CLIMATE CHANGE SCIENCE PROGRAM

Climate has a pervasive effect on the U.S. through its impact on the environment, natural resources, and the economy. To respond to the challenge of understanding climate and climate variability, the Climate Change Science Program (CCSP) was established in 2002 (www.climatescience.gov) as a follow-on to the U.S. Global Change Research Program (USGCRP). It is providing the Nation and the world with the science-based knowledge to predict change, manage risk, and take advantage of opportunities resulting from climate change and climate variability. Research conducted through CCSP builds on the scientific advances of the last few decades and deepens our understanding of how the interplay between natural factors and human activities affects the climate system. The CCSP engages thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and development of products for decision-makers. NSF provides support for a broad range of fundamental research activities that provide a sound scientific basis for decisions in mission-oriented agencies and the Nation at large.

The Earth's climate is determined by highly complex interactions between and among the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere. NSF programs address these components by investing in fundamental discovery, utilizing the full range of intellectual resources of the scientific community; research infrastructure that provides advanced capabilities; and innovative educational activities. As a key participating agency in the CCSP, NSF encourages interdisciplinary activities and focuses particularly on Earth system processes and the consequences of change. High priorities for the agency include data acquisition and information management activities necessary for global change research; the enhancement of models designed to improve our understanding of Earth system processes and the feedbacks that link ecosystems and the physical climate; the development of new, innovative Earth observing instruments and platforms; and the development of advanced analytic research methods. NSF also supports fundamental research on the general processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to varying environmental conditions. Through its investment, NSF contributes to CCSP by providing a comprehensive scientific foundation for many of the synthesis and analysis products identified in the CCSP Strategic Plan.

Climate Change Science Program Funding

(Dollars in Millions)

	FY 2008 Actual	FY 2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request
Biological Sciences	$15.10	$15.10	$20.00	$46.00
Engineering	1.00	1.00	-	1.00
Geosciences	157.72	163.00	25.00	209.00
Mathematical and Physical Sciences	6.90	6.69	2.67	7.13
Social, Behavioral and Economic Sciences	15.48	15.48	3.00	18.48
Office of Polar Programs	10.50	18.30	44.79	18.30
Total, Climate Change Science Program	$206.70	$219.57	$95.46	$299.91

Totals may not add due to rounding.

FY 2010 Areas of Emphasis

NSF's FY 2010 investment in CCSP increases by $80.34 million, or 36.6 percent, over the FY 2009 Current Plan level of $219.57 million. The Directorates for Biological Sciences and Geosciences together contribute the largest portion of this increase, totaling $76.90 million. Specific foci include:

- Supporting a broad research portfolio in carbon cycling, biodiversity, and ecological systems including major themes such as abrupt environmental changes; balancing the carbon budget; water, ice, and ecosystems; and the impact of ocean acidification; expanding the Nation's workforce trained to address complex environmental challenges; and strengthening computing infrastructure;
- Enhancing scalability of climate and ecosystem models to move climate modeling from the global to the regional scale; move ecological modeling from the local to the regional scale; and improve predictability at multiple scales to inform decision makers; and
- Improving, upgrading and deploying critical environmental observing platforms and systems.

The overarching themes of the CCSP program in FY 2010 are as follows:

Atmospheric Composition – NSF programs in tropospheric and stratospheric chemistry will continue in FY 2010 to address the composition of the atmosphere and its relation to climate variability and change, and linkages between the atmosphere and the biosphere, land surface, oceans, and cryosphere. Studies of the transport and transformation of gaseous constituents and aerosols provide insights into the radiative and cloud nucleating properties of the atmosphere. Greenhouse gases are particularly important since they are the principal absorbers and re-radiators of heat. Results of these studies serve as important inputs for the assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

