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. Research includes climate modeling, atmospheric properties and processes affecting Earth's radiation balance (including clouds and aerosols), and sources and sinks of energy-related greenhouse gases (primarily CO_2). It also includes research on consequences of climatic and atmospheric changes on ecological systems and resources, development of improved methods and models for conducting integrated economic and environmental assessments of climate change and of options for mitigating climate change, and education and training of scientists for climate change research.

Program Highlights for FY 2006

DOE will continue the support of climate change research at its National Laboratories and other public and private research institutions, including universities. In support of CCSP, the Office of Science research program includes activities in four areas 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 and hydrology, atmospheric chemistry and carbon cycle, ecological processes, and human dimensions.

Climate and Hydrology

DOE will continue 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. Climate modeling activities planned for FY 2006 will place particular emphasis on analyzing climate feedbacks and sensitivity to natural and human-induced forcing, as well as on enhancing climate modeling systems. DOE will lead the effort on the CCSP Synthesis and Assessment Product 3.1, *Climate Models: Model Sensitivities, Feedbacks, and Uncertainties*.

In FY 2006, DOE will complete the suite of Community Climate System Model (CCSM) and Parallel Climate Model (PCM) ensemble simulations of climate change projections under various forcing scenarios as part of the U.S. contribution to the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report*. IPCC model simulations from major national and international high-end modeling centers will be archived at Lawrence Livermore National Laboratory (LLNL)/Program for Climate Model Diagnosis and Intercomparison (PCMDI), and made accessible to the climate research community. DOE will continue to support model development of the 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. Finally, DOE will continue support of innovative approaches to climate model development—for example, the geodesic grid model intended to lead to a prototype climate model that could potentially overcome some of the problems and limitations of current generation climate models.

Collection and analysis of data from DOE's Atmospheric Radiation Measurement (ARM) Cloud and Radiation Test Bed (CART) sites will continue in FY 2006 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 results of the Mixed Phase Arctic Cloud Experiment (M-PACE), a major field experiment to improve scientific understanding of the dynamic processes in Arctic mixed-phase clouds, including cloud microphysical processes and radiative transfer through Arctic clouds. The ARM Mobile Facility (AMF) will be deployed in Niger, Africa, in FY 2006 as part of the field phase of the African Monsoon Multidisciplinary Analysis (AMMA) to obtain atmospheric and radiation data on meteorological conditions ranging from deep, tropical convective clouds in the humid tropical air masses prevalent in the wet season to the aerosol-laden dry air masses found during the dry season. AMMA field data will provide unique opportunities to evaluate and improve the parameterization schemes used in climate models across a wide range of meteorological conditions. A measurement campaign around the ARM site in Darwin, Australia, is in planning for FY 2006 that will focus on the effects of cirrus clouds on the transfer of radiation in the atmosphere. This so-called Tropical Warm Pool International Cloud Experiment (TWP-ICE) will employ multiple research aircraft and balloon-borne meteorological sensors from an array of sites to measure cloud properties and their impacts on the transfer of radiation in the atmosphere throughout the storm life cycle as well as the atmospheric state. Data from this experiment will be used to both evaluate and test how well existing models simulate cloud properties and to improve the modeling of cloud properties and their effects on the transfer of radiation in the atmosphere.

Atmospheric Chemistry and Carbon Cycle

In FY 2006, DOE's Atmospheric Science Program will continue research begun in FY 2005 to reduce uncertainties in aerosol radiative forcing of climate. Research will include modeling, instrument development, laboratory measurements, and field measurements. The scope of research will include sources of particles and gaseous precursors; transport of particles and gaseous precursors on local to regional and greater spatial scales; concentrations of gas-phase aerosol precursors; aerosol characterization, including optical properties, size distribution, number concentrations, humidity effects, cloud condensation nuclei properties, single particle composition, and physical and chemical characterization of carbonaceous particles; transformations, including gas-phase transformations, condensed-phase and surface transformations, gas-to-particle conversion, new particle formation, evolution of aerosol size and composition, aerosol dynamics, aerosol activation, size distribution, precipitation development, and in-cloud and below-cloud scavenging; and atmospheric radiation.

In FY 2006, DOE's Atmospheric Science Program will analyze data from its FY 2005 marine stratus field campaign in collaboration with ARM, and will conduct a major campaign in collaboration with other CCSP agencies to examine and characterize changes in aerosol composition, size distribution, light scattering coefficient, absorption coefficient, optical depth, soot-specific absorption, and radiative fluxes at the surface in a large megacity plume. Results from these campaigns will be utilized to develop or improve detailed models of aerosol processes required by the climate modeling community. These activities support *CCSP Strategic Plan* Goals 2 and 3, and address Questions 3.1 and 3.2.

