

# OUR CHANGING PLANET

The U.S. Global Change Research Program for Fiscal Year 2015  
A Supplement to the President's Budget for Fiscal Year 2015



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

# OUR CHANGING PLANET

The U.S. Global Change Research Program for Fiscal Year 2015  
A Supplement to the President's Budget for Fiscal Year 2015



---

*"Climate change, once considered an issue for the distant future, has moved firmly into the present. ...Using scientific information to prepare for climate changes in advance can provide economic opportunities, and proactively managing the risks can reduce impacts and costs over time."*

*—The Third National Climate Assessment, 2014*

---

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

This material was developed with Federal support through the U.S. Global Change Research Program under  
National Science Foundation Award No. NSF DACS13C1421

## SUBCOMMITTEE ON GLOBAL CHANGE RESEARCH

### LEADERSHIP

**Thomas Karl**, SGCR Chair, Department of Commerce

**Thomas Armstrong**, USGCRP Executive Director, U.S. Global Change Research Program, White House Office of Science and Technology Policy

**Christopher Weaver**, USGCRP Deputy Executive Director, U.S. Global Change Research Program, White House Office of Science and Technology Policy

**Samantha Brooks**, SGCR Executive Secretary, U.S. Global Change Research Program

### EXECUTIVE COMMITTEE

**Michael Freilich**, National Aeronautics and Space Administration

**Gerald Geernaert**, Department of Energy

**Craig McLean**, Department of Commerce

**Roger Wakimoto**, National Science Foundation

**Jeffrey Arnold** (Adjunct), Department of Defense

### PRINCIPALS

**John Balbus**, Department of Health and Human Services

**Katharine Batten**, U.S. Agency for International Development

**Joel Clement**, Department of the Interior

**Scott Harper** (Acting), Department of Defense

**Wayne Higgins**, Department of Commerce

**Leonard Hirsch**, Smithsonian Institution

**William Hohenstein**, Department of Agriculture

**Jack Kaye**, National Aeronautics and Space Administration

**Michael Kuperberg**, Department of Energy

**C. Andrew Miller**, Environmental Protection Agency

**Craig Robinson**, National Science Foundation

**Arthur Rypinski** (Acting), Department of Transportation

**Trigg Talley**, Department of State

### EXECUTIVE OFFICE OF THE PRESIDENT

**Tamara Dickinson**, Principal Assistant Director for Environment and Energy, White House Office of Science and Technology Policy

**Richard Duke**, Associate Director for Energy and Climate Change, White House Council on Environmental Quality

**Fabien Laurier**, Director, Third National Climate Assessment, U.S. Global Change Research Program, White House Office of Science and Technology Policy

**Kimberly Miller**, Program Examiner, White House Office of Management and Budget

**Jayne Morrow**, Executive Director, National Science and Technology Council

#### Image Credits

Cover: Earth from space, NASA; thumbnail images, Shutterstock and UCAR.

Page 1, Shutterstock; page 4, NASA; page 21, Shutterstock; page 29, NASA; page 31, UCAR; page 33, UCAR.

Since 1989, the U.S. Global Change Research Program (USGCRP) has submitted annual reports to Congress called *Our Changing Planet*. The reports describe the status of USGCRP research activities, provide progress updates, and document recent accomplishments. This FY 2015 edition of *Our Changing Planet* provides a summary of programmatic achievements, recent progress, future priorities, and budgetary information. It thereby meets the requirements set forth in the U.S. Global Change Research Act of 1990 (Section 102, P. L. 101–606) to provide an annual report on Federal global change research priorities and programs. It does not express any regulatory policies of the United States or any of its agencies, or make any findings that could serve as predicates for regulatory action.

October 2014

Members of Congress:

On behalf of the National Science and Technology Council, I am pleased to transmit *Our Changing Planet: The U.S. Global Change Research Program for Fiscal Year 2015*. USGCRP coordinates and integrates scientific research across 13 Federal agencies whose missions include understanding changes in the global environment and their implications for society. In accordance with the Global Change Research Act (GCRA) of 1990, the enclosed report summarizes USGCRP's recent progress and achievements, future priorities, and associated budget information.

This latest edition of *Our Changing Planet* includes an overview of the USGCRP research enterprise and recent highlights that demonstrate how the Program is meeting the mandate of the GCRA and fulfilling its 2012–2021 Strategic Plan. The report also illustrates linkages between USGCRP's strategic research goals and President Obama's Climate Action Plan, spotlighting several aspects of the President's Plan in which USGCRP plays a critical implementation role.

From collecting satellite observations and modeling near-term climate, to supporting adaptation in the Federal Government and building skills among informal educators, to delivering the National Climate Assessment and sustaining the Nation's assessment capacity, USGCRP's efforts reach across the spectrum of research, decision support, education, and communication. This approach is fully responsive to the GCRA's mandate to “*understand, assess, predict, and respond to human-induced and natural processes of global change.*”

*Our Changing Planet FY 2015* summarizes USGCRP's significant progress toward achieving its strategic goals, supporting the President's Climate Action Plan, and building a knowledge base that effectively informs human responses to global change. I appreciate the close cooperation of the participating agencies and look forward to working with members of the Congress to implement the continuation of this essential national program.

Sincerely,

A handwritten signature in black ink that reads "John P. Holdren". The signature is written in a cursive, flowing style.

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

# TABLE OF CONTENTS

- 1. Introduction** ..... 2
- 2. Federal Investments in Global Change Research** ..... 5
  - 2.1. Understanding and Assessing Global Climate and the Earth System ..... 5
  - 2.2. Preparing for the Impacts of Global Change ..... 15
- 3. Leveraging Global Change Research for Societal Needs** ..... 22
  - 3.1. Identifying Vulnerabilities of Key Sectors to Climate Change ..... 22
  - 3.2. Developing Actionable Climate Science ..... 24
  - 3.3. Strengthening Global Resilience to Climate Change ..... 26
- 4. A Look Ahead: Interagency Research Priorities for FY15** ..... 30
- 5. Budget Information** ..... 32
- 6. Appendices** ..... 34
  - 6.1. About USGCRP ..... 34
  - 6.2. Member Agencies ..... 35
  - 6.3. Glossary ..... 41
  - 6.4. Acronyms ..... 45

