

# Our Changing Planet

## The U.S. Global Change Research Program for Fiscal Year 2011

A Report by the U.S. Global Change Research Program  
and the Subcommittee on Global Change Research

A Supplement to the President's Budget for Fiscal Year 2011



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This document describes the U.S. Global Change Research Program (USGCRP) for FY 2011. It provides a summary of the achievements of the program, an analysis of the progress made, and budgetary information. It thereby responds to the annual reporting requirements of the U.S. Global Change Research Act of 1990 (Section 102, P. L. 101-606). It does not express any regulatory policies of the United States or any of its agencies, or make any findings of fact that could serve as predicates for regulatory action. Agencies must comply with required statutory and regulatory processes before they could rely on any statements in this document or by the USGCRP as a basis for regulatory action.

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January 2011,

Members of Congress:

On behalf of the National Science and Technology Council, I am transmitting a copy of *Our Changing Planet: The U.S. Global Change Research Program for Fiscal Year 2011*. The report describes the activities and plans of the U.S. Global Change Research Program (USGCRP) established under the Global Change Research Act (GCRA) of 1990. The USGCRP coordinates and integrates scientific research on climate and global change and is supported by 13 participating departments and agencies of the U.S. government. This Fiscal Year 2011 edition of *Our Changing Planet* highlights recent advances and progress made by participating agencies and includes budget information on each agency's contribution.

This report describes a program in transition. In accordance with the GCRA, the USGCRP agencies requested guidance from the National Research Council on how to best meet the changing needs of the nation to understand climate change and respond to its impacts, and the NRC responded with a 2009 report entitled "Restructuring Federal Climate Research to Meet the Challenges of Climate Change". In accord with that report's recommendations, the USGCRP is undergoing a strategic realignment that will ensure that the science produced is maximally useful for decision makers at all scales.

As described in the new edition of *Our Changing Planet*, the program going forward will place greater emphasis on impacts, vulnerabilities, and on understanding the options for adapting to the changing climate. The program will also continue its long-standing support for activities that contribute to a better understanding of the Earth system, including observations, research, and predictive modeling. All of these focuses will be reflected in the USGCRP's new strategic plan and its National Climate Assessment.

The USGCRP is committed to its mission to build a knowledge base that informs human responses to global change through coordinated and integrated federal programs of research, education, communication, and decision support. I appreciate the close cooperation of the participating agencies, and I look forward to working with the Congress in the continued development and implementation of this essential national program.

Sincerely,



John P. Holdren  
Director, Office of Science and Technology Policy  
Assistant to the President for Science and Technology





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**THE U.S. GLOBAL CHANGE RESEARCH PROGRAM  
FOR FISCAL YEAR 2011**



**OUR  
CHANGING PLANET**



# PROGRAM OVERVIEW



The U.S. Global Change Research Program (USGCRP) brings together 13 agencies into a single interagency program.<sup>1</sup> The program is currently in a period of transition. A strategic planning process has begun that will restructure the program to improve research for decisionmaking and to better meet the needs of the Nation.

Growing out of interagency activities and planning that began in 1988-1989, creation of the USGCRP energized cooperative interagency activities, with each agency bringing its strength to the collaborative effort. In 1990, the USGCRP received congressional support under the Global Change Research Act (GCRA, P.L. 101-606), which called for “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”<sup>2</sup> In 2001, President Bush established the Climate Change Research Initiative (CCRI) to investigate uncertainties and set research priorities in climate change science, aiming to fill gaps in understanding within a few years.<sup>3</sup> In the following year, it was announced that the USGCRP and CCRI together would become the Climate Change Science Program (CCSP). The USGCRP label remained attached to many of the program’s activities. Now, consistent with the statutory language of the GCRA, the whole effort continues to move forward in the Obama Administration as the USGCRP.

In June 2009, the USGCRP released a report entitled *Global Climate Change Impacts in the United States*. The report summarized the science and impacts of climate change in the United States, now and in the future, and included results not available during the preparation of previous major national and global assessments. The report was produced by a consortium of experts from the 13 USGCRP participating agencies and from several major universities and research institutes. It went through extensive reviews by the public, “blue ribbon” experts, and U.S. federal agencies.

<sup>1</sup> See [www.usgcrp.gov/](http://www.usgcrp.gov/)

<sup>2</sup> See [www.gcraio.org/gcact1990.html](http://www.gcraio.org/gcact1990.html)

<sup>3</sup> See [www.climate-science.gov/about/ccri.htm](http://www.climate-science.gov/about/ccri.htm)

The report disaggregated climate change impacts on the United States into nine regions and seven sectors. A central finding of the report was that the vast majority of climate scientists agree that global warming is unequivocal and primarily human-induced. The report also identified widespread climate-related impacts that are occurring now in the United States and are expected to increase:

## GUIDING VISION

A nation, globally engaged  
and guided by science,  
meeting the challenges of  
climate and global change

- Climate change is expected to stress water resources. Water supply and demand is already altered and will continue to change how, when, and where events causing more significant stress will occur. Water resource management processes and infrastructure must adapt to new rates and intensities of water supply and demand events. Dry regions are generally projected to become drier and wet areas wetter. The intensity of both droughts and floods will further stress systems built on the assumption of little change.
- Crop and livestock production increasingly will be challenged in a warmer climate. Each plant variety has an optimal temperature for vegetative growth, with growth dropping off as temperatures increase or decrease. Similarly, a plant will produce seed within a range of temperatures; outside of this range, the plant will not reproduce. For example, corn fails to reproduce at temperatures above 35°C (95°F) and soybean will fail to reproduce at temperatures above 39°C (102°F).

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- Risks to human health will increase. These will include harmful health impacts related to heat stress, waterborne diseases, poor air quality, and diseases transmitted by insects and rodents.
- Climate change will interact with many other social and environmental stresses to create larger impacts than would any one of these stresses alone. Heat-advisory days also generate air-quality warnings because higher air temperatures result in greater concentrations of ground-level ozone. In addition, energy production is likely to be constrained by rising temperatures and limited water supplies in many regions while demand continues to increase.

The report concludes with the finding that the future climate and its resulting impacts on society depend on choices made today. Even if societies substantially reduce their emissions of greenhouse gases, some changes are unavoidable due to millennium-scale processes in the atmosphere and oceans. Nonetheless, the choices that we make today about mitigation will affect both the adaptation choices we voluntarily make now when preparing for the future and the choices we may be forced to make in the future. Careful planning and assessment of climate change impacts will be important for effective mitigation and adaptation policies.

The USGCRP continues to support a variety of research activities to gain a more detailed predictive understanding of climate change. Also, the program is undergoing a period of restructuring and transition to enable better response to the impacts already identified and to reflect the changing needs of society. Increased emphasis is being placed on bridging the significant gaps between estimating how much climate may change and the effects these changes may have on society, including ecosystem services, water and energy resources, natural resource utilization, human health, and societal well-being. The USGCRP is making a strong commitment to providing information that will better inform decisions across various scales and sectors in order to reduce vulnerabilities and improve resilience to climate variability and change. This change represents a dramatic increase in the scope of the USGCRP because of the magnitude of the effort required to address these new aspects.

Reports recently released by the National Academies' National Research Council (NRC), discussed below, provide recommendations for organizing the research and responses needed to better understand and address the challenges and opportunities of climate variability and change. More specifically, recommendations were made to restructure the USGCRP around "...the end-to-end climate change problem, from understanding causes and processes to supporting actions needed to cope with the impending societal problems of climate change." The USGCRP is committed to supporting a balanced portfolio of fundamental and application-oriented research activities, from expanded modeling efforts to studies of coupled human-natural systems and institutional resilience. Plans are being developed to boost adaptation research; to bolster the capacity to monitor change and its impacts; to produce the integrated assessments of the pace, patterns, and regional impacts of climate change that will be needed by decisionmakers; and to make climate data and information more easily accessible.

The USGCRP is directed by the Subcommittee for Global Change Research (SGCR), which falls under the National Science and Technology Council. The SGCR comprises representatives from 13 departments and agencies and is led by a Chair from one of the participating agencies (currently from the Department of Commerce, National Oceanic and Atmospheric Administration [NOAA]). In order to align the program's governance with the needs, Vice-Chairs have been identified for Strategic Planning, Integrated Observations, and Adaptation Research. Additional vice-chairs will be identified as needed. The program is supported by the USGCRP Integration and Coordination Office and conducts many of its activities through interagency working groups that plan and implement research and crosscutting activities, such as communications, decision support, and information and data concerns. The Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB) work closely with the SGCR, the Integration and Coordination Office, and the interagency working groups to establish research priorities and funding plans to ensure that the program is aligned with national priorities, reflects agency planning, and meets the requirements of the GCRA. In preparation for the FY 2011 crosscut budget, the USGCRP agencies began an interagency



## MISSION

To build a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication, and decision support

final section of this report provides an analysis of the USGCRP budget by focus area and the agencies/ departments involved.



discussion that involves more coordination and alignment of agency efforts across strategic program elements.

The 13 departments and agencies participating in the USGCRP are as follows:

- Department of Agriculture (USDA)
- Department of Commerce (DOC)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Department of Health and Human Services (HHS)
- Department of the Interior (DOI)
- Department of State (DOS)
- Department of Transportation (DOT)
- Agency for International Development (USAID)
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Science Foundation (NSF)
- Smithsonian Institution (SI)

The FY 2011 budget requests \$2.7 billion for USGCRP programs—an increase of about 24% over the FY 2010 level.<sup>4</sup> This increase reflects the expanded needs discussed above and represents a commitment by the Obama Administration to the USGCRP. The

<sup>4</sup> See page 342, *Analytical Perspectives FY 2011*, [www.whitehouse.gov/sites/default/files/omb/budget/fy2011/assets/spec.pdf](http://www.whitehouse.gov/sites/default/files/omb/budget/fy2011/assets/spec.pdf)



# ADVICE AND GUIDANCE FOR THE USGCRP



The program often has sought guidance from the NRC, as required by the GCRA, and other external sources to provide perspective for the program and to ensure that key aspects of global change research are not overlooked. The NRC report entitled *Restructuring Federal Climate Research to Meet the Challenges of Climate Change*<sup>5</sup>, provided high-level and independent advice on the program strategy and evolution. Its authors concluded that the program helps provide the scientific foundation required to address the urgent needs of society in responding to climate change, but that the future program should be broader in scope and should strive to play a key role in informing decisionmaking. This would require transforming how climate change research is organized at the Federal level and incorporated into public policy.

<sup>5</sup> NRC, 2009: *Restructuring Federal Climate Research to Meet the Challenges of Climate Change*, National Academies Press, Washington, D.C., 254 pp.

The authors identified six top priorities:

- Reorganize the program around integrated scientific-societal issues to facilitate crosscutting research focused on understanding the interactions among the climate, human, and environmental systems and on supporting societal responses to climate change.
- Establish a U.S. climate observing system, defined as including physical, biological, and social observations, to ensure that the collection of data needed to address climate change is initiated or continued.
- Develop the science base and infrastructure to support a new generation of coupled Earth system models to improve attribution and prediction of high-impact regional weather and climate, to initialize seasonal to decadal climate forecasting, and to provide predictions of impacts affecting



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adaptive capacities and vulnerabilities of environmental and human systems.

- Strengthen research on adaptation, mitigation, and vulnerability.
- Initiate a national assessment process with broad stakeholder participation to determine the risks and costs of climate change impacts on the United States and to evaluate options for responding.
- Coordinate Federal efforts to provide climate services (scientific information, tools, and forecasts) routinely to decisionmakers.

In addition to the “Restructuring” report, the USGCRP recognizes the value of the recent suite of congressionally requested NRC reports known as America’s Climate Choices. Four reports that make up America’s Climate Choices are:

- *Advancing the Science of Climate Change*, which concludes that “the nation needs a flexible, comprehensive, and integrative climate change science enterprise, one that not only contributes to our fundamental understanding of climate change but also informs and expands America’s climate choices” by emphasizing research to improve understanding of human-environment systems; research to support effective responses to climate change; and tools and approaches to improve both understanding and responses.
- *Limiting the Magnitude of Future Climate Change*, which concludes that “there is an urgent need for U.S. action to reduce greenhouse gas emissions” and gives guidance on how to do so.
- *Adapting to the Impacts of Climate Change*, which recommends the development of a national adaptation strategy that would include better attribution and assessment of climate change impacts and vulnerabilities.
- *Informing an Effective Response to Climate Change*, which provides guidance concerning the need for adaptive management; systems and services to support decisionmaking; and improvements in communication and education on climate-related issues.

A fifth, overarching report is in preparation. These reports are consistent with the previous “Restructuring” report and provide a comprehensive set of guiding principles that will serve to inform the USGCRP’s strategic planning process.

In 2009, planning for a *National Climate Adaptation Summit* was initiated in order to examine how the United States could best incorporate adaptation into the ongoing planning and implementation of climate research and climate services. The Summit took place in Washington, DC, on 25-27 May 2010. This event brought together approximately 180 invited users and providers of climate-adaptation information to examine the needs, knowledge, and roles required for effective adaptation to climate change, with a goal of informing Federal, state, regional, and local climate adaptation efforts, including the planning of the Federal Interagency Climate Change Adaptation Task Force and the USGCRP.<sup>6</sup>

The Summit provided an important venue for discussing the challenges and opportunities surrounding climate change adaptation, which is seen as increasingly necessary to complement mitigation of greenhouse gas emissions. Climate change and climate impacts are no longer a primarily Federal concern. Presentations at the Summit described creative new private sector, state, regional, and local programs that address climate challenges, many of which span the levels of government and between the public and private sectors. The Summit also highlighted a variety of new scientific tools and programs, including very high-resolution climate models, new observational networks designed to document climate change and impacts, and integrated analytical methods that draw together physical science, ecology, and social science. The outcome of the summit was a report providing information and suggestions for consideration by federal decisionmakers and other stakeholders as they continue to craft and refine strategies, programs, and policies to address climate change adaptation.<sup>7</sup> Input gained from the Summit will be used to inform adaptation activities of the USGCRP.

<sup>6</sup> See [www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf).

<sup>7</sup> Report available at [www.joss.ucar.edu/events/2010/ncas/ncas\\_report.pdf](http://www.joss.ucar.edu/events/2010/ncas/ncas_report.pdf).



- In addition to these external sources of advice and guidance, the USGCRP undertook a self-assessment exercise and included it as a part of the 2009 *Global Climate Change Impacts in the United States* report. Below is a summary of the recommendations from that report.
- *Recommendation 1: Expand our understanding of climate change impacts.* There is a clear need to increase understanding of how ecosystems, social and economic systems, human health, and infrastructure will be affected by climate change in the context of other stresses.
- *Recommendation 2: Refine ability to project climate change, including extreme events, at local scales.* One of the main messages to emerge from the past decade of synthesis and assessments is that while climate change is a global issue, it has a great deal of regional variability. There is an indisputable need to improve understanding of climate system effects at these smaller scales, because these are often the scales of decisionmaking in society.
- *Recommendation 3: Expand capacity to provide decisionmakers and the public with relevant information on climate change and its impacts.* The United States has tremendous potential to create more comprehensive measurement, archive, and data-access systems and to convey needed information that could provide great benefit to society.
- *Recommendation 4: Improve understanding of thresholds likely to lead to abrupt changes in climate or ecosystems.* Non-linear changes, especially those related to positive feedbacks, could have significant impacts on future climate, and lead to irreversible changes such as species extinction.
- *Recommendation 5: Improve understanding of the most effective ways to reduce the rate and magnitude of climate change, as well as unintended consequences of such activities.* Impacts of climate change during this century and beyond are projected to be far larger and more rapid in scenarios in which greenhouse gas concentrations continue to grow rapidly compared to scenarios in which concentrations grow more slowly. Additional research will help identify the optimal mix of mitigation options necessary to control the rate and magnitude of climate change. In addition to their intended reduction of atmospheric concentrations of greenhouse gases, mitigation options also have the potential for unintended consequences, which should be examined in future research.
- *Recommendation 6: Enhance understanding of how society can adapt to climate change.* There is currently limited knowledge about the ability of communities, regions, and sectors to adapt to future climate change. It is important to improve understanding of how to enhance society's capacity to adapt to a changing climate in the context of other environmental stresses. It is also important to carry out regular assessments of adaptation measures that address combined scenarios of future climate change, population growth, and economic development paths.





# III STRATEGIC USGCRP ELEMENTS



Based on the 2003 strategic plan, the USGCRP has organized itself around seven main research elements and a number of crosscutting activities to coordinate scientific research and the flow of information through interdisciplinary and interagency working groups. These research elements included atmospheric composition, climate variability and change, the global water cycle, land-use and land-cover change, the global carbon cycle, ecosystems, and human contributions and responses to environmental change. The program also has assembled crosscutting working groups that focused on communications, education, observations, and international research and cooperation. The working groups traditionally focused on meeting the needs of the five goals outlined in the 2003 strategic plan, including: improving knowledge of the Earth's past and present climate and environment, including its natural variability, and improving understanding of the causes of observed variability and change; improving quantification of the forces bringing about changes in the Earth's climate and related systems; reducing uncertainty in projections of how the Earth's

climate and related systems may change in the future; understanding the sensitivity and adaptability of different natural and managed ecosystems

## STRATEGIC USGCRP ELEMENTS (PRELIMINARY LIST)

- A. Integrated Observations
- B. Fundamental Research
- C. Adaptation Research
- D. End-to-end Modeling
- E. Assessment
- F. Support for Climate Services
- G. Communications, Outreach, and Education
- H. Scientific-Societal Areas of Interest
- I. USGCRP-Supported International Activities

and human systems to climate and related global changes; and exploring the uses and identifying the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

These traditional strengths of the program that support a wide variety of research activities to gain more detailed predictive understanding of climate change must be maintained. However, there remain significant gaps in going from an estimate of how much the climate may change to the effects these changes may have on ecosystem services, water resources, natural resource utilization, human health, and societal well-being. In response to recent recommendations provided by the NRC and others, the USGCRP currently is reviewing the organization of the program to determine how best to respond to the changing needs of society, such as providing information in order to reduce vulnerabilities and improve resilience to climate variability and change. For example, a recent National Research Council report recommends restructuring the USGCRP around "...the end-to-end climate change problem, from understanding causes and processes to supporting actions needed to cope with the impending societal problems of climate change."<sup>8</sup> This means supporting a balanced portfolio of fundamental and application-oriented research activities from expanded modeling efforts to studies of coupled human-natural systems and institutional resilience.

In addition, it would mean boosting adaptation research; bolstering capacity to monitor change and its impacts (including not only enhancing our monitoring networks on land and for the oceans but also strengthening our system of Earth-observation satellites); producing the sorts of integrated assessment of the pace, patterns, and regional impacts of climate change that will be needed by decision makers as input into their deliberations on the metrics and goals to be embraced for both mitigation and adaptation; and making climate data and information accessible to those who need it.

The USGCRP has taken the initial steps to review historical program elements and priorities, as well

as recent recommendations for restructuring the program. This has led to the identification of a set of strategic program elements that will be needed for realizing this "end-to-end" approach. These elements range from research to decision support and include fundamental research; integrated observations; end-to-end modeling; national climate assessment; adaptation science; support for climate services; communications, outreach, and education; scientific-societal areas of interest; and USGCRP-supported international activities. These elements are described in detail in the following sections. However, it should be noted that these elements represent a preliminary conceptualization of the future USGCRP; the strategic planning process will define the program's new direction. The culmination of this process will be a new strategic plan for the USGCRP for 2013 – 2023, as required under the GCRA.

The individual execution of the new strategic program elements, and success in meeting the USGCRP mission, will depend strongly on communication and collaboration among the proposed strategic elements. Indeed, the "end-to-end modeling" program element will strongly depend on interactions with the "integrated observations" program element for data input into models, data assimilation, model audits, and for end-to-end modeling input into the design of integrated observation networks. In turn, both elements will require frequent communications with the "fundamental research" and "adaptation research" program elements, and will feed into and draw from the "National Climate Assessment" program. This will also require coordination with sector-specific programs, such as those serving the water resources communities, the health communities, etc. These interactive needs, which apply to all proposed strategic USGCRP elements, will be met through a structured communication process.

### A. INTEGRATED OBSERVATIONS

Long-term, high-quality observations are essential for defining the current state of the Earth's system, discovering the magnitude and sources of past trends, and providing the scientific basis for future predictions of its variability. Observational capability should support determination of trends in means and changes in distributions of extremes, and cover spatial scales from global to local. The broader

<sup>8</sup> National Research Council, 2009. *Restructuring Federal Climate Research to Meet the Challenges of Climate Change*. National Academy Press, Washington DC.

U.S. governmental context for Earth observations, including those for climate, has been documented by the OSTP in its September 2010 report, *Achieving and Sustaining Earth Observations: A Preliminary Plan Based on a Strategic Assessment by the U.S. Group on Earth Observations*.

The observational system required is an integrated mix of satellite and non-satellite systems. These systems complement each other in a variety of ways—satellites provide the global coverage frequently inaccessible to surface-based measurements, while *in situ* measurements can achieve greater spatial and/or temporal resolution, as well as measure parameters inaccessible to satellites and provide information on earlier periods in Earth system history. The USGCRP agencies are leading contributors to the national and global observing system. Many of the U.S. observations important for documenting climate change are produced by operational systems not reflected in the USGCRP Budget Crosscut (see last section of this report). The determination of long-term trends and the requirement for measurement consistency place enormous burdens on the measurement systems in terms of calibration and validation, as well as the need for transparency in algorithm and instrument knowledge. In implementing its measurement programs, the United States follows wherever possible the Monitoring Principles established by the Global Climate Observing System (especially as documented in the 2010 *Update of the Implementation Plan for the Global Observing System for Climate in Support of the United Nations Framework Convention on Climate Change* (UNFCCC)).

In FY 2010, a number of important steps were taken by the Administration to improve the observing system. A major change in plans for the operational meteorological satellites was restructuring the previous National Polar Orbiting Operational Environmental Satellite System into the Joint Polar Satellite System and its DOD counterpart for the morning orbit; in addition, sea surface altimetry observations are being successfully moved from research to operations. A significant addition to USGCRP agency budgets will allow for acceleration of previously planned observations (especially those recommended by the NRC in its 2007 Decadal Survey *Earth Science and Applications from Space: National Imperatives for the Next Decade*

*and Beyond*), and several new satellite programs to provide follow-up measurements not accessible in the near term by operational programs. A multi-mission data acquisition strategy for space-based carbon measurements (especially atmospheric carbon dioxide (CO<sub>2</sub>)) was also initiated that, when combined with already implemented surface-based and airborne observations, will significantly improve our ability to document the distributions, sources, and sinks of atmospheric CO<sub>2</sub>.

The collection of all these data and their importance to global change research makes the long-term stewardship of data an essential part of the observational program. Not only is the volume of these data sets ever increasing, but they also come from a multiplicity of sources. All of these data sets must be archived and disseminated in ways to facilitate more conveniently and comprehensively their long-term use by the full range of user communities, especially by those involved in truly multidisciplinary scientific work and an increasing variety of adaptation and assessment uses.

## B. FUNDAMENTAL RESEARCH

Fundamental research directed at understanding climate change provides the foundation for all aspects of the USGCRP. This research has made enormous inroads in understanding climate change and its causes, and is beginning to develop a strong understanding of current and potential impacts that will affect human and natural systems today and in coming decades. Scientific evidence has shown that climate change is occurring, can be attributed to human activities, and poses significant risks for both human and natural systems. In addition to temperature increases, this evidence shows a broad spectrum of other climate changes, such as increases in the frequency of intense rainfall, decreases in snow cover and sea ice, more frequent and intense heat waves, rising sea levels, and widespread ocean acidification. Individually and collectively, these changes pose risks for a wide range of human and environmental systems, including freshwater resources, the coastal environment, ecosystems, agriculture, fisheries, human health, and national security, among others.

As society responds to the risks and opportunities brought on by climate change, decisionmakers will require scientific information to help inform their



actions. The scientific community must continue to conduct research that will improve understanding of the causes and consequences of climate change, and improve our understanding of the options available to limit the magnitude of climate change, adapt to impacts, and capitalize on the opportunities that may arise. In addition, the scientific community should strive to be as comprehensive, integrated, and flexible as possible to meet the evolving scientific needs of society.



A particular emphasis of our fundamental research is the study of Earth system processes, including both those that are relevant to a traditional Earth system component (atmosphere, ocean, biosphere, cryosphere, land surface, etc.), and those that couple them together. Through comprehensive observations, discoveries are made, hypotheses are tested, and quantitative models are developed that can mathematically describe the processes and their relationship to the broader Earth environment. These models also become critical components of the Earth system models described below.

To assist the government and society as a whole with understanding, mitigating, and adapting to climate change, U.S. government agencies deploy a wide range of powerful resources for research and development. Each agency has different sets of key specialists and capabilities, different networks and relationships with the external research community, and separate program and budget authorities.

As a single interagency program, the USGCRP brings together the essential capacities for research that are distributed across U.S. government agencies. Success in translating and delivering the scientific information necessary for decisionmaking relies on the coordination of programmatic and budgetary decisions of the 13 agencies that make up the USGCRP.

### C. ADAPTATION RESEARCH

There currently exists limited knowledge about the ability of communities, regions, and sectors to adapt to a changing climate. To address this shortfall, research on climate change impacts and adaptation must include complex human dimensions, such as economics, management, governance, behavior, and equity. Interdisciplinary research on adaptation that

takes into account the interconnectedness of the Earth system and the complex nature of the social, political, and economic environment in which adaptation decisions must be made would be central to this effort.

To begin to address climate change adaptation across the Federal government, in parallel and in coordination with the USGCRP, the White House Council on Environmental Quality (CEQ), the OSTP, and NOAA convened the Interagency Climate Change Adaptation Task Force. On 5 October 2009, President Obama signed the Executive Order on Federal Leadership in Environmental, Energy, and Economic Performance, which, among other things, called on this Task Force to begin developing Federal recommendations for adapting to climate change impacts both domestically and internationally. The Task Force reported back to the President on 5 October 2010 with recommendations regarding the development of a U.S. strategy for adaptation to climate change.<sup>6</sup> The report offers recommendations for how Federal policies and programs can better prepare the United States to respond to the impacts of climate change. It urges Federal agencies to make adaptation a standard part of agency planning and to make scientific information about climate change impacts accessible to public and private decisionmakers. It also recommends that the Federal Government strengthen existing efforts to help developing countries reduce their vulnerability to climate change and build strong partnerships to support state, local, and tribal adaptation. The USGCRP will continue to support efforts related to the Task Force and the implementation of recommendations contained in the report. In particular, the Science Working Group of the Task Force, which focused on addressing the challenge of translating science for decisionmakers, will continue its work under the USGCRP.

### D. END-TO-END MODELING

In order to ensure that the results of the USGCRP are of relevance to national interests, a key focus of the program is the development of an end-to-end perspective in providing information of sufficient breadth to decisionmakers. Thus, strengthening the end-to-end nature of the modeling component is a priority.

Climate models encapsulate scientists' best understanding of climate and related Earth system processes and are important tools for understanding past, present, and future climate change. Most modern climate models also include representations of the oceans, atmosphere, cryosphere, and land surface, and their interactions. Some Earth system models also simulate a range of biogeophysical processes that involve terrestrial and marine ecosystems and human activities.

Climate and Earth system models use computer-based numerical techniques to solve mathematical equations, yielding a projected evolution of the climate system. Rather than trying to predict the exact future state of the atmosphere (i.e., weather), climate models predict changes in the frequency and characteristics of weather phenomena (e.g., hurricanes, heat waves, droughts, etc.) and average seasonal weather patterns.

In order to take on the challenge of projecting impacts and vulnerability caused by climate change, we must strengthen our ability to predict climate at regional and local scales and at the decadal time scale. This information serves as the starting point for policymaking, planning and decision support models, as well as impacts, adaptation, and vulnerability studies of energy, the environment, and economic security. The results can also inform significant U.S. infrastructure decisions and investments.

Understanding the consequences of climate change, with particular attention to options for mitigation and adaptation at regional and local scales, requires that next-generation models dramatically improve their depiction of local precipitation patterns, extreme events in temperature, and wind; reduce uncertainties regarding key elements affecting climate such as aerosols and carbon fluxes; and capitalize on leadership-class computers and related cyber-infrastructure.

A substantial expansion of impact, adaptation, and vulnerability science and models is required to deliver a robust set of discrete component models in areas such as agriculture, coastal systems, energy, transportation, health, forestry, water resources, fisheries, ecosystem services, and more.

Finally, a new generation of Integrated Assessment Models (IAMs) is required that combines both the drivers and consequences of climate change within common modeling frameworks. At the center of IAMs are representations of present and projected future human activities (greenhouse gas emissions, land or water use changes, etc.) and their potential influence on the climate system. IAMs address the two-way coupling between changes in the natural climate system and human activities, including those undertaken to mitigate climate change, to adapt to climate change, or as consequences of changes in climate or other aspects of the Earth system.

These three focus areas (Earth System Modeling; Impacts, Adaptation, and Vulnerability modeling; and Integrated Assessment Modeling) need to be more tightly integrated through cooperation among communities and better coupling and interoperability across modeling frameworks. With better integration, the current disciplinary and agency boundaries will blur, resulting in an adaptive, agile U.S. modeling infrastructure. The result will be an analysis and assessment capability that can quickly respond to the challenging questions the nation faces, at multiple geographic and time scales.

## E. ASSESSMENT

Assessment has long been a mainstay of the global change community, and USGCRP research has been at the heart of U.S. contributions to assessing climate change and its impacts. Investigators funded through USGCRP programs consistently play leadership roles in international assessments such as those of the Intergovernmental Panel on Climate Change (IPCC) and the World Meteorological Organization/United Nations Environment Programme. Data and model results from USGCRP-funded research are central to these assessments. When other one-time assessments take place, USGCRP models, data, and researchers are important components. The USGCRP also historically provides the funding for one of the Technical Support Units that enables preparation of the IPCC reports—for the Fourth Assessment Report (2007) it was for Working Group I on the physical basis of climate change, and for the Fifth Assessment Report it is for Working Group II on impacts, adaptation, and vulnerability.