Climate Variability and Change – In FY 2010, NSF programs will continue to emphasize climate variability and change across temporal and spatial scales, supporting observational campaigns and numerous analytical and modeling activities. These activities will improve parameterizations of unresolved dynamics and address biases in global climate models. A newer focus is on changes in the Atlantic Meridional Overturning Circulation and its interactions with the atmosphere to improve understanding of the processes and explore possible future changes, particularly those that may happen abruptly. The Community Climate System Model will continue to improve through incorporation of small-scale ocean processes, aerosol radiative forcing, stratospheric dynamics, interactive chemistry and biogeochemical cycles. Coupled climate model studies on decadal predictability at regional scales will be initiated and will include exploratory research on initialized climate modeling. Analyses of model output will focus on extreme climate events, such as hurricanes, droughts, and major ecological disturbances, in order to determine the mechanisms responsible and to evaluate their representation in models. Studies of paleoclimatology will continue to be supported as a means to provide baseline data on natural climate variability from the past and from key climatic regions. These studies improve our understanding of the natural variability of the climate system and in particular will enable reconstructions and evaluations of past environmental change as inputs for model validations.

The Global Water Cycle – NSF supports research to understand all aspects of the global water cycle. Relevant programs will continue to explore ways to utilize more effectively the wide range of hydrologic data types – continuous and discrete information from a variety of platforms – for research purposes. A community-initiated Hydrologic Information System, that can provide data access and analysis tools, continues to expand, serving both research and operational communities. Data from process studies will be used to refine models through parameterizations of sub-grid processes, particularly the fluxes of water through the Earth system. High resolution cloud system models are being refined to address the persistent problems of moist convection and cloud processes – two of the more challenging and uncertain components in climate change calculations. NSF will expand capabilities at its Critical Zone Observatories which are devoted to studying integration and coupling of Earth surface processes as mediated by the presence and flux of fresh water. The Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA) Science and Technology Center, working with regional stakeholders, is translating research advances into useful products and addressing uncertainty.

Land-Use and Land-Cover Change – Several NSF programs continue to address key aspects of land-use and land-cover change through studies in ecological rates of change and related aspects of biodiversity, Arctic systems, temporal variability, biophysical feedbacks to the climate system, water and energy influences on vegetative systems, and diverse human influences on land use.

Global Carbon Cycle – NSF provides support for a wide variety of carbon cycle research activities, from the underlying biological and geophysical processes to critical long-running oceanic time series stations and the Keeling CO_2 record as well as planning and data management. FY 2010 investigations will continue to examine a wide range of topics in terrestrial and marine ecosystems and their relations to the carbon cycle. Research in terrestrial settings will explore, for example, carbon storage, delivery of carbon by rivers, carbon fluxes from wetlands and high-latitude soils, the role of microbial processes, and submarine groundwater discharge in the oceans, ocean acidification and remineralization in mesopelagic zones. Studies on the role of ocean acidification and the capacity of the oceans to absorb carbon will be highlighted, as will research on the coupling of nitrogen and carbon cycles - both are critical to improvement of ocean and global carbon models. Carbon cycle studies will integrate observational data into models to provide insights for understanding key aspects of the global carbon cycle and feedbacks on the climate system and on strategies to investigate and adapt to climate change through CO_2 sequestration.

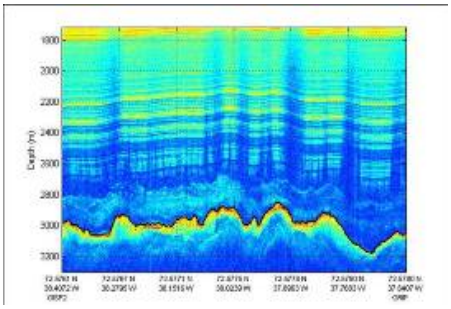
Ecosystems – Several NSF programs address terrestrial and marine ecosystems through observational, experimental, modeling, and laboratory studies. The Long Term Ecological Research (LTER) Program supports the collection of time-series data on key ecosystem processes and funds research on the drivers of ecosystem change in terrestrial and marine systems. The Global Ocean Ecosystem Dynamics program and follow-on activities will continue studies on the impact of global ocean changes on marine ecosystems through specific syntheses focused on the North Atlantic, the North Pacific and the Southern Ocean. Research will continue to focus on understanding the impact of increasing carbon dioxide on ocean pH levels (ocean acidification) and the impacts on marine organisms, ecosystems and chemistry from tropical coral reefs to polar regions.