**LIST OF RESEARCH HIGHLIGHTS**

**Highlight 1.** Two Cutting-Edge Missions to Measure Global Change ..... 5

**Highlight 2.** Arctic Observations to Meet Scientific and Societal Needs..... 6

**Highlight 3.** Strengthening Global Observations of Biodiversity ..... 8

**Highlight 4.** Carbon Cycle Science for a Changing World ..... 9

**Highlight 5.** Climate Change and Nitrogen: Interacting Impacts on Ecosystem Services ..... 10

**Highlight 6.** Extending Climate Records Beyond Instrumental Measurements ..... 10

**Highlight 7.** Modeling Pollution to Understand Localized Climate Trends ..... 11

**Highlight 8.** DYNAMO: Linking Observations and Models to Predict Near-Term Climate ..... 12

**Highlight 9.** Climate Change Here and Now: The Third National Climate Assessment..... 13

**Highlight 10.** Impacts, Risks, and Responses in the 2014 IPCC Reports ..... 14

**Highlight 11.** Supporting Federal Climate Preparedness with Resources and Data ..... 15

**Highlight 12.** Building a Climate-Resilient National Capital Region ..... 16

**Highlight 13.** Tracing Global Change Science Back to the Source..... 17

**Highlight 14.** Empowering the Nation with Climate Data..... 17

**Highlight 15.** Building Capacity Among Climate-Change Interpreters ..... 18

**Highlight 16.** A Global Carbon Atlas for Educators, Policymakers, and the Public ..... 19

**Highlight 17.** GlobalChange.gov Reloaded: USGCRP’s New Website..... 19

**Highlight 18.** Modeling Climate Impacts on Agriculture and Adaptation by the Agro-Economy ..... 22

**Highlight 19.** Assessing Risks to Freshwater Fish ..... 23

**Highlight 20.** Linking Climate Change to Health Impacts ..... 23

**Highlight 21.** Tracking Climate Change with Indicators ..... 24

**Highlight 22.** Drought Research to Support Management and Preparedness ..... 25

**Highlight 23.** Using the National Climate Assessment to Help Protect Federal Assets..... 26

**Highlight 24.** Understanding Global Urbanization and Environmental Change..... 27

**Highlight 25.** Supporting Sustainability and Resilience in Coastal Zones ..... 27

**Highlight 26.** Informing Risk Management and Agricultural Decisions in the Caribbean ..... 28



# 1 Introduction

Global change alters the capacity of the Earth to sustain life. It encompasses global climate change and processes that interact with climate to affect Earth systems. The impacts of global change are being felt now, both around the world and here in the United States.

America and the world are getting warmer, global sea level is rising, and some types of extreme weather events are becoming more frequent and more severe. The most recent decade was the hottest ever recorded, and temperatures are projected to rise another 2°F to 4°F in most areas of the United States over the next few decades.<sup>1</sup>

In some regions of the country, prolonged heat and drought are contributing to larger wildfires and longer fire seasons. For coastal communities, sea level rise, combined with coastal storms, has increased the risk of erosion, flooding, and damage to property and infrastructure. The rising temperature and increasing acidity of ocean water is combining with other stresses, such as overfishing and pollution, to impact marine ecosystems and resources.<sup>1</sup>

Climate impacts on agriculture and water supplies have been increasing and are projected to become more severe. Extreme heat, sea level rise, and heavy rains are threatening infrastructure like roads, airports, port facilities, energy systems, and military bases. Climate change affects human health through more extreme weather events, decreased air quality, and changing ranges of diseases transmitted by food, water, and insects.<sup>1</sup>

These and other aspects of climate and related global change are having increasingly significant effects on the American economy and quality of life. The Nation needs

reliable scientific information about current and future changes, their impacts, and effective response options. The U.S. Global Change Research Program (USGCRP) is at the center of the Federal Government's efforts to fulfill this critical need.

In June 2013, President Obama launched a comprehensive Climate Action Plan<sup>2</sup> to reduce carbon pollution, prepare the United States for the impacts of climate change, and lead international efforts to address climate change as a global challenge. The Plan invokes the key role of USGCRP in developing sound science to support the

## Box 1. USGCRP Agencies



<sup>1</sup> Climate Change Impacts in the United States: The Third National Climate Assessment. 2014. Melillo, J.M., T.C. Richmond, and G.W. Yohe, Eds. U.S. Global Change Research Program. [nca2014.globalchange.gov](http://nca2014.globalchange.gov)

<sup>2</sup> The President's Climate Action Plan. 2013. [whitehouse.gov/climate-change](http://whitehouse.gov/climate-change)

management of climate change and its impacts now and in the future. Since its establishment by Presidential initiative in 1989 and the Global Change Research Act (GCRA) of 1990,<sup>3</sup> USGCRP has been advancing Earth system science and expanding the knowledge base needed to respond to a changing climate and a transforming world.

USGCRP fulfills the mandate of the GCRA, executes the National Global Change Research Plan 2012–2021 (hereafter, the 2012–2021 Strategic Plan),<sup>4</sup> and helps to implement the President’s Climate Action Plan by coordinating the Federal Government’s sustained annual investment in global change research. Since its inception, USGCRP has supported a research enterprise that provides taxpayers substantial returns on this investment, including major advances in the knowledge of Earth’s past and present climate, improved climate-change projections for the future, and a better understanding of society’s vulnerabilities to global change impacts. This vast body of work is carried out by 13 Federal agencies (*Box 1; Section 6.2*), each contributing its distinct expertise, that work together in a unified research framework toward a more holistic, actionable understanding of global change.

This report provides an overview of the USGCRP enterprise (*Box 2; Section 2*); examples of recent accomplishments and investments in advancing, disseminating, and leveraging global change research to support scientific progress and societal needs (*Sections 2 and 3*); an outlook on research priorities for Fiscal Year (FY) 2015 (*Section 4*); and supporting budgetary information (*Section 5*).

USGCRP’s ability to produce the results described herein is made possible in large part by sustained, long-term investments in observations, research, modeling, and data stewardship. These long-term investments build the necessary foundation for scientific breakthroughs, and they provide critical support for the U.S. scientific community, including young scientists who will form the backbone of future global change research. From monitoring changes in the Arctic to supporting a climate-resilient U.S. capital, the activities highlighted in this report reflect the fruition of foundational research investments needed to meet the requirements of the GCRA, fulfill the 2012–2021 Strategic Plan, and deliver on the President’s Climate Action Plan.