In addition to its contributions to international assessments, the USGCRP has a statutory requirement under the Global Change Research Act of 1990 to produce a quadrennial assessment of climate change and its impacts on the United States. The Act further requires an assessment of the impacts of global change on a variety of sectors and projections of future conditions for 25 to 100 years. Strategic planning and implementation for the current assessment is underway and the next complete report is expected in June 2013.



The vision for this National Climate Assessment incorporates recommendations from the NRC and others and will differ in multiple ways from previous U.S. climate assessment efforts. It will be more focused on evaluating the Nation's progress in adaptation and mitigation; building a long-term, consistent process for evaluation of climate-related risks and opportunities; providing information that supports decisions within regions and sectors of the United States; and evaluating the current state of scientific knowledge relative to climate impacts and trends.

A primary goal is to establish an enduring assessment capacity within the federal government that provides essential links with and is accessible to outside experts and stakeholders for use in decisionmaking. In addition to producing a report by June 2013, this new National Climate Assessment will be an ongoing process that involves stakeholders and scientists across the country. Assessment activities will result in the capacity to perform ongoing assessments of vulnerability to climate stressors, to observe and project impacts of climate change within regions and sectors, to develop consistent indicators of progress in adaptation and mitigation, and will allow for production of a set of reports and web-based products that are useful for decisionmaking at multiple levels.

Substantial recent progress has been made toward preparing the next Assessment and in establishing this assessment capacity. A preliminary outline and work plan for the next Assessment has been developed and a series of workshops are being held in 2010 and will be held in early 2011 to provide guidance on the methodologies that will be used by the Assessment effort. Beginning in January 2011, regional and sectoral networks will be mobilized

to support the initial writing and provide informed reaction to the Assessment.

### F. SUPPORT FOR CLIMATE SERVICES

Coordinated climate information and services are needed to assist decisionmaking across public and private sectors. Local planners will want information on likely changes in precipitation amount and flooding; farmers and farm cooperatives will want information on changes in season length and temperature for both their own farms and those of their local and distant competitors; coastal zone managers will want information on likely changes in sea level, storms, and estuarine temperatures; water resource managers and energy/electricity producers will want information on likely changes in snowpack and runoff and the chance of floods and drought; community health planners will want information on changes in location of freezing conditions and the frequency of extreme precipitation and heat waves; industry will want information on changes in extremes that might affect their businesses and shipping; those preparing environmental impact statements will need information on how changes in a given location affect environmental outcomes; those doing economic analyses will want information across the region, and much more.

While much work has been done to develop implementation strategies and program structures, and to evaluate the need for improved climate services, especially in individual agencies, the Administration believes that interagency coordination is essential for delivering comprehensive Federal climate services. Therefore, OSTP has established, under the National Science and Technology Council, the Roundtable on Climate Information and Services, a high-level group that will develop a common definition of climate services, examine national assets, and provide a roadmap of how the federal government can provide services in a coordinated way. The USGCRP will work with the Roundtable to provide information, data, and expertise to support these efforts.

## G. COMMUNICATIONS, OUTREACH, AND EDUCATION

Demand for scientific information to support decisions that will help understand, mitigate, and adapt to climate change will continue to grow as society responds to the challenges and opportunities brought on by climate change. In order to meet this demand, a comprehensive and coordinated effort is needed to assist in translating and providing technical information in forms that are timely, credible, and supportive of decisionmaking at various scales.

A wide variety of approaches and activities are currently being undertaken across the Federal government to communicate scientific knowledge and socioeconomic information related to climate change. A number of Federal agencies provide state and local governments, industry, nongovernmental organizations (NGOs), the general public, and other stakeholders with information about national and global climate change research and risk assessment studies, U.S. mitigation activities, and policy development. They work both independently and in partnership toward the common goal of increasing awareness and understanding.

The USGCRP is responsible for communicating credible scientific information related to climate change and its impacts to a variety of stakeholders, both nationally and globally. The USGCRP is currently developing an integrated communication, outreach, and engagement strategy to enhance coordination of Federal agency efforts and to support ongoing activities, such as the National Climate Assessment. This coordinated effort will continue to build public understanding of climate change and serve as a foundation for improved adaptation and mitigation.

The USGCRP also has the opportunity to assist formal education systems that educate the scientists, engineers, and citizens of tomorrow to understand and be able to make decisions appropriate to climate conditions in the future. By providing content and supporting research and training, USGCRP agencies can partner with professionals in education and the education industry to improve the training of teachers and students and to provide more usable material that can enhance student interest and learning.

## H. SCIENTIFIC-SOCIETAL AREAS OF INTEREST

Guidance received from the NRC and elsewhere has suggested that the USGCRP should be restructured around crosscutting, integrated, societally relevant themes to ensure that the research it supports is maximally useful to the nation. The NRC report, *Restructuring Federal Climate Research to Meet the Challenges of Climate Change*, called these “scientific-societal issues” while the America’s Climate Choices report, *Advancing the Science of Climate Change*, referred to “areas of interest to decisionmakers.” By structuring the program around these elements, the research agenda will better reflect the overarching USGCRP mission “to build a knowledge base that informs human responses to climate and global change.” Examples of scientific-societal themes from the NRC reports include sea level rise and the coastal environment; freshwater resources; ecosystems, ecosystem services, and biodiversity; agriculture and fisheries; cities and the built environment; transportation systems; energy systems; national and human security; extreme weather and disasters; and human health.

The strategic planning process will guide the USGCRP on how to address societally relevant themes, what areas most reflect the priorities of the program, and how to best integrate them into the research agenda. A pilot effort addressing human health, described below, is already underway.

*Interagency Crosscutting Group on Climate Change and Human Health Pilot.* In response to the recommendations to restructure the USGCRP around crosscutting scientific-societal themes, the USGCRP piloted a new interagency working group on climate change and human health. Established in December 2009, the Interagency Crosscutting Group on Climate Change and Human Health (CCHHG) addresses an important societally relevant area of research and also serves to inform the program’s overall strategic planning process. The CCHHG strives to increase the overall effectiveness and productivity of Federal research and development efforts in the area of climate change and health. Membership includes participants from various divisions and offices of traditional USGCRP agencies, as well as agencies not traditionally associated with the USGCRP, such as the Department of Homeland Security (DHS).



The CCHHG is charged by the USGCRP with planning, coordinating, implementing, evaluating, and reporting on Federal research and related activities that expand the scientific and technical knowledge base regarding the human health impacts of global environmental change, focusing specifically on climate variability and change. The CCHHG seeks to integrate relevant science and technology programs and capabilities through interagency, interdisciplinary, and intergovernmental collaborations that span a continuum from basic research to decisionmaking to application, with the ultimate goal of building more resilient communities. This group also serves as a pilot to inform future USGCRP efforts.

Although membership is limited to representatives of Federal agencies, the CCHHG intends to fully engage relevant stakeholders as appropriate, to inform prioritization of research needs, increase understanding of potential health impacts in various sectors, and increase coordination with on-the-ground public health applications at the regional, state, local, and tribal levels through mechanisms such as workshops and listening sessions.

### I. USGCRP-SUPPORTED INTERNATIONAL ACTIVITIES

Since climate change is a global phenomenon, U.S. activities related to climate change are necessarily linked to the global community. The USGCRP and the large community of U.S. scientists supported by or associated with it have a global reach. Activities in which the United States is involved include supporting global environmental change research programs, including those that operate under the aegis of the International Council for Science (ICSU); supporting international assessments, particularly those of the IPCC; supporting regional global change research networks; playing an active role in informal organizations that are involved with the advancement of global environmental change research; and participating in and leading international efforts to provide coordination and cooperation in Earth observations. This support includes work with the DOS at a variety of levels, but particularly with respect to the IPCC and the UNFCCC as well as bilateral arrangements in climate change science and technology. This also includes contributions to and participation in international observational efforts

such as the Group on Earth Observations (GEO) and the Global Climate Observing System (GCOS).

The international global change research programs continue to provide sound frameworks for core research projects, capacity-building programs, and regional networks. These programs include the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), and DIVERSITAS (an international biodiversity science program) that together constitute the Earth System Science Partnership (ESSP). These programs also provide a framework for regional and sectoral programs such as the Monsoon Asia Integrated Regional Study (MAIRS) and the Northern Eurasia Environmental Science Partnership Initiative (NEESPI), as well as the Global Observations of Forest Cover/Global Observations of Land Dynamics (GOFC/GOLD). The ESSP-sponsored global change SysTEM for Analysis, Research, and Training (START) provides an international framework for capacity building.

The following provides additional detail on recent activities involving international programs:

*Intergovernmental Panel on Climate Change Fifth Assessment Report.* The IPCC is an international scientific governmental body established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical, and socioeconomic information concerning climate change, its potential effects, and options for adaptation and mitigation. The IPCC periodically assesses original research on climate and related environmental change. A main activity of the IPCC is publishing special reports and periodic assessment reports on topics relevant to the implementation of the UNFCCC, an international treaty that acknowledges the possibility of harmful climate change and encourages the reduction of greenhouse gas emissions by member states. The Fifth Assessment Report (AR5) of the IPCC will be the next in a series of such assessment reports. The IPCC is open only to member states of the WMO and UNEP, and it bases its assessments on peer-reviewed, published scientific literature.

The IPCC has completed the selection of contributors to AR5. The USGCRP, in close coordination with

DOS' Office of Global Change and OSTP, coordinated the nominations process for the United States. In total, over 170 experts from the United States were chosen to contribute to AR5 across its three Working Groups (WGI focuses on the physical science basis; WGII assesses the impacts, adaptation strategies, and vulnerability related to climate change; and WGIII covers mitigation response strategies in an integrated risk and uncertainty framework). The research activities of many of these experts are supported by US agencies as part of their USGCRP investment.

*United Nations Framework Convention on Climate Change.* The UNFCCC is an international environmental treaty produced at the United Nations Conference on Environment and Development, with the objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The treaty provides for updates (called "protocols") that would set negotiated emission limits. The principal update is the Kyoto Protocol, concluded in 1997, which has become much better known than the UNFCCC itself. The 15th Conference of the Parties (COP-15) was held 7-18 December, 2009 in Copenhagen, Denmark. USGCRP participating agencies accompanied the U.S. delegation and hosted side events at the conference. The DOS' Bureau of Oceans, Environment, and Science (OES), in coordination with the Office of the Special Envoy for Climate Change (SECC) and the USGCRP, organized the U.S. Center, an unprecedented outreach initiative that provided a platform for 35,000 conference attendees to learn about U.S. climate actions. The topics highlighted the variety of U.S. climate programs and scientific research and underscored the strong actions the United States is taking to combat climate change.

The USGCRP and its participating agencies have been engaged in preparations for COP-16, which was held from 29 November to 10 December 2010, in Cancun, Mexico.

*International Civil Aviation Organization's Committee on Aviation Environmental Protection.* The Federal Aviation Administration (FAA), as an arm of DOT, participates in the work program of the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection "to develop and assess standards and recommended practices

concerning aircraft/engine emissions (including oxides of nitrogen, carbon dioxide, and particulate matter emissions)." For example, FAA is conducting a study to identify and assess metrics for CO<sub>2</sub> emissions from aircraft that may potentially be used to set standards for the certification of new aircraft (including the benchmarking of existing aircraft) and to monitor the operational performance of the commercial aircraft fleet. The results of the study will be provided within the work program of ICAO's Committee on Aviation Environmental Protection for considering development of the aircraft CO<sub>2</sub> standard by the end of 2012.

*GEO-VI Plenary.* Over 300 representatives of 45 governments and 34 international organizations participated in the Sixth Plenary Session of the Group on Earth Observations (GEO-VI), hosted by the United States in Washington, DC on 17-18 November 2009. A summary report of national activities was provided, including announcements that the United States will reposition the GOES-12 satellite to provide coverage of South America (replacing the GOES-10 satellite) and, as part of a new initiative, monitor the polar ice sheets of Greenland and Antarctica with airborne remote sensing and *in situ* monitoring.

The delegates discussed a number of priority areas for Earth observations in 2010, including forest monitoring for carbon, global carbon monitoring and analysis, global biodiversity observations through the emerging GEO Biodiversity Observation Network (GEOBON), and an initiative to establish a "2010 Baseline" for key Earth observation data sets, including the need for a land imaging data set. The delegates also took a number of critical actions to advance the global sharing and exchange of Earth observations data through the implementation of Global Earth Observation System of Systems (GEOSS), including facilitating the integration of global Earth observations data into a common information architecture of portals, clearinghouses, and registries through the GEOSS Common Infrastructure (GCI) and the creation of a GCI Team.



# IV USGCRP RECENT PROGRESS AND FY 2011 PLANS



The strategic program elements in the previous section represent a preliminary concept of some of the pieces that will comprise the future USGCRP and some of the progress made has already been described. The remainder of this report was developed by compiling information based on the following six focus areas:

- Improving our knowledge of Earth's past and present climate
- Improving our understanding of natural and human forces of climate change
- Improving our capability to model and predict future conditions and impacts
- Assessing the Nation's vulnerability to current and anticipated impacts of climate change
- Providing climate information and decision support tools
- Climate change communication and education

These focus areas represent some of the traditional goals of the USGCRP, and work done in these areas will be critical to the future of the program.

In addition, they will form an important basis for progress under a new strategic framework that incorporates the elements listed in the previous section. For example, the section on "Assessing the Nation's vulnerability" discusses activities that will support the new National Climate Assessment as well as efforts toward adaptation. Activities listed under "Providing climate information and decision support tools" may help the program provide support for climate services. Progress under "Improving our knowledge" and "Improving our understanding" will underpin any future developments in integrated observations and fundamental research. While the program is undergoing a strategic realignment, it has a lot of competencies, progress, and plans to build on.

## Improving our knowledge of Earth's past and present climate

### RECENT PROGRESS AND ACTIVITY

*Climate Reanalysis.* Reanalyses serve as vitally important climate records for both research and

applications. Atmospheric reanalyses are obtained by synthesizing both *in situ* and remotely sensed observations together within a model to provide a complete, temporally continuous, objective record of how the atmosphere has evolved over extended periods of time. Reanalyses typically extend over several decades or longer, and cover the entire globe from Earth's surface to well above the stratosphere. The USGCRP has placed a high priority on improving the quality and spatial resolution of reanalyses, with emphasis on decision- and application-relevant variables, extending the length of reanalysis records, and broadening future reanalyses to include other components of the Earth system (ocean, cryosphere, and land-surface hydrology). Remarkable progress has been made in all three of these areas over the past few years through research supported under the USGCRP. A NASA-led reanalysis project called the Modern Era Retrospective-Analysis for Research and Applications (MERRA) has constructed a high-quality reanalysis at six-hour intervals extending from 1979 to the present.<sup>8</sup> The MERRA reanalysis particularly emphasizes the use of satellite observations and improving the quality of water cycle observations. A second effort, supported by NOAA and DOE, demonstrated the feasibility of extending atmospheric reanalysis records back in time using only surface observations. While prior reanalysis efforts only extended back to 1948, coinciding with the modern radiosonde era, the 20th-century reanalysis project now provides six-hourly atmospheric maps from January 1891 to the present. This data set should enable a vast range of new research, such as on the causes of the 1930s Dust Bowl drought and other outstanding weather and climate events of the late 19th and early 20th centuries. In a third major effort, NOAA completed the first-ever reanalysis with a coupled climate model, called the Coupled Forecast System Reanalysis and Reforecast (CFSRR) project. This reanalysis, which extends back to 1979, includes ocean, land surface, and sea ice components in addition to the atmosphere. This is a major step toward what has been a long-term USGCRP priority to develop an ongoing analysis of how the full Earth system is changing over time, which USGCRP has termed Integrated Earth System Analysis.

*Fidelity of Regional Climate Simulations.* As the need for higher resolution climate information for sound decisionmaking increases, USGCRP agencies are

improving the fidelity of climate change projections at regional scales. A current multiagency effort, the North American Regional Climate Change Assessment Program (NARCCAP) has the following goals: 1) to provide multiple high-resolution (50 km) climate change scenarios over North America for use by the climate impacts and adaptation communities, and 2) to explore the uncertainties in regional model and global model regional projections of future climate over North America.<sup>9</sup> By the end of FY 2010, all simulations will be completed and model output made available to researchers and users. The main probabilistic models of uncertainty developed by NARCCAP will also be completed and made available.

*Terrestrial Carbon.* Accurately characterizing and monitoring the carbon cycle by understanding the carbon stocks and fluxes is a requirement of scientists, managers, and policymakers so that they can understand how to sustain and enhance carbon storage capacity, and important to researchers in order that carbon cycle forcing and feedbacks can be represented in Earth system models to more accurately project the results of future climate change. Numerous advances have been made in better characterizing carbon pools and fluxes from different data platforms, and efforts are underway to improve coordination of these data: (1) NASA, NOAA, and the U.S. Geological Survey (USGS), through their participation in the Committee on Earth Observing Satellites (CEOS) working groups, and particularly the Land Surface Imaging Constellation, have been supporting the satellite and field measurement needs for the GEO Forest Carbon Tracking task; (2) in an effort lead by USDA's Forest Service, in conjunction with the North American Carbon Program, a comprehensive handbook has brought together the field methods and measurements used in forest carbon inventory and monitoring; and (3) the multiagency Ameriflux network, led by DOE, continues to provide important information from flux towers that advances the understanding of processes regulating carbon assimilation, respiration, and storage, and linkages between carbon, water, energy, and nitrogen through measurements and modeling. In all these efforts, better methods of data coordination among data collection modalities are being pursued.

<sup>8</sup> See [gmao.gsfc.nasa.gov/research/merra/](http://gmao.gsfc.nasa.gov/research/merra/)

<sup>9</sup> See [www.narccap.ucar.edu/about/index.html](http://www.narccap.ucar.edu/about/index.html)

## *Building long-term ecological research networks.*

Assessing long-term changes in ecological systems due to environmental change, disturbance, and human impacts is essential for adaptation strategies, conservation, and resource management. As a collaborative effort with universities, NGOs, and government agencies to investigate ecological processes over long temporal and broad spatial scales, NSF established the Long Term Ecological Research (LTER) Network in 1980. The Network promotes synthesis and comparative research across 26 ecosystems and other related national and international research programs. Many of the LTER sites are co-located with existing agency research sites, for example, USDA Forest Service Experimental Forest and Range locations and USGS watershed research sites. A new program, Urban Long-Term Research Areas exploratory research (ULTRA-Ex), managed jointly by NSF and the USDA Forest Service, made its first awards in 2009. The goal of ULTRA-Ex is to stimulate and support interdisciplinary teams of investigators and practitioners working together to contribute to the broader base of scientific knowledge regarding human-ecosystem interactions in urban settings. The LTER and USDA Forest Service community have highlighted the need for greater integration of the social and ecological sciences across the LTER network, as evidenced in the LTER decadal plan and the strategic research initiative, *Integrative Science for Society and the Environment*. ULTRA-Ex project objectives are to advance basic theoretical knowledge regarding both human and ecological dimensions of ecosystems and to generate results with a range of scientific, educational, and practical uses and applications.

## *Field Experiments to Study Clouds in the Global Climate System.*

Marine boundary layer clouds are particularly important in the global climate system, not only as passive modulators of solar energy, but as interactive systems that influence and modulate sea surface temperature and the strength of the trade winds on seasonal to interannual timescales. Their microphysical properties are important, strongly sensitive to manmade aerosol, and poorly understood, especially over remote oceans. From May 2009 through December 2010 the DOE ARM (Atmospheric Radiation Measurement) Mobile Facility conducted intensive field observations near the Portuguese Azorean island of Graciosa in support of the Clouds, Aerosol, and Precipitation in the

## Marine Boundary Layer (CAP-MBL) field campaign.<sup>10</sup>

The goal of the campaign is to study processes controlling the radiative properties and microphysics of marine boundary layer clouds, a high-priority science question.

In a five-month field campaign centered at the DOE's ARM Southern Great Plains site in Oklahoma, improved analysis techniques were applied to a variety of airborne measurements in a study to determine how aerosols affect cloud formation and the energy balance from the sun. Significantly improved techniques were used in the analysis of Raman lidar data to enhance the accuracy of interpretation of aerosol observations, which will reduce scientific uncertainties in computer models used to simulate climate change.

*Global Land Survey 2010.* The Global Land Survey (GLS) 2010 allows land cover and ecological changes to be monitored on a five-year observation cycle, as recommended by the Global Terrestrial Observing System and its panel on the Global Observation of Forest and Land Cover Dynamics. During 2009, USGS and international partners acquired some 32,000 images from eight specially operated Landsat-5 receiving stations in order to maximize the pool of available observations. NASA and USGS are collaborating to support national and international efforts to map land cover change. This effort will assemble a substantially cloud-free, leaf-on (i.e., growing season) collection of Landsat and EO-1 Advanced Land Imager imagery for the world's land areas centered on the period 2009 to 2010. GLS 2010 follows previous projects that assembled similar Landsat data sets for 1975, 1990, 2000, and 2005.

*Global Climate Observing System Reference Upper Air Network.* The GCOS Reference Upper Air Network (GRUAN) is an international reference observing network, designed specifically to meet climate research requirements and to be used for validation as a baseline for all other purposes.<sup>11</sup> While the global upper-air observing network has provided useful observations for operational weather forecasting for decades, those measurements lack the accuracy and long-term continuity needed for understanding climate change. Consequently, the climate research community faces uncertainty about such key issues as

<sup>10</sup>. See [www.arm.gov/campaigns/amf2009clapmb1](http://www.arm.gov/campaigns/amf2009clapmb1)

<sup>11</sup>. See [www.gruan.org](http://www.gruan.org)



the nature of temperature trends in the troposphere and stratosphere; the climatology, radiative effects, and hydrological role of water vapor in the upper troposphere and stratosphere; and the vertical profile of changes in atmospheric ozone, aerosols, and other trace constituents. In the past year, a data management plan was developed by the U.S. partners to address data archiving, a meta-database, a data dissemination portal, and organization of data flows. The GRUAN is a partnership between NOAA, DOE, NASA, the National Center for Atmospheric Research, and Howard University.

### PLANS FOR FY 2011

*Future Plans to Improve Fidelity of Regional Climate Simulations.* Building on NARCCAP and other regional climate modeling activities, NSF, DOE, and USDA are investing significant resources to support research beginning in FY 2011 into Decadal and Regional Climate Prediction using Earth System Models. Project goals are to improve current modeling capabilities in order to achieve comprehensive, reliable global and high-resolution regional predictions of decadal climate variability and change through advanced understanding of the coupled physical, chemical, biological, and human processes that drive the climate system. This activity utilizes interagency cooperation to focus on one of the most pressing problems facing society: climate change, how it is likely to affect the nation, and how we can proactively plan for its consequences.

*Charting Future Global Carbon Cycle Research.* The global carbon cycle is changing rapidly as a result of human activities that are altering Earth's climate. A decade ago, the 1999 U.S. Carbon Cycle Science Plan identified research priorities and many of these remain important today. However, additional new priorities for carbon cycle research are vitally important for the coming decade, including the effects of human activities on carbon cycling, the vulnerability and resilience of ecosystems to changes in carbon cycling and associated changes in climate, and the efficacy and environmental consequences of carbon management policies, strategies, and technologies. Under the auspices of the U.S. Carbon Cycle Interagency Working Group of the USGCRP, the Carbon Cycle Scientific Steering Group began developing and charting a strategy for carbon cycle science to be conducted by U.S. scientists for the

next decade. Early strategy sessions in 2009 with the National Academy of Sciences' Committee on Human Dimension of Global Change, lead to new collaborations with social scientists and research on socioeconomic issues that will be needed in coordinating the science across diverse but equally important disciplines. Spring 2011 has been targeted for the release of another US. Carbon Cycle Science Plan, fully vetted by the communities researching the natural and socioeconomic aspects of the carbon cycle.

*The National Ecological Observatory Network: A multi organizational effort to assess ecological change.* The National Ecological Observatory Network (NEON) will collect data across the United States on the impacts of climate change, land use change, and invasive species on natural resources and biodiversity. NEON is supported by the NSF, with many other U.S. agencies and NGOs cooperating. Many of the 20 NEON sites will be co-located with existing agency research sites, for example, USDA Forest Service Experimental Forest and Range locations. NEON will be the first observatory network of its kind designed to detect and enable forecasting of ecological change at continental scales over multiple decades.

*Interagency Integration of Existing and Newly Developing Watershed Observatories.* Planning to strengthen and further integrate existing and newly developing watershed observatories from multiple agencies into a more cohesive national network will be conducted. Observatories from the Forest Service, Agricultural Research Service, USGS, NOAA precipitation monitoring, and NSF-sponsored Critical Zone Observatories (CZO) and LTER sites are being examined for further investment and expanded research to address the effects of climate change and variability on the water cycle at scales required for local and regional decisionmaking. Internet access to a rich history of hydrometeorological data from existing long-term observatories and national networks is being facilitated by the development of a Water Markup Language (WaterML). This effort is being extended internationally via the joint WMO and Open Geospatial Consortium (OGC) Hydrology Domain Working Group to develop voluntary consensus standards to enhance and further enable web-based interoperability and exchange of hydrologic data. NASA, along with interagency participants, will initiate projects that leverage these



observations and networks to improve downscaling techniques to provide more useful information from both satellites and large-scale models.

*Planned Intensive Field Studies with Interagency and International Coordination.* DOE's ARM Climate Research Facility is planning three major intensive field studies for 2011. These campaigns address major scientific uncertainties, have significant international or interagency collaborations, and will be the first major experiments to incorporate new capabilities acquired under the American Recovery and Reinvestment Act of 2009. The first will be the Ganges Valley (India) Aerosol Experiment to study the impact of increasing aerosols on the Indian summer monsoon, specifically their impact on precipitation. Many in-country collaborators will provide valuable complementary measurements. A second major campaign near the DOE facility at Manus (Tropical Western Pacific site) will be the Madden-Julian Oscillation (MJO) Investigation Experiment, coordinated with a large international MJO investigation field campaign called CINDY2011 (Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011). The mechanism and cause of the MJO, an equatorial traveling pattern of anomalous rainfall that is planetary in scale, is not well understood and has the distinction of not being accurately simulated in any current model. The third field study, entitled Mid-latitude Continental Convective Clouds Experiment, will be an interagency campaign supported by ARM and the NASA Global Precipitation Measurement Project. This experiment, to be conducted at the DOE Southern Great Plains site, will study cloud and precipitation transitions and environmental quantities that are important for convective parameterization in large-scale models and cloud-resolving model simulations.

*Mid-Latitude Airborne Cirrus Properties Experiment.* The Mid-Latitude Airborne Cirrus Properties Experiment (MACPEX) will provide reliable measurements of cirrus cloud properties, especially ice particle size and shape, in the mid-latitudes of the northern hemisphere. These new measurements are important because cirrus cloud properties have a significant impact on Earth's energy budget and because previous *in situ* measurements were compromised by ice particle shattering on aircraft surfaces and sensor inlets. In addition, MACPEX will

include measurements of water vapor at very low concentrations (<10 ppm) in the upper troposphere/lower stratosphere. These water measurements will help resolve discrepancies between various measurement techniques. The MACPEX project, which will make use of NASA's WB-57F aircraft flying from its home base in Houston, Texas, is coordinated with a DOE project, Small Particles in Cirrus (SPartICus). SPartICus measured a number of important cirrus cloud properties over a relatively long time period. Over a shorter period of time, MACPEX will make a number of identical measurements along with additional observations to more completely characterize the processes controlling cirrus properties.

*Global Landsat Data from 2009 to 2011.* During FY 2011, NASA and USGS will collaborate on scene selection, data processing, and release of the data set to the science and applications communities. The free availability of all Landsat imagery from USGS also opens other opportunities for the Global Land Survey 2010. For example, cloud-cleared (composited) data for the humid tropics are being considered in addition to the release of individual images.

*GRUAN Commencement of Operations.* The GCOS Reference Upper Air Network (GRUAN) was initiated to provide high-quality observations using specialized radiosondes and complementary remote-sensing profiling instrumentation to be used for validation as a climate observations baseline. FY 2011 plans are to initiate GRUAN operations at DOE's ARM Climate Research Facility in Lamont, Oklahoma. In line with the recently developed GRUAN data management plan, data archiving will begin. Also in FY 2011, development will begin on a true reference radiosonde for climate quality water vapor detection in the upper troposphere and lower stratosphere. Collaboration will be broadened to take advantage of synergies between the Network for the Detection of Atmospheric Composition Change and GRUAN.

*Carbon Cycle Science Research.* Federal agencies responsible for carbon cycle research have planned and are coordinating a multidisciplinary research strategy through various working groups to integrate the broad range of needed infrastructure, resources, expertise, and stakeholder input essential to understanding the components of the carbon

cycle. NOAA continues its development of the Carbon Observing and Analysis System (COAS), itself a multiagency effort with DOI, DOE, NSF, and NASA, as an observational and analysis network that measures atmospheric CO<sub>2</sub> and other greenhouse gases (GHGs) to provide the data necessary for supporting reanalysis efforts and predicting future climate change and ocean acidification. This network will further serve as the backbone of an integrated multiagency system for understanding the influence of the North American continent on Earth's atmosphere and verifying future mitigation efforts. NASA's Carbon Monitoring System (CMS) is developing a pre-Phase-A plan to conduct one or more pilot studies as part of a comprehensive system to provide information about the distribution of carbon in the atmosphere, ocean, and biosphere at a range of spatial scales, and to provide information about carbon storage in biomass. Additionally, NOAA will install new tall towers in the COAS network and increase the frequency of sampling flights to improve the CarbonTracker modeling tool that assimilates carbon modeling modules from other Federal agencies to produce its suite of products. CarbonTracker results, in conjunction with direct aircraft profiles, are used to compare, verify, and validate CO<sub>2</sub> retrievals by NASA satellites to promote understanding of the carbon cycle across all spatial scales. The AmeriFlux network, supported by DOE in collaboration with other agencies, continues to provide ecosystem-level understanding of the role of terrestrial biomes in the global carbon cycle. DOE's Carbon Dioxide Information Analysis Center (CDIAC) provides full and open access to data from many of these activities.

