxide in terrestrial systems, and assessing the potential environmental consequences and ancillary benefits of that enhanced sequestration. It also includes research to develop biotechnological approaches for sequestering carbon either before or after it is emitted to the atmosphere. Funding for DOE's carbon sequestration research is part of the Climate Change Technology Program (CCTP). CCTP also provides related research funding to support a balanced and diversified portfolio of advanced technology R&D, focusing on energy-efficiency enhancements; low greenhouse gas emission energy supply technologies; carbon capture, storage, and sequestration; and technologies to reduce emissions of non-CO_2 gases. Together, CCSP and CCTP will help lay the foundation for future progress. Advances in the climate change sciences under CCSP can be expected to improve understanding about climate change and its impacts. Similarly, advances in climate change technology mitigation under CCTP can be expected to bring forth an expanded array of advanced technology options at a lower cost that will reduce greenhouse gas emissions.