## Box 2. USGCRP’s Vision, Mission, & Strategic Goals

**Vision:** A Nation, globally engaged and guided by science, meeting the challenges of climate and global change.

**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.

**Strategy for Global Change Research:** USGCRP’s 2012–2021 Strategic Plan maintains a clear emphasis on advancing global change science, but it also calls for a strengthened focus on ensuring that USGCRP science informs real-world decisions and actions. USGCRP’s four strategic goals are to:

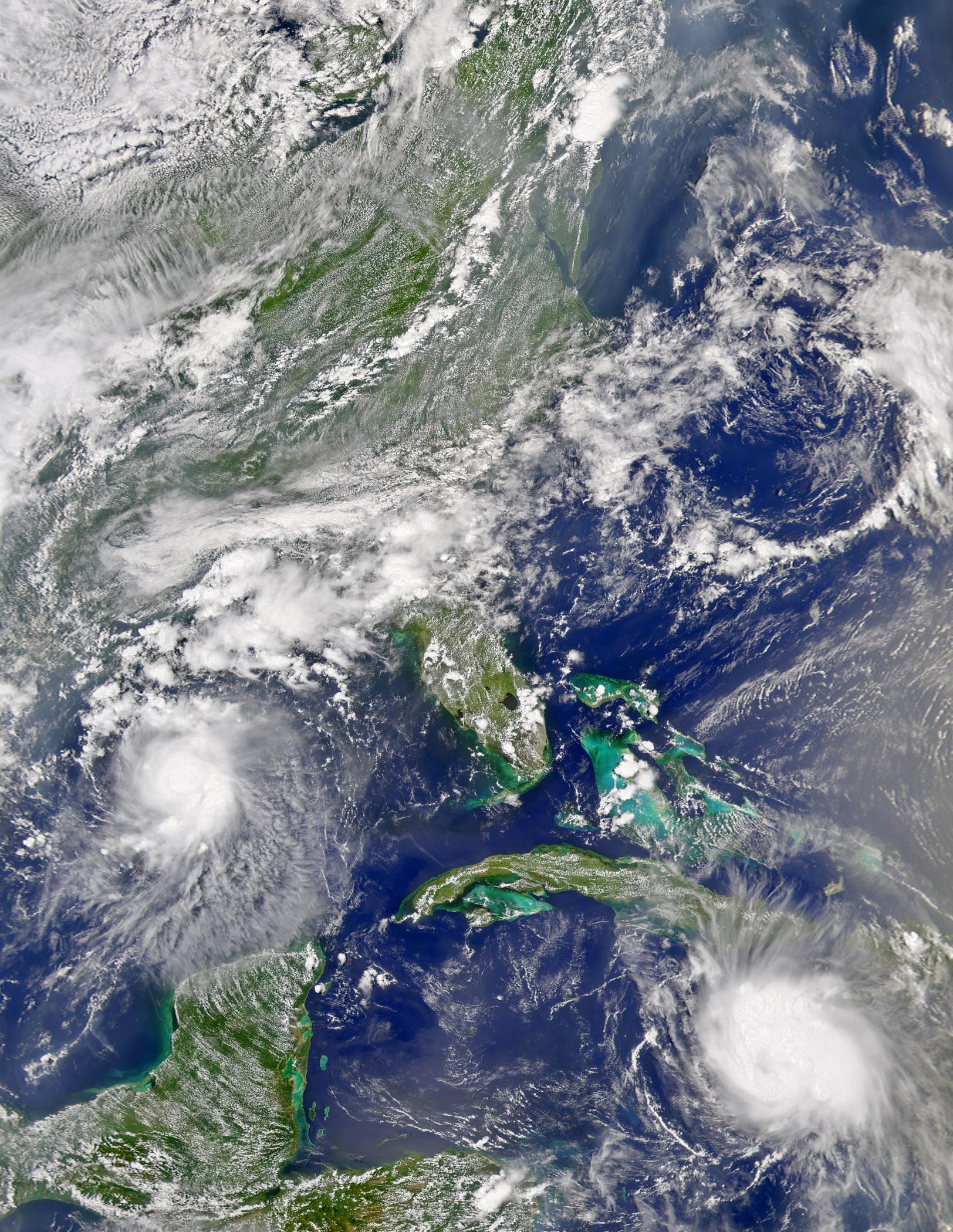
- *Advance Science* - Advance scientific knowledge of the integrated natural and human components of the Earth system to understand climate and global change.
- *Inform Decisions* - Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation.
- *Conduct Sustained Assessments* - Build sustained assessment capacity that improves the Nation’s ability to understand, anticipate, and respond to global change impacts and vulnerabilities.
- *Communicate and Educate* - Advance communication and education to broaden public understanding of global change and develop the scientific workforce of the future.

To learn more about the 2012–2021 Strategic Plan, visit: <http://go.usa.gov/8VUm>

To learn more about USGCRP, see *Section 6.1*.

<sup>3</sup> USGCRP’s legal mandate. <http://go.usa.gov/8VU9>

<sup>4</sup> The National Global Change Research Plan 2012–2021: A Strategic Plan for the U.S. Global Change Research Program. 2012. <http://go.usa.gov/8VUA>



# 2 Federal Investments in Global Change Research

## 2.1. Understanding and Assessing Global Climate and the Earth System

### 2.1.1. Observing Changes in the Earth System

To understand global change, we must first be able to observe and measure its manifestations. USGCRP science—including fundamental research, modeling, assessments, and science for decision support—depends upon comprehensive, continuous, and multidisciplinary observations of global change across Earth’s atmosphere, oceans, land, and ice. These observations are collected using a variety of high-tech instruments and transformed through data analysis into value-added products that underpin our understanding of ongoing and future changes, impacts, and vulnerabilities. USGCRP’s portfolio of Earth observations includes satellite, airborne, ground-based, and ocean-based missions, platforms, and networks—all of which provide measurements of Earth system variables that are necessary for understanding and responding to global change (*Highlight 1*). New

observation systems require long-term planning horizons and thus depend on a sustained programmatic focus in this area.

Looking ahead to FY 2015, USGCRP will enhance and integrate observations needed to support its mission, with particular emphasis on interagency research priorities (*see Section 4*) including seasonal to multi-decadal predictions, causes and consequences of drought in a changing climate, the impacts of global change on the Arctic (*Highlight 2*), and providing actionable science to inform decisions (*Highlight 3*; *see also Section 3.2*). USGCRP also will work to assess critical observational gaps in collaboration with the U.S. Group on Earth Observations (USGEO). The recently released National Plan for Civil Earth Observations,<sup>5</sup> developed by the White House Office of Science and Technology Policy through an interagency effort led by USGEO, places high priority on sustaining observations for Earth system research—directly supporting USGCRP’s strategic goals.