*Aquarius/SAC-D Mission.* The cycling of water and energy through the atmosphere and oceans is crucial to life on Earth, yet the interactions among the water cycle, ocean circulation, and climate are poorly understood. Interestingly, global measurements of sea surface salinity (SSS) over time provide a clear way to resolve these relationships. By tracking SSS we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, and evaporation and precipitation over the oceans. Global SSS data will allow us to create unprecedented computer models that bridge ocean-atmosphere-land-ice systems, with the goal of predicting future climate conditions. The Aquarius/SAC-D mission is one of original exploration. Salinity has been

sparsely measured at sea, limited mostly to summer observations in shipping lanes until the recent global deployment of Argo floats. Within a few months, Aquarius will collect as many SSS measurements as are in the entire 125-year historical record from ships and buoys. Aquarius will be able to resolve global SSS changes at monthly, seasonal, and yearly timescales. The research-related goals of Aquarius include better understanding in three areas. For the water cycle, in which 86% of global evaporation and 78% of global precipitation occur over the ocean, SSS is the key variable for understanding how freshwater input and output affects ocean dynamics. For ocean circulation, in which temperature and salinity determine seawater density and buoyancy, salinity governs the extent of ocean stratification, mixing, and water mass formation. For climate, as computer models evolve, Aquarius will provide the essential SSS data needed to link two major components of the climate system: the water cycle and ocean circulation. The Aquarius/SAC-D science objectives address ocean circulation, the global hydrological cycle, climate variability, land processes, land use, soil moisture, natural hazards, health applications, cryosphere, and others. The satellite observatory will provide measurements of ocean salinity (the primary measurement goal of the mission) plus ocean winds, rain, sea ice, sea- and land-surface temperatures, soil moisture, high-temperature events (fires and volcanic activity), nighttime light sources, atmospheric temperature/humidity soundings, and the space environment, and will also provide autonomous data relay from remote ground stations. The launch of the Aquarius/SAC-D Mission is scheduled for FY 2011.

*Understanding the Changing Arctic.* The Arctic region is expected to continue to experience rapid alteration in the coming decades, with reduced sea ice, increased temperatures, and ocean acidification. NASA, working with the Army's Cold Regions Research Laboratory (CRREL), the Coast Guard, and NSF, began a four-year research program on the impact of a varying and changing climate on the ecology and chemistry of the Arctic Ocean. The ICESCAPE (Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment) project<sup>12</sup> includes a strong ship-based field program and intensive use of satellite assets in 2010 and 2011 that will help define the effects of forcing factors such as changes in the amount of incoming solar

<sup>12</sup> See [www.espo.nasa.gov/icescape/](http://www.espo.nasa.gov/icescape/)

radiation, sea ice extent, and acidification. Results from the measurement program will enable combined physical and biogeochemical modeling studies of the region. A close collaboration with Canadian and French researchers has been fostered to extend and complement the field campaign beyond the U.S. effort, with foreign colleagues participating aboard the ship and in coordinated workshops. In collaboration with CRREL and regional universities, DOE, through a consortium of National Laboratories, has initiated a large-scale, long-term ecosystem experiment to evaluate the effects of changing climate on Arctic permafrost.

*A Study of Environmental Arctic Change (SEARCH).* The Interagency Arctic Research Policy Committee (IARPC), an agency partnership involving eight agencies and currently led by NSF, sponsors an academic and government collaborative effort to plan and implement a broad interdisciplinary study of environmental arctic change called Study of Environmental Arctic Change (SEARCH). The goal of this effort is to understand the nature, extent, linkages, and future development of the system-scale changes now being observed in the Arctic. These changes include, for example, increasing average annual surface air temperatures, decreasing summer sea ice extent and sea ice mass, changing ocean circulation, northward movement of tree lines and vegetation zones, changing hydrological cycle, thawing glacial ice masses and permafrost, and changing socioeconomic dynamics. SEARCH has launched an Arctic Observing Network for oceanographic, atmospheric, terrestrial, and socioeconomic observations that includes data management, discovery, and dissemination. SEARCH includes reanalysis, synthesis, modeling, and model intercomparison efforts linked to the Observing Network. A new thrust will focus on human and environmental responses to the changes occurring.

## IMPROVING OUR UNDERSTANDING OF NATURAL AND HUMAN FORCES OF CLIMATE

### RECENT PROGRESS AND ACTIVITY

*Improving Understanding of the Atlantic Meridional Overturning Circulation.* The Atlantic Meridional Overturning Circulation (AMOC) plays a major role in transporting heat within the world's oceans, with past changes in the AMOC linked to abrupt

climate changes in some paleoclimate studies. The decadal-scale variability and predictability of the AMOC and the corresponding climate impacts have been explored through a series of studies using both numerical models and observations. Ongoing work supported by NSF, NASA, NOAA, and DOE suggests that AMOC fluctuations may play a significant role in Arctic climate and sea ice changes. To better characterize the AMOC, analyses of sea surface height and subsurface temperature have been conducted, and these show distinctive structures in the North Atlantic that appear to be “fingerprints” of AMOC variability. These structures have led to the development of a statistical prediction model for AMOC fluctuations. Predictions from this model suggest a weakening of the AMOC over the next decade, although there is significant uncertainty in this prediction. This statistical approach complements a substantial effort to predict AMOC changes with state-of-the-art climate models. These decadal-scale predictions rely on coupled data assimilation systems that translate observations into a form suitable for initializing climate predictions. Production of the first set of decadal-scale predictions of the climate system, including the AMOC, is now underway.

*Understanding Causes of U.S. Droughts.* The USGCRP has supported focused research efforts to advance understanding of the causes of U.S. droughts and to determine to what extent future droughts may be predictable. These efforts are providing a scientific underpinning for products delivered through the multiagency National Integrated Drought Information System (NIDIS). In the past few years, the U.S. Climate Variability and Predictability (CLIVAR) program has coordinated an interagency-supported drought research program, the Droughts in Coupled Climate Models Project (DRICOMP). DRICOMP results have been reported in approximately twenty journal articles and are summarized in a special issue of the *Journal of Climate*.<sup>13</sup> As part of this work, climate model responses to sea surface temperature (SST) changes were examined that consisted of three different oceanic patterns: an El Niño-Southern Oscillation (ENSO) pattern over the Pacific Ocean, a pattern resembling the Atlantic Multi-decadal

<sup>13</sup> Schubert, S., and Coauthors, 2009: A U.S. CLIVAR project to assess and compare the responses of global climate models to drought-related SST forcing patterns: Overview and results. *J. Climate*, **22**, 5251–5272. doi: 10.1175/2009JCLI3060.1.

Oscillation (AMO), and a pattern representing global ocean SST trends. The results show that the largest precipitation response tends to occur when the two oceans have SST changes of opposite signs, with cold tropical Pacific conditions and warm Atlantic conditions favoring reduced U.S. precipitation. In all models examined, the U.S. precipitation response to the global SST trend forcing was weak. Changes in soil moisture were found to be another factor influencing U.S. droughts, but this factor needs further study. This work collectively highlights crucial links between Pacific and Atlantic SST variations and many U.S. droughts, identifying features that will need to be correctly modeled to improve future drought predictions.



*2005 North American Land Cover Map.* The North American Land Change Monitoring System (NALCMS) is a collaborative initiative between USGS; Mexico's Instituto Nacional de Estadística, Geografía e Informática (INEGI), Comisión Nacional Para el Conocimiento y Uso de la Biodiversidad (CONABIO), and Comisión Nacional Forestal (CONAFOR); and the Canada Centre for Remote Sensing (CCRS) to monitor land cover and its changes over time. Based on satellite images, NALCMS products are designed to depict information about land cover and land cover change in a seamless, consistent, and automated way across North America at regular intervals. The NALCMS team recently completed and published a 2005 North American Land Cover map and database.<sup>14</sup> Multiple national agencies within each country collaboratively developed respective land cover products for their national areas of stewardship, which were then combined into a seamless continental product. This geo-spatial database will help the scientific community analyze continental-scale land cover changes resulting from climate change, as well as aid carbon sequestration assessments.

### PLANS FOR FY 2011

#### *Ecological Carbon Sequestration Methodology.*

Ecological carbon sequestration refers to the transfer and storage of atmospheric carbon in vegetation, soils, and aquatic environments to help offset the net atmospheric increase due to carbon emissions. Understanding the capacities, associated opportunities, and risks of carbon sequestration

by vegetated ecosystems provides scientific information to support the formulation of policies governing climate change mitigation, adaptation, and land management strategies. Section 712 of the Energy Independence and Security Act (EISA) of 2007 mandates the DOI to develop a methodology and assess the capacity of our nation's ecosystems for ecological carbon sequestration and GHG flux mitigation. The USGS LandCarbon Project is currently developing a methodology that meets specific EISA requirements. The project team consults the scientific community and partner Federal agencies (USDA, EPA, DOE, and NOAA). The result will be a report defining ecosystem monitoring goals and plans, as well as data products that will inform policymakers and land managers about the ecological integrity of the Nation's land resources.

*Solar Radiative and Aerosol Forcing of Climate.* NASA plans to launch the Glory satellite in 2011.<sup>15</sup> Glory has two instruments—one to measure total solar irradiance, which will help to assure continuity of data on this fundamental climate-forcing parameter (currently measured by the ACRIMSAT and SORCE satellite missions, launched in 1999 and 2003, respectively), and another, the Aerosol Polarimetry Sensor (APS), to measure the radiative properties of aerosols. APS will measure the global distribution of natural and anthropogenic aerosols (black carbons, sulfates, etc.) with accuracy and coverage sufficient for reliable quantification of the aerosol effect on climate. It will also delineate the anthropogenic component of the aerosol effect, and the potential regional trends in natural and anthropogenic aerosols. An important aspect of the APS is quantification of the direct impact of aerosols on the radiation budget and their natural and anthropogenic components; and quantification of the effect of aerosols on clouds (microphysics and coverage) and their natural and anthropogenic components. APS will also investigate the feasibility of improved techniques for the measurement of black carbon and dust absorption to provide more accurate estimates of their contribution to climate forcing.

#### *International Scientific Assessment of the Ozone Layer.*

USGCRP scientists are participating as co-chairs, coordinating lead authors, lead authors, co-authors, contributors, and reviewers in the 2010/2011 international state-of-understanding assessment of

<sup>14</sup> See [www.cec.org/atlas/](http://www.cec.org/atlas/)

<sup>15</sup> See [glory.giss.nasa.gov/](http://glory.giss.nasa.gov/)

the science related to the ozone layer, prepared for the Parties to the United Nations' Montreal Protocol on Substances that Deplete the Ozone Layer. The assessment was delivered to the Parties in December 2010 and will be published in Spring 2011. The Parties use this assessment as an essential source of scientific information for their decisionmaking process concerning how best to achieve recovery of the ozone layer.

## IMPROVING OUR CAPABILITY TO MODEL AND PREDICT FUTURE CONDITIONS AND IMPACTS

### RECENT PROGRESS AND ACTIVITY

*Development of Earth System Models.* The development of Earth System Models (ESMs) is a major accomplishment of U.S. modeling groups over the past two years. ESMs have extended climate models by adding a carbon cycle that includes biogeochemical components to the physical and chemical components contained in earlier-generation climate models. ESMs are leading toward a more holistic understanding of the behavior of the climate system and its interactions with other Earth system components. They are also expected to contribute to advances in the detection, attribution, and prediction of weather and climate changes around the world. Such progress is vital to assessing potential future impacts of climate change, as well as for evaluating adaptation and mitigation options. U.S. modeling centers are also conducting extensive simulations that will serve as major contributions to IPCC's AR5. In particular, they are conducting an unprecedented set of coordinated climate model experiments designed to address outstanding scientific questions identified in the last IPCC reports, to improve understanding of climate variations and change, and to aid in evaluating possible consequences of future changes. Another major accomplishment has been the development of techniques to initialize the models from the observed state of the climate system, enabling the possibility of regional climate predictions out to a few decades.

*Southern Ocean.* The Southern Ocean is a primary sink for anthropogenic CO<sub>2</sub> and plays a central role in the long-term control of the 'natural' CO<sub>2</sub> content of the atmosphere. Recent evidence indicates that increasing wind stress in the Southern Ocean is having a profound effect on the biogeochemical

cycles of CO<sub>2</sub> and other climate-relevant compounds. The comprehensive study of air-sea gas transfer of CO<sub>2</sub>, dimethyl sulfide (DMS), the helium isotope <sup>3</sup>He, and sulfur hexafluoride (SF<sub>6</sub>) as part of the Southern Ocean Gas Exchange Study coordinated by the USGCRP's carbon cycle interagency working group showed, for the first time, an apparent strong effect of solubility of the gas on air-sea gas transfer, suggesting that bubble-mediated exchange is more important than current models indicate.<sup>16</sup> The gas exchange results, along with a comprehensive suite of biogeochemical and optical properties obtained from shipboard, floats, and remote sensing, are being assembled in a relational database such that all aspects of the process study can be investigated synergistically.

*Interagency Solicitation Addressing Climate Impacts on Species and Ecosystems.* NASA, USGS, the U.S. Fish and Wildlife Service, the National Park Service, and the SI released a joint solicitation that will fund both research and applications activities under the topic of "Climate and Biological Response." Funded projects will combine airborne and satellite remote-sensing observations with *in situ* observations and climate and ecological models to understand the impacts of climate variability and change on species distribution and abundance and ecosystem integrity and connectivity.

### PLANS FOR FY 2011

*Accessible, Open Source Models in Integrated Assessment with Accompanying Computational Capabilities.* A major challenge for the field of integrated assessment in the United States is that the code used in highly detailed integrated assessment models has historically not been open source, which has limited the ability of the broader research community to aid and accelerate model development. This topic was raised in the June 2009 "Science Challenges" report, mentioned in Accomplishments, and has been a recurring theme in the community for some time.<sup>17</sup> To begin the shift to open source code, and to enable broader interagency collaboration and integration of work products, DOE's Integrated Assessment Research Program has provided funding to make the code used in the Global Change Assessment Model

<sup>16</sup>. See [so-gasex.org/index.html](http://so-gasex.org/index.html)

<sup>17</sup>. See [www.sc.doe.gov/ober/IA%20Workshop%20low%20res%2006-25-09.pdf](http://www.sc.doe.gov/ober/IA%20Workshop%20low%20res%2006-25-09.pdf)

(GCAM) of the Joint Global Change Research Institute (JGCRI ; a collaboration between the Pacific Northwest National Laboratory and the University of Maryland) fully open source. Additionally, a new high-performance cluster (supercomputer) with extensive data storage capabilities will come on line toward the end of CY 2010 owing to funds provided under the American Reinvestment and Recovery Act. This enhanced computational infrastructure will enable stronger collaborations, data sharing, and development of critical modeling components that are computationally intensive. Working with the JGCRI, the goal is to make such capabilities more widely available to other researchers and to strengthen interagency efforts in Integrated Assessment. A workshop is planned for late spring or early summer 2011 that will include members of major modeling teams, other scientists, and a range of other agencies that might have an interest in this new activity that supports science infrastructure and the development of improved modeling capabilities.

### ASSESSING THE NATION'S VULNERABILITY TO CURRENT AND ANTICIPATED IMPACTS OF CLIMATE CHANGE

#### RECENT PROGRESS AND ACTIVITY

*Ocean Scoping Workshops and Reports.* Since 2007, under the auspices of the USGCRP Carbon Cycle Interagency Working Group, the Ocean Carbon and Biogeochemistry (OCB) Program has convened four scientific scoping workshops that have targeted very specific and timely research topics such as ocean acidification, coastal carbon fluxes in the Gulf of Mexico, global biogeochemical observations using profiling floats and gliders, and Southern Ocean biogeochemistry and ecosystem research. These workshops, which convene small factions of the OCB community around highly focused scientific questions, provide a critical venue for scientific planning and have yielded frequently cited workshop reports and papers that are helping to seed new programs and research opportunities. Two OCB scoping workshops were held in 2010, one on the future of marine biogeochemical time-series research, and the other on the application of molecular tools to link ocean chemistry with biological activity.<sup>18</sup>

<sup>18</sup>. See [www.us-ocb.org/](http://www.us-ocb.org/) for information on the program, workshops, and workshop reports.

*Land Use and Land Cover Change and the Carbon Cycle.* In June 2009, the USGCRP interagency working groups (IWGs) for Land Use and Land Cover Change and the Carbon Cycle, with the support of the National Institute of Food and Agriculture (NIFA), USGS, and the University of Michigan, held a workshop to bring together scientists from diverse government, academic, public, and private institutions engaged in land use/land cover change science and carbon cycle science to share research results, identify uncertainties, caucus on means to reduce those uncertainties, and foster collaboration in land use/land cover change and carbon studies across traditional disciplinary lines. Organized by the science steering groups for the two IWGs, the workshop breakout sessions focused on identifying research needs in land management and carbon cycling, data and observational gaps and needs, and opportunities and challenges in integrated modeling of land use/land cover change and carbon cycling. A workshop report includes findings and recommendations in all of these areas. Major issues addressed included coupled human and natural sciences, the needs of carbon markets and bioenergy policies, competing demands for land and natural resources biodiversity, and ecosystem diversity. Users included national, regional, state, local, and private land managers; Federal, state, and local climate planners; the forest industry; conservation groups; climate treaty negotiators; and industries converting to sustainable approaches in a climate-constrained world. An outcome of the workshop will be a book on Land Use and the Carbon Cycle, currently in the writing stage, to put together these issues and synthesize findings and research to date in this area. The book will examine the social, political, economic, and ecosystem processes of land-use and land-cover change and land management and how they drive carbon flux and storage in terrestrial ecosystems.

*Soil Carbon and Climate Change Issues.* Resources from the Natural Resources Conservation Service (NRCS), NIFA, the Agricultural Research Service (ARS), DOE, the Carbon Management Center (CMC; a research center of the Colorado Renewable Energy Collaboratory), the International Plant Nutrition Institute, 25X25, and Colorado State University were combined to host a conference, the *International Symposium on Soil Organic Matter Dynamics: Land Use, Management and Global Change*. This symposium covered a wide range of topics related to the vital

role of soil organic matter in the function and sustainability of terrestrial ecosystems and the global carbon cycle. Soil organic matter (SOM) research in terrestrial ecosystems from around the world was presented. The goal of the symposium was to present the latest research on SOM across the globe and to highlight future research directions. General topics included SOM and climate, flooded soil, organic soils, high-latitude soils, biofuels, quantification and accounting, vulnerability and long-term carbon storage, relationship to net greenhouse gas fluxes, disturbance, and tillage and other management practices. A special issue of the journal *Plant and Soil* will be published with volunteered peer-reviewed papers presented at the conferences. Researchers from 28 countries and six continents participated.

*Interagency Workshop on the Plight of Ecosystems in a Changing Climate Emphasizes Thresholds, Land Use and Invasive Species.* A workshop was held in Seattle, WA, in May 2009 on research resulting from interagency solicitations (EPA, NIFA, DOE) on ecosystem services, non-linear responses to climate change, and ecosystem effects of interactions between climate change, land use and land cover change, and invasive species. Highlights included results from both aquatic and terrestrial ecosystems, and invasive species considered ranged from transgenes and pathogens to trees, fish, and wildlife. In particular, great progress was reported on models to identify locations prone to species invasions and to predict these areas based on future climate scenarios. Reliable predictions of this sort are crucial for implementing control or eradication measures for harmful invasive species, and to support adaptive management to minimize economic and environmental damage. The importance of land use history and the implications of future land use trends coupled with climate change in determining types of invasive species and ecological disturbance was also highlighted. The importance of greater variability versus steady temperature and moisture changes was noted for pathogen invasions.

*International Workshop on Integrated Assessment and Impacts, Adaptation, and Mitigation.* In June 2009, a two-week workshop was held with leading U.S. and international integrated assessment scientists and modelers, impacts researchers, and Earth system modelers to explore critical research topics related to climate change mitigation and adaptation and the interactions among human and natural systems.

Through Federal sponsorship, Stanford Universities' Energy Modeling Forum coordinated the activity, with one week devoted to impacts, adaptations, and vulnerabilities and the second to mitigation and the implications of technological change. The workshop brought many divergent research communities together to explore modeling challenges at the intersections of the various fields. Two agencies coordinated and five agencies participated in planning a major three-day session on urban/regional impacts, adaptations, and vulnerabilities where scientists provided perspectives ranging from health to infrastructure interdependencies.

*Workshop on Water Infrastructure Sustainability and Adaptation to Climate Change.* In January 2009, EPA sponsored a workshop on water infrastructure sustainability and adaptation to climate change, held in Washington, DC. More than 130 invited experts and stakeholders from the Federal, research, utility, engineering, NGO, and academic communities attended. The workshop included two concurrent tracks: Climate Change Impacts on Hydrology and Water Resource Management and Adaptive Management and Engineering: Information and Tools. The focus of the workshop was on precipitation-related impacts and adaptation (i.e., sea level rise and mitigation efforts were not addressed). An extensive list of suggestions and ideas for moving forward on adaptation were developed and captured in a proceedings volume.<sup>19</sup>

## PLANS FOR FY 2011

*Climate Ready Estuaries Vulnerability Assessment.* Estuaries and coastal areas are particularly vulnerable to climate variability and change. In order to protect their ecosystems from projected impacts of sea level rise, increasing temperatures, and other effects, coastal managers may need to develop and implement adaptation measures. The Climate Ready Estuaries program works with the National Estuary Program, established by Congress in 1987, and other coastal managers to: 1) assess climate change vulnerabilities; 2) develop and implement adaptation strategies; 3) engage and educate stakeholders; and 4) share the lessons learned with other coastal managers. The Climate Ready Estuaries

<sup>19</sup> See [www.epa.gov/nrmrl/wsrd/wqm/wrap/workshop.html](http://www.epa.gov/nrmrl/wsrd/wqm/wrap/workshop.html)

Vulnerability Assessments are a partnership with the Massachusetts Bays Program (MBP) and the San Francisco Estuary Project (SFEP). The goal of these vulnerability assessments is to provide place-based information on the potential implications of climate change for estuarine processes in a form that is directly relevant for adaptation planning in the estuary.<sup>20</sup>

*Encouraging Multiagency Research Integration in a Recent Research Call for Integrated Assessment.* In order to encourage stronger collaborations across agency research programs, a recent multiagency call for proposals has been jointly issued for climate change Integrated Assessment Inter-model Development, Testing, and Diagnostics. Specifically, the Integrated Assessment Research Program included language in a December 2009 call that provides incentives for applicants to reach out and draw linkages with programs such as Decision Making Under Uncertainty for Climate Change (DMUU), LTER, and Regional Integrated Sciences and Assessments, all activities supported by other agencies. Discussed in the Human Contributions and Response Working Group of the USGCRP, this call adopted language that will test the viability and effectiveness of this one simple approach for improving integration of federal research programs.

*Planned Study of Impacts of Climate Variability and Change on Facilities.* NASA's Earth Science Division and Environmental Management Division will begin full-scale implementation of a joint activity begun in FY 2010 in which scientists at NASA's field centers will be working as part of a coordinated activity with the facilities planners and environmental management personnel at the individual field centers to better understand the magnitude and impacts of future climate variability and change on NASA's centers and facilities. Since the field centers have unique capabilities to support NASA's mission, and several are in vulnerable regions (especially those along the coasts), the development of this close partnership should have important impacts on future planning as well as demonstrate how such partnerships can be applied more generally. In this activity, NASA climate model forecasts of future environmental conditions for the NASA field center locations will be provided to the investigators, who can then focus on aspects of particular interest to their

region, as well as apply their individual expertise in coordinating with their centers' environmental management team. A combination of workshops, scientific cooperation, and networking approaches will be used to implement this program.

### PROVIDING CLIMATE INFORMATION AND DECISION SUPPORT TOOLS

#### RECENT PROGRESS AND ACTIVITY

*Climate Diagnostics Directory.* The Climate Diagnostics (CD) directory<sup>21</sup> has been developed jointly by NASA (through the CEOS International Directory Network (IDN)) and NOAA. The IDN staff at NASA subsequently implemented this into a fully functional information system. The ultimate goal of this directory is to identify climate visualizations (diagnostics) that assist in the assessment of climate trends and fluctuations by scientists and decisionmakers for long-term societal benefit. Because the content covers all the Earth Science disciplines, the complete set of the IDN's Earth Science keywords were reused. In addition, all the directory entries were tagged with appropriate keywords from the controlled set of keywords associated with their potential Societal Benefit Areas (SBA).

Searching for visualizations by Earth Science "Topic" currently appears to remain the primary method for identifying visualizations of interest. However, interested users may also query by location (controlled vocabulary), using a Google map search, or by using a full-text search. As usage expands within the policy arenas, it is expected that the SBAs may become a more common method for identifying visualizations of interest. One of the most attractive features of the directory is the availability of an authoring tool for creators of Climate Diagnostics records to clearly document their visualizations. When using this authoring tool, contributors are guided through the process of entering the metadata (descriptive information) associated with the specific visualization. Requested information includes the visualization description, the visualization itself, and the Visualization URL (Uniform Resource Locator). In addition, providers can characterize the contributions of Climate Diagnostic entries by either visualization or analysis type. These characterizations

<sup>20</sup>. See [www.epa.gov/cre/](http://www.epa.gov/cre/)

<sup>21</sup>. See [idn.ceos.org/](http://idn.ceos.org/) and [idn.ceos.org/climdiag/Home.do?Portal=climatediagnostics&MetadataType=0](http://idn.ceos.org/climdiag/Home.do?Portal=climatediagnostics&MetadataType=0)

## PLANS FOR FY 2011

are selected from controlled lists by the providers to clarify the analyses used to create the specific Climate Diagnostics and specify this information for the end user. The CD directory has been demonstrated at national and international meetings and has been well received by all audiences.

*Western Watersheds and Climate Change: Water and Aquatic System Tools Workshop.* The Forest Service, in partnership with other federal agencies and universities, addressed western climate change, water, and aquatic issues through a *Western Watersheds and Climate Change: Water and Aquatic System Tools* workshop. The workshop began a dialogue among managers and scientists in the western United States about knowledge and tools that are currently available or needed to address water and climate change issues. There will be follow-up discussions to address various topics, potentially including ways to adequately address water and climate change issues; a presentation on legal challenges; and the creation of an information network that would contain synthesized and organized climate information as well as climate data implementation tools.

*Enabling and Improving Responses to Climate Variability and Change by Providing Reliable and Accessible Climate Information and Decision Support Tools to Address Gaps in Our Ability to Adapt to and Mitigate Climate Change.* The Southeast Climate Consortium (SECC) is one of eight Regional Integrated Sciences and Assessments Centers sponsored by NOAA with agriculture research, education, and extension activities funded through USDA. Faculty from the SECC's seven member universities in five states have developed climate variability and forecast information systems to deliver climatic risk management outlooks and advice to agricultural producers and water resource managers. Over the past 10 years, the SECC has become recognized as a world-class leader in adaptive research that addresses stakeholders' climate information needs and effectively integrates trusted stakeholder advisors in the delivery and use of that information. SECC continues to increase the number of clientele trained to use the online decision support tool, AgroClimate; to increase the number of crops in the yield forecast model, irrigation tool, county yield database and regional yield maps; and to produce relevant and timely scientific and technical publications, with over 100 peer-reviewed publications since 2005.

*Climate Diagnostics Directory.* For FY 2011 and beyond, the plan is to continue to populate this directory and encourage participation worldwide through contributions that can be made through the metadata authoring tool, available from the website. The work is being performed through the CEOS Working Group on Information Systems and Service (WGISS), but all agencies are encouraged to contribute. A performance measure includes a Maturity Index that is being used to assess the continued viability of the site.

*National Climate Change and Wildlife Climate Science Center (NCCWSC).* The NCCWSC is an organization of regional climate science centers at the DOI that was designed with input from Federal, state, and tribal science and management agencies; nongovernmental organizations; academic institutions; and others having an interest in conserving America's fish and wildlife resources. Center activities will focus on providing habitat and population modeling and forecasting information and tools, integrating physical climate models with ecological models, assessing vulnerabilities and forecasting changes, and developing standardized approaches. This research will be accomplished through collaboration among Federal, state, and academic researchers to develop science information and tools in order to better inform management strategies for responding to climate change.

*Gulf of Mexico Coastal and Marine Elevation Pilot.* NOAA will invest in a joint project with the DOI (i.e., USGS and the Minerals Management Service (MMS)) to develop a national integrated high-resolution topographic and bathymetric data set to address a range of high-priority coastal issues including coastal and marine spatial planning (CMSP), modeling climate impacts, and ecosystem assessments. This project will include strong interagency collaboration related to data collection, modeling, data standards, information access, and other foundational elements needed to develop an end-to-end, integrated ocean and coastal mapping program. Due to the critical nature of the issues facing the Gulf region, NOAA will begin pilot efforts in Mississippi and Louisiana in support of the Gulf Coast Ecosystem Restoration Working Group and the Interagency Working Group on Long Term Disaster Recovery and later expand to other regions of the country.

### *Preparing Coastal Communities for Climate Hazards.*

NOAA is investing resources to reduce the vulnerability of coastal communities and the U.S. economy to the hardship and costs associated with climate-related natural hazards. NOAA will apply its scientific and technical expertise to develop improved tools and work with communities to apply these tools to address the impacts of events such as sea level change and other forms of coastal inundation. Specifically, this investment will provide climate adaptation assessment and planning and coastal inundation modeling, forecasting, and prediction. NOAA will incorporate sea level change data to provide training and information on understanding coastal risk and vulnerability assessments and develop associated products with Federal (the Federal Emergency Management Agency (FEMA), USGS, and the U.S. Army Core of Engineers (USACE)), state, and local agencies to translate science into management applications. Coastal decision support resources (e.g., web portals, Geographic Information System (GIS) tools) that integrate social, economic, and climate data in useful and interactive formats will also be developed. Additionally, NOAA will integrate observations into climate change projection products to address impacts and assessments at global, regional, and local scales and provide accurate and timely predictions of changing sea level.