DOE's carbon cycle research will continue to improve understanding of the role and importance of terrestrial and marine ecosystems in the global carbon cycle. The research in FY 2006 will address the research questions and elements described in Chapter 7 of the *CCSP Strategic Plan*. DOE will continue its contributions to the North American Carbon Program (NACP) through the support of

experimental field studies, observations, and modeling of the terrestrial carbon cycle. Major commitments in FY 2006 include continued support for a variety of experimental studies, syntheses of some of the carbon cycle research results, and support of new studies to better understand the carbon impacts of climate-related effects on ecosystems. These efforts will include the development of an integrated framework for using AmeriFlux measurements and ecosystem models to understand terrestrial carbon cycling processes. It will yield information on ecosystem states and carbon sinks in real-time, and will be an effective tool for investigating fundamental ecological processes that are difficult to observe directly. DOE will also support 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 at the regional scale, focusing on the Southern Great Plains of the United States. Predicted temporally and spatially resolved gross and net carbon dioxide fluxes will be made available to researchers to help evaluate NACP-related results for regional carbon dioxide exchange, climate, and land use. DOE will also support research to incorporate biogeochemical and physiological responses and feedbacks associated with climate change in terrestrial ecosystem models and to link the ecosystem models with climate simulation models.

In ocean carbon cycle research, DOE will continue to enhance the understanding, in mechanistic terms, of the biological controls on net carbon dioxide uptake by the ocean (from the atmosphere). In FY 2006, the ocean science program will place an emphasis on understanding what the ecological and biogeochemical effects have been of the net uptake of carbon dioxide by the ocean (and related chemical changes in seawater) during the past 2 centuries, and what ecological and biogeochemical effects may result from further net carbon dioxide uptake during the coming decades. The program will continue to take advantage of the availability of data on newly sequenced diatom and marine bacterial genomes and will incorporate findings on microbially mediated transformations of carbon and nitrogen into models of the ocean carbon cycle.

Ecological Processes

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 the Free-Air CO_2 Enrichment (FACE) experimental facilities for study of the response of terrestrial ecosystems to elevated atmospheric concentrations of carbon dioxide and/or other trace gases such as ozone. The goal is to understand, and be able to predict, effects of environmental change and variability on the structure and functioning of terrestrial ecosystems. The research focuses on the physiology, growth, and reproduction of plants and microbes; nutrient and water cycling in ecosystems; plant community dynamics; plant-microbe interactions; and acclimation and adaptation of plants, microbes, and whole ecosystems to environmental change and variability.

Final data collection will occur in FY 2006 from the large-scale Throughfall Displacement Experiment (TDE) located in a deciduous hardwood forest in eastern Tennessee. TDE—a continuous study begun in 1993 of whole-forest responses to altered precipitation—has served as an important source of data for the development and testing of a wide range of ecosystem models. In FY 2006, the precipitation manipulations will be ended and extensive characterization of the effects of 13 years of chronic changes in the precipitation inputs to the forest ecosystem will be completed. An ongoing synthesis of existing data, model projections, and conceptual hypotheses of the interactions and feedbacks between terrestrial ecosystems and the climate system is expected to be completed in FY 2006. The synthesis will draw on

output from workshops, reviews of existing scientific literature, and new model calculations to provide an initial definition of the requirements for ecosystem observations needed to quantify ecological feedbacks to climate and atmospheric composition. The definitions will be directed in part at enhancing the use of existing observing systems, but will also consider needs for the development of new observing capabilities. The activities to be completed in FY 2006 will focus on the western United States, but are expected to provide a solid scientific base for similar activities directed at other regions.

Experimental research will also be continued in FY 2006, including field manipulations of temperature, precipitation, carbon dioxide concentration, and/or enhanced atmospheric nitrogen deposition in a boreal forest, arid shrubland, temperate old field grassland undergoing succession, and a temperate deciduous forest. Such experiments will provide the data and information needed to evaluate (test) the ability of ecological models to realistically predict effects of environmental change and variability on terrestrial ecosystems; such models form the basis of most assessments of potential effects of environmental change on ecosystems. The research initiative implemented in FY 2004 dealing with "scaling" in ecological systems will also be continued in FY 2006. This initiative will continue to examine how quantitative information obtained at the level of macromolecules (e.g., genes and enzymes) can be used to understand and predict how processes and states of whole terrestrial ecosystems would be affected both directly and indirectly by natural and human-induced environmental changes, such as climatic changes caused by energy production.

Human Dimensions

The DOE human dimensions program will continue its support of fundamental research to develop and improve data, models, and methods for use by others to analyze and assess the economic, social, and environmental implications of climate change and of various potential policy options for mitigating or adapting to climate change. In FY 2006, research will continue on climate change technology innovation and diffusion, with particular emphasis on understanding forces that will assist the prediction of the penetration of new technologies to non-Organisation for Economic Cooperation and Development (OECD) countries such as China. Projections of energy demand and associated greenhouse gas emissions will be improved by analyzing demographic variables. The research is using three case studies: the United States, China, and Indonesia. The emphasis will continue to be on household composition, using survey data to estimate relationships with energy use. The objective is to improve projections of energy demand in integrated assessment models by taking into account variations in energy use across household types. Ongoing investigations of factors that have affected the adoption in the past of technologies for controlling nitrous oxide and sulfur emissions from power plants in the United States will provide new information to help infer future adoption of new carbon emission technologies. DOE's human dimensions research in FY 2006 will also include analysis and application of explicit models of methane and other non-CO_2 greenhouse gas emissions. This will result in revised supply curves and improved estimates of costs associated with emission reductions in one or more of the integrated assessment models used to assess the economic costs and benefits of alternative climate change technology options for reducing greenhouse gas emissions.

DOE will also continue support of its Global Change Education program in FY 2006, 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 and ocean 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 research and development, focusing on energy-efficiency enhancements; low-GHG-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.