DEPARTMENT OF ENERGY

Principal Areas of Focus

Research supported by the Department of Energy (DOE) Office of Science focuses on the effects of energy production and use on the global climate system. The research seeks to understand the regional and global 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 2009

DOE will enhance and 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 effects on climate of human-induced forcing due especially to energy-related emissions and the potential consequences of human-induced climate change.

Climate Change Modeling

DOE will enhance climate modeling research 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 and that simulate regional climate variability and change with greater fidelity. This effort will be closely coordinated with the DOE-wide Scientific Discovery through Advanced Computing (SciDAC) for Climate Change Research activities and will enhance partnerships with the Office of Science's Advanced Scientific Computing Research program. The focus will be on incorporation and testing of various aerosol schemes, convection schemes, ice sheets, and land-surface schemes in coupled models, and evaluation using innovative metrics that span a variety of climate time scales, specifically:

- Testing of newly developed convection schemes, cloud parameterization schemes, and global cloud-resolving models against observations, with emphasis on testing cloud-aerosol-radiation parameterization schemes in GCMs
- Characterizing aerosol-climate interactions, including testing and improving aerosol parameterization schemes in atmospheric GCMs
- Exploring decadal predictability of the climate system, and understanding cryospheric processes and their role in the climate system
- Understanding climate extremes in a changing climate
- Developing metrics for evaluation of climate models, including model diagnostics and intercomparison
- Developing new metrics for ocean model evaluation and diagnostics
- Developing and employing enabling technologies for climate model simulation dissemination.

Climate change information is being increasingly sought for impact studies and national and international assessments. These activities are at the interface of process research and global climate modeling, and are expected to accelerate process representation in coupled Earth system models for climate change projections. The DOE leadership class computational facilities now provide computing resources for models to be run at resolutions at which complex issues of data archival, management, and dissemination need to be addressed. DOE will develop such tools and capability.

DOE will continue projects initiated in FY 2008 on the topic of abrupt climate change. Also DOE's SciDAC for Climate Change Research will continue partnerships with the Advanced Scientific Computing Research program, including work towards the creation of a first-generation Earth System Model based on the Community Climate System Model which treats the coupling between the physical, chemical, and biogeochemical processes in the climate system. The model will include comprehensive treatments of the processes governing well-mixed greenhouse gases, natural and anthropogenic aerosols, the aerosol indirect effect, and tropospheric ozone for climate change studies. Research will develop and test a global cloud-resolving model using a geodesic grid, with grid-cell spacing of approximately 3 km, capable of simulating the circulation associated with large convective clouds.

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 2009 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. In FY 2009, ARM will complete the deployment of the ARM Mobile Facility (AMF) to China and will begin developing a second AMF for deployment in FY 2010. 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. In FY 2009, 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), the Convective and Orographically Induced Precipitation Study (COPS), the aerosol study in China, and the Cloud and Land Surface Interaction Campaign (CLASIC) will give scientists ample opportunities to validate and improve the representation of radiation-cloud-aerosol processes in climate models.

DOE's Atmospheric Science Program (ASP) will continue research in FY 2009 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 2009, ASP will participate in a major collaborative interagency field campaign (VOCALS) aimed at measuring interactions of aerosols with clouds in a region that is affected 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 Cumulis Humilis Aerosol Processing Study (CHAPS) campaign, that examined interactions of aerosols with fair-weather cumulus clouds.

DOE's Terrestrial Carbon Processes (TCP) 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 carbon dioxide (CO_2) exchange with ecosystems and that affect the rate of atmospheric increase and

climate forcing by this greenhouse gas. Research in FY 2009 will address the questions and elements described in Chapter 7 of the *Strategic Plan for the Climate Change Science Program*. 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. Research will continue to focus on the AmeriFlux network of observations, experiments, modeling, and syntheses. Temporal and spatial observations of gross and net CO_2 fluxes in several mid-latitude ecosystems in North America, and real-time information on ecosystem carbon states and sinks in these systems, will continue to be made available to researchers who 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 CO_2 fluxes for different regions of the United States. As part of joint carbon cycle-climate change research to improve simulation models, DOE will provide information on biogeochemical and physiological responses and terrestrial ecosystem feedbacks related to climate change in several mid-latitude ecosystems of North America. 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.

Climate Change Response

In FY 2009, DOE continues to sponsor experimental studies of the potential effects of warming, and changes in precipitation, on multiple terrestrial ecosystems. The new scientific data and understanding obtained by this research will facilitate informed decisionmaking about the means of producing the energy needed by society. It will do this by defining relationships between climatic changes that might be caused by energy production and the potential effects of those changes on the health of terrestrial ecosystems, and the organisms that they contain.

The primary focus in FY 2009 will be experimental studies of the potential effects of warming on the abundance and geographic distribution of plant and animal species in several ecosystem types. The experiments will be conducted to fill specific critical knowledge gaps. In particular, experiments will determine linkages between warming and the possibility of species migrations, the expansion of species into areas that are presently too cool for their success, and the decline of species or ecosystems presently at the warm edge of their ranges. Field experiments will be conducted in high-elevation forests and meadows associated with the alpine tree line, the transition zone (ecotone) between temperate and boreal forests, and western shrubland. In addition to field experiments, laboratory experiments will determine relationships between warming and the success of plants and animals in model ecosystems. Laboratory studies will focus on key testable hypotheses about ecological effects of warming.

DOE will continue to provide core support for operation of the world's largest long-term field study of the potential effects of changes in atmospheric composition caused by energy production on a terrestrial ecosystem. That experiment (in central Wisconsin) is enriching the atmosphere within forest communities with CO_2 and ozone (O_3) concentrations that are anticipated to occur within 50 years. The experiment is documenting direct and indirect effects of elevated CO_2 and/or O_3 on three tree species, soil microorganisms, and pests that feed on trees.

The 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. 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. Consistent with recommendations by the Biological and Environmental Research Advisory Committee, the research will undergo a transformation and will shift considerable attention to the challenge of representing climate change impacts and adaptations within integrated assessment models. Development of non-monetary valuation and visualization methods and tools will be an important dimension of this new work. Additionally, DOE will explore the application of more advanced computational platforms reflecting the need for tighter coupling between what are presently reduced-form models and the rich detail and reduced uncertainty of underlying biogeophysical models.

DOE will also continue support of its Global Change Education Program in FY 2009, including support of undergraduate and graduate students through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREFs).

Related Research

DOE plays a major role in carbon sequestration research to reduce atmospheric concentrations of energy-related greenhouse gases, especially CO_2, 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 CO_2 in terrestrial systems, and assessing the potential environmental consequences and ancillary benefits of that enhanced sequestration. It also includes research to develop biological 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 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 which will help reduce greenhouse gas emissions.