## CLIMATE CHANGE COMMUNICATION AND EDUCATION

### *RECENT PROGRESS AND ACTIVITY*

*Completion of Second Student Airborne Research Program (SARP).* This summer program, organized by the National Suborbital Research and Education Center at the University of North Dakota, brought together 30 students (both undergraduates and graduates) from around the country for a six-week period in which they worked with principal investigators from the University of California (UC) at Santa Cruz, Irvine, and Davis using the MODIS/ASTER (Moderate Resolution Imaging Spectroradiometer/Advanced Spaceborne Thermal Emission and Reflection Radiometer) Simulator (MASTER) and Whole Air Sampler (WAS) instruments.<sup>22</sup> The program was based at UC Irvine and NASA's Dryden Aircraft Operations Facility in Palmdale, California. The focus of the program was on making observations aboard

NASA's DC-8 aircraft as well as related surface-based measurements to provide both calibration/validation and complementary scientific information for the aircraft-based observations. During the six-week program, there were two DC-8 data collection flights plus one short instrument testing flight. Students addressed problems in several areas, including agricultural emissions from dairy farms in the Central Valley of California, giant kelp in the Santa Barbara Channel, and evapotranspiration from orchards and row crops in the Central Valley of California. Students were involved in mission planning, including consideration of the local meteorology and its impacts on flight conditions and the environmental context of the observations. Students heard presentations from scientists and managers from universities and government, and made presentations to their fellow students, faculty mentors, and NASA personnel at the end of the program. The SARP program maintains connectivity among its alumni through social networking.<sup>23</sup>

*DEVELOP Program Involves Students in Earth Science Applications.* NASA's DEVELOP Program, based at Langley Research Center, awarded 201 student internships supporting 34 applications projects at seven NASA centers. Mentored by multi-disciplined scientists and engineers, students conducted a series of applications projects nationwide to enhance decisionmaking activities. Project highlights included an air quality team that investigated NASA Earth Observing System (EOS) capabilities during and after the Deepwater Horizon oil spill to monitor impacts on air and water quality in the Gulf of Mexico; an eco-coastal management project that researched satellite capabilities for measuring estuarine shoreline change, vegetation succession, and salt water inundation to assist the North Carolina state government; a biomass burning project that examined potential impacts of sugarcane and marsh burning on air quality and carbon storage to assist Federal air quality monitoring in Louisiana; use of NASA's Invasive Species Forecasting System to map at-risk habitats and demonstrate how Maryland state land managers could enhance their decision making processes; and a natural disasters project that assessed damage, air quality impacts, and public health risks relating to the 2009 Station Fire to assist local forest managers with enhanced forest fire management and mitigation.

<sup>22</sup> See [www.nserc.und.edu/learning/SARP2010.html](http://www.nserc.und.edu/learning/SARP2010.html)

<sup>23</sup> See dedicated Facebook page, [www.facebook.com/pages/Grand-Forks-ND/SARP-2010/299754969335?ref=ts](http://www.facebook.com/pages/Grand-Forks-ND/SARP-2010/299754969335?ref=ts)

DEVELOP students demonstrated project research at over 30 international, national, state, and regional conferences, and the DEVELOP Program was highlighted in a series of five articles in *The Earth Observer*.<sup>24</sup>

*Postdoctoral Students Applying Climate Expertise Fellowship Program.* NOAA and the U.S. Bureau of Reclamation (BoR) have sponsored three postdoctorate students (postdocs) since 2008 under the Postdocs Applying Climate Expertise (PACE) Fellowship Program. The Program places climate scientists at decisionmaking institutions for two-year appointments, during which they are expected to transfer the most recent developments in climate science to decisionmaking in climate-sensitive sectors. NOAA contributes 50% of the cost, and the decisionmaking institutions are asked to contribute the other 50%. The three postdocs funded under this new initiative thus far have all been working on water management-related issues at the DOI (BoR). Each postdoc is assigned a mentor at BoR, while also receiving mentorship from scientists at NOAA's Earth System Research Laboratory (ESRL) and the NOAA-funded Western Water Assessment (WWA) Regional Integrated Sciences and Assessments (RISA) program. The first postdoc is expected to complete her two-year term in 2010. The title of her project is "Potential Future Changes in Temporal Variability of Precipitation in the Colorado River Basin." Two postdocs also began appointments in 2009. One has been working on the issue of future climate variability and change and the effect on the water resources of the Intermountain West. The other is working on ways that mesoscale modeling could better define potential changes in precipitation patterns and extremes in a changing climate. This work would help better equip water resources decisionmakers with assessments of changes under climate change scenarios as well as quantification of uncertainty. All postdocs are encouraged to publish papers with the assistance of their mentors and are expected to present at meetings and conferences. But the success of the postdocs will ultimately be determined by their ability to incorporate science into decisionmaking tools and frameworks that improve the decisionmaking capacities of the host institutions. The BoR has expressed interest in hosting postdocs in 2010-2011, and NOAA has received host institution

<sup>24</sup> See [eosps0.gsfc.nasa.gov/eos\\_homepage/for\\_scientists/earth\\_observer.php](http://eosps0.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php)

applications from other agencies as well. Postdocs applying to the program for 2010-2011 are invited to submit proposals to work with BoR or any of the other hosting institutions that have applied to the program.

## PLANS FOR FY 2011

*Global Climate Change Education Activities.* NASA's Earth Science Division, NOAA, and NSF are planning on coordinating the efforts selected by each agency under their Global Climate Change Education (GCCE) activities funded in 2010. In FY 2011, NASA's GCCE will be a component of NASA's Minority University Research and Education Program with targeted funding to strengthen climate change education at minority-serving institutions and their collaboration with the broader academic and research enterprise. At the start of FY 2011, NASA's Office of Education was sponsoring 57 projects to improve climate change education at universities, community colleges, and K-12 schools, and through non-profit organizations. The joint planning among NASA, NSF, and NOAA will include a cross-agency evaluation of climate change education sponsored by these agencies.

*Global Learning and Observations to Benefit the Environment.* NASA, along with NOAA and NSF, provides Federal support to the Global Learning and Observations to Benefit the Environment (GLOBE) program, providing students around the world the opportunity to make hands-on measurements and conduct research about the Earth system and its changes. The interagency collaboration includes continued planning of the GLOBE Student Climate Research Campaign, modernization of the GLOBE data and information system, and implementation of the recommendations outlined in the OSTP report on its review of GLOBE.<sup>25</sup>

<sup>25</sup> See [www.globe.gov](http://www.globe.gov) and [www.whitehouse.gov/blog/2010/04/22/ostp-celebrates-earth-day-2010-with-public-lecture-new-globe-report](http://www.whitehouse.gov/blog/2010/04/22/ostp-celebrates-earth-day-2010-with-public-lecture-new-globe-report)





## PROGRAM ACTIVITY DESCRIPTION BY AGENCY/DEPARTMENT



The following pages present information about the contributions to the USGCRP by each of the program's participating agencies, including program highlights and plans for FY 2011. For each department, the section titled "Principal Areas of Focus" highlights and summarizes activities ongoing within that department. The sections titled "Activities or Projects Related to the Six USGCRP Focus Areas" follow the same six focus areas as described in the previous section, and the activities described in these sections correlate with the budget crosscut tables in Section VI. While DOD and DOS are active supporters of the USGCRP, their activities and projects are not described in the same format as the others, and they are not included in the budget crosscut and budget tables.

- Department of Agriculture (USDA)
- Department of Commerce (DOC)
- Department of Defense (DOD)
- Department of Energy (DOE)
- Department of Health and Human Services (HHS)
- Department of the Interior (DOI)
- Department of State (DOS)
- Department of Transportation (DOT)
- Agency for International Development (USAID)
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Science Foundation (NSF)
- Smithsonian Institution (SI)

## U.S. DEPARTMENT OF AGRICULTURE



### Principal Areas of Focus

The U.S. Department of Agriculture (USDA) supports climate change science activities to empower farmers, foresters, ranchers, land owners, resource managers, policymakers, and Federal agencies with science-based knowledge to manage the risks and challenges of climate change and to reduce emissions of atmospheric greenhouse gases and enhance carbon sequestration. USDA conducts and sponsors a broad range of research that supports the USGCRP, focused on evaluating risk to natural resources, estimating the role of forestry and agricultural activities in greenhouse gas emissions and carbon sequestration, and developing practical management strategies and approaches to manage emissions and adapt to changes. USDA's research program seeks to determine the significance of terrestrial systems in the global carbon cycle; promotes the capture and use of methane emitted from livestock waste facilities for on-farm power generation; assesses the potential of bioenergy as a substitute for fossil fuels; identifies agricultural and forestry activities that can help reduce atmospheric greenhouse gas concentrations and increase carbon sequestration; quantifies the risks and benefits arising from environmental changes to agricultural lands and forests; and develops management practices that can adapt to the effects of global change, including potential beneficial and adverse effects.

### USDA Activities or Projects Related to the Six USGCRP Focus Areas

#### 1. Improving our knowledge of Earth's past and present climate variability and change

Climate Change, Soils, and Emissions Program (USDA-ARS).<sup>26</sup> This program is developing remote-sensing systems and algorithms to quantify the states and process of Earth systems affecting or affected by agriculture. It addresses the hydrologic cycle, energy

<sup>26</sup> Agricultural Research Service

balance, biomass, species, plant nutrient status, land cover/land use, and changes in terrestrial states and processes, and includes parameterization of models with remotely sensed data and information.

*Forest Inventory and Analysis National Program (USDA-FS).*<sup>27</sup> The USDA Forest Service is responsible for providing the official U.S. estimates of forest carbon inventory. This entails extensive, regular monitoring along with maintaining instrument networks and responsible data stewardship. The Forest Inventory Analysis (FIA) efforts are integral to understand not only where the carbon is in U.S. ecosystems, but also how to effectively measure it. Numerous tools have been developed, including some national standards to assess carbon in forests.

*UV-B Monitoring Network (USDA-NIFA-UVBR&M).*<sup>28,29</sup> The stratospheric ozone layer, which blocks most of the harmful ultraviolet B (UV-B) radiation before it reaches the Earth's surface, has suffered considerable erosion in recent decades due to man-made chemicals. UV-B is not typically monitored at weather stations throughout the United States, leaving the UV-B Program as the only source of complete UV measurements, reaching back to 1996, that span the entire United States. Program data are being used in atmospheric, plant, and animal research in collaboration with partners from government and land grant universities. Each of the 37 network sites has four primary instruments: an ultraviolet multifilter rotating shadowband radiometer; a visible shadowband radiometer; a UVB-1 broadband meter; and a PAR (photosynthetically active radiation) sensor. Each site also measures solar radiation at six wavelengths in the visible range to determine solar attenuation due to clouds and aerosols. The UV-B instruments measure PAR (400 to 700 nm) with the same sensor that is widely used by agricultural researchers. Temperature, humidity, and surface reflectance are also measured at all sites. The network provides daily and hourly estimates of PAR, UV-B radiation, and ozone to the agricultural community and any other interested users via its web page at <uvb.nrel.colostate.edu>.

<sup>27</sup> Forest Service

<sup>28</sup> National Institute of Food and Agriculture

<sup>29</sup> Ultraviolet B Research and Monitoring Program

## 2. Improving our understanding of natural and human forces of climate change

*Carbon Cycle Science in Ecosystems (USDA-ARS).* The goals of this project are to understand and measure emissions of greenhouse gases from agricultural sources; develop process level understanding of GHG emissions; and to develop improved technologies and agricultural systems to manage greenhouse gas emissions. It includes the Greenhouse gas Reductions through Agricultural Carbon Enhancement network (GRACEnet) project.

*Carbon Cycle Science in Ecosystems (USDA-FS).* The Forest Service investigates pools and fluxes of carbon in ecosystems throughout the country. Studies examine how the carbon cycle is influenced by forest type, age, and land use change, along with synergistic and interacting ecosystem feedbacks like fire and insects. The Forest Service also evaluates the impacts of forest management on carbon sequestration and greenhouse gas emissions at multiple spatial and temporal scales. This information facilitates incorporation of carbon sequestration considerations into land management strategies.

*Agriculture and Food Research Initiative Competitive Grants Program (USDA-NIFA).* The objectives of this program are to reduce atmospheric greenhouse gas emissions in agricultural and forestry production systems and maximize carbon sequestration potential in agriculture and forest working lands by providing producers and decisionmakers with new management methods and technologies and new plant cultivars and animal breeds through classical/conventional breeding, relevant biotechnologies, and other appropriate approaches. This program has the potential to help mitigate the climate impacts of agricultural and forestry production and advance emerging economic opportunities through a market system.

## 3. Improving our capability to model and predict future conditions and impacts

*Enable Agriculture to Adapt to Climate Change (USDA-ARS).* As part of the Carbon Cycle Science in Ecosystems Program, experiments are conducted to understand the effects of changing climate on agricultural systems and to develop process-level models to better understand the impact of anticipated climate change on endemic and exotic pests, weeds, and diseases.

*Refining the prediction of climate change impacts on ecosystems and natural resources (USDA-FS).* The Forest Service has generated downscaled climate data for different regions of the country and developed indices for weather, fire, growing season, and changes to primary vegetation over time for different IPCC emissions scenarios. Simulations have examined how climate change will affect ecosystems with complex topography, and an important decision support tool has been developed to incorporate land management decisions into climate change scenarios. Predicted changes in vegetation and other ecosystem components have also been used to refine predictions of future climate conditions through enhancing our understanding of the past. For example, research on intra-annual tree ring growth in bristlecone pine has improved the interpretation of historic climate change. Finally, the Forest Service's Resources Planning Act Assessment incorporates IPCC scenarios to predict the future state of natural resources and forest carbon stores 50 years out.

*Agriculture systems and technology (USDA-NIFA-AFRI).* The Agriculture and Food Research Initiative (AFRI) Competitive Grants Program includes a joint modeling program with NSF. Other related projects are multidisciplinary, involve multiple investigators, and address a significant regional issue with respect to greenhouse gas mitigation and adaptation through increased resiliency in agriculture production and sustainable natural resources management under variable climates. These Integrated Projects are expected to develop and implement a network for multi-institutional cooperation and coordination, data management structures, and defined milestones and goals for the duration of the project.

*Integrated Agricultural Impact Assessment System (USDA-NIFA-UVBR&M).* Understanding agricultural response to climate and environmental change is critical for providing decision support to stakeholders, such as agricultural producers, land managers, and policymakers trying to meet the food and fiber needs of a growing world population. A fully integrated impact assessment system has been developed to predict climate-crop interactions and manage sustainable agricultural production for high profitability and environmental quality. Such a system must be sufficiently comprehensive to include crop growth models, UV and visible solar radiation, Earth's climate, air and water quality models, and satellite and *in situ* observations. The system by design incorporates models of crop growth and other

vegetation life cycle processes, as well as their living environments. Thus, the system is a unique tool that is capable of, and readily applicable to, providing fundamental scientific bases for effective planning and control of managed and unmanaged ecosystems. Current crops included in the assessment system are cotton and corn. Future versions will also include soybean, wheat, and rice crops. An economic analysis component is also under development.

#### *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

*Enable Agriculture to Adapt to Climate Change (USDA-ARS).* As part of the Carbon Cycle Science in Ecosystems Program, the objective of this project is to evaluate germplasm, identify genetic variations that will respond positively to climate change, and develop management strategies and crop varieties for adaptation to changing climate conditions. The approach taken is to measure and quantify impacts, and then develop process models that describe impacts including management strategies, cropping systems, and crop varieties.

*Impacts of climate change on ecosystems, species, and natural resources (USDA-FS).* The focus of this research is to explore the vulnerability of ecosystems to climate change and examine impacts on specific natural resources and the environmental services on which society depends. The factors affecting species survival and distribution are studied along with historic patterns of species migration (trees, mammals, birds, and other species groups) relevant to forecasting under different future scenarios. Further, this research cultivates an understanding of how the changing climate affects the quantity, quality, and timing of water flows and what the implications are for fish populations, aquatic habitat, and human water supply. This extensive body of work on climate change impacts informs management practices that encourage ecosystem resilience and facilitate species migration and seed movement, and assists in defining appropriate watershed stewardship approaches and identifying critical connecting hydrologic and terrestrial corridors.

*Plant health, animal health, production, and products (USDA-NIFA).* Within the AFRI, these projects will include the evaluation of several factors important to agriculture including limits to the adaptability of animal agriculture to increased heat and disease, the potential for increased weed problems, and increases

in pests and diseases of crops and forests. Through realistic modeling of future impact scenarios the Integrated Agricultural Impact Assessment System can accurately demonstrate regional and national impacts for selected agronomic crops. The models also incorporate past and current agronomic practices to reflect realistic management scenarios, which can then also be used as modeling variables to investigate those practices that might mitigate future climate change impacts.

*Economic Implications of Climate Change and Adaptation in the Agricultural Sector (USDA-ERS).* Economic Research Service (ERS) research will examine how farmers' responses to a changing climate—including changes in yields, extreme events, and pest invasions—will affect domestic crop and livestock production patterns, productivity growth, input use, crop rotations, economic returns, and environmental outcomes. To the extent possible, this effort will link to climate, crop, and biophysical modeling efforts in other agencies. This line of inquiry focuses on farmer, domestic, and international market responses to a new climate regime. It will also assess the economic implications of policy options for addressing climate-related increases in risk and costs, including the role of technologies such as improved genetic resources.

#### *5. Providing climate information and decision support tools*

*Scalable methodologies for assessing potential impacts and adaptation of agriculture to climate change (USDA-ARS).* As part of the Carbon Cycle Science in Ecosystems Program, this project develops crop growth, erosion, and soil-vegetation-atmosphere models that can be used to build decision support systems for climate change and agriculture and develops guidelines for germplasm, production, and water management strategies that enable agriculture to adapt to changing climate conditions.

*Environmental Services Markets Design (USDA-ERS).* As part of the Resource and Rural Economics Program, support will be given to the development of analytical tools and assessments of the economic, environmental, and land use implications of alternative climate policies. A primary focus is analysis of options for offset market design, including predicted responses of farmers to greenhouse gas mitigation options and energy cost increases. The objective of this effort is to help inform the policy process.

*Technology transfer and science delivery for Forest Service managers and partners (USDA-FS).* The Forest Service is developing strategies for climate change adaptation and mitigation. The Research and Development branch of the agency provides scientific information and the tools that help land managers estimate carbon stocks or determine appropriate seed sources, for example. A web portal is maintained with essential climate change information and tools.<sup>30</sup> The Forest Service hosts workshops for diverse audiences to aid in the development of adaptation plans through manuals for the National Forest System.

*Plant health, production, and plant products (USDA-NIFA-AFRI).* Through the AFRI, funded projects investigate how to maximize resiliency; reduce the impact of climate change on the productivity of agriculture and forest systems; and reduce carbon, nitrogen, and water footprints under changing climates by providing producers and decisionmakers with new management methods, technologies, new plant cultivars and animal breeds adapted to changing climates through classical/conventional breeding, and other appropriate approaches to adapt to changing climates.

*Policy and economic impact of future scenarios (USDA-NIFA-UVBR&M).* Through the Integrated Agricultural Impact Assessment System Program, scenarios and yield maps are generated for policymakers to better understand regional and national shifts in productivity. Combined with economic analyses, these shifts can illustrate significant geographically linked changes in U.S. food systems.

## 6. Climate Change Communication and Education

*Public outreach to engage communities, tribes, partners, and youth (USDA-FS).* The Forest Service engages communities, tribes, and partners by synthesizing and making available its research by conducting outreach for family forest owners and also through local workshops. For example, “science days” have been sponsored at several National Forests to facilitate an understanding of the impacts of climate change. Youth participation has been expanded to connect them with ongoing research and the resources and benefits of public lands while gaining an understanding of the challenges posed by climate change.

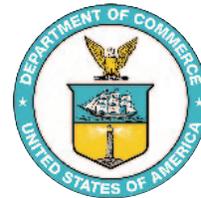
*Renewable energy, natural resources, and environment (USDA-NIFA-AFRI).* The goal of this project is to

<sup>30</sup>. See [www.fs.fed.us/ccrc](http://www.fs.fed.us/ccrc)

increase the number of scientists, educators, and extension professionals in the workforce with the skills and knowledge to address climate change issues in agriculture and improve understanding of climate change, its impacts, and options for environmental stewardship among producers and consumers of agricultural and forestry products.

*Public outreach, student training, applied research, K-16 education, workforce development, and technology transfer (USDA-NIFA-UVBR&M).* Data generated by the UV-B network is shared within 24 hours with the research community through the Program’s web site. Data are also available to the public, with mapped data being particularly public-friendly. Graduate student training at Colorado State University, at several Chinese institutions, and other land-grant universities is also supported by the UV-B Program. In 2009, the Program joined the AmericaView network, a nationwide program that focuses on satellite remote-sensing data and technologies in support of applied research, K-16 education, workforce development, and technology transfer.<sup>31</sup>

## DEPARTMENT OF COMMERCE



### Principal Areas of Focus

The National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST) comprise the Department of Commerce contribution to the USGCRP.

NOAA’s climate mission is to “understand climate variability and change to enhance society’s ability to plan and respond.” This is an end-to-end endeavor whose overall objective is to provide decisionmakers with a predictive understanding of the climate and to communicate climate information so that the public can incorporate it into their decisions. These outcomes are achieved through implementation of a global observing system, focused research to understand key climate processes, improved modeling capabilities, and the development and delivery of climate information services. NOAA aims to achieve

<sup>31</sup>. See [americaview.org/](http://americaview.org/)

its climate mission and outcomes through the following objectives:

- Describe and understand the state of the climate system through integrated observations, monitoring, and data management
- Understand and predict climate variability and change from weeks to decades to a century
- Improve the ability of society to plan for and respond to climate variability and change.

NOAA relies on its Federal, academic, private, and international partners to achieve its objectives. These objectives are implemented through three distinct, yet integrated, programs: Climate Observation and Monitoring, Climate Research and Modeling, and Climate Services Development.

NIST provides measurements and standards that support accurate, comparable, and reliable climate observations. NIST also performs calibrations and special tests of a wide range of instruments and techniques for accurate measurements. In FY 2009, NIST was included as a discrete element of the USGCRP crosscut to provide specific measurements and standards of direct relevance to the program.

### DOC Activities or Projects Related to the Six USGCRP Focus Areas

#### 1. Improving our knowledge of Earth's past and present climate variability and change

The 2009 State of the Climate Report. Every year since 1990, NOAA has released an annual report detailing the state of the climate. The latest annual report, the *2009 State of the Climate*, is a 218-page report compiled by more than 300 scientists from 48 countries, including many USGCRP contributors. As in previous years, the report provides information on the impacts of globally increasing temperatures. This year's report highlights the conclusion to the hottest decade on record. The final year of the decade had the third-lowest Arctic sea ice extent since 1979; the warmest and second-warmest years on record for India and Australia, respectively; and CO<sub>2</sub> concentrations that are increasing at a rate well above average.

*Climate Variability Research (NOAA-OAR).*<sup>32</sup> The goal of this effort is to understand climate variability and change by providing new and improved components of climate models, new and improved understanding

on causes of climate extremes and climate change, and new and improved methodologies to create more reliable climate predictions at all time scales.

*Global Ocean Observation System (NOAA-OAR).*

The Global Ocean Observation System (GOOS) is maintained by the Climate Program Office and is necessary for climate research and prediction as well as long-term monitoring for climate change detection and attribution. NOAA provides the major U.S. contribution to the Global Component of the Integrated Ocean Observing System (IOOS)—the U.S. contribution to the GOOS and ocean baseline of the Global Earth Observation System of Systems (GEOSS). GOOS was designed to meet climate requirements, but it also provides the global ocean backbone needed to support weather and storm prediction, global and coastal ocean prediction, marine hazards warning, transportation, marine environment and ecosystem monitoring, and naval applications. The major elements of GOOS are: Argo profiling floats, surface drifting buoys, tide gauge stations, tropical moored buoys, ocean reference stations, Ships of Opportunity Program (SOOP), ocean carbon networks, Arctic Ocean observing system, dedicated ships, data management, data assimilation, and analysis. Satellites are also critical elements of this composite system, but they are listed elsewhere in the NOAA and NASA budgets. It must be emphasized that all of these interdependent elements working together provide the needed system.

*Climate Data and Information Products and Climate Operations (NOAA-OAR).* These efforts provide backbone atmospheric reference observing systems (temperature and precipitation) and the necessary administrative support structure to implement and steward various climate programs and earmarks.

*National Data Centers, environmental data, information, products, and services (NOAA-NESDIS).*<sup>33</sup> Together, NOAA's three National Data Centers provide environmental data, information, products, and services to support atmospheric, hydrologic, oceanographic, and the solid Earth and solar-terrestrial physical sciences. The National Climatic Data Center (NCDC) is the largest climate data center in the world, and is the Nation's designated Federal records center for climate data. NCDC receives, processes, archives, provides access, disseminates, and conducts objective assess-

<sup>32</sup>. Office of Oceanic and Atmospheric Research

<sup>33</sup>. National Environmental Satellite, Data, and Information Service

ments of remote (satellite) and *in situ* (land, ocean, and atmosphere) observations.

*Jason 3 (NOAA-NESDIS).* Jason-3 will allow the continuity of high-precision ocean topography measurements beyond TOPEX/Poseidon, Jason-1, and Jason-2, which are now operational in orbit. It will also provide a bridge to an operational mission to enable the continuation of multi-decadal ocean topography measurements. Jason 3 will offer the same ocean measurement accuracy as Jason 2, including near-coastal zones, as well as lakes and rivers.

*Climate Satellite Sensors (NOAA-NESDIS).* These instrument development projects are essential to meeting the NOAA Strategic Plan Climate Goal to understand climate variability and change. These sensors will ensure that NOAA continues to provide current, accurate, relevant, and timely climate information to the scientific community and other interested parties through the monitoring of atmospheric conditions (including CO<sub>2</sub>, sulfur dioxide, nitrous oxide, water vapor, methane, ozone, soot, and aerosols), measurements of solar energy reaching the Earth's atmosphere (radiative forcing), and the Earth's reflected and radiated energy.

*National and International Standards for Measurement (NIST).* NIST, through its Greenhouse Gas and Climate Change Program, provides the measurement science and standards to help ensure the accuracy, reliability, compatibility, and traceability of climate and greenhouse gas observations, which underpin climate model predictions and policy decisions.

## 2. Improving our understanding of natural and human forces of climate change

*Improve understanding of how atmospheric composition affects climate (NOAA-OAR).* This activity performs research to understand and quantify the chemical processes responsible for the changes and transformations in the atmosphere related to climate, the stratospheric ozone layer, and air quality; closely related meteorological, dynamical, and radiative processes are also addressed when necessary. These goals are met through studies in the laboratory, extensive measurements in the atmosphere in focused field studies, diagnostic analyses, representation of these processes in models (in collaboration with others in NOAA and the extramural community), and interpreting the results to elucidate the roles of these processes. Several recent studies improve

our understanding of how atmospheric composition affects climate. For example, an analysis shows that the observed decline in stratospheric water vapor of about 10% since 2000 helps explain why global surface temperatures have not risen as fast in the last 10 years as they did in the 1980s and 1990s; a model-independent energy balance analysis confirms the cooling effect of atmospheric aerosols from human-related sources (pollution, biomass burning, and other sources) previously estimated in the 2007 IPCC assessment; and another recent study shows that anthropogenic nitrous oxide (N<sub>2</sub>O) emissions are now the highest of any ozone-damaging substance currently emitted, and are projected to remain so for the rest of this century.

*Other Greenhouse Gas Observations and Research (NOAA-OAR).* This activity provides observations and research on non-CO<sub>2</sub> greenhouse gases, including water vapor, methane, N<sub>2</sub>O, ozone, and fluorocarbons. The activity also carries out research on a variety of processes that impact air quality. The Air Resources Laboratory (ARL) primarily addresses the transport, transformation, and removal of trace substances in the atmosphere, as well as the interaction between trace substances and the Earth's radiative balance. ARL's field and laboratory studies lead to the development of air quality simulation models.

*Carbon Cycle Observations and Research (NOAA-OAR).* The U.S. scientific community coordinates its carbon cycle activities through an integrated interagency effort that aims to quantify, understand, and project the evolution of global carbon sources and sinks in order to better predict future climate. As part of this multiagency effort, NOAA has launched a network of airborne and tall-tower based sampling sites over North America. With input from other agencies, this program forms the foundation for routine spatial carbon maps and periodic State of the Carbon Cycle reports that will keep scientists and policymakers abreast of progress in understanding the North American carbon cycle.

## 3. Improving our capability to model and predict future conditions and impacts

*Climate Modeling (NOAA-OAR).* The goals of this activity are to improve decadal to centennial climate change projections and to provide more reliable estimates of the impacts of climate variability and change on physical variables, ecosystems, and life resources. The activity addresses predictability of

weather on large and small scales; the structure, variability, predictability, stability, and sensitivity of global and regional climate; the structure, variability and dynamics of the ocean over its many space and time scales; the interaction of the atmosphere and oceans, and how the atmosphere and oceans influence and are influenced by various trace constituents; and Earth's atmospheric general circulation within the context of the family of planetary atmospheric circulations.

*Operational Short-Term Forecasting and Monitoring (NOAA-NWS).*<sup>34</sup> This activity includes the strategic vision and production of climate services consisting of operational prediction of climate variability; monitoring of the climate system and development of databases for determining current climate anomalies and trends; and analysis and assessment of their origins and linkages to the rest of the climate system. The activity supports development of policy and requirements for climate prediction products and other services related to the period of week two out to one year, including seasonal forecasts and threat assessments.