### Recent Highlights

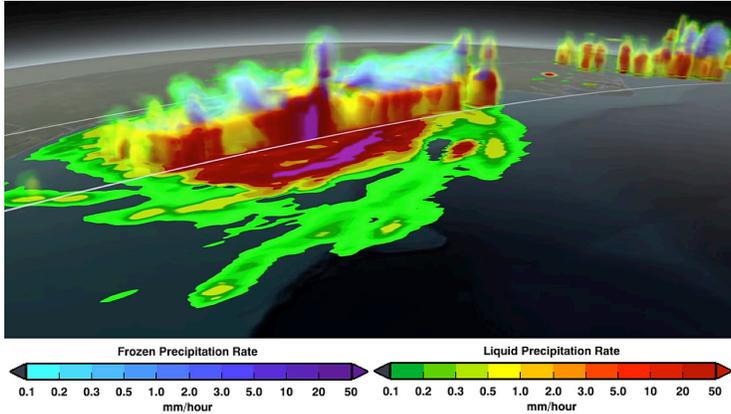
#### Highlight 1. Two Cutting-Edge Missions to Measure Global Change

In 2014, NASA launched two new satellite missions that will enable fundamental advancements in our understanding of climate and global change. The Global Precipitation Measurement satellite, launched in February in collaboration with the Japan Aerospace Exploration Agency (JAXA), carries state-of-the-art instrumentation that will collect unparalleled observations of rain and snow worldwide every three hours. Such high-resolution data will improve forecasts of extreme weather and climate events, lead to a better understanding of the global water and energy cycles, and support predictions of freshwater availability. The GPM mission is already returning unprecedented observations, including recently captured measurements of Hurricane Arthur, the first hurricane of the 2014 season. To learn more, visit: <http://go.usa.gov/NgWY>

In July, NASA launched the Orbiting Carbon Observatory-2 (OCO-2), its first satellite dedicated to measuring atmospheric carbon dioxide from space. This new satellite mission will provide a global picture of human and natural sources of carbon dioxide, and will also help to quantify

<sup>5</sup> National Plan for Civil Earth Observations. 2014. <http://go.usa.gov/5VuJ>

carbon dioxide sinks—places on Earth that naturally pull carbon dioxide out of the atmosphere. OCO-2 will deliver a dramatic increase in the resolution of carbon dioxide observations, collecting hundreds of thousands of measurements each day. These measurements will be combined with data from ground stations, aircraft, and other satellites to help answer key questions about the global carbon cycle (see related *Highlight 4*) and how it interacts with climate change. To learn more, visit: <http://go.usa.gov/NgWB> ♦



This frame from an animation of GPM data shows the internal structure of Hurricane Arthur off the coast of South Carolina. This event marks the first time that a satellite has followed a hurricane through its full life cycle with high-resolution measurements of rain and ice. The GPM mission’s observations of storms like Arthur will help scientists answer pressing questions about hurricanes, such as how and why they intensify. (Credit: NASA Scientific Visualization Studio/JAXA)

## Highlight 2. Arctic Observations to Meet Scientific and Societal Needs

Advancing science in the Arctic is crucial to understanding global climate dynamics, supporting policy decisions, and managing nationally and internationally important resources. In coordination with the Interagency Arctic Research Policy Committee (IARPC) and USGEO, USGCRP member agencies observe and monitor the Arctic environment to understand the impacts of global change on this ecologically, culturally, and economically significant region. Polar orbiting satellites provide data that are combined with information from surface-based measurement networks, airborne and field campaigns, and research initiatives. U.S. Arctic observing capabilities and campaigns are highly multidisciplinary, spanning the physical, biological, and social sciences, and rely on the cooperative and complementary efforts of many agencies. In FY 2015, Arctic observations will build upon capabilities developed in recent years to support new science on sea level rise, changes to sea ice extent, weather forecasting, and permafrost ecosystems; strengthen international partnerships; and provide new information for environmental protection and decision support (*Box 3*). ♦

### Box 3. Arctic Observational Campaigns

The Arctic is an FY 2015 interagency research priority for USGCRP (Section 4) within the Program’s ongoing emphasis on weather and climate extremes and Earth system tipping points. Major long-term and upcoming Arctic observational campaigns are detailed below.

#### FUNDAMENTAL RESEARCH AND MONITORING

- NASA’s **Operation IceBridge** measures polar ice bodies to better understand their connection to the global climate system. Using aircraft equipped for radar and precision laser observations, IceBridge assesses annual changes in the thickness of sea ice, glaciers, and continental ice sheets in Greenland and Antarctica, while simultaneously measuring other key parameters required to improve forecasts of ice loss and sea level rise. IceBridge is part of a multi-decadal NASA mission to collect a time series of ice thickness changes. To learn more, visit: <http://go.usa.gov/8Vmk>
- DOE maintains two **Atmospheric Radiation Measurement** observatories on the North Slope of Alaska, one at Barrow and one at Oliktok Point, designed to investigate relationships between the atmosphere, ocean, and sea ice across the Arctic. To learn more, visit: <http://go.usa.gov/8VPB>
- DOE’s **Next Generation Ecosystem Experiment – Arctic** represents a decadal-scale effort to observe and understand processes that drive changes in permafrost ecosystems, based on intensive field campaigns in Alaska. To learn more, visit: <http://go.usa.gov/5PSw>

*(continued on next page)*

*Arctic Observational Campaigns (continued)*

- The **Arctic-Boreal Vulnerability Experiment**, led by NASA, will use ground-based research paired with geospatial data from aircraft and satellites to better understand ecosystem and societal vulnerabilities to climate change in the Arctic and boreal regions of western North America. To learn more, visit: <http://go.usa.gov/8VmP>
- Among its many applications, NASA's upcoming **Soil Moisture Active Passive satellite mission** will provide new information about soil moisture and permafrost freeze/thaw cycles to support Arctic and boreal ecological research. To learn more, visit: <http://go.usa.gov/8VEH>
- A number of ongoing **polar-orbiting satellite missions** routinely provide key data for Arctic monitoring and research, including weather data from the National Oceanic and Atmospheric Administration (NOAA), passive microwave measurements of sea ice from the Defense Meteorological Satellite Program, NASA Aqua/MODIS imaging data, visible and thermal infrared Landsat data from NASA and DOI's U.S. Geological Survey (USGS), and others.

**U.S. SUPPORT FOR INTERNATIONAL NETWORKS**

- The **Arctic Observing Network** contributes to international sustained Arctic observations and comprises an interagency system of environmental monitoring capabilities—from ocean buoys to satellites—to advance understanding of the significant and rapid changes occurring in the Arctic. A few examples of current Arctic observing efforts that support this effort are the Distributed Biological Observatory (NSF, NOAA, and international partners), the Thermal State of Permafrost (NSF; DOI's U.S. Fish and Wildlife Service, Bureau of Land Management, and National Park Service; DOE; and international partners), and the Community-based Observation Network for Adaptation and Security (NSF and international partners). To learn more, visit: <http://goo.gl/KWBWFB>
- NOAA, NASA, NSF, the U.S. Navy, and the U.S. Coast Guard work with partners in academia to deploy buoys in Arctic seas as part of the **International Arctic Buoy Program**. This network of drifting buoys provides critical meteorological and oceanographic data that are used for both research and operational purposes. The buoys provide information on sea ice age, extent, movement, and other factors. To learn more, visit: <http://goo.gl/Lyhy3C>