Human Contributions and Responses – NSF supports basic research on the processes through which people (individually, in groups, or through organizations) interact with natural environmental systems. FY 2010 funding supports projects that focus on decision-making under uncertainty associated with climate change. These projects are expected to produce new knowledge and tools that should facilitate improved decision-making by various stakeholder groups trying to deal with uncertainties associated with future climate variability and change. In addition, climate studies will be a major theme in NSF's cross directorate program, Dynamics of Coupled Human and Natural Systems, which examines the complex interactions and feedbacks between these systems.

Recent Research Highlights

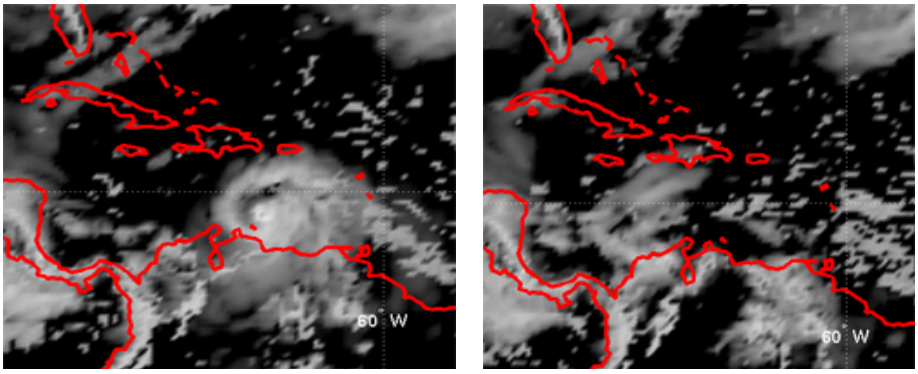
► **New Ways to Image Ice Sheets:** NSF-supported researchers at the Center for Remote Sensing of Ice Sheets (CReSIS) have been developing new ways to image the base of the polar ice sheets. CReSIS is conducting multidisciplinary research that will result in technology, new data sets, and models necessary to achieve a better understanding of the mass balance of the Antarctic and Greenland ice sheets and their contributions to sea-level rise. The center is developing several sensors (radar and seismic) and platforms (UAVs) that will provide long-term benefits to the polar community as enabling technologies for various other investigations. The sensors will also have wide applications outside of the polar community. One of these advanced sensors is a synthetic aperture radar that can sound ice and map layers with fine resolution. It can also image the ice-bed interface and has produced the first successful demonstration of imaging through 3-km-thick ice. This sensor has the potential to revolutionize the study of ice sheets. This work is jointly supported by the Office of Integrative Activities and the Office of Polar Programs (both Arctic and Antarctic sections).

Collecting Data in Greenland. *Credit: CReSIS University of Kansas.*



Internal Layers in the Greenland Ice Sheet. *Credit: CReSIS University of Kansas.*

► **Innovative Satellite System Improves Weather Forecasts, Provides Climate Data:** A revolutionary system of six microsatellites is significantly improving weather forecasts and monitoring climate change with unprecedented accuracy. The Constellation Observing System for Meteorology, Ionosphere, and Climate is a joint collaboration between the United States and Taiwan, based on a design provided by the University Corporation for Atmospheric Research. The system's unique global coverage provides unprecedented information on the lower stratosphere. Measurements from the system have led to significant improvements in our ability to predict and understand atmospheric phenomena, such as hurricanes and other severe weather hazards, by providing extremely accurate data with better coverage in time and space than were previously available. The system also demonstrates pioneering technology in its use of GPS signals for atmospheric measurements.



These images show how well a computer model was able to simulate the early development of Hurricane Ernesto in the eastern Caribbean. Each image shows a 66-hour forecast of cloud-water concentration (resembling a satellite photo). The forecasts are valid for 8:00 p.m. AST on August 25, 2006. In the first image, the model's starting-point conditions included 15 COSMIC profiles of atmospheric conditions in and near the Caribbean. In the second image, the profiles were not included, and the model was unable to show Ernesto's formation. *Credit: Yongsheng Chen, NCAR.*