*High Performance Computing (NOAA-OAR/CIO).*<sup>35</sup> The High Performance Computing (HPC) activity supports many NOAA Strategic Plan objectives through support of information technology (IT) research targeted at improving NOAA's mission, services, and science education. HPC seeks to make major improvements in the ability to forecast weather and climate, and disseminate environmental information by stimulating modernization of NOAA's computationally intensive services. HPC provides NOAA with mission agency representation in the Interagency Working Group on IT Research and Development.

#### 4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change

*Climate and Ecosystems (NOAA-NMFS).*<sup>36</sup> The goal of this activity is to predict the probable consequences of global climate change for ecological systems and their living resources, and to deliver to fisheries and coastal zone managers the knowledge and tools needed to incorporate climate variability into the management of living marine ecosystems. The activity is developing climate-forced models

used to improve recruitment prediction and stock assessments; developing and generating indices and assessment tools used in fisheries management; and conducting research that provides accessible environmental and ecosystem data for the eastern Bering Sea.

#### 5. Providing climate information and decision support tools

*Adaptive Management Support (NOAA-OAR).* This activity provides national leadership in developing interdisciplinary science and services for application in climate-sensitive sectors (including drought) and regions. The goals include: 1) identification and articulation of user-community requirements in multiple sectors, initially with regard to water resources and the coastal zone and then branching to related sectors; 2) research and development of innovative and broadly applicable approaches to support decisionmaking, especially for risk characterization, both through a broad network of regionally scoped, long-term efforts and stakeholder-specific efforts; and 3) promotion of the transfer of knowledge, tools, and products across climate service development efforts (within NOAA, across the Federal government, nationally, and internationally).

*Assessments (NOAA-OAR).* The goal of this activity is to sustain a program of assessment services linking climate science and climate services via the following activities: developing cross-sectoral climate assessments at national and regional scales; establishing a sustained climate attribution program; and monitoring national and regional socioeconomic trends.

*The National Integrated Drought Information System (NIDIS).* The NIDIS improves the Nation's capacity to proactively manage drought-related risks by providing those affected with the best available information and tools to assess the potential impacts of drought, and to better prepare for and mitigate the effects of drought. The NIDIS will enable users to determine the risks associated with drought and provide supporting data and tools to inform drought mitigation. The development of the NIDIS is happening through a coordinated, multi-faceted program of research, observations, forecast improvements, drought early warning systems, and a portal to provide access to drought-related data and information.

<sup>34</sup> National Weather Service

<sup>35</sup> Chief Information Officer

<sup>36</sup> National Marine Fisheries Service

## 6. Climate Change Communication and Education

*Communication and Education (NOAA-OAR).* NOAA's climate communication and education programs support the development of strong and comprehensive communications and education materials about climate and oceanic and atmospheric sciences. NOAA is committed to supporting and facilitating system-wide change of the formal and informal education system to build educators' capacity to produce climate-literate citizens. Such change requires engagement and participation across the spectrum of the communications and education community—including policymakers, academic institutions, professional associations, teachers, and students. Some of these programs include:

- **Climate Portal:** The program provides an audience-focused approach to promoting climate science literacy among the public. It communicates the challenges, processes, and results of NOAA-supported climate science through stories and data visualizations on the web and in popular media. Provides information to a range of audiences to enhance society's ability to plan and respond to climate variability and change. Additionally, the Climate Portal Education section provides a collection of excellent educational resources so educators, students, and citizens can increase their climate literacy and their ability to make informed decisions.
- **Climate Literacy:** *The Essential Principles of Climate Sciences—A Guide for Individuals and Communities.* This guide presents important information for individuals and communities to understand Earth's climate, the impacts of climate change, and approaches for adapting to and mitigating change. Principles in the guide can serve as discussion starters or launching points for scientific inquiry. The guide can also serve educators who teach climate science as part of their science curricula, and is available to help individuals of all ages understand how climate influences them—and how they influence climate. The Education Interagency Working Group led by NOAA and with NSF and NASA participation compiled the guide. This guide is a resource for the management of Federal education grant programs and both Federal and non-Federal educational programs across the nation.
- **Climate and Society Master's Program:** This program enables understanding of climate science, decision processes, and social needs to deliver management strategies that incorporate climate. The International Research Institute has developed the core courses of the program for Climate and Society in collaboration with Columbia University faculty in climate, engineering, policy, public health, economics, political science, statistics, psychology, sociology, and anthropology.

## DEPARTMENT OF DEFENSE



### Principal Areas of Focus

The Department of Defense (DOD) —while not supporting a formal mission dedicated to global change research—continues a history of participation in the USGCRP through sponsored research that concurrently satisfies both national security requirements and the goals of the USGCRP.<sup>37</sup> All data and scientific results obtained using DOD basic research funds are routinely made available to the civil science community. DOD science and technology investments are coordinated and reviewed by the Office of the Secretary of Defense (Office of Basic Sciences) and the individual research agencies—the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Defense Advanced Research Projects Agency (DARPA). Together they have the responsibility to jointly develop the DOD Basic Research Plan (BRP), which undergoes a biennial program review by a panel of experts from universities, industry, and nonprofit research institutions (Defense Basic Research Review). As the performance of DOD systems, platforms, and operations may be influenced by the natural environmental conditions, understanding the variability in the Earth's environment is of interest to many DOD science programs. Much of the research performed under the ONR's Operational Environ-

<sup>37</sup>. While DOD is an active supporter of the USGCRP, there are no DOD activities included in the budget crosscut and therefore, DOD does not appear in the budget tables.

ments focus area and the ARO's Environmental Sciences Division, for example, lead to fundamental understanding of physical processes that are of particular relevance to the USGCRP.

In the 2010 Quadrennial Defense Review (QDR), the DOD formally recognized the need to understand and adapt to the impacts of climate change on DOD facilities and military capabilities. The DOD relies on the Strategic Environmental Research and Development Program (SERDP), a joint effort among DOD, DOE, and EPA, to develop climate change assessment tools. The DOD will regularly reevaluate climate change risks and opportunities in order to develop policies and plans to manage its effects on the Department's operating environment, missions, and facilities.

### Program Highlights for FY 2011

#### *Global Model Development*

In coordination with other Federal agencies responsible for operational weather and climate forecasting, the Navy is participating in research activities to develop an Earth System Prediction Capability. This next-generation prediction system will consist of a computationally efficient integrated Earth system model, global observations, advanced data assimilation capabilities, and a data communication strategy to enable the system's implementation at multiple operational centers. The centerpiece of the effort is the design and implementation of a global, high-resolution, coupled atmosphere, ocean, cryosphere, and space modeling framework that will support a daily-to-decadal forecast capability. This activity will support basic and applied research to develop innovative approaches and techniques that originate not only within the Federal laboratories of the participating agencies, but also at non-governmental research agencies and academic institutions. The effort is expected to involve an initial 10-year investment in the research and development phase, beginning in FY 2011.

The Navy is a principal member of the National Oceanographic Partnership Program (NOPP), a broad consortium of agencies that collaborate in the development and demonstration of integrated ocean observations systems, data management systems, and real-time coastal, basin-scale, and global ocean prediction systems. Via NOPP, the ONR funds ongoing development of the Hybrid Coordinate Ocean Model

(HYCOM), a predictive model that runs efficiently in parallel computing environments and includes sophisticated techniques for the assimilation of satellite and *in situ* observations. These HYCOM-based ocean predictions are made available to coastal and regional users, as well as to the wider oceanographic and scientific community, including climate and ecosystem researchers, students, and the general public.

The DOD also supports a number of basic research programs within its individual science agencies that are directed toward mission-specific science requirements, but which often also project onto the science goals of the USGCRP. For example, within the "Operational Environments" focus area at the ONR, both observational and modeling elements are incorporated into major field programs designed to advance basic understanding of the physics and dynamics of the Earth's environment. The development of new sensors, sensing platforms, and sensing strategies is supported in order to achieve these goals, and ongoing research into predictive systems for the ocean and atmosphere is supported with the goal of improving environmental forecasts for DOD, although these are also of primary importance in climate models. One recent outcome from this focus area was a new coupled ocean-wave-atmosphere model for hurricanes that shows significant promise in improving forecasts of storm intensity. This work continues in FY 2011 to explore the generation mechanisms of tropical cyclones and their resulting impact on upper ocean thermal structure. The research may lead to a better representation of these systems in climate simulations and improved understanding of the sensitivity of these high-impact weather events to climate change.

#### *Polar Regions Research*

Of particular recent interest to the DOD are the observation, understanding, and prediction of diminished Arctic sea ice cover, as the military may be required to respond to any emerging national security issues. The US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL) actively investigates the impacts of climate trends for USACE, the Army, DOD, and other agencies. The CRREL research program responds to the needs of the military, but much of the research also benefits the civilian sector and is funded by non-military customers such as NSF, NOAA, NASA, DOE, and state governments. Satellite

data show a downward trend in the summer extent of Arctic sea ice in recent years, and the sonar data collected by U.S. Navy submarines in the Arctic between 1957 and 2000 show the average ice thickness has decreased between 33 and 42%. CRREL applies science and engineering research to address climate impacts for DOD and other Federal and state agencies, and through cooperative agreements with academic institutions and private industry.

In FY 2010, the Navy decided to re-invigorate the Science Ice Exercise (SCICEX) program, under which nuclear submarines are used to make observations of Arctic sea ice extent and thickness in support of scientific understanding. SCICEX Phase I (1993 to 1999) made significant *in situ* observations of sea ice for the scientific community, and these efforts will continue in SCICEX Phase II, beginning in 2011. The Navy's Arctic Submarine Laboratory will help facilitate a new era of support for Arctic observations using the Navy's nuclear submarine assets, and in collaboration with the scientific research community will devise sampling plans to add to the body of scientific knowledge and increase understanding of the dynamic Arctic environment.

### *Related Assessment and Adaptation Activities*

Given current best estimates of future climate change, as well as directly observed trends in sea ice cover in the Arctic, the DOD has begun to assess the impacts on DOD assets and missions areas. In FY 2009, the Navy formed Task Force Climate Change (TFCC) to advise the Chief of Naval Operations on the impact of climate change on the Navy and develop science-based recommendations, plans, and actions to adapt to climate change. In FY 2010, TFCC developed an "Arctic Road Map" and a broader "Climate Change Road Map" to guide Navy investment, assessment, research, and operational activities related to changes in the Navy's operational environment. Activities initiated or completed in FY 2009 and FY 2010 under these two road maps include several studies regarding the impact of climate change on Navy installations and missions, three table-top exercises and war games to inform future strategic planning regarding the Arctic and global climate change, incorporation of climate change science and security considerations in the curricula of Navy educational institutions (U.S. Naval Academy, Naval Post Graduate School, and the Naval War College), completion of the SCICEX Plan, signature by the CNO of the Navy's Strategic Objectives for the Arctic Region, participation in several

Arctic exercises and operations (e.g., Northern Edge 2009, Arctic Care 2010, NATSIQ/NANOOK 2010 with Canada, Pacer Goose 2010), approval by the CNO of a three-year plan for Navy-Coast Guard activity in the Arctic, the completion of two Arctic research cruises by scientists from the Naval Research Laboratory, and the development of a U.S. interagency consortium to improve operational and climatic environmental modeling. Activities planned for FY 2011 include the conduction of the Arctic Ice exercise by the Navy Submarine Force, sponsorship of a Navy Climate Change Forum, initiation of a Navy climate change adaptation capabilities-based assessment, conducting several Arctic exercises and operations (e.g., Arctic Care 2010), and formal discussions to expand cooperative international partnerships regarding the Arctic and climate change.

The SERDP funds multiple research and development efforts to understand the impacts that climate change will have on military natural and built infrastructure across the United States and its territories. In FY 2009, a program was begun to develop analysis methods to assess the impact of sea level rise on military infrastructure. Numerous U.S. DOD facilities are located on the coast, on water bodies that are or will become tidally influenced, or in coastal or island areas that will be affected by sea level rise. As a result of the inherent correlation between sea level rise and storm surge damage, this research also includes assessment of the potential impacts caused by increased sea level compounded by accompanying storm activity. A separate program was initiated to develop the science to support managing and restoring coastal ecosystems in the southeastern United States in the context of potential climate change. Of particular interest are the potential impacts of climate change and the attendant ecological response of already stressed ecological systems and their associated threatened, endangered, and at-risk species on military lands in the Southeast. Both of these programs will continue through FY 2011. In FY 2010, work began to develop the science and tools to support managing and recovering ecological systems in the southwestern United States that are currently impacted by altered fire regimes and non-native invasive plant species. Of particular interest are the interactions between non-native invasive plants and altered fire regimes, their potential impacts on southwest ecological systems and associated threatened, endangered, and at-risk species, and the role that climate change may play in further exacerbating these interactions. In FY 2011, new research will begin to improve our under-

standing of the potential impacts of climate change on ecological systems that occur on DOD testing and training lands in Alaska. Of particular concern are climate change impacts that could lead to state changes or regime shifts in ecological systems, and the quantification of impacts due to changes in fire and hydrologic regimes, establishment and spread of invasive species and forest pests, and freeze-thaw cycles associated with permafrost.

Other DOD-sponsored research contributes to observing, understanding, and predicting environmental processes related to global change. These associated research programs include theoretical studies and observations of solar phenomena, monitoring and modeling of unique features in the middle and upper atmosphere, terrestrial and marine environmental quality research, alternative energy generation, and energy conservation measures. The DOD's continued investment in environmental research infrastructure—such as the Navy's procurement of two new ocean-going research vessels for the University-National Oceanographic Laboratory System (UNOLS) fleet, scheduled for delivery in 2014, and the various services' operational oceanographic and meteorological computational centers—will continue to provide data and services useful to the scientific community and the USGCRP.

### 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. This predictive, systems-level understanding of the fundamental science associated with climate change is key to the DOE mission. The integrated portfolio of research ranges from molecular-level to field-scale studies with emphasis on multidisciplinary experimentation and the use of advanced computer models. The science and cutting-edge research capabilities supported enable DOE leadership in climate-relevant atmospheric process research and modeling, includ-

ing clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change modeling; experimental research on the effects of climate change on ecosystems; and integrated analysis of climate change impacts.

DOE supports three primary research activities along with a national scientific user facility. The areas of research are Atmospheric System Research, Environmental System Science, and Climate and Earth System Modeling. DOE also supports the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF), a scientific user facility.

While not included in the USGCRP crosscut, the DOE Office of Climate Change Policy and Technology located within the Office of Policy and International Affairs serves as the focal point within DOE for the development, coordination, and implementation of DOE-related aspects of climate change technical programs, policies, and initiatives. This office also serves as the secretariat for the Climate Change Technology Program (CCTP).

#### DOE Activities or Projects Related to the Six USGCRP Focus Areas

##### *1. Improving our knowledge of Earth's past and present climate variability and change*

*ARM Climate Research Facility and Data Management (DOE-BER).*<sup>38</sup> As a scientific user facility, the ACRF provides the broad climate change scientific community with technical capabilities, scientific expertise, and unique information. ARM provides long-term continuous field measurements of climate data from stationary and mobile platforms and instruments at fixed and varying locations around the globe. These measurements support the advancement of process understanding of the cloud lifecycle, aerosol lifecycle, and cloud-aerosol-precipitation interactions. The stationary sites are located in three different climate regions (mid-latitude, arctic, and tropical); the operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The two mobile facilities provide a capability to address high-priority scientific questions in other regions. The ACRF aerial capability provides *in situ* cloud and radiation measurements that complement the ground-based measurements.

<sup>38</sup>. Office of Biological and Environmental Research

*The Carbon Dioxide Information Analysis Center (DOE-CDIAC).* The CDIAC provides full and open access to quality-assured carbon cycle data for climate change research. Data holdings include records of the concentrations of atmospheric CO<sub>2</sub> and other greenhouse gases; the role of the terrestrial biosphere and the oceans in biogeochemical cycles of greenhouse gases; emissions of CO<sub>2</sub> to the atmosphere; long-term climate trends; the effects of elevated CO<sub>2</sub> on vegetation; and the vulnerability of coastal areas to rising sea level. Supported projects include DOE-supported Free-Air CO<sub>2</sub> Enrichment (FACE) experiments and major interagency projects such as the AmeriFlux network and measurements of CO<sub>2</sub> taken aboard ocean research vessels.

## *2. Improving our understanding of natural and human forces of climate change*

*Atmospheric System Research (DOE-BER).* The Atmospheric System Research activity seeks to resolve the two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosol emissions on the atmospheric radiation balance. The emphasis for Atmospheric System Research is on understanding and modeling the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increases in the concentration of greenhouse gases in the atmosphere.

## *3. Improving our capability to model and predict future conditions and impacts*

*Climate and Earth System Modeling (DOE-BER).* This activity focuses on the development, evaluation, and use of large-scale climate change models to determine the impacts and possible mitigation of climate change. These efforts include the following:

- Regional and Global Climate Modeling focuses on the development, evaluation, and use of regional and global climate models to project future climate with quantified uncertainty. The models span temporal scales of decades to centuries and spatial scales from regional to global. Regional and Global Climate Modeling supports the basic research needed to support national and international climate modeling research and assessments.
- Earth System Modeling focuses on the development and integration of various components

of climatic processes into Earth System Models (ESMs) with high computational throughput to provide simulations of climate variability and change over decadal to centennial time scales. Research includes the incorporation of improved physical representations (e.g., atmospheric, biogeochemical, terrestrial, land-surface-ice, aerosols, and clouds) in the specific modules of the coupled model; development of algorithms and computational methods for coupling of ESM components; coupling and testing of ESM components; abrupt climate change; and visualization and analysis.

- Integrated Assessment research provides scientific insights into options for mitigation of and adaptation to climate change through multi-scale models of the entire climate system, including human processes responsible for greenhouse gas emissions, land use, and combined impacts on and feedbacks from changing human and natural systems, including the energy system. Importantly, Integrated Assessment research develops advanced quantitative tools for exploring the implications of science and technology decisions and innovations for our energy, environmental, and economic futures.

## *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

*Terrestrial Ecosystem Science (DOE-BER).* This research develops a scientific understanding of the effects of climate change on terrestrial ecosystems and the role of terrestrial ecosystems in global carbon cycling. The research focuses on determining the effects of climate change on the structure and functioning of terrestrial ecosystems, understanding the processes controlling the exchange rate of CO<sub>2</sub> between the atmosphere and terrestrial biosphere, evaluating terrestrial source-sink mechanisms for atmospheric CO<sub>2</sub>, and improving the reliability of global carbon cycle models for predicting future atmospheric concentrations of CO<sub>2</sub>. A large-scale, long-term ecosystem experiment to test the effects of climate change on Arctic permafrost has been initiated.

## *5. Providing climate information and decision support tools*

### 6. Climate Change Communication and Education

*Global Change Education Program (DOE-BER).* This program supported graduate and undergraduate fellows, and was completed in FY 2010.

#### DEPARTMENT OF HEALTH AND HUMAN SERVICES



#### Principal Areas of Focus

The Department of Health and Human Services (HHS) supports a broad portfolio of research related to environmental health and the health effects of global change. The National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC) provide the focus for this effort.

The potential health effects of climate change are not fully understood. Complex interactions between humans, ecosystems, and the changing environment will lead to a variety of complicated health effects. Some of these effects are already occurring. Higher temperatures will likely increase tropospheric ozone concentrations that contribute to cardiovascular and pulmonary illness. Droughts and floods can cause injury and lead to sanitation problems as well as mold and chemical exposures. The ranges of vector-borne and zoonotic pathogens and the transmission of food and water-borne pathogens are likely to be affected. Extreme heat events are predicted to become more frequent and intense, and such events will have a major impact on areas and populations that are not well adapted to them. The limited set of activities and projects identified in the FY 2009 through FY 2010 USGCRP HHS budgets are focused on improving our capability to model and predict the impacts of climate change on human health. These are briefly described relative to the USGCRP Goals in the following section. More extensive HHS efforts not identified in the USGCRP budget are described further on in this agency description. The full scope of HHS activities and projects will help to predict and address these and other health consequences of climate change.

### HHS collaborative efforts

HHS actively participated in the ad-hoc Interagency Working Group on Climate Change and Health (IWGCCCH) that produced and published a comprehensive overview of research needs in climate change and health. The report, *A Human Health Perspective on Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change*, provides a starting point for agencies to use in evaluating and prioritizing future climate change and health research. The National Institute of Environmental Health Sciences (NIEHS) coordinated this effort and provided both the coordinating lead author and editor, while CDC also provided authorship and editing support. Similarly, HHS is involved in the new Crosscutting Group on Climate Change and Human Health (CCHHG) that has been created under the auspices of the USGCRP. NIH and CDC both participate in this effort. NIEHS co-chairs the effort, with EPA and OSTP serving as the other co-chairs. This new group will define research and scientific priorities for the human health consequences of climate change across the Federal government and span the continuum of research to application by aiming to provide decision support tools and other resources that will enable informed decisionmaking at local, state, tribal, national, and international levels.

### National Institutes of Health

NIH work in climate change involves numerous Institutes and Centers and focuses principally on the mechanisms of climate-sensitive diseases and conditions and their impacts on health outcomes. NIH supports USGCRP research on the health effects of air pollution and temperature, water quality and quantity, infectious disease transmission, and materials used in new technologies to mitigate or adapt to climate change. Topics being investigated by NIH include the direct health impacts of increased temperatures and extreme weather events; impacts of climate change on water and food quality including contamination during extreme events and the health effects of changes in temperature of coastal waters; and direct and indirect effects of climate change on human diseases such as asthma and respiratory diseases and vector-borne and infectious diseases. NIH also supports research and training activities on physical injuries and post-traumatic stress disorders, development of disaster and emergency response planning tools, and the use of microbes to reduce CO<sub>2</sub> emissions.

NIH has been involved in several targeted initiatives and activities focused on climate change and health. NIEHS and the Fogarty International Center (FIC) co-chair a trans-NIH Working Group on Climate Change and Health with active participation from 18 NIH Institutes and Centers. The group's goals are to identify research needs and priorities for an NIH research agenda for climate change and health, to identify and coordinate relevant research and training activities, and to engage the broader biomedical research community in discussions of the health effects of climate change. NIEHS also partnered with the London School of Hygiene and Tropical Medicine and the Wellcome Trust to commission a series of studies examining the relationships between climate change mitigation measures and household energy emissions, urban land transportation, low-carbon electricity generation, agriculture and food, and short-lived greenhouse pollutants.

NIH recently initiated a new focused research program that encourages research applications to assess and characterize the differential risk factors of populations that lead to or are associated with increased vulnerability to exposures, diseases, and other adverse health outcomes related to climate change. The ultimate goal of this research program is to help inform climate change adaptation and public health interventions to reduce vulnerability of various populations to the health effects of climate change. NIEHS is the primary institute issuing the funding opportunity announcement, with 10 of the remaining 26 Institutes and Centers of the NIH participating. Research applications will be accepted over a three-year period with a first set of awards made in FY 2011. This activity is not listed in the HHS budget table.

### *Centers for Disease Control and Prevention*

CDC uses a multi-pronged strategy to investigate the health effects of climate change while bolstering research efforts and implementing adaptation strategies. In collaboration with the Association for State and Territorial Health Officials (ASTHO) and the National Association of County and City Health Officials (NACCHO), CDC provides funding and technical assistance to five state health departments and seven local health departments to develop pilot projects addressing the public health consequences of climate change. In FY 2010, CDC expanded this effort by launching a series of grants to build the capacity of state and local health departments to develop and

implement comprehensive climate and health adaptation plans. CDC also has developed and produced decisionmaking tools for local health practitioners, including a Code Red Heat Awareness Campaign toolkit for athletic trainers to educate on how to recognize, treat, and prevent heat-related illness among their student athletes.

A focus on workforce development and capacity building in the public health sector has been implemented through a series of CDC-hosted webinars titled "Climate Change: Mastering the Public Health Role." The series focuses on effectively communicating the health-related aspects of climate change. In addition, CDC and the National Center for Atmospheric Research (NCAR) co-host a postdoctoral research fellowship focusing on climate and health. CDC also directly funds and provides technical assistance to 18 research projects investigating specific aspects of climate and health, ranging from a University of California Davis study on the impact of climate change on mosquito-borne arbovirus transmission to a Georgia Institute of Technology study on the impact of Climate-Responsive Design on heat-related morbidity and mortality

### **HHS Activities or Projects Related to the Six USGCRP Focus Areas**

- 1. Improving our knowledge of Earth's past and present climate variability and change*
- 2. Improving our understanding of natural and human forces of climate change*
- 3. Improving our capability to model and predict future conditions and impacts*

*Human Health Impacts of Climate Change (NIH-NIEHS, FIC, NIGMS, NLM).* As part of the American Recovery and Reinvestment Act of 2009, NIH requested research proposals that focused on the development of models to predict the health effects of climate change. Five studies were funded under this mechanism: two by NIEHS, and one each by FIC, the National Institute of General Medical Sciences (NIGMS), and the National Library of Medicine (NLM). This research will directly support the development of quantitative and predictive models of the effects of climate change on disease burden and health outcomes that are needed to facilitate public health planning and

inform adaptation strategies. Health outcomes that are being modeled under these grants include heat morbidity and mortality, respiratory and cardiovascular effects of wildfires, asthma, skin cancer, salmonellosis, cholera, and diseases associated with climate-induced population displacement. Unsolicited Grants in Health and Climate Change Research (NIH-NIEHS, FIC, NIGMS, NLM). The NIH Research Portfolio Online Reporting Tools lists 17 projects under the category Climate Change funded by seven different Institutes and Centers.

#### *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

#### *5. Providing climate information and decision support tools*

#### *6. Climate Change Communication and Education*

*Centers for Disease Control.* CDC leads and participates in a number of educational programs focusing climate and health. CDC, along with the American Public Health Association (APHA), NACCHO, ASTHO, and the Society for Public Health Education (SOPHE), is co-sponsoring and hosting a series of webinars titled "Climate Change: Mastering the Public Health Role." The series focuses on effectively communicating the health-related aspects of climate change, promoting workforce development, and ensuring capacity building at local levels, all core areas of focus within the CDC Climate Change Program. CDC also designed and disseminates the Extreme Heat Media Toolkit—a suite of communications materials including websites, public service announcements, heat alerts, press releases, and other downloadable/customizable materials aimed at supplementing existing emergency management plans through better targeting of vulnerable populations and reducing deaths during excessive heat events.

*National Institute of Environmental Health Sciences.* NIEHS has engaged in a variety of communications and education activities on the topic of climate change and health aimed at diverse audiences. For researchers, public health professionals, and other relevant audiences, NIEHS supported and produced two seminal documents in the last year: A Human Health Perspective on Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change, and a series of studies

published in The Lancet on the health benefits of tackling climate change. These reports were published in print and online and disseminated broadly. The Lancet series was launched in a joint U.S.-UK videoconference with global climate change and health leaders participating. The research needs paper was published on Earth Day by Environmental Health Perspectives (EHP), and was accompanied by Congressional briefings in the House and Senate. The NIEHS website contains climate change-related information pages throughout the site for different audiences and in relation to different institute programs. The EHP website also contains a large body of research and information on climate change including a dedicated news topic page. NIEHS staff frequently speak at scientific and stakeholder meetings, seminars, and conferences on the subject of climate change and health. NIEHS staff are also currently engaged in multiple interagency climate change communications planning and strategy activities as core representatives of HHS.

## DEPARTMENT OF THE INTERIOR



### Principal Areas of Focus

Like several other USGCRP agencies, the Department of the Interior (DOI) is both a natural resource management agency and a science agency. DOI global change research is conducted mainly through the U.S. Geological Survey (USGS), but several other DOI bureaus are contributing to the goals of the USGCRP strategic plan through activities such as monitoring, impact assessments, and adaptation planning.

Evolving from an organization that was created to inventory the Nation's public lands and natural resources, the mission of the 21st-century USGS is most simply expressed in its maxim "Science for a Changing World." Emphasis on global change, its causes and effects, has increased substantially over the past five years as USGS scientists have worked in collaboration with other USGCRP agencies to meet the pressing needs of the DOI, policymakers, and resource managers for scientifically valid state-of-the-

science information and predictive understanding of global change and its effects.

USGS studies of the interactions among climate, Earth surface processes, and ecosystems across space and time contribute directly to the strategic goals and core competencies of the USGCRP. To answer questions about how the world is changing, USGS is expanding its research and monitoring initiatives in the science of carbon, nitrogen, and water cycles; hydroclimatic and ecosystems effects of climate change; and land cover and land use change. The USGS will continue studies of paleoclimate and past interactions of climate with landscapes and ecosystems, and apply the knowledge gained to understanding potential future states and processes. Expanded and modernized USGS observing networks of land, water, and biological resources will be crucial to rigorous analyses of future responses to climate change. The USGS will provide robust predictive and empirical tools for managers to test adaptive strategies, reduce risk, and increase the potential for hydrologic and ecological systems to be self-sustaining, resilient, or adaptable to climate change and related disturbances.

Many of the U.S. observations important for documenting climate change are produced by operational systems not reflected in the USGCRP Budget Cross-cut (see last section of this report). For example, DOI's streamgage system and the Water Census activity are key activities that provide objective data on climate-Earth system interaction and support adaptation decisionmaking.

## DOI Activities or Projects Related to the Six USGCRP Focus Areas

### 1. Improving our knowledge of Earth's past and present climate variability and change

*Climate History and Past Environmental Change Research Focus (USGS-GCP).*<sup>39</sup> The past is the key to the future. In order to understand future climate change and its impacts, USGS scientists in the Climate History and Past Environmental Change Research Focus conduct research using the geologic record to extract scientific information about changes in temperature, hydrologic conditions, vegetation, and atmospheric greenhouse gas concentrations in Earth's past, as a way to constrain and test models used to forecast future climate and climate effects. Climate history and paleoenvironmental data—including informa-

tion gathered from sediments, tree rings, ice cores, and fossil pollen records—provide insights into the length, intensity, and character of past climate trends and the causes and mechanisms of climate change (including abrupt changes in climate), and help to improve forecasts of the impacts of climate change and variability on landscapes, watersheds, ecosystems, and human communities.