**SUSTAINABILITY AND ADAPTATION**

- DOI's **Alaska Climate Science Center** aims to understand and support sustainable solutions for the impacts of climate change on Alaska's ecosystems and natural and cultural resources. A recent project uses satellite altimetry, radar, and gravity observations collected by NASA to quantify the impact of changing glacial runoff on coastal ecosystems. To learn more, visit: <http://go.usa.gov/8VyF>
- USDA operates a nationwide **Soil Climate Analysis Network**—which includes stations in the Arctic—to support natural resource assessments and conservation activities. In addition to weather parameters, this network collects soil temperature and soil moisture data at various depths. To learn more, visit: <http://go.usa.gov/NxgF>
- NOAA's **Alaska Center for Climate Assessment and Policy**, part of the Regional Integrated Sciences & Assessments (RISA) program, recently worked with research partners to produce an atlas of Alaska sea ice. The atlas—developed in response to the needs of coastal communities, maritime industries, and the military—features digitized observational data on sea ice for Alaska coastal waters to a distance of 300 miles from shore. To learn more, visit: <http://goo.gl/nmHJwj>



The sun reflects over thin sea ice and a few floating icebergs near the Denmark Strait off eastern Greenland, as seen from NASA's P-3B aircraft during an IceBridge flight. (Credit: NASA)



Iceberg trapped in sea ice in North Star Bay, near Thule Air Base, Greenland. (Credit: M. Studinger, NASA)

### Highlight 3. Strengthening Global Observations of Biodiversity

Reducing the rate of biodiversity loss and averting precipitous ecosystem changes are internationally shared goals. Through its funding to DIVERSITAS, USGCRP supports the international Group on Earth Observation's Biodiversity Observation Network (GEO BON) in building a global, scientifically robust framework for detecting biodiversity change, intended to fill gaps in existing data and create links between globally dispersed observing systems. To meet this goal, GEO BON is developing a set of Essential Biodiversity Variables (EBVs). EBVs are designed to detect changes in representative elements of Earth's biodiversity, especially those most relevant to ecosystem services and societal needs, and can inform scenarios of biodiversity change under different management and policy scenarios. To learn more, visit: <http://goo.gl/8Uip0g>



Monitoring biodiversity in the field. (Credit: C. Körner)

Biodiversity is a key indicator of the health of coastal and marine ecosystems and of the ability of those ecosystems to provide services on which society

depends. Recognizing the need to monitor this important metric, USGCRP agencies DOI, NASA, and NOAA released a Federal Funding Opportunity in 2013 to develop prototypes for a Marine Biodiversity Observation Network (Marine BON) in U.S. coastal waters, the Great Lakes, and the Exclusive Economic Zone. To learn more, visit: <http://go.usa.gov/NcjA> ♦

#### 2.1.2. Understanding the Complex Planet

Understanding global change is critical to our Nation's welfare and economic vitality. Research, supported by increasingly sophisticated tools for collecting and analyzing data, can provide essential knowledge to governments, businesses, and communities as they plan for and respond to aspects of climate and related global change—including sea level rise, ocean acidification, and the more severe heat waves, droughts, and other extreme events that pose an ever-growing risk to life, property, food resilience, and natural resources.

As part of its long-term programmatic focus, USGCRP conducts and supports state-of-the-art research to understand the interactive processes that influence the total Earth system—which includes the atmosphere, oceans,

land, ice, biogeochemical cycles (*Highlight 4*), ecosystems (*Highlight 5*), and people. Though past (*Highlight 6*), present-day, and future climate change is a central theme of this research, USGCRP continues to work toward deeper integration of climate research with other critical dimensions of global change, such as the dynamics of land use and land cover, the water cycle, and natural and human systems. Recognizing the need to better integrate expertise from the social sciences, USGCRP established a task force to identify options and provide recommendations for accelerating this integration. In FY 2014, the task force fulfilled its mandate, and its members are coordinating with many of USGCRP's other working groups (see *Section 6.1*) to advise on activities and foster partnerships that strengthen the Program's connection to social sciences research.

## Recent Highlights

### Highlight 4. Carbon Cycle Science for a Changing World

The continual cycling of carbon through the atmosphere, oceans, soil, and living organisms is an essential function of the Earth system. The U.S. Carbon Cycle Science Program (under the auspices of USGCRP; [carboncyclescience.us](http://carboncyclescience.us)) and USGCRP agencies are working to understand how climate change and human activities are altering this foundational component of the environment, and how these alterations feed back to affect climate change. Some examples are highlighted below:

- At least two thirds of the world's land-based organic carbon is stored in soil, but potentially major feedbacks between climate change and the release of soil carbon into the atmosphere are not well understood yet. To address this knowledge gap, the **International Soil Carbon Network (ISCN)** has been established to characterize the distribution and stability of soil carbon; forecast the vulnerability of soil carbon to changing climate, land use, and other disturbances; and distribute this information in formats that are useful to land managers, modelers, and policy makers. To learn more, visit: <http://goo.gl/oWXqjJ>
- The **Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) experiment**, a unique collaboration between DOE and the U.S. Forest Service (USDA-FS), will explore the vulnerability of peatland forests to changing climate. The loss of these ecosystems could lead to the release of ten thousand years of stored soil carbon into the atmosphere as greenhouse gases, further exacerbating climate change. The experiment, held in the Marcell Experimental Forest in Minnesota, provides a platform for testing mechanisms that control the vulnerability of peatland organisms and ecosystems to climate change, and will enable more accurate representations of these processes in Earth system models. Initial sampling and infrastructure development began in 2012, and experiments are slated to begin in 2015. To learn more, visit: <http://go.usa.gov/8VV9>
- The **Carbon Monitoring System (CMS)**, a NASA-led effort also involving USDA-FS, NOAA, USGS, and non-governmental scientists, focuses on improving the monitoring of carbon stocks and fluxes. Key outcomes of this effort include biomass maps and other data products covering spatial scales ranging from local to global; demonstrations of carbon monitoring and accounting in support of local- and regional-scale management projects; and engagement with stakeholders to better understand their needs for carbon data products. New CMS studies are using airborne measurements to support national and international carbon management efforts, such as SilvaCarbon and the United Nations Reducing Emissions from Deforestation and Forest Degradation Programme (UN-REDD). To learn more, visit: <http://go.usa.gov/NYze>
- A full understanding of the carbon cycle requires research not only in natural systems but also in human-managed systems, and especially urban environments, which account for between 60 and 80 percent of global energy consumption and carbon emissions. As a first step in building an interdisciplinary community of social and natural scientists studying human-carbon interactions in urban systems, the U.S. Carbon Cycle Science Program sponsored a workshop in late 2013 with participants from government and academia. Participants delved into the challenges and opportunities involved in building a holistic research program on urbanization and the carbon cycle. To inform related efforts in the broader scientific community, workshop outcomes will be shared through several reports, two of which have been released.<sup>6</sup> Urban-carbon research not only has the potential to advance carbon cycle science, but also to inform the management of urban green spaces and support climate resilience in heavily populated urban settings. To learn more, visit: <http://goo.gl/lJyvbs> ♦