*National Satellite Land Remote Sensing Data Archive (USGS-LRSP).*<sup>40</sup> The Earth is changing in ways that are not fully understood. It is not possible to comprehend the meaning of these changes without a clear and consistent record of observable surface phenomena. In 1992, Congress directed DOI to establish a permanent government archive containing satellite remote-sensing data of the Earth's land surface, and to make these data easily accessible and readily available for study. Residing in the USGS Earth Resources Observation Systems (EROS) Data Center near Sioux Falls, South Dakota, this collection of information is known legally as the National Satellite Land Remote Sensing Data Archive (NSLRSDA). It is a comprehensive, permanent, and impartial record of the planet's land surface derived from more than 40 years of satellite remote sensing. Only with satellites, which can cover large areas of the globe at regular intervals, is it practical to quickly understand such developments as deforestation, desertification, some kinds of environmental contamination, and natural hazards. Comparisons of satellite images of a specific site from different times can make these phenomena quite clear. In addition to providing a record of change at the global scale, NSLRSDA permits scientists to study water, energy, and mineral resource problems; to help protect environmental quality; and to contribute to prudent, orderly management and development of our Nation's natural resources.

### 2. Improving our understanding of natural and human forces of climate change

*Carbon Cycle Science Research Focus (USGS-GCP).* Carbon cycle science at USGS includes a range of activities from assessments of geologic and biologic carbon sequestration potential through basic and applied research into atmospheric, terrestrial, and oceanic carbon. The Global Change Research and Development Carbon Cycle Science Research Focus provides rigorous research data to support multiple other carbon, resource and landscape monitoring, assessment, and management activities. USGS scientists

<sup>39</sup>. USGS Global Change Programs

<sup>40</sup>. Land Remote Sensing Program

in this focus conduct longitudinal studies of carbon cycling and carbon flux in ecosystems and the water cycle, carbon in lateral transport to coastal oceans, carbon paleohistory, isotopic research including Carbon-14, implications and consequences of ocean acidification and anoxia, carbon in urban settings, as well as carbon in soils, peat, permafrost, wetlands, and biomass as a function of land use and land cover change. Work includes studies of CO<sub>2</sub>, methane emissions and storage (terrestrial and oceanic), dissolved organic carbon, oceanic and lacustrine carbonates of both organic and inorganic sources, and other species, and quantitative modeling and dynamic vegetation modeling. Research in this Focus is conducted across the landscape and includes collaborative efforts at LTER sites and Ameriflux sites. Research in this Focus is linked to the North American Carbon Program (NACP) and the Ocean Carbon Program (OCP).

### *3. Improving our capability to model and predict future conditions and impacts*

*Hydrology and Hydrologic Consequences of Climate Change Research Focus (USGS-GCP).* USGS scientists in the Hydrology and Hydrologic Consequences of Climate Change Research Focus investigate and monitor the hydrological system, including glacier mass balance, drought, snowpack, and water availability, and conduct studies of the physical and biological processes—including the effect of atmospheric and climatic variables—that control water, energy, and biogeochemical fluxes over a range of temporal and spatial scales. Included within this Focus is the Water, Energy, and Biogeochemical Budgets (WEBB) small watershed research program. WEBB's long-term data sets represent watersheds along a continuum of annual precipitation and temperature. The variety of conditions (tropical, subtropical, temperate, subalpine, alpine) provide a gradient in which to study and contrast processes, such as weathering and sediment transport, within and across watersheds. This focus has documented how water and solute fluxes; nutrient, carbon, and mercury dynamics; and weathering and sediment transport respond to natural and human-caused drivers, including climate, climate change, and atmospheric deposition. WEBB conducts integrated science that links issues of water cycling and availability, carbon and inorganic solute movement and transformation, and effects on ecosystem services of a changing climate to elucidate the vital transfers of water, energy, solutes, and gases within and across ecosystems. These results will feed

directly into the next generation of climate effects models.

*Land Use and Land Cover Change Research Focus (USGS-GCP).* Land use and land cover change are both drivers and consequences of climate change. Land cover change affects a broad range of socioeconomic, biologic, and hydrologic systems, with potential feedbacks to the climate system and impacts on land management practices, economic health and sustainability, and social processes. The objectives of the Land Cover and Land Use Change Research Focus are to (1) determine the amount, rates, and trends of contemporary land use and land cover change by ecoregion for the period 1973 to 2000 for the 84 ecoregions that comprise the conterminous United States; (2) document the regional driving forces and consequences of change; and (3) synthesize individual ecoregion results into a national assessment of land use and land cover change. Results from this research focus help to provide a basis for understanding the rates, patterns, and driving forces of past and present land use and land cover change for improved predictions of future changes, thereby supporting decisionmaking for improved management of lands, resources, and ecosystem goods and services.

*Effects of Climate Change on Terrestrial, Freshwater, and Marine Ecosystems (USGS-BRD).*<sup>41</sup> Civilization depends on life-support services that natural ecosystems perform, including regulating climate, mitigating floods and drought, protecting shorelines from erosion, purifying air and water, detoxifying and decomposing wastes, and pollinating crops and natural vegetation. Healthy ecosystems provide habitat for diverse fish and wildlife communities. Studies conducted by USGS Terrestrial, Freshwater, and Marine Ecosystems scientists describe factors that control ecosystem structure, function, condition, and the provision of goods and services. This information is used to predict future changes in ecosystems and to describe the results of management alternatives. Ecosystem science is thus used to restore degraded landscapes and freshwater systems, sustain plants and animals, and find means to adapt management to conditions of global change.

### *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

*Climate Effects Network (USGS-GCP).* The vision for the DOI Climate Effects Network (CEN) is to “provide

<sup>41</sup>. Biological Research Division

Earth system information for understanding, tracking, and forecasting the effects of climate change on ecosystems, natural resources, and society; and to empower and assess adaptation or mitigation responses to those changes in the most cost effective, timely, and scientifically-rigorous manner possible” (DOI Climate Impacts Task Force, 2009). In the CEN Pilot area in the Yukon River Basin, CEN conducts continuous ecosystem response research and assessment, integrates with wildlife and climate change initiatives, and completes assessment products. In other areas, CEN is developing collaborations with NSF’s National Ecological Observatory Network (NEON) to leverage the rapid increase in observational capability being initiated in 2011 by NEON in the USGS Central Region.

*Impacts of Climate Change on Communities, Landscapes, Ecosystems, and Organisms Research Focus (USGS-GCP).* USGS scientists in the Impacts of Climate Change on Communities, Landscapes, Ecosystems, and Organisms Research Focus conduct basic and applied research into the response of systems to climate change, and the feedbacks from those responses. Current areas of concentration include vulnerability and adaptation to climate change; assessing and narrowing uncertainties in population projections for threatened species; understanding and forecasting responses of ecosystems, habitats, and migratory species to climate change and climate change effects such as warming, drying, or sea level rise; thresholds and ecosystem sensitivity to climate change; effects of climate change on the structure and function of ecosystems; modeling and simulations of potential future habitats under IPCC future climate scenarios; and hydrologic assessment of coastal vulnerability and sea level rise impacts on natural resources. The data, process-response, and feedback information, and modeling outcomes that result from these studies, provide science-based inputs to land and resource managers and other decisionmakers.

*Support for Fish and Wildlife Service Climate Change Activities (USGS-BRD).* The USGS will provide ecological and population modeling capacity to Fish and Wildlife Service (FWS) Landscape Conservation Cooperatives and information to FWS geospatial specialists. These specialists will characterize species-habitat interactions for Strategic Habitat Conservation. This vital activity will help to merge large-scale global change information with more local information that is relevant to resource managers. The information will be used to integrate USGS ca-

pabilities in modeling current and projected physical and biological change across extensive landscapes and aquatic systems with studies of ecosystem and population processes. The new models will be applied to adaptive management of fish and wildlife faced with climate change. This will require strengthened population and ecosystem modeling capacities at the regional and local levels, better integration of remotely sensed and other existing data sets, standardization of monitoring protocols in local applications, and a renewed focus on analytical support for FWS and state and tribal resource managers.

## 5. *Providing climate information and decision support tools*

*Decision and Support Science Applications (USGS-GCP).* USGS scientists work directly with resource managers in the field and understand their needs. The Science Applications and Decision Support element of the USGS Global Change program develops decision support tools that enable resource managers and policymakers to cope with and adapt to a changing climate. Collaboration with a number of universities including Cornell, Colorado State University, the Massachusetts Institute of Technology, and Montana State University has been established and spans the fields of social science, natural resources, artificial intelligence, statistics, and Earth sciences. Decision support will be developed through new partnerships, enhancement of existing collaborations, and in training the next generation of applications scientists. The emphasis is to bring scientists and natural resource managers together to plan, develop, use, and evaluate decision support programs. This spans everything from web sites to hands-on extension programs, from computerized tools to public workshops. Providing application support to DOI’s Landscape Conservation Cooperatives is particularly important.

*National Climate Change and Wildlife Science Center (USGS-GCP).* The Earth’s climate, including changes in temperature, weather patterns, and precipitation, is expected to have significant effects on the Nation’s fish and wildlife resources now and in the future. Relatively little scientific information exists to inform adaptation or management of fish and wildlife in the face of climate change. The USGS is meeting this challenge through the new National Climate Change and Wildlife Science Center. Climate change crosses jurisdictional boundaries and affects all Earth processes. The Center is therefore being designed with input from Federal, state, and tribal science

and management agencies; NGOs; academic institutions; and others having an interest in conserving America's fish and wildlife resources. Mobilization of existing assessment and monitoring capabilities, and coordination of interagency and inter-organizational efforts from across the country, is needed for timely forecasting of responses at multiple spatial and temporal scales. The National Climate Change and Wildlife Science Center provides our fish and wildlife partners with access to other USGS Global Change Science capabilities and products.

*DOI Regional Climate Science Centers (USGS-GCP and other DOI bureaus).* Under the direction of P. L. 110-161, the National Climate Change and Wildlife Science Center had begun establishing regional offices in close collaboration with Interior agencies and other Federal, state, university, and non-governmental partners. The Secretary broadened the scope of the regional offices to encompass other climate-change related impacts on departmental resources, and created DOI Climate Science Centers. In 2010, USGS worked with other DOI bureaus to establish Regional Climate Science Centers. These centers will synthesize and integrate climate change impact data and develop tools that DOI's managers and partners can use when managing DOI's land, water, fish and wildlife, and cultural heritage resources. The Secretarial Order recognized that, because of the broad impacts of climate change, management responses must be coordinated at a landscape scale. Because of the unprecedented scope of affected landscapes, the Executive Order directs Interior bureaus to work together, with other Federal, state, tribal, and local governments, including private landowners, to develop landscape-level strategies for understanding and responding to climate change impacts. The Department began to establish a network of Landscape Conservation Cooperatives to work cooperatively with the DOI Regional Climate Science Centers to coordinate natural resource adaptation efforts across the Nation.

*Biological Carbon Sequestration Assessment (USGS-GCP).* USGS is leading a DOI process to develop a methodology for a National Assessment of Biological Carbon Sequestration Resources. This activity, authorized by the Energy Independence and Security Act of 2007, was initiated in 2009. The assessment methodology was completed in 2010.<sup>42</sup> Biological carbon sequestration refers to both natural and deliberate processes by which CO<sub>2</sub> is removed from the atmosphere and

stored in vegetation, soils, and sediments. Biological carbon storage is susceptible to disturbances like fire, disease, and changes in climate and land use. Deliberate biological sequestration can be accomplished through forest and soil conservation practices that enhance the storage of carbon (such as restoring or establishing forests, wetlands, and grasslands) or reduce CO<sub>2</sub> emissions (such as reducing agricultural tillage and managing wildfires strategically). Assessment of biological carbon sequestration resources requires quantifying the factors that control potential capacities of sequestration, and providing information for use in complex resource management decisions and policies. USGS historical data sets provide information to test and update time-dependent models used to estimate potential future carbon sequestration and greenhouse gas fluxes. DOI's land and resource management responsibilities provide a practical context for applying information about potential rates and capacities of carbon storage in ecosystems.

*Geological Carbon Sequestration Assessment (USGS-GCP).* In 2009, in accordance with the Energy Independence and Security Act of 2007, USGS developed a methodology to assess the Nation's resources for geologic carbon sequestration in oil and gas reservoirs and saline formations. This methodology is designed to estimate storage resource potential that can be applied uniformly to geologic formations across the United States. The resource assessed is the volume of pore space into which CO<sub>2</sub> can be injected and retained. The methodology uses probabilistic methods to incorporate uncertainty and natural variability in volumetric parameters. This assessment methodology focuses on the technically accessible resource, not a total in-place resource volume. This is a resource that may be available using present day geological and engineering knowledge and technology for CO<sub>2</sub> injection into geologic formations. This methodology was published and made available for comment by the public and an independent review panel was convened of individuals with expertise in these issues.<sup>43</sup> Application of the new geological sequestration assessment methodology to evaluate the Nation's potential resources for geological stor-

<sup>42</sup>. See [pubs.usgs.gov/sir/2010/5233/](http://pubs.usgs.gov/sir/2010/5233/)

<sup>43</sup>. Burruss, R.C., S.T. Brennan, P.A. Freeman, M.D. Merrill, L.F. Ruppert, M.F. Becker, W.N. Herkelrath, Y.K. Kharaka, C.E. Neuzil, S.M. Swanson, T.A. Cook, T.R. Klett, P.H. Nelson, and C.J. Schenk, 2009: Development of a Probabilistic Assessment Methodology for Evaluation of Carbon Dioxide Storage. U.S. Geological Survey Open-File Report 2009-1035, 81 p., available only online at [pubs.usgs.gov/of/2009/1035/](http://pubs.usgs.gov/of/2009/1035/)

age began in 2010 after revision of the methodology following the external review.

*Chesapeake Bay Executive Order—Treasured Landscapes Initiative (USGS-GCP).* The USGS is working with Federal agencies (NOAA, EPA, FWS, the National Park Service (NPS), and USACE) to address the highest priorities of the Chesapeake Bay Executive Order, with a focus on addressing the impacts of climate change and providing science to improve decision-making. As described in the 9 November 2009 Draft Strategy, USGS and NOAA will increase efforts to provide science to and engage state, local, and private partners in a collective effort to improve water quality; conserve and restore habitats, fish, and wildlife; and plan for climate change in the Chesapeake Bay and watershed. For FY 2011, the President’s budget calls for USGS, working with NOAA and other Federal partners, to build on their current activities as described in the President’s Executive Order Strategy, released 12 May 2010.

## 6. Climate Change Communication and Education

*Earth Science Education.* USGS provides scientific information intended to help educate the public about natural resources, natural hazards, land use change, climate change, and issues that affect our quality of life. Online resources are also provided, including lessons, data, maps, and more, to support teaching, learning, education (K-12), and university-level inquiry and research. USGS Educational Resources for Secondary Grades Middle School and High School are designed to assist educators in secondary school grades (Grade 7 to Grade 12). Many of these resources address climate change and variability and can be used either directly in the classroom or as resources for teacher education and curriculum development.

*Mendenhall Research Fellowship Program.* The USGS Mendenhall Research Fellowship Program provides an opportunity for postdoctoral fellows to conduct concentrated research in association with selected members of the USGS professional staff, often as a final element to their formal career preparation. Roughly one-third of 73 Mendenhall research opportunities advertised for FY 2011 relate to climate change. The number of postdoctoral fellows hired depends on funding available; the expected range is 12 to 20 each year. Examples of topics advertised for Mendenhall fellowships in FY 2011 include: Forecasting the Effects of Climate Change on the

Interactions of Native and Nonnative Salmonids, Climate Forcing of Volcanic and Earthquake Hazards, Methane Hydrates and Global Climate Change, and Simulating Interactive Responses of Stream Flow and Temperature Distributions to Climate Change.

## DEPARTMENT OF STATE



### Principal Areas of Focus

Through Department of State (DOS) annual funding, the United States is the world’s leading financial contributor to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Intergovernmental Panel on Climate Change (IPCC)—the principal international organization for the assessment of scientific, technical, and socioeconomic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. Recent DOS contributions to these organizations provide substantial support for global climate observation and assessment activities in developing countries. DOS also works with other agencies in promoting international cooperation in a range of bilateral and multilateral climate change initiatives and partnerships.<sup>44</sup>

### Program Highlights for FY 2011

During FY 2011, DOS will continue to support the activities of the UNFCCC and the IPCC, and will advance and develop international climate and related energy partnerships.

<sup>44</sup> The DOS is an active supporter of the USGCRP. However, there are no DOS activities included in the budget crosscut and therefore, DOS does not appear in the budget tables.

## DEPARTMENT OF TRANSPORTATION



### Principal Areas of Focus

The Department of Transportation (DOT) conducts research and uses existing science to improve decisionmaking tools to address climate change. DOT supports research that 1) examines the potential impacts of climate variability and change on transportation infrastructure and services; 2) examines increasing energy efficiency and reducing greenhouse gases; and 3) improves transportation greenhouse gas data and modeling. DOT has many programs that have either direct or indirect climate benefits, and is working to develop cross-modal strategies to reduce greenhouse gas emissions.

DOT's Center for Climate Change is the Department's focal point for information and technical expertise on climate change. The Center coordinates research, policies, and actions related to transportation and climate change with DOT's component organizations. The Center promotes comprehensive approaches to reduce greenhouse gases, to prepare for the potential impacts of climate change, and to develop necessary adaptations to transportation operations and infrastructure. The Center supports the USGCRP focus areas through these objectives.

The Federal Aviation Administration (FAA) participates in the Center and also has programs to identify and assess and identify potential measures to reduce fuel consumption and greenhouse gas emissions. FAA conducts research to support USGCRP Focus Area 2: leveraging research with other U.S. government agencies to reduce uncertainties surrounding aviation emissions and their effect on climate change. More specifically, FAA works with NASA, NOAA, and EPA in the Aviation Climate Change Research Initiative (ACCRI), which is a practical-need driven research program with an objective to identify and address key scientific gaps and uncertainties regarding aviation climate impacts while providing timely scientific input to inform optimum mitigation actions and policies. FAA also works with NASA and Trans-

port Canada in the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence, which fosters advances in alternative fuels, emissions, noise, operations, aircraft technologies, and science and decisionmaking for the betterment of mobility, economy, national security, and the environment.

FAA has a number of ongoing operational initiatives to reduce fuel consumption and thus the amount of greenhouse gas emissions produced by aviation, including improved air traffic management, reduced vertical separation minimums, and the voluntary airport low-emissions program that assists in deploying low-emissions technology to airport operations. Additionally, FAA participates to a significant extent in the work program of the International Civil Aviation Organization's Committee on Aviation Environmental Protection, and provides technical expertise and data to the IPCC and the UNFCCC in support of the overall DOT mission on international climate change work.

Other Departmental initiatives also address climate change and improve the overall sustainability of the U.S. transportation sector but are not specifically part of the USGCRP budget crosscut for DOT. These include:

The FAA, with support from NASA, has developed the continuous lower energy, emissions, and noise (CLEEN) program as a government-industry consortium to develop and mature environmentally promising technologies for more efficient energy use, reductions in aircraft noise and emissions, and advancing alternative fuels for civil subsonic jet aircraft. Similarly, the Commercial Aviation Alternative Fuels Initiative (CAAIFI) is a forum that engages national and international stakeholders and coordinates their activities to advance exploration, qualification, certification, and deployment of alternative aviation fuels.

DOT is developing models to predict future conditions and impacts of climate on the Nation's transportation system. The Federal Highway Administration (FHWA) is leading the development of strategies for risk and vulnerability assessments as well as providing climate information on the regional impacts of climate change in order to assist the transportation community in making decisions. FHWA, in collaboration with other agencies, provides climate change information to the transportation community. An example is the May 2010 FHWA publication, Regional

Climate Change Effects: Useful Information for Transportation Agencies. In addition, FHWA is in the process of developing official risk and vulnerability assessment tools for transportation professionals.

Through the National Highway Traffic Safety Administration (NHTSA), DOT is improving the fuel economy of the nation's on-road vehicles, including a recent joint rulemaking with EPA to establish fuel economy and greenhouse gas emission standards for model years 2012 to 2016. Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) is a grant program from the American Recovery and Reinvestment Act of 2009 that is awarding \$100 million in funding to transit agencies that reduce energy consumption and/or greenhouse gas emissions.

DOT is working with EPA and the U.S. Department of Housing and Urban Development in the Partnership for Sustainable Communities to ensure that housing and transportation goals are met while simultaneously protecting the environment, promoting equitable development, and helping to address the challenges of climate change.

The Center for Climate Change leverages resources by building strategic partnerships and reaches out to state and local agencies, environmental advocates, industry, and academia. This ranges from simple information exchange to ongoing partnerships in major research initiatives and conferences. The Center builds DOT capacity and awareness by conducting educational forums and establishing a clearinghouse for research and policy coordination related to transportation and climate change.

## DOT Activities or Projects Related to the Six USGCRP Focus Areas

### *1. Improving our knowledge of Earth's past and present climate variability and change*

### *2. Improving our understanding of natural and human forces of climate change*

ACCRI and PARTNER climate change research activities (FAA-OEE). The objective of these activities is to better quantify the influence of aviation emissions on climate change; to reduce uncertainties in our understanding of aviation climate impacts through model simulations, data analysis, and laboratory

measurement; and to develop a global inventory of aircraft emissions.

### *3. Improving our capability to model and predict future conditions and impacts*

### *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

### *5. Providing climate information and decision support tools*

*Support for DOT Climate Center's Study, the Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 2 (FHWA-HEP).*<sup>45</sup> The Gulf Coast Study—Phase 2, building on Phase 1, will develop more definitive information about impacts at a particular local level, analyze the key transportation links, and develop more precise tools and guides for state DOT and Metropolitan Planning Organization planners to use in adapting to potential climate impacts and determining vulnerability for key links for each mode. Phase 2 will develop a risk assessment tool to allow decisionmakers to understand vulnerability to climate change and develop a process to implement transportation facility improvements in a systematic manner. Estimated completion time is three years. Phase 1, completed in 2008, studied how changes in climate over the next 50 to 100 years could affect transportation systems in the U.S. central Gulf Coast region and the need to address potential impacts in transportation planning.

*Transportation's Role in Reducing U.S. Greenhouse Gas Emissions (DOT).* This April 2010 report to Congress on transportation and climate change meets requirements of the Energy Independence and Security Act of 2007 and helps inform the debate on surface transportation reauthorization and climate change legislation. The report examines greenhouse gas emission levels and trends from the transportation sector and analyzes the full range of strategies available to reduce these emissions. These strategies include introducing low-carbon fuels, increasing vehicle fuel economy, improving transportation system efficiency, and reducing carbon-intensive travel activity. The report also provides an analysis of policy options for implementing the strategies.

<sup>45</sup>. FHWA Office of Planning, Environment, and Realty

*6. Climate Change Communication and Education*

**AGENCY FOR INTERNATIONAL DEVELOPMENT**



**Principal Areas of Focus**

The U.S. Agency for International Development (USAID) supports a number of programs that enable decisionmakers to apply high-quality climate information to decisionmaking. USAID is the lead contributor to bilateral assistance, with a focus on capacity building, civil society building, governance programming, and creating the legal and regulatory environments needed to address climate change. USAID leverages its significant technical expertise to provide leadership in development and implementation of low-emissions development strategies, creating policy frameworks for market-based approaches to emission reduction and energy sector reform, promoting sustainable management of agricultural lands and forests, and mainstreaming adaptation into development activities in countries most at risk. USAID has long-standing relationships with host country governments that enable it to work together with these countries to develop shared priorities and implementation plans. USAID's engagement and expertise in agriculture, biodiversity, health, and other critical climate-sensitive sectors provide an opportunity to implement innovative cross-sectoral climate change programs. Finally, USAID bilateral programs work in key political and governance areas that multilateral agencies cannot.

**USAID Activities or Projects Related to the Six USGCRP Focus Areas**

*1. Improving our knowledge of Earth's past and present climate variability and change*

*2. Improving our understanding of natural and human forces of climate change*

*3. Improving our capability to model and predict future conditions and impacts*

*Famine Early Warning System Network (DCHA).*<sup>46</sup> In general, the Famine Early Warning System Network (FEWS NET) uses existing global and local weather, climate, agriculture, and food security early warning data to identify, monitor, and predict specific regional, national, and sub-national ("local") climate change impacts in food insecure countries, and then assesses how local food security conditions may be affected by them, and identifies the type of general adaptation strategies that may be most appropriate to mitigate or avoid negative food security outcomes. FEWS NET also uses global historical climate and agricultural observations, augmented by dense national climate records from food insecure countries. From this, it detects recent, and predicts near- to medium-term, impacts of climate change in specific local food insecure environments. Using this same data, FEWS NET also attempts to identify significant regional (e.g., East Africa) drivers of decadal climate variability, evaluate their recent and near- to medium-term trends, and evaluate their likely future impacts on local climate.

*4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

*5. Providing climate information and decision support tools*

*SERVIR (EGAT).*<sup>47</sup> USAID and NASA partner to support the Sistema Regional de Visualización y Monitoreo (SERVIR), an Earth observation, monitoring, and visualization system that integrates satellite and other geospatial data for improved scientific knowledge and decisionmaking by managers, researchers, students, and the general public in developing countries. These systems utilize multiple information streams to fill a number of data and capability gaps that limit developing country capabilities to deal with changing climate.

*6. Climate Change Communication and Education*

<sup>46</sup>. Democracy, Conflict, and Humanitarian Assistance

<sup>47</sup>. Economic Growth, Agriculture, and Trade

## ENVIRONMENTAL PROTECTION AGENCY



### Principal Areas of Focus

The core purpose of the Global Change Research Program in the U.S. Environmental Protection Agency (EPA) Office of Research and Development is to provide scientific information to stakeholders and policymakers to support them as they decide whether and how to respond to the risks and opportunities presented by global change. The program is stakeholder-oriented, with primary emphasis on assessing the potential consequences of global change (particularly climate variability and change) on air quality, water quality, aquatic ecosystems, and human health in the United States. EPA's mission and statutory and programmatic requirements drive the program's focus on these four areas. EPA uses the results of these studies to investigate adaptation options to improve society's ability to effectively respond to the risks and opportunities presented by global change, and to develop decision support tools for resource managers coping with a changing climate. EPA has also invested in decision support tools to help decisionmakers evaluate alternative strategies for reducing greenhouse gas emissions and the environmental implications of those strategies.

The program uses a place-based approach because the impacts of global change and their solutions are often unique to a location (e.g., a watershed). Partnerships are established with locally based decisionmakers to ensure that the program is responsive to their unique scientific information needs and the socioeconomic realities at their locales.

Planning and implementation of EPA's program is integrated with other participating Federal departments and agencies to reduce overlaps, identify and fill programmatic gaps, and add value to products and deliverables produced under the USGCRP's auspices. EPA coordinates with other USGCRP agencies to develop and provide timely, useful, and scientifically sound information to decisionmakers. EPA is

committed to the support of USGCRP's research and assessment activities. This commitment includes assessments uniquely focused on EPA's mission and statutory requirements (e.g., assessments of the impacts of global change on air and water quality) and support to the USGCRP to produce periodic assessments of the potential impacts of climate change for Congress.

EPA's program has two major areas of emphasis: air quality and water quality. Within these two areas, the program evaluates the consequences for human health and ecosystems due to the changes in air quality and water quality likely to result from global change.

### EPA Activities or Projects Related to the Six USGCRP Focus Areas

1. *Improving our knowledge of Earth's past and present climate variability and change*
2. *Improving our understanding of natural and human forces of climate change*
3. *Improving our capability to model and predict future conditions and impacts*
4. *Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

*Climate Change and Air Quality, Water Quality, and USGCRP Assessments (EPA-ORD).*<sup>48</sup> This activity's research is focused on understanding and assessing the effects of global change on air quality, water quality, aquatic ecosystems, human health, and social well being in the United States. The Agency strives to produce timely and useful information, decision support tools, and adaptation strategies that will enable resource managers, policymakers, and other stakeholders to account for global change when making decisions.

### 5. *Providing climate information and decision support tools*

*Environmental Assessment of Mitigation Technologies (EPA-ORD).* This activity focuses on the development of decision support tools to help decisionmakers evaluate alternative strategies for reducing greenhouse gas emissions to better quantify the

<sup>48</sup>. Office of Research and Development

associated environmental implications (and potential co-benefits).

### 6. *Climate Change Communication and Education*

EPA has multiple activities underway to inform and educate the public about climate change, its current and future impacts, the efforts underway to address the problem, and what individuals can do to help. These efforts include the development of a new climate change web portal and new educational materials on climate change for middle school students; development of informational materials for a range of audiences; outreach to EPA stakeholders at the state and local levels; and development of data systems to ensure public access to greenhouse gas emissions data reported under the Agency's recently finalized greenhouse gas reporting rule. Support of these communications and education activities is provided through other focus areas.

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



### Principal Areas of Focus

The National Aeronautics and Space Administration (NASA) conducts a program of breakthrough research to advance fundamental knowledge on the most important scientific questions about the global and regional integrated Earth system. NASA Earth Science conducts and sponsors research, collects new observations from space, develops technologies, and extends science and technology education to learners of all ages. NASA's goal is to understand the changing climate, its interaction with life, and how human activities affect the environment. In association with national and international agencies, NASA applies this understanding for the well-being of society. The NASA program encompasses most of the core competency areas of the USGCRP.

NASA presently has 13 on-orbit satellite missions: the Activity Cavity Radiometer Irradiance Monitor SAT-

ellite (ACRIMSAT), Aqua, Aura, the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), the Cloud Satellite (CloudSat), the Earth Observer (EO), the Gravity Recovery and Climate Experiment (GRACE), Jason, Landsat-7, the Ocean Surface Topography Mission (OSTM), the Solar Radiation and Climate Experiment (SORCE), Terra, and the Tropical Rainfall Measuring Mission (TRMM). On 24 February 2009, NASA's Orbiting Carbon Observatory (OCO) satellite did not reach orbit altitude when the launch vehicle malfunctioned. On 11 October 2009 and 23 November 2009, respectively, the Ice, Cloud, and land Elevation Satellite (ICESat) and Quick Scatterometer (QuikSCAT) satellites ceased their primary geophysical missions after many years of extended service.

NASA has seven missions in development for launch between 2010 and 2015. Five missions (Aquarius, Glory, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), the Landsat Data Continuity Mission (LDCM), and Global Precipitation Measurement (GPM)) are foundational missions, which the Decadal Survey<sup>49</sup> assumed would be precursors to Decadal Survey missions. Two missions, Soil Moisture Active-Passive (SMAP) and ICESat-2, are Tier 1 Decadal Survey missions. The Decadal Survey is the principal determinant of the priorities of NASA's Earth Science satellite missions beyond those currently in development.<sup>50</sup>

The President's FY 2011 Budget Request will greatly accelerate NASA's formulation, development, and launch of all 15 Decadal Survey missions, all of which are relevant to research on global climate change. Launch readiness dates of the remaining Tier 1 Decadal Survey missions, the Climate Absolute Radiance and Refractivity Observatory (CLARREO) and Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI), were moved up to 2017. The augmentation makes possible a larger number of Decadal Survey missions in the coming decade. For example, the budget enhancement advances the average launch date of each Tier 1 mission, two Tier 2 missions (Active Sensing of CO<sub>2</sub> Emissions over Nights, Days, and Seasons (ASCENDS) and Surface Water Ocean Topography (SWOT)), and a Venture-class satellite mission by about 30 months.

<sup>49</sup>. National Research Council, 2007: Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. National Academies Press, Washington, DC, 428 pp.

<sup>50</sup>. Ibid.

The President's FY 2011 Budget Request recognizes the need for continuity in climate observations and data records, and continues funding to develop an Orbiting Carbon Observatory (OCO<sub>2</sub>) mission to measure atmospheric CO<sub>2</sub> to replace the mission that failed to reach orbit in 2009, with a target launch date of early 2013. NASA will also begin development of a GRACE-Continuity mission working toward a launch in 2016; refurbish a SAGE-III (Stratospheric Aerosol and Gas Experiment) instrument to measure aerosols, ozone, water vapor, and other trace gases in the upper troposphere and stratosphere as early as 2014; and develop a Pre-ACE (Aerosol-Cloud-Ecology) mission to measure ocean color, clouds and aerosols as early as 2018.

The Decadal Survey recommended creation of a Venture class program of small, frequent, predictably scheduled science mission opportunities to spur innovation and enable the training of future Earth science leaders. In 2009, NASA released the Earth Venture-1 (EV-1) call for extended airborne science observing campaigns. Selections of five EV-1 airborne investigations were announced in May 2010, with field campaigns to run from 2011 through 2015. The selected EV-1 missions will investigate soil moisture in major ecosystems as it relates to the uptake or emission of carbonaceous gases (e.g., CO<sub>2</sub> and methane); the exchange of water vapor and other chemical constituents between the stratosphere and troposphere along with cirrus cloud properties and chemical processes with a variety of instruments on NASA's Global Hawk unmanned aerial system (UAS) in widely separated areas in the tropical Pacific; the emission of CO<sub>2</sub>, methane, and other gases from Arctic permafrost with a variety of instruments deployed on aircraft and the ground; the air quality impact of aerosols, ozone, and other gases over a number of major North American urban areas utilizing NASA's B-200 and P-3B aircraft to improve the use of satellite remote sensing in air quality assessment and forecasting; and tropical storm development with instruments deployed on two NASA Global Hawk UASs that can remain aloft for up to 30 hours. NASA plans to release the first call for a complete space flight mission, EV-2, in 2011, with selections to be made in 2012. The solicitations for suborbital and orbital missions will continue in alternate years. The President's FY 2011 Budget Request provides funding for an annual solicitation to develop satellite instruments for a mission of opportunity.

NASA aircraft- and surface-based instruments are used to calibrate and enhance interpretation of high-accuracy, climate-quality, stable satellite measurements. NASA supports state-of-the-art computing capability and capacity for extensive global integrated Earth system modeling. NASA, in recording approximately four terabytes of data every day, maintains the world's largest scientific data and information system for collecting, processing, archiving, and distributing Earth system data to worldwide users.

## NASA Activities or Projects Related to the Six USGCRP Focus Areas

NASA has made significant progress in FY 2010 and will continue this progress in FY 2011 in nearly all core competency areas of the U.S. Global Change Research Program.

### *1. Improving our knowledge of Earth's past and present climate variability and change*

*Earth Systematic Missions.* These missions are the main component of NASA's flight program, which encompasses operating missions and missions in development. Ten of NASA's thirteen major satellite missions that comprise today's fleet of NASA Earth observing satellites, providing comprehensive observations of the Earth system, come from this program (the remaining three come from the Earth System Science Pathfinder Mission program described in the next paragraph). Five additional foundational missions are in various stages of formulation through assembly and testing, and constitute the bridge between the Earth Observing System and the Decadal Survey missions to follow. These foundational missions and the four Tier-1 systematic missions (SMAP, ICESAT-2, DESDynI, and CLARREO-1) were recommended by the National Academy of Sciences for NASA launch during 2010 to 2020 as an integrated slate of missions. A number of the satellite missions play an important role in documenting the forcings of climate change (solar irradiance, land cover, aerosol distributions) addressed under focus area 2 below.

*Earth System Science Pathfinder Missions.* This is the component of the flight program that implements low- to moderate-cost missions, fostering innovation. It includes the three operating ESSP missions (GRACE, CALIPSO, and CloudSat) and the new Venture class program recommended in the Decadal Survey, including suborbital and orbital missions as well as instruments for missions of opportunity.

### *2. Improving our understanding of natural and human forces of climate change*

*Earth Science Research.* NASA's Research Program supports multi-disciplinary and interdisciplinary research to provide improved understanding of the Earth system, its components, their interactions, and the evolution of these interactions. The program also funds field campaigns conducted with aircraft and balloon-based platforms, which are used to test new measurement approaches and collect detailed *in situ* and remote-sensing observations for process studies and calibration/validation of satellite observations. Research is solicited annually through NASA's Research Opportunities in Space and Earth Sciences (ROSES) call, which invites proposals in numerous areas from academia, NASA Centers, other U.S. government agencies, the private sector, and non-profit organizations.

### *3. Improving our capability to model and predict future conditions and impacts*

*Global Modeling and Assimilation.* NASA funds development and utilization of comprehensive, interactive Earth System models, as well as data assimilation systems built upon those models. A particular focus is the enhanced use of NASA space-based data for weather and climate prediction, to support national multi-model ensemble predictions and assessments.

*Scientific Computing.* NASA recognizes the need for maintaining high-end computing, networking, and storage capabilities, which are required to convert satellite observations to science data products and are made available to a wide range of users, including modeling and reanalysis. Computing resources are provided upon request to proposers responding to research solicitations. In addition, NASA funds computational science research and development activities, including software development to improve Earth system modeling and data assimilation.

### *4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change*

### *5. Providing climate information and decision support tools*

*Applied Science – Pathways.* The Applied Science Program funds activities targeting the discovery, demonstration of innovative uses, and practical benefits of NASA research and observations. It primarily works

through partnerships with organizations that have established connections to users and decisionmakers. Projects promote the use of research results and their transition to public and private organizations, and integration of Earth science in organizations' decisionmaking and services.

### *6. Climate Change Communication and Education*

*Earth Science Education and Outreach Activity - Fellowships and New Investigators.* NASA funds activities through open competition that target workforce enrichment by focusing on scientists and engineers. The Earth Science Fellowship program supports the training of graduate students in Earth System science and/or remote sensing. The New Investigator program funds activities aimed to integrate Earth System research and education by scientists and engineers at the early stage of their professional career, with particular emphasis on the investigators' ability to promote and increase the use of space-based remote sensing through the proposed research and education projects. NASA also provides the major support for the Global Learning and Observations to Benefit the Environment (GLOBE), which provides students around the world the opportunity to make hands-on measurements of Earth system parameters and to have their data archived and shared as part of a global community of learners.

## NATIONAL SCIENCE FOUNDATION



### Principal Areas of Focus

National Science Foundation (NSF) programs address global change issues through investments that advance frontiers of knowledge and provide state-of-the-art instrumentation and facilities while also cultivating a diverse highly trained workforce and developing resources for public education. In particular, NSF global change research programs support research and related activities to advance the fundamental understanding of physical, chemical, biological, and human systems and the interactions

among them. The programs encourage interdisciplinary activities and focus particularly on Earth system processes and the consequences of change for organisms and ecosystems and the essential services they provide to society. NSF programs facilitate data acquisition and information management activities necessary for fundamental research on global change, and promote the enhancement of models designed to improve understanding of Earth system processes and feedbacks that link ecosystems to global climate systems, and develop advanced analytic methods to facilitate basic research. NSF also supports fundamental research on the processes used by organizations to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of varying environmental conditions. Through its investment, NSF contributes to the overall USGCRP focus areas identified earlier in this annual report.

## NSF Activities or Projects Related to the Six USGCRP Focus Areas

### 1. Improving our knowledge of Earth's past and present climate variability and change

*Long-term Climate Cycle Studies (NSF-BIO, GEO, MPS, and OPP).*<sup>51,52,53,54</sup> NSF investments include activities to understand long-term climate cycles across varying latitudes using a range of paleoclimate and instrumental data and modeling approaches as well as increasing confidence in our understanding of how and why climate has changed through support of basic research that documents past climate changes and the processes responsible for those changes. NSF also supports activities to improve our understanding of climate extremes and modulations in the past and how those may manifest in the future.

### 2. Improving our understanding of natural and human forces of climate change

*Fundamental Research on all Aspects of the Carbon Cycle (NSF-BIO, ENG, GEO, MPS, and OPP).*<sup>55</sup> NSF activities in this area are primarily centered on supporting fundamental research on all aspects of the carbon cycle, including the current status of fluxes and the probable responses of the biota and ecosystems to anthropogenic changes in global cycles and climate.

<sup>51.</sup> Directorate for Biological Sciences

<sup>52.</sup> Directorate for Geosciences

<sup>53.</sup> Directorate for Mathematical and Physical Sciences

<sup>54.</sup> Office of Polar Programs

<sup>55.</sup> Directorate for Engineering

Foci include effects of physical forcing, carbon fluxes and links to other biogeochemical cycles, biological and chemical-biological interactions in terrestrial and oceanic regimes, and the atmospheric processes that couple these. Support is also provided for basic research in greenhouse gas processes relevant to regional and global climate change as well as into the factors controlling regional and global transport and transformation of atmospheric constituents.

### 3. Improving our capability to model and predict future conditions and impacts

*Climate System Feedback Processes Responding to Natural and Human-induced Forcing (NSF-BIO, GEO, MPS, SBE, and OPP).*<sup>56</sup> NSF supports basic research to examine major feedback processes related to the response of the climate system to natural and human-induced forcing, and to activities leading to the development and application of the next generation Community Climate System Model through the addition of more complete representations of coupled interactive atmospheric chemistry, terrestrial and marine ecosystems, biogeochemical cycling, and middle atmospheric processes. Support is also provided for basic research to examine major feedback processes related to the response of the climate system to natural and human-induced forcing and feedbacks of the ocean and terrestrial ecosystems on climate systems by way of biogeochemical processes. Foci include controls on the balance of nitrogen fixation and denitrification in the world's oceans and the dynamics of feedbacks between ocean and terrestrial ecosystem biogeochemistry as mediated by changes in atmospheric CO<sub>2</sub>.

### 4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change

*Population Response to Natural and Anthropogenic Changes in Global Climate (NSF-BIO, GEO, SBE, and OPP).* NSF supports fundamental research on how populations respond to natural and anthropogenic changes in global climate. This includes determining the processes that control circulation and transport of biological, chemical, and geological materials that drive population dynamics of the target organisms; developing conceptual and quantitative models of ecosystem dynamics and responses at a broad range of space and time scales; and determining the effects of climate variability and climate change on the distribution, abundance, and production of the target organisms. NSF-supported researchers will continue

<sup>56.</sup> Directorate for Social, Behavioral and Economic Sciences

to develop integrated river basin models to address water management issues related to stream flow, such as endangered species, agricultural needs, and trans-boundary requirements, and will support basic research on the interactions between ecosystems and human infrastructure over extended periods.

### 5. *Providing climate information and decision support tools*

*Tools for Stakeholders to Improve Decision Making Under Uncertainty Associated with Climate Change (NSF-BIO, GEO, and SBE).* NSF supports basic research on the processes through which humans affect climate and other natural systems, through which people respond to changing natural conditions, and through which human and natural systems engage in complex interactions across multiple spatial, temporal, and organizational scales. Support will continue for basic research on decisionmaking under uncertainty associated with climate change and to develop and test decision support tools that can be used by stakeholders to improve decisionmaking in the face of uncertainty.

### 6. *Climate Change Communication and Education*

All NSF projects involve a “broader impacts” component, which is directed at student training, public outreach, and other forms of communication and education. The support is counted under the other focus areas.

## SMITHSONIAN INSTITUTION



### Principal Areas of Focus

Within the Smithsonian Institution, global change research is primarily conducted at the National Air and Space Museum, the National Museum of Natural History (NMNH), the National Zoological Park, the Smithsonian Astrophysical Observatory (SAO), the Smithsonian Environmental Research Center (SERC), and the Smithsonian Tropical Research Institute

(STRI). Research is organized around themes of atmospheric processes, ecosystem dynamics, observing natural and anthropogenic environmental change on daily to decadal time scales, and defining longer term climate proxies present in the historical artifacts and records of the museums as well as in the geologic record at field sites. The Smithsonian Institution program strives to improve knowledge of the natural processes involved in global climate change, to provide a long-term repository of climate-relevant research materials for present and future studies, and to bring this knowledge to various audiences, ranging from scholarly to the lay public. The unique contribution of the Smithsonian Institution is a long-term perspective—for example, undertaking investigations that may require extended study before producing useful results and conducting observations on sufficiently long (e.g., decadal) time scales to resolve human-caused modification of natural variability.

### SI Activities or Projects Related to the Six USGCRP Focus Areas

#### 1. *Improving our knowledge of Earth's past and present climate variability and change*

*Forest dynamics, carbon, and biodiversity (STRI-SIGEO).* Multiple Smithsonian science units collaborate in the Smithsonian Institution Global Earth Observatory (SIGEO) global network of forest plots headquartered at the Smithsonian Tropical Research Center. This network provides a globally unique data set on forest growth, forest carbon sequestration, and ecological dynamics. It provides long-term scientific data about biodiversity and ecological, hydrological, soil, and meteorological processes associated with climate change at local spatial scales and comparatively at regional and global scales. This research platform enables Smithsonian scientists and their university and Federal agency partners to better understand the storage and movement of carbon and water in tropical and temperate forests, as well as the impacts of climate change on the relationships of forests with wildlife, the atmosphere, and sources of fresh water. It provides an early warning system for changes in key ecological signals ranging from the timing of leafing, flowering, and fruiting to interactions with biological and ecological factors. This program works around the world and has been a vital link in developing strong scientific and technological interactions in important tropical countries, while showing the utility of science-based management. It leverages

USGCRP investment by creating a platform where partners, the USGCRP, and domestic and international academic and other research institutions can build additional research components.

*Paleontological research (NMNH, STRI).* Focused in the research of the NMNH and the Smithsonian Tropical Research Center, Smithsonian research on paleontology, through analysis of our collections and in field research, documents and interprets the history of terrestrial and marine ecosystems from 400 million years ago to the present. Program scientists study the impacts of historical environmental change on the ecology and evolution of organisms, including humans. Archaeobiologists examine the impact of early humans resulting from their domestication of plants and animals, creating the initial human impacts on planetary ecosystems. USGCRP funding enables the Smithsonian to leverage private funds for additional research and education programs.

## 2. Improving our understanding of natural and human forces of climate change

The Smithsonian has a very long history of work with traditionally underserved communities (Native Americans, Inuit) to understand how traditional modes are impacted by changing culture, and now by climate change. Researchers at the NMNH, the National Museum of the American Indian, and the Smithsonian Center for Folklife and Cultural Heritage work with communities to understand how they are striving to adapt to these changes.

## 3. Improving our capability to model and predict future conditions and impacts

*Geological processes research (GVP).* Smithsonian geological systems research examines the dynamics of key geological processes such as volcanism and subsidence. The Global Volcanism Program (GVP) is the hub of an international network for monitoring, reporting, and maintaining data related to volcanic activity around the world. The GVP plays a leadership role in global volcano information—tracking events as they happen, building the database of critical information, and using these resources both for our own forefront research projects and for answering a multitude of questions on volcanology from other scientists, the media, and the public. One project is the Nile Delta Subsidence/Sea Level Rise—a long-term research effort involving 25 specialists from 13 international laboratories that assesses the

speed with which environmental changes are threatening fertile river deltas around the world.

*Atmospheric research (SAO, SERC).* Research at the SAO and the SERC examine specific responses of the atmosphere and biosphere to solar activity, ultraviolet radiation, and atmospheric composition. Using both remotely sensed data (including from instruments designed by Smithsonian scientists) and *in situ* measurements, these programs make observations of natural variability, human-induced greenhouse gas concentrations, and their impacts on climate and the organisms taking up and responding to atmospheric conditions. Specific research includes the impact of increased CO<sub>2</sub> on microalgae and phytoplankton communities, which form a key base for carbon sequestration in the coastal and marine world.

## 4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change

*Biodiversity and ecosystem responses.* Biological diversity research at multiple Smithsonian locations measures the changes in species occurrence and distribution based on climate, land use change, and changes in the chemistry of the oceans. Researchers use multiple methods, including geographic information system (GIS), DNA barcoding, and chemical markers, to interpret the effects of changes in land/seascapes and changes in animal and plant populations. Researchers work with communities, such as in the Arctic Studies program, to understand how these changes are affecting human populations. Such work gives us baselines for species responses and primary data for use in landscape and seascape planning. An organism group of concern is migratory birds that have to adapt to changes in multiple landscapes throughout their annual cycles of migration between their wintering and breeding locales. Smithsonian marine research builds on the expertise at NMNH, SERC, STRI, and the National Zoological Park; our network of marine field stations; our history of integrated marine research funded by our Marine Science Network; the world's most extensive marine biological collections (NMNH); and our collaborations with NOAA, the US Coast Guard, the Census of Marine Life, and many public and private organizations throughout the world.

### *5. Providing climate information and decision support tools*

*Digitization of collection and research records.* Scientific data on the occurrence of species, as well as their environmental context, and results from different research programs are made available through internet access and upon request to researchers around the world to uncover patterns in order to better understand environmental patterns and change and increase the ability to use the best and most unbiased scientific information. The Smithsonian is increasing its digitization of historic data that are not currently available in digital form (e.g., only stored in paper files or specimen labels), or are not currently available in formats that support community access. Attention is being given to digitization, quality control, and analysis of (a) species occurrence data for taxa that are used for climate change sensitivity and health analyses (amphibians, birds, butterflies, disease vectors, parasites) from museum specimens and field records; (b) long-term monitoring data, especially from Smithsonian-managed field stations; and (c) remote-sensing data that are not available from other sources.

### *6. Climate Change Communication and Education*

*Outreach and Education.* Research by Smithsonian researchers and collaborators is the basis for the many educational programs at the many Smithsonian sites, on its websites, and in visits to communities around the United States and the world. Smithsonian researchers leverage the USGCRP seed funding to attract additional resources from public and private sources to build the renowned exhibitions, prepare publications, and sponsor events.

## VI

USGCRP BUDGET ANALYSIS BY FOCUS AREA  
AND AGENCY/DEPARTMENT

The following tables give a quantitative measure of the USGCRP budgets for FY 2009, FY 2010, and FY 2011, arranged by agency/department and the six USGCRP focus areas.

Definitions of the six USGCRP focus areas.

- Improve our knowledge of Earth's past and present climate variability and change through remote and in situ observing and monitoring capabilities to ensure a long-term, high-quality and high-resolution record of the state of the Earth's climate system, natural variability, and change, as well as activities that improve our understanding of natural long-term climate cycles.
- Improve our understanding of natural and human forces of climate change through fundamental research focused on improving our understanding of the natural and human-induced forces of change as well as the interactions among the physical, chemical, geological, and biological components of the Earth system.
- Improve our capability to model and predict future conditions and impacts by enhancing the Nation's predictive capability and infrastructure through enhanced scenarios and more accurate models and projections of future conditions at finer spatial scales and across a wider range of timescales (including both global circulation models and integrated assessment models).
- Assessing the Nation's vulnerability to current and anticipated impacts of climate change through activities that contribute to assessing the environmental, economic, and societal vulnerability of human and natural systems to current and anticipated impacts of climate change.
- Provide climate information and decision support tools that improve the Nation's ability to respond to climate change by providing climate information and decision support tools that are useful to policymakers and the general public.
- Develop or expand communication and education capabilities, training, and activities for students, educators, and the public to create a climate-literate society.

The U.S. Global Change Research Program for Fiscal Year 2011

Table I. FY 2009-2011 U.S. Global Change Research Program  
**Budget By Focus Area**

	<b>USGCRP Focus Area</b>	<b>FY09 Actual</b>	<b>FY10 Enacted</b>	<b>FY11 Proposed</b>	<b>Agencies/ Departments</b>
1	Improving our knowledge of Earth's past and present climate variability and change	1387.5	1093.2	1429.4	USDA, DOC, DOE, DOI, NASA, NSF, SI
2	Improving our understanding of natural and human forces of climate change	513	488.6	548.8	USDA, DOC, DOE, DOI, DOT, NASA, NSF
3	Improving our capability to model and predict future conditions and impacts	445.9	240.4	281	USDA, DOC, DOE, HHS, DOI, USAID, NASA, NSF, SI
4	Assessing the Nation's vulnerability to current and anticipated impacts of climate change	171.4	190.4	234.8	USDA, DOC, DOE, DOI, EPA, NSF, SI
5	Providing climate information and decision support tools	116.4	139.7	178.1	USDA, DOC, DOI, DOT, USAID, EPA, NASA, NSF, SI
6	Climate Change Communication and Education	19.9	26.1	41.4	USDA, DOC, NASA, SI
<b>USGCRP Total</b>		<b>2654.1</b>	<b>2178.4</b>	<b>2713.5</b>	

Table 2. FY 2009-2011 U.S. Global Change Research Program<sup>1</sup>  
**Budget by USGCRP Focus Area and Participating Agency/Department**

	USDA	DOC	DOE	HHS	DOI	DOT	USAID <sup>2</sup>	EPA	NASA	NSF <sup>3</sup>	SI	Research	Observations	TOTAL
<b>FY 2011</b>														
<b>Focus Area 1</b>	8.3	282.8	48.5	0.0	13.0	0.0	0.0	0.0	995.0	75.7	6.1	434.4	995.0	1429.4
<b>Focus Area 2</b>	30.4	50.1	28.4	0.0	2.3	3.0	0.0	0.0	361.3	73.3	0.0	548.8		548.8
<b>Focus Area 3</b>	21.8	53.4	85.6	4.0	8.1	0.0	18.0	0.0	24.5	82.7	0.9	281.0		281.0
<b>Focus Area 4</b>	43.1	2.2	28.6	0.0	17.0	0.0	0.0	20.8	0.0	120.9	2.2	234.8		234.8
<b>Focus Area 5</b>	33.8	46.1	0.0	0.0	41.1	0.5	25.0	1.2	36.6	17.3	1.5	178.1		178.1
<b>Focus Area 6</b>	21.1	2.8	0.0	0.0	0.0	0.0	0.0	0.0	17.2	0.0	0.3	41.4		41.4
<b>FY2011 Total</b>	<b>158.5</b>	<b>437.4</b>	<b>191.1</b>	<b>4.0</b>	<b>81.5</b>	<b>3.5</b>	<b>43.0</b>	<b>22.0</b>	<b>1434.6</b>	<b>369.9</b>	<b>11.0</b>	<b>1718.5</b>	<b>995.0</b>	<b>2713.5</b>
<b>FY 2010</b>														
<b>Focus Area 1</b>	8.1	227.9	44.6	0.0	13.7	0.0	0.0	0.0	727.7	67.1	4.1	365.5	727.7	1093.2
<b>Focus Area 2</b>	20.2	44.8	26.5	0.0	2.4	3.0	0.0	0.0	324.5	67.2	0.0	488.6		488.6
<b>Focus Area 3</b>	20.8	42.4	69.8	4.0	8.3	0.0	18.0	0.0	20.6	73.6	0.9	240.4		240.4
<b>Focus Area 4</b>	29.7	2.1	27.9	0.0	12.3	0.0	0.0	19.6	0.0	97.6	1.2	190.4		190.4
<b>Focus Area 5</b>	23.0	41.9	0.0	0.0	26.6	1.0	18.0	1.2	32.0	13.5	0.5	139.7		139.7
<b>Focus Area 6</b>	8.3	1.3	1.4	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.3	26.1		26.1
<b>FY2010 Total</b>	<b>110.1</b>	<b>360.4</b>	<b>170.2</b>	<b>4.0</b>	<b>63.3</b>	<b>4.0</b>	<b>36.0</b>	<b>20.8</b>	<b>1119.6</b>	<b>319.0</b>	<b>7.0</b>	<b>1450.7</b>	<b>727.7</b>	<b>2178.4</b>
<b>FY 2009</b>														
<b>Focus Area 1</b>	6.8	306.5	102.4	0.0	12.2	0.0	0.0	0.0	866.8	89.7	3.1	520.7	866.8	1387.5
<b>Focus Area 2</b>	8.5	39.7	25.4	0.0	2.0	2.0	0.0	0.0	345.0	90.4	0.0	513.0		513.0
<b>Focus Area 3</b>	5.6	214.9	75.6	5.0	7.4	0.0	16.7	0.0	36.8	99.7	0.9	445.9		445.9
<b>Focus Area 4</b>	15.2	3.9	27.9	0.0	8.4	0.0	0.0	17.3	0.0	97.5	1.2	171.4		171.4
<b>Focus Area 5</b>	11.1	29.1	0.0	0.0	14.5	0.3	1.5	0.6	47.8	12.5	0.5	116.4		116.4
<b>Focus Area 6</b>	0.4	1.3	1.4	0.0	0.0	0.0	0.0	0.0	16.5	0.0	0.3	19.9		19.9
<b>FY2009<sup>4</sup> Total</b>	<b>47.6</b>	<b>595.4</b>	<b>232.7</b>	<b>5.0</b>	<b>44.5</b>	<b>2.3</b>	<b>18.2</b>	<b>17.9</b>	<b>1312.9</b>	<b>389.8</b>	<b>6.0</b>	<b>1787.3</b>	<b>866.8</b>	<b>2654.1</b>

<sup>1</sup> All data supersede numbers released in the 2011 Federal Climate Change Expenditures Report.

<sup>2</sup> USAID funding supports USGCRP and the Climate Change International Assistance effort. In the past, some USAID funding was counted under both categories. USAID spending is now only reported under international assistance and does not add to the USGCRP total.

<sup>3</sup> Subsequent to publication of the Federal Climate Change Expenditures Report, NASA's FY 2009 and FY 2010 Budget Authority were changed due to a Congressionally-approved reprogramming. The FY 2011 Proposed Budget Authority was updated to include the augmentation to NASA for the FY 2011 climate change initiative. These changes then impacted the budgetary values for the focus areas, as well as the overall budget total.

<sup>4</sup> FY 2009 totals include ARRA enacted budget authority amounts for agencies/departments receiving these funds.

The U.S. Global Change Research Program for Fiscal Year 2011

<b>U.S. Department of Agriculture</b>			
<b>USDA Focus Area/Agency</b>	<b>FY 2009 Actual</b>	<b>FY 2010 Enacted</b>	<b>FY 2011 Proposed</b>
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>	<b>6.8</b>	<b>8.1</b>	<b>8.3</b>
Agricultural Research Service	2.4	2.4	2.4
Forest Service	3.5	4.8	5.0
National Institute of Food and Agriculture	0.9	0.9	0.9
<b>2. Improving our understanding of natural and human forces of climate change</b>	<b>8.5</b>	<b>20.2</b>	<b>30.4</b>
Agricultural Research Service	4.5	4.5	5.0
Forest Service	3.5	7.5	4.5
National Institute of Food and Agriculture	0.5	8.2	20.9
<b>3. Improving our capability to model and predict future conditions and impacts</b>	<b>5.6</b>	<b>20.8</b>	<b>21.8</b>
Agricultural Research Service	3.9	3.9	3.9
Forest Service	1.0	0.4	2.0
National Institute of Food and Agriculture (AFRI) <sup>1</sup>	0.5	16.4	15.7
National Institute of Food and Agriculture (GC/UVBR&M) <sup>2</sup>	0.2	0.2	0.2
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>	<b>15.2</b>	<b>29.7</b>	<b>43.1</b>
Agricultural Research Service	5.1	5.1	5.3
Economic Research Service	0.0	0.5	0.5
Forest Service	9.5	13.0	11.0
National Institute of Food and Agriculture	0.6	11.1	26.3
<b>5. Providing climate information and decision support tools</b>	<b>11.1</b>	<b>23.0</b>	<b>33.8</b>
Agricultural Research Service	3.9	3.9	5.3
Economic Research Service	1.0	2.0	2.0
Forest Service	4.5	6.1	5.5
National Institute of Food and Agriculture (AFRI)	1.6	10.9	20.9
National Institute of Food and Agriculture (GC/UVBR&M)	0.1	0.1	0.1
<b>6. Climate Change Communication and Education</b>	<b>0.4</b>	<b>8.3</b>	<b>21.1</b>
Forest Service	0.2	0.0	0.1
National Institute of Food and Agriculture (AFRI)	0.2	8.2	20.9
National Institute of Food and Agriculture (GC/UVBR&M)	0.1	0.1	0.1
<b>USDA Total</b>	<b>47.6</b>	<b>110.2</b>	
<b>President's Request</b>			<b>158.5</b>
<sup>1</sup> Agriculture and Food Research Initiative Competitive Grants Program			
<sup>2</sup> Global Change/B Radiation Research and Monitoring Program			



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Department of Agriculture USGCRP activities are funded under Title I–Agricultural Programs, within the ARS, NIFA, and ERS accounts; and under Title II–Conservation Programs, within the NRCS Conservation Operations account. Also in Appropriations Committee reports, U.S. Department of Agriculture USGCRP activities are funded in the USDA FS section under Title II–Related Agencies, within the FS Forest Research account.