Inside the prototype for SPRUCE experimental chambers. (Credit: DOE)

<sup>6</sup> Hutrya, L.R. et al. 2014. Urbanization and the carbon cycle: Current capabilities and research outlook from the natural sciences perspective. *Earth's Future* (published online 13 Aug 2014). <http://goo.gl/S5FsO1>  
 Marcotullio, P. J. et al. 2014. Urbanization and the carbon cycle: Contributions from social science. *Earth's Future* (published online 20 Aug 2014). <http://goo.gl/pqIVzi>

### Highlight 5. Climate Change and Nitrogen: Interacting Impacts on Ecosystem Services

Society derives many benefits from biodiversity and ecosystems, including clean air and water, as well as a host of recreational and culturally valued services. Climate change and nitrogen pollution—or excess nitrogen in the air and water, usually caused by human activities—are two major stressors affecting ecosystems nationwide, leading to shifts in habitat ranges, loss of species, and increased soil acidity. A partnership of researchers from EPA, USDA-FS, USGS, and academia are collaborating to assess the interacting impacts of nitrogen and climate change on biodiversity and ecosystem services. The first stage of the project, now underway, is establishing a baseline understanding of how nitrogen in the atmosphere affects plant biodiversity. This stage involves the largest such national assessment to date, assembling over 40,000 data records from various agency efforts into a single analysis, and has led to the identification of regions and species groups that are most vulnerable. The second stage will investigate where and how climate change may amplify or mitigate changes in biodiversity. The third stage will assess how these interacting stressors will affect key ecosystem services such as carbon storage, reduction of nutrient pollution, and timber production. As a whole, this work will support the development of air quality standards to protect ecosystems and ensure a healthy environment for future generations. To learn more, visit: <http://go.usa.gov/8VJ> ♦

### Highlight 6. Extending Climate Records Beyond Instrumental Measurements

Paleoclimate studies extend records of climate beyond the time period for which we have instrumental measurements. Such research not only answers questions about what Earth was like in the past, but also provides context for the climate changes that we are experiencing today and informs our understanding of how climate is likely to change in the future. In 2013, an international team of researchers published the most comprehensive reconstruction of past temperature changes ever generated at the continental scale. The reconstruction, published in the journal *Nature Geoscience*,<sup>7</sup> confirms an overall cooling trend across nearly all continents during the last one to two thousand years. Recent warming, beginning in some regions at the end of the 19th century, reversed this trend. The study found that temperature variations were more similar within hemispheres than between the Northern and Southern Hemispheres, and that anomalous periods such as the Little Ice Age (ca. 1350–1850) and Medieval Warm Period (ca. 900–1300) were detectable but did not show a globally synchronous pattern across multiple decades.

This research was led by the International Geosphere-Biosphere Programme's (IGBP's) Past Global Changes (PAGES) project, which is supported in part by NSF, NOAA, and USGCRP's funding for IGBP. The temperature reconstruction was produced by combining data from tree rings, pollen, corals, sediments, ice cores, stalagmites, and historical documents at hundreds of locations across seven continents. As part of PAGES, researchers from USGS and academia are reconstructing continental-scale patterns of hydrologic variability over the last few thousand years, which, combined with the temperature reconstruction, will shed light on the response of ecosystems to climate variability over periods of years to centuries. To learn more, visit: <http://goo.gl/l8s9S8> ♦



Data from tree rings contributed to the 2000-year temperature record.

<sup>7</sup> Pages 2K Consortium. 2013. Continental-scale temperature variability during the past two millennia. *Nature Geoscience* 6, 339–346. <http://goo.gl/NCk2qd>

### 2.1.3. Modeling Global Change

Models can be critical tools for understanding the behavior of natural and human systems that sometimes interact in surprising ways. Models also support informed decision making by predicting and projecting future conditions and pinpointing areas of uncertainty. In addition to the atmosphere, land surface, and oceans, modern climate models may also incorporate ice sheets, aerosols (*Highlight 7*), and biogeochemical cycles, and can link to models of terrestrial hydrology and socioeconomic systems. Collectively, these models lead to better approximations of real-world conditions. “Integrated assessment” models, for instance, connect economic factors, energy technologies, and natural processes in a single interdependent framework, allowing researchers

and decision makers to explore a range of global and regional change scenarios.

Modeling bridges many components of USGCRP’s research portfolio, synthesizing the understanding of the Earth system gained from theory, measurement (*Highlight 8*), and experimentation, and identifying gaps in observations and understanding. USGCRP modeling efforts bring together researchers from many different disciplines (see related *Highlight 18*), and using models to support decision making can bring scientists and stakeholders into close collaboration. As such, a sustained programmatic focus on model development and application activities—both for research and decision support—is fundamental to fulfilling USGCRP’s mandate.

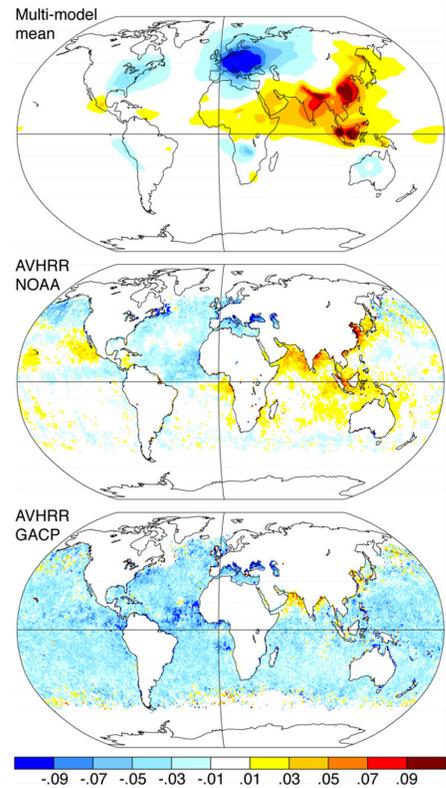
### Recent Highlights

#### Highlight 7. Modeling Pollution to Understand Localized Climate Trends

Pollution from the combustion of fossil fuels and wood has contributed to climate change in complex ways, with some pollutants causing cooling and others causing warming, accompanied by effects on patterns of atmospheric circulation and precipitation. To better understand these complex relationships, the Atmospheric Chemistry Climate Model Intercomparison Project, part of the international 5<sup>th</sup>-phase Coupled Model Intercomparison Project (CMIP5), conducted a series of pollution-focused modeling experiments to reveal spatial patterns, sectoral influences, chemical components, and climate impacts—all critical for understanding how Earth’s climate is likely to respond to different energy pathways.

These studies, conducted by academic research institutions and modeling centers supported by NASA, DOE, NOAA, and NSF, considered both model results and instrumental measurements. They found that aerosol pollution peaked globally around the 1980s, and that the solar radiation-blocking effect of the aerosols was strong enough to mask the progression of global warming in most industrialized parts of the world. After 1980, global warming was “unmasked” in most regions following declines in aerosol pollution—except in eastern and southeastern Asia, where aerosol pollution continues to create a localized cooling effect and has been shown to impact monsoon patterns. To learn more about results from the Atmospheric Chemistry Climate Model Intercomparison Project, visit: <http://go.usa.gov/8VpY> ♦

Modeled (top panel) and observed (bottom two panels) changes in atmospheric aerosol loads between 1980 and 2000. A decrease over Europe and North America (blue) and an increase over southeastern and eastern Asia (red)—evident in all three panels—contributed to localized warming and cooling, respectively, during this period. (Credit: Shindell et al., 2013<sup>8</sup>)



<sup>8</sup> Shindell, D.T. et al. 2013. Radiative forcing in the ACCMIP historical and future climate simulations. *Atmospheric Chemistry and Physics* 13 (6): 2939–297. <http://goo.gl/et0Phq>

## Highlight 8. DYNAMO: Linking Observations and Models to Predict Near-Term Climate

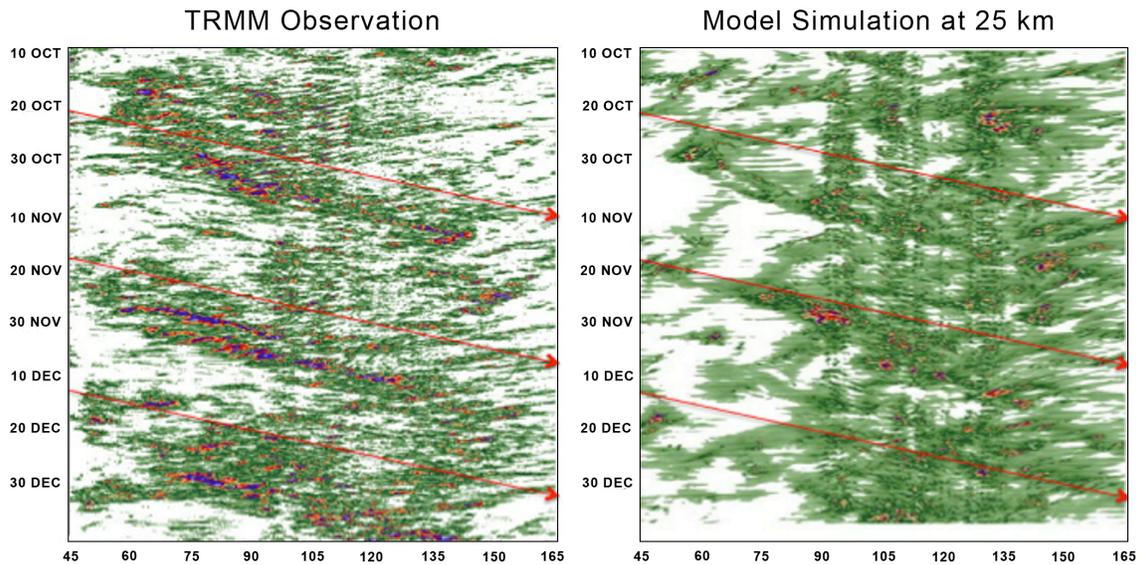
Predicting climate conditions anywhere from two weeks to a season in advance is critical for making informed decisions and safeguarding infrastructure across various sectors of the U.S. economy, including water resources, energy supply, public safety, and agriculture, among many others.

USGCRP agencies are supporting improved climate forecasts on these relatively short timescales through field campaigns coupled with model development and analysis efforts. DOE, NASA, NOAA, NSF, and DOD’s Office of Naval Research funded a campaign known as “DYNAMO” to conduct concentrated observations of the Madden Julian Oscillation (MJO), an atmospheric phenomenon that exerts major influence on North American near-term climate, including extreme weather like hurricanes, heavy downpours, and tornadoes.

The detailed observations collected by the DYNAMO campaign are currently being used to analyze and improve climate models, an effort that is already yielding progress in near-term climate prediction. More accurate understanding and modeling of the MJO, made possible by DYNAMO observations, will advance the Nation’s capacity to anticipate and respond to the impacts of near-term climate variability. ♦



Doppler radar deployed during the DYNAMO mission, with MJO-associated cumulus clouds growing over the Indian Ocean. (Credit: E. Maloney, Colorado State University)



The NASA GEOS5 model has made significant progress in simulating the MJO, demonstrated by how closely its output (right panel) visually resembles satellite observation data (left panel; in both panels, MJO events are represented as lines of green, red, and purple sloping from top left to bottom right). Although continued model improvements are necessary, this effort constitutes a substantial leap in near-term climate modeling capability. (Credit: S. Tulich, NOAA)

### 2.1.4. Conducting and Sustaining Assessments

Assessments help scientists and decision makers anticipate likely changes, evaluate scientific information for potential use in decision making, and pinpoint knowledge gaps and needs. Here, the term “assessments” refers to syntheses of peer-reviewed literature and other credible sources that convey the current scientific understanding of global change. Some assessments focus on specific geographical regions, while others focus on specific aspects or impacts of global change. Since its inception, USGCRP has placed significant emphasis on national and international assessments: USGCRP is mandated to conduct a National Climate Assessment (NCA) every four years and to coordinate Federal participation in international assessment efforts such as those led by the Intergovernmental Panel on Climate Change (IPCC).

In May 2014, USGCRP delivered its Congressionally mandated quadrennial NCA report (*Highlight 9*). The 30 chapters of this Third National Climate Assessment—available in downloadable and digitally interactive formats—provide a comprehensive synthesis of current knowledge about climate change, its impacts, and response strategies in the United States. The report also serves as a focal point for the development of useful, climate-relevant scenarios, including those that incorporate complex variables, such as changing patterns of extreme events at regional scales.

USGCRP is implementing a sustained assessment process to support more efficient and effective production of quadrennial reports and to provide timely information to decision makers on an ongoing basis. Examples

of this sustained assessment process include the development of a pilot set of climate indicators (see related *Highlight 21*), workshops on developing scenarios for changing population and land use dynamics, and interim special reports focusing on key sectors like human health (see related *Highlight 20*). By facilitating ongoing participation by scientists and stakeholders across regions and sectors, USGCRP is enabling new information and insights to be synthesized as they emerge. More robust and regular engagement between scientists and stakeholders through sustained assessment strengthens the ability of the United States to respond to the challenges of climate and related global change.

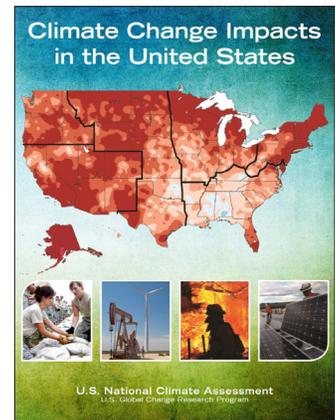
At the international level, USGCRP continues to ensure that U.S. research is represented in and integrated with global assessment efforts. USGCRP is closely engaged with the Arctic Monitoring and Assessment Programme’s Adaptation Actions in a Changing Arctic (AACAA) project. One of AACAA’s upcoming regional assessments will cover U.S. Arctic lands and seas and is being considered as a potential contribution to the sustained assessment process. USGCRP also coordinates and supports U.S. participation in and review of the IPCC’s Fifth Assessment Report (*Highlight 10*) and the World Meteorological Organization/U.N. Environmental Programme’s (WMO/UNEP’s) 2014 Scientific Assessment of Ozone Depletion. Scientists affiliated with and supported by USGCRP agencies continue to play key roles in the development of such major international assessments as lead authors, editors, working group co-chairs, and reviewers who provide technical support and expertise. Moreover, research supported through USGCRP provides major contributions to the scientific foundations for these assessments.

### Recent Highlights

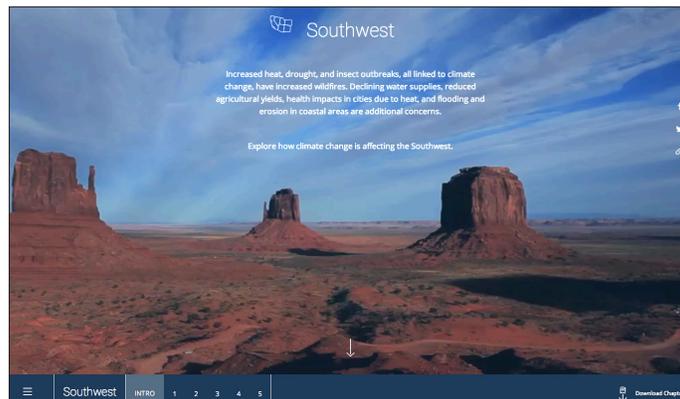
#### Highlight 9. Climate Change Here and Now: The Third National Climate Assessment

In May 2014, delivering on the Global Change Research Act of 1990 and the President’s Climate Action Plan, USGCRP released the Third National Climate Assessment (NCA), the most comprehensive, authoritative, and transparent scientific report on U.S. climate-change impacts to date. The report confirms that climate change, once considered a distant threat, is already affecting every region of the country and key sectors of the economy, and will continue to do so into the future. The release of the report garnered much attention nationwide, including among stakeholder groups, community leaders, the media, educators, scientists, and policy makers at every level of government.

As with previous assessments, the Third NCA is available to download—but for the first time, it also can be explored interactively through USGCRP’s newly redeployed website (see related *Highlight 17*). In this mobile-ready site, every piece of the report—including graphics, key messages, and chapters—is easily shareable with individualized links and social sharing buttons. The report’s findings are fully traceable, and supporting information for key report sections is provided through the Global Change Information System (GCIS; see related *Highlight 13*), a new web-based gateway to Federal global change information that aligns with the Administration’s goals for improved transparency and access to data. In its first week, the site received over 300,000 visits, and 2.5 terabytes of report PDFs were downloaded—equivalent to about 70,000 downloads of the full report at web resolution. To explore the site, visit: [nca2014.globalchange.gov](http://nca2014.globalchange.gov)



The Third NCA was co-produced over four years by hundreds of the Nation’s top climate scientists and technical experts from the public, private, and academic sectors; guided by a 60-member Federal Advisory Committee; and informed by extensive input from the public and outside organizations gathered through town hall meetings, public comment opportunities, and technical workshops across the country—all made possible by USGCRP coordination. To learn more about USGCRP’s NCA program, visit: <http://go.usa.gov/9Y5x> ♦



The interactive web-based version of the Third National Climate Assessment’s chapter on the Southwest Region.

## Highlight 10. Impacts, Risks, and Responses in the 2014 IPCC Reports

Building on 2013’s working group report on the physical science basis for climate change, the IPCC released two additional installments of its Fifth Assessment Report in spring 2014—this time focused on climate impacts, risks, and responses.

The first of these two 2014 installments dealt with impacts, adaptation, and vulnerability, finding that the effects of climate change are already occurring worldwide; that the world, in many cases, is ill-prepared for the associated risks; and that there are opportunities to respond with effective action, though the risks will be difficult to manage with high levels of warming. The second, which concentrated on mitigation, found that global emissions of greenhouse gases have risen to unprecedented levels; nevertheless, if implemented by mid-century, an array of technological measures and behavioral changes could limit the increase in global mean temperature to two degrees Celsius above pre-industrial levels.

USGCRP hosts and provides financial support for the operations of the IPCC Technical Support Unit that coordinated the production of the volume on impacts, adaptation, and vulnerability. In partnership with DOS, USGCRP coordinated and supported the U.S. Government’s review, revision, and vetting of the Fifth Assessment Report, the final synthesis volume for which is expected in October 2014. Development of a process for subsequent assessments began in 2014 and will be finalized in 2015. To learn more, visit: <http://goo.gl/acNbXH>

## 2.2. Preparing for the Impacts of Global Change

### 2.2.1. Understanding and Supporting Preparedness and Resilience

Across America and around the world, people are making decisions to effectively minimize and prepare for the impacts of climate and related global change. Many states, cities, and communities are investing in more resilient infrastructure, curbing emissions, updating resource management practices, and planning for rapid recovery from unavoidable impacts. When considering options to reduce the risks of global change, decision makers need timely scientific information to understand a range of potential impacts, vulnerabilities, opportuni-

ties, and trade-offs. Likewise, decision makers need to understand how aspects of the complex Earth system respond to the strategies that they implement.

USGCRP’s efforts to understand the causes and consequences of global change create a strong scientific foundation for informing and enabling decisions on adaptation and mitigation. USGCRP coordinates with producers and users of global change science to ensure that research is translated into information, tools, and practices that decision makers can understand and apply. In particular, USGCRP works across multiple scales of government—from Federal (*Highlight 11*) to local (*Highlight 12*)—to increase the preparedness and resilience of American assets, natural resources, and communities.

### Recent Highlights