U.S. Department of Commerce					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>306.5</b>	<b>227.9</b>	<b>282.8</b>
NOAA	OAR	Climate variability research	37.4	42.6	43.2
NOAA	OAR	Global Ocean Observation System	59.2	63.9	68.8
NOAA	OAR	Climate data and information products and climate operations	7.0	14.7	10.6
NOAA	NESDIS	National data centers, enviromental data, information and products	73.9	74.7	40.8
NOAA	NESDIS	Jason 3	0.0	20.0	50.0
NOAA	NESDIS	Climate satellite sensors	127.0	10.0	67.4
NIST	NIST	National and international standards for measurement	2.0	2.0	2.0
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>39.7</b>	<b>44.8</b>	<b>50.1</b>
NOAA	OAR	Other GHG observations and research	20.0	24.1	21.6
NOAA	OAR	Carbon cycle observations and research	19.7	20.7	28.5
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>214.9</b>	<b>42.4</b>	<b>53.4</b>
NOAA	OAR	Climate modeling	28.1	20.1	27.4
NOAA	NWS	Operational short-term forecasting and monitoring	10.4	10.9	14.6
NOAA	OAR/CIO	High performance computing	176.4	11.4	11.4
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>3.9</b>	<b>2.1</b>	<b>2.2</b>
NOAA	NMFS	Climate and ecosystems	3.9	2.1	2.2
<b>5. Providing climate information and decision support tools</b>			<b>29.1</b>	<b>41.9</b>	<b>46.1</b>
NOAA	OAR	Adaptive management support	29.1	32.9	36.1
NOAA	OAR	Assessments	0.0	9.0	10.0
<b>6. Climate Change Communication and Education</b>			<b>1.3</b>	<b>1.3</b>	<b>2.8</b>
NOAA	OAR	Communication and education	1.3	1.3	2.8
<b>DOC Total</b>			<b>595.4</b>	<b>360.4</b>	
<b>President's Request</b>					<b>437.4</b>



**Mapping of Budget Request to Appropriations Legislation.** In Appropriations Committee reports, funding for National Oceanic and Atmospheric Administration USGCRP activities is specified in the Laboratories and Cooperative Institutes, Competitive Research Programs, Climate Operations, and Climate Data and Information lines of the Oceanic and Atmospheric Research budget; in the Climate Regimes and Ecosystem Productivity line of the National Marine Fisheries Service budget; the Data Centers and Information Services line of the National Environmental Satellite, Data, and Information Service (NESDIS) budget; the Local Warnings and Forecasts and Central Forecast Guidance lines of the National Weather Service (NWS) budget; and the Ocean Assessment Program's Coastal Services Center line of the National Ocean Service budget within NOAA's Operations, Research, and Facilities account. In addition, a portion of NOAA's climate funding is found within the Procurement, Acquisition, and Construction account for NESDIS, NWS, and OAR. Funding for National Institute of Standards and Technology USGCRP activities is specified in the Scientific and Technical Research and Services account.

The U.S. Global Change Research Program for Fiscal Year 2011

U.S. Department of Energy					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>102.4</b>	<b>44.6</b>	<b>48.5</b>
DOE	BER	ARM Climate research facility and data management	102.4	44.6	48.5
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>25.4</b>	<b>26.5</b>	<b>28.4</b>
DOE	BER	Atmospheric system research	25.4	26.5	28.4
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>75.6</b>	<b>69.8</b>	<b>85.6</b>
DOE	BER	Climate and earth system modeling	75.6	69.8	85.6
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>27.9</b>	<b>27.9</b>	<b>28.6</b>
DOE	BER	Terrestrial ecosystems science	27.9	27.9	28.6
<b>5. Providing climate information and decision support tools</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>6. Climate Change Communication and Education</b>			<b>1.4</b>	<b>1.4</b>	<b>0.0</b>
DOE	BER	Global change education program	1.4	1.4	0.0
<b>DOE Total</b>			<b>232.7</b>	<b>170.2</b>	
<b>President's Request</b>					<b>191.1</b>



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Department of Energy USGCRP activities are funded under Title III—Department of Energy, within the Energy Supply, Research, and Development Activities account. Also in these Appropriations Committee reports, funding for Department of Energy USGCRP activities is included as part of the appropriation for Biological and Environmental Research.

U.S. Department of Health and Human Services					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>5.0</b>	<b>4.0</b>	<b>4.0</b>
NIH	NIEHS, FIC, NIGMS, NLM	Human health impacts of climate change	2.0	2.0	0.0
NIH	NIEHS, FIC, NIGMS, NLM	Unsolicited Grants	3.0	2.0	4.0
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>5. Providing climate information and decision support tools</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>HHS Total</b>			<b>5.0</b>	<b>4.0</b>	
<b>President's Request</b>					<b>4.0</b>



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Department of Health and Human Services USGCRP activities are funded under the National Institutes of Health section of Title II—Department of Health and Human Services.

The U.S. Global Change Research Program for Fiscal Year 2011

U.S. Department of the Interior					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>12.2</b>	<b>13.7</b>	<b>13.0</b>
DOI	USGS	Global Change R&D: Climate History and Past Environmental Change Research Focus	8.6	9.9	9.7
DOI	USGS	NSLRSDA: National Satellite Land Remote Sensing Data Archive	3.6	3.8	3.3
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>2.0</b>	<b>2.4</b>	<b>2.3</b>
DOI	USGS	Global Change R&D: Carbon Cycle Science Research Focus	2.0	2.4	2.3
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>7.4</b>	<b>8.3</b>	<b>8.1</b>
DOI	USGS	Global Change R&D: Hydrology and Hydrologic Consequences of Climate Change Research Focus	3.4	3.9	3.8
DOI	USGS	Global Change R&D: Land Use and Land Cover Change Research Focus	2.9	3.3	3.3
DOI	USGS	Terrestrial, Freshwater and Marine Ecosystems Research	1.1	1.1	1.0
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>8.4</b>	<b>12.3</b>	<b>17.0</b>
DOI	USGS	Climate Effects Network	4.0	7.3	7.3
DOI	USGS	Global Change R&D: Impacts of Climate Change on Communities, Landscapes, Ecosystems and Organisms Research Focus	4.4	5.0	4.7
DOI	USGS	Climate Impacts: Support for Fish and Wildlife Service Climate Change Activities FY 2010*	0.0	5.0	5.0
<b>5. Providing climate information and decision support tools</b>			<b>14.5</b>	<b>26.6</b>	<b>41.1</b>
DOI	USGS	Decision Support and Science Applications	1.5	1.5	2.5
DOI	USGS	National Climate Change and Wildlife Science Center	10.0	13.6	14.0
DOI	USGS	DOI Regional Climate Science Centers	0.0	1.5	9.0
DOI	USGS	Biological Carbon Sequestration Assessment	1.5	5.0	7.0
DOI	USGS	Geological Carbon Sequestration Assessment	1.5	5.0	5.0
DOI	USGS	Chesapeake Bay Executive Order Treasured Landscapes Initiative	0.0	0.0	3.6
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>DOI Total</b>			<b>44.5</b>	<b>63.3</b>	
<b>President's Request</b>					<b>81.5</b>
*Note: Not included in FY 2010 total because it is a new item not in the direct USGS Global Change budget line. This item is identified and discussed in the USGS FY 2010 Green Book (page C-31) and in the DOI FY 2011 Budget-in-Brief (page C-1).					



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Department of the Interior USGCRP activities are funded under Title I—Department of the Interior. Funding for U.S. Geological Survey USGCRP programs is included within the USGS Survey, Investigations, and Research account.

U.S. Department of Transportation					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>2.0</b>	<b>3.0</b>	<b>3.0</b>
FAA	AEE	Aviation Climate Change Research Initiative (ACCRI) and PARTNER (Partnership for AiR Transportation Noise and Emissions Reduction) aviation climate change research activities	2.0	3.0	3.0
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>5. Providing climate information and decision support tools</b>			<b>0.3</b>	<b>1.0</b>	<b>0.5</b>
FHWA	HEP	Support for DOT Climate Center's Study, the <i>Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 2</i> , and the report to Congress: <i>Transportation's Role in Reducing U.S. Greenhouse Gas Emissions (DOT, April 2010)</i>	0.3	1.0	0.5
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>DOT Total</b>			<b>2.3</b>	<b>4.0</b>	
<b>President's Request</b>					<b>3.5</b>
<p>Note: * Projects still in planning phase. The budgets for these projects are not determined in advance.                      AEE - Office of Environment and Energy                      CCCEF - USDOT Center for Climate Change and Environmental Forecasting                      FAA - Federal Aviation Administration                      FHWA - Federal Highway Administration                      FTA - Federal Transit Administration                      HEP - Office of Planning, Environment and Realty                      URC - University Research Centers</p>					



**Mapping of Budget Request to Appropriations Legislation.** Since 2000, the Department's climate change research has been funded by contributions from eight of DOT's operating administrations and the Office of the Secretary.

U.S. Agency for International Development					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>16.7</b>	<b>18.0</b>	<b>18.0</b>
USAID	DCHA <sup>1</sup>	Famine Early Warning System Network	16.7	18.0	18.0
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>5. Providing climate information and decision support tools</b>			<b>1.5</b>	<b>18.0</b>	<b>25.0</b>
USAID	EGAT <sup>2</sup>	SERVIR—the Regional Visualization and Monitoring System	1.5	18.0	25.0
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>USAID Total</b>			<b>18.2</b>	<b>36.0</b>	
<b>President's Request</b>					<b>43.0</b>

<sup>1</sup> Democracy, Conflict and Humanitarian Assistance  
<sup>2</sup> Economic Growth, Agriculture, and Trade



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, U.S. Agency for International Development USGCRP activities are funded under Title II–Bilateral Economic Assistance: United States Agency for International Development.

U.S. Environmental Protection Agency					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>17.3</b>	<b>19.6</b>	<b>20.8</b>
EPA	ORD <sup>1</sup>	Climate Change and 1) Air Quality, 2) Water Quality, and 3) USGCRP Assessments	17.3	19.6	20.8
<b>5. Providing climate information and decision support tools</b>			<b>0.6</b>	<b>1.2</b>	<b>1.2</b>
EPA	ORD	Environmental assessment of mitigation technologies	0.6	1.2	1.2
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>EPA Total</b>			<b>17.9</b>	<b>20.8</b>	
<b>President's Request</b>					<b>22.0</b>

<sup>1</sup> ORD - Office of Research and Development



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Environmental Protection Agency USGCRP activities are funded under Title II—Environmental Protection Agency, within the Science and Technology account. Appropriations Committee report language may specify more directly the funding for global change research.

The U.S. Global Change Research Program for Fiscal Year 2011

U.S. National Aeronautics and Space Administration <sup>1</sup>					
Agency	Program	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>866.8</b>	<b>727.7</b>	<b>995.0</b>
NASA	SMD/ESD <sup>2</sup>	Earth Systematic Missions	850.2	665.1	720.6
NASA	SMD/ESD	Earth System Science Pathfinder	16.6	62.6	274.4
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>345.0</b>	<b>324.5</b>	<b>361.3</b>
NASA	SMD/ESD	Earth Science Research	345.0	324.5	361.3
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>36.8</b>	<b>20.6</b>	<b>24.5</b>
NASA	SMD/ESD	Global Modeling and Assimilation Scientific Computing	36.8	20.6	24.5
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>5. Providing climate information and decision support tools</b>			<b>47.8</b>	<b>32.0</b>	<b>36.6</b>
NASA	SMD/ESD	Applied Science - Pathways	47.8	32.0	36.6
<b>6. Climate Change Communication and Education</b>			<b>16.5</b>	<b>14.8</b>	<b>17.2</b>
NASA	SMD/ESD	Fellowships and New Investigators Earth Science Education and Outreach Activity	16.5	14.8	17.2
<b>NASA Total</b>			<b>1312.9</b>	<b>1119.6</b>	
<b>President's Request</b>					<b>1434.6</b>

<sup>1</sup> Subsequent to publication of the Federal Climate Change Expenditures Report, NASA's FY 2009 and FY 2010 Budget Authority were changed due to a Congressionally-approved reprogramming. The FY 2011 Proposed Budget Authority was updated to include the augmentation to NASA for the FY 2011 climate change initiative. These changes then impacted the budgetary values for the focus areas, as well as the overall budget total.

<sup>2</sup> Science Mission Directorate/Earth Science Division



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, National Aeronautics and Space Administration USGCRP activities are funded under NASA Earth science and technology programs within Title III–Independent Agencies, as part of the Science, Aeronautics, and Technology account.

National Science Foundation					
Agency	Directorates*	Project/Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>89.7</b>	<b>67.1</b>	<b>75.7</b>
NSF	BIO, GEO, MPS, OPP	Long-term climate cycles, paleoclimate, past climate extremes and modulations	89.7	67.1	75.7
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>90.4</b>	<b>67.2</b>	<b>73.3</b>
NSF	BIO, ENG, GEO, MPS, OPP	Carbon cycle and response of biota and ecosystems to changes in climate, biogeochemical cycles	90.4	67.2	73.3
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>99.7</b>	<b>73.6</b>	<b>82.7</b>
NSF	BIO, GEO, MPS, SBE, OPP	Feedback processes involved in response of climate system to natural and human induced forcing	99.7	73.6	82.7
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>97.5</b>	<b>97.6</b>	<b>120.9</b>
NSF	BIO, GEO, SBE, OPP	Societal response to natural and anthropogenic changes in global climate, ecosystem dynamics, water management	97.5	97.6	120.9
<b>5. Providing climate information and decision support tools</b>			<b>12.5</b>	<b>13.5</b>	<b>17.3</b>
NSF	BIO, GEO, SBE	Decision making under uncertainty associated with climate change, decision support tools for stakeholders	12.5	13.5	17.3
<b>6. Climate Change Communication and Education</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>NSF Total</b>			<b>389.8</b>	<b>319.0</b>	
<b>President's Request</b>					<b>369.9</b>

\* Directorates identified in the NSF agency description.



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, National Science Foundation USGCRP activities are supported under the NSF section of Title III–Independent Agencies within the NSF Research and Related Expenses account.

Smithsonian Institution					
Agency	Program	Project/ Activity	FY 2009 Actual	FY 2010 Enacted	FY 2011 Proposed
<b>1. Improving our knowledge of Earth's past and present climate variability and change</b>			<b>3.1</b>	<b>4.1</b>	<b>6.1</b>
SI	USS*	Forest dynamics, carbon, and biodiversity	1.6	2.6	4.6
SI	USS	Paleontological research	1.5	1.5	1.5
<b>2. Improving our understanding of natural and human forces of climate change</b>			<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
<b>3. Improving our capability to model and predict future conditions and impacts</b>			<b>0.9</b>	<b>0.9</b>	<b>0.9</b>
SI	USS	Geological processes research	0.5	0.5	0.5
SI	USS	Atmospheric research	0.4	0.4	0.4
<b>4. Assessing the Nation's vulnerability to current and anticipated impacts of climate change</b>			<b>1.2</b>	<b>1.2</b>	<b>2.2</b>
SI	USS	Biodiversity and ecosystem responses	1.2	1.2	2.2
<b>5. Providing climate information and decision support tools</b>			<b>0.5</b>	<b>0.5</b>	<b>1.5</b>
SI	USS	Digitization collection and research records	0.5	0.5	1.5
<b>6. Climate Change Communication and Education</b>			<b>0.3</b>	<b>0.3</b>	<b>0.3</b>
SI	USS	Outreach and education	0.3	0.3	0.3
<b>SI Total</b>			<b>6.0</b>	<b>7.0</b>	
<b>President's Request</b>					<b>11.0</b>
*Note: Office of the Under Secretary for Science.					



**Mapping of Budget Request to Appropriations Legislation.** In the Appropriations Committee reports, Smithsonian Institution USGCRP activities are funded in the Smithsonian section of Title III-Related Agencies, within the Salaries and Expenses account. Appropriations Committee reports specify funding for a Sciences line item component of this account, [Under the heading Understanding and Sustaining a Biodiverse Planet] which includes USGCRP programs.

## DEFINITION OF KEY TERMS

## APPENDIX – GLOSSARY AND ACRONYMS

**Adaptation** - Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

**Aerosols** - Tiny particles suspended in the air. Anthropogenic - Human-induced.

**Biomass** - The mass of living organic matter (plant and animal) in an ecosystem; biomass also refers to organic matter (living and dead) available on a renewable basis for use as a fuel. Biomass includes trees and plants (both terrestrial and aquatic), agricultural crops and wastes, wood and wood wastes, forest and mill residues, animal wastes, livestock operation residues, and some municipal and industrial wastes.

**Black Carbon** - Soot particles primarily from fossil fuel burning.

**Carbon Cycle** - The term used to describe the flow of carbon (in various forms such as carbon dioxide [CO<sub>2</sub>], organic matter, and carbonates) through the atmosphere, ocean, terrestrial biosphere, and lithosphere

**Carbon Sequestration** - The process of increasing the carbon content of a carbon reservoir other than the atmosphere; often used narrowly to refer to increasing the carbon content of carbon pools in the biosphere and distinguished from physical or chemical collection of carbon followed by injection into geologic reservoirs, which is generally referred to as “carbon capture and storage.”

**Climate** - The statistical description of the mean and variability of relevant measures of the atmosphere-ocean system over periods of time ranging from weeks to thousands or millions of years.

**Climate Change** - A statistically significant variation either in the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or to external forcing, including changes in solar radiation and volcanic eruptions, or persistent human-induced changes in atmospheric composition or land use.

**Climate Feedback** - An interaction among processes in the climate system in which a change in one process triggers a secondary process that influences the first one. A positive feedback intensifies the change in the original process, and a negative feedback reduces it.

**Climate Forcing** - A process that directly changes the average energy balance of the Earth-atmosphere system by affecting the balance between incoming solar radiation and outgoing or “back” radiation. A positive forcing tends to warm the surface of the Earth and a negative forcing tends to cool the surface.

**Climate System** - The highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface, the biosphere, and the interactions among them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, and human-induced forcings such as the changing composition of the atmosphere and land use change.

**Climate Variability** - Variations in the mean state and other statistics of climatic features at temporal and spatial scales beyond those of individual weather events. These often are due to internal processes within the climate system. Examples of cyclical forms of climate variability include the El Niño-Southern Oscillation, the North Atlantic Oscillation, and the Pacific Decadal Oscillation.

**Cyclone** - A storm system that rotates around a center of low atmospheric pressure.

**Deforestation** - The process of removing or clearing trees from forested land.

**Ecosystem** - A community (i.e., an assemblage of populations of plants, animals, fungi, and microorganisms that live in an environment and interact with one another, forming, together, a distinctive living system with its own composition, structure, environmental relations, development, and function) and its environment treated together as a functional system of complementary relationships and transfer and circulation of energy and matter.

**El Niño-Southern Oscillation (ENSO)** - The waxing and waning every two to seven years of El Niño and La Niña ocean temperature cycles along with the related atmospheric pressure component of the Southern Oscillation; the primary centers of ENSO variability are in the tropical Pacific, but ENSO effects can be felt across much of the globe.

**Forcing** - a natural or human-induced factor that influences climate.

**Fossil Fuels** - Fuels such as coal, petroleum, and natural gas derived from the chemical and physical transformation (fossilization) of the remains of plants and animals that lived during the Carboniferous Period 360 to 286 million years ago.

**Global Change** - Changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life (from the Global Change Research Act of 1990, PL 101-606).

**Greenhouse gases** - Atmospheric gases including water vapor, carbon dioxide, methane, nitrous oxide, and halocarbons that trap infrared heat, warming the air near the surface and in the lower levels of the atmosphere

**Mitigation** - An intervention to reduce the human-induced factors that contribute to climate change. This could include approaches devised to reduce emissions of greenhouse gases to the atmosphere; to enhance their removal from the atmosphere through storage in geological formations, soils, biomass, or the ocean; or to alter incoming solar radiation through several “geo-engineering” options.

**Observations** - Standardized measurements (either continuing or episodic) of variables in climate and related systems.

**Ocean Acidification** - The phenomenon in which the pH of the oceans becomes more acidic due to increased levels of CO<sub>2</sub> in the atmosphere, which, in turn, increase the amount of dissolved CO<sub>2</sub> in sea water.

**Permafrost** - Soils or rocks that remain below 0°C for at least two consecutive years.

**Prediction** - A probabilistic description or forecast of a future climate outcome based on observations of past and current oceanic and atmospheric conditions and quantitative models of climate processes (e.g., a prediction of an El Niño event).

**Projection** - A description of the response of the climate system to an assumed level of future radiative forcing. Changes in radiative forcing may be due to either natural sources (e.g., volcanic emissions) or human-induced factors (e.g., emissions of greenhouse gases and aerosols, or changes in land use and land cover). Climate “projections” are distinguished from climate “predictions” in order to emphasize that climate projections depend on scenarios of future socioeconomic, technological, and policy developments that may or may not be realized.

**Sink** - In general, any process, activity, or mechanism that removes a greenhouse gas or a precursor of a greenhouse gas or aerosol from the atmosphere; in this report, a sink is any regime or pool in which the amount of carbon is increasing (i.e., is being accumulated or stored).

**Source** - In general, any process, activity, or mechanism that releases a greenhouse gas or a precursor of a greenhouse gas or aerosol into the atmosphere; in this report, a source is any regime or pool in which the amount of carbon is decreasing (i.e., is being released or emitted).

**Stratosphere** - The highly stratified region of the atmosphere above the troposphere extending from about 10 kilometers (km) (ranging from 9 km in high latitudes to 16 km in the tropics on average) to about 50 km.

**Troposphere** - The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and “weather” phenomena occur; in the troposphere, temperatures generally decrease with height

**Weather** - The specific condition of the atmosphere at a particular place and time, measured in terms of variables such as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation.

## ACRONYMS

<b>ACCRI</b>	Aviation Climate Change Research Initiative	<b>GCCE</b>	Global Climate Change Education
<b>ACRF</b>	ARM Climate Research Facility	<b>GCOS</b>	Global Climate Observing System
<b>ACRIMSAT</b>	Activity Cavity Radiometer Irradiance Monitor SATellite	<b>GCP</b>	USGS Global Change Programs
<b>AFRI</b>	Agriculture and Food Research Initiative	<b>GCRA</b>	Global Change Research Act
<b>AMOC</b>	Atlantic Meridional Overturning Circulation	<b>GEO</b>	Group on Earth Observations
<b>APHA</b>	American Public Health Association	<b>GEOSS</b>	Global Earth Observation System of Systems
<b>APS</b>	Aerosol Polarimetry Sensor	<b>GHG</b>	Greenhouse Gas
<b>AR5</b>	IPCC Fifth Assessment Report	<b>GIS</b>	Geographic Information System
<b>ARM</b>	Atmospheric Radiation Measurement	<b>GLOBE</b>	Global Learning and Observations to Benefit the Environment
<b>ARS</b>	Agricultural Research Service	<b>GLS</b>	Global Land Survey
<b>ASTHO</b>	Association for State and Territorial Health Officials	<b>GOOS</b>	Global Ocean Observation System
<b>CALIPSO</b>	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation	<b>GPM</b>	Global Precipitation Measurement
<b>CCHHG</b>	Interagency Crosscutting Group on Climate Change and Human Health	<b>GRACE</b>	Gravity Recovery and Climate Experiment
<b>CCSP</b>	Climate Change Science Program	<b>GRACenet</b>	Greenhouse gas Reductions through Agricultural Carbon Enhancement network
<b>CCTP</b>	Climate Change Technology Program	<b>GRUAN</b>	GCOS Reference Upper Air Network
<b>CD</b>	Climate Diagnostics	<b>HPC</b>	High Performance Computing
<b>CDC</b>	Centers for Disease Control and Prevention	<b>HYCOM</b>	Hybrid Coordinate Ocean Model
<b>CDIAC</b>	Carbon Dioxide Information Analysis Center	<b>IAM</b>	Integrated Assessment Model
<b>CEOS</b>	Committee on Earth Observing Satellites	<b>IARPC</b>	Interagency Arctic Research Policy Committee
<b>CEQ</b>	Council on Environmental Quality	<b>ICAO</b>	International Civil Aviation Organization
<b>CLARREO</b>	Climate Absolute Radiance and Refractivity Observatory	<b>ICESat</b>	Ice, Cloud, and land Elevation Satellite
<b>CLIVAR</b>	Climate Variability and Predictability	<b>ICSU</b>	International Council for Science
<b>CloudSat</b>	Cloud Satellite	<b>IDN</b>	International Directory Network
<b>CMC</b>	Carbon Management Center	<b>IGBP</b>	International Geosphere-Biosphere Programme
<b>CMS</b>	Carbon Monitoring System	<b>IHDP</b>	International Human Dimensions Programme
<b>CO<sub>2</sub></b>	Carbon Dioxide	<b>IOOS</b>	Integrated Ocean Observing System
<b>EHP</b>	Environmental Health Perspectives	<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>ENSO</b>	El Niño-Southern Oscillation	<b>IT</b>	Information Technology
<b>EO</b>	Earth Observer	<b>IWG</b>	Interagency Working Group
<b>EOS</b>	Earth Observing System	<b>IWGCCH</b>	Interagency Working Group on Climate Change and Health
<b>EROS</b>	Earth Resources Observation Systems	<b>JGCRI</b>	Joint Global Change Research Institute
<b>ERS</b>	Economic Research Service	<b>LCDM</b>	Landsat Data Continuity Mission
<b>ESM</b>	Earth System Model	<b>LRSP</b>	Land Remote Sensing Program
<b>ESSP</b>	Earth System Science Partnership	<b>LTER</b>	Long Term Ecological Research Network
<b>EV</b>	Earth Venture	<b>MERRA</b>	Modern Era Retrospective-Analysis for Research and Applications
<b>FACE</b>	Free-Air CO <sub>2</sub> Enrichment	<b>MJO</b>	Madden-Julian Oscillation
<b>FEWS NET</b>	Famine Early Warning System Network	<b>MODIS</b>	Moderate Resolution Imaging Spectroradiometer
<b>FIA</b>	Forest Inventory Analysis	<b>N<sub>2</sub>O</b>	Nitrous Oxide
<b>GCI</b>	GEOSS Common Infrastructure		
<b>GCAM</b>	Global Change Assessment Model		

## The U.S. Global Change Research Program for Fiscal Year 2011

<b>NACCHO</b>	National Association of County and City Health Officials	<b>UNEP</b>	United Nations Environment Programme
<b>NACP</b>	North American Carbon Program	<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>NARCCAP</b>	North American Regional Climate Change Assessment Program	<b>URL</b>	Uniform Resource Locator
<b>NEON</b>	National Ecological Observatory Network	<b>UV-B</b>	Ultraviolet B
<b>NGO</b>	Nongovernmental Organization	<b>UVBR&amp;M</b>	Ultraviolet B Research and Monitoring Program
<b>NIDIS</b>	National Integrated Drought Information System	<b>WCRP</b>	World Climate Research Programme
<b>NOPP</b>	National Oceanographic Partnership Program	<b>WGISS</b>	CEOS Working Group on Information Systems and Science
<b>NPOESS</b>	National Polar-orbiting Operational Environmental Satellite System	<b>WMO</b>	World Meteorological Organization
<b>NPP</b>	NPOESS Preparatory Project	<b>WWA</b>	Western Water Assessment
<b>NPS</b>	National Park Service		
<b>NRC</b>	National Research Council		
<b>NSLRSDA</b>	National Satellite Land Remote Sensing Data Archive		
<b>OCB</b>	Ocean Carbon and Biogeochemistry		
<b>OCO</b>	Orbiting Carbon Observatory		
<b>OCP</b>	Ocean Carbon Program		
<b>OMB</b>	Office of Management and Budget		
<b>OSTM</b>	Ocean Surface Topography Mission		
<b>OSTP</b>	Office of Science and Technology Policy		
<b>PAR</b>	Photosynthetically Active Radiation		
<b>PARTNER</b>	Partnership for Air Transportation Noise and Emissions Reduction		
	ppm – parts per million		
<b>QuikSCAT</b>	Quick Scatterometer		
<b>RISA</b>	Regional Integrated Sciences and Assessments		
<b>SAGE</b>	Stratospheric Aerosol and Gas Experiment		
<b>SBA</b>	Societal Benefit Areas		
<b>SCICEX</b>	Science Ice Exercise		
<b>SECC</b>	Southeast Climate Consortium		
<b>SERDP</b>	Strategic Environmental Research and Development Program		
<b>SERVIR</b>	Sistema Regional de Visualización y Monitoreo		
<b>SF<sub>6</sub></b>	Sulfur Hexafluoride		
<b>SGCR</b>	Subcommittee for Global Change Research		
<b>SMAP</b>	Soil Moisture Active-Passive		
<b>SORCE</b>	Solar Radiation and Climate Experiment		
<b>SSS</b>	Sea Surface Salinity		
<b>SST</b>	Sea Surface Temperature		
<b>START</b>	SysTem for Analysis, Research, and Training		
<b>TRMM</b>	Tropical Rainfall Measuring Mission		
<b>UAS</b>	Unmanned Aerial System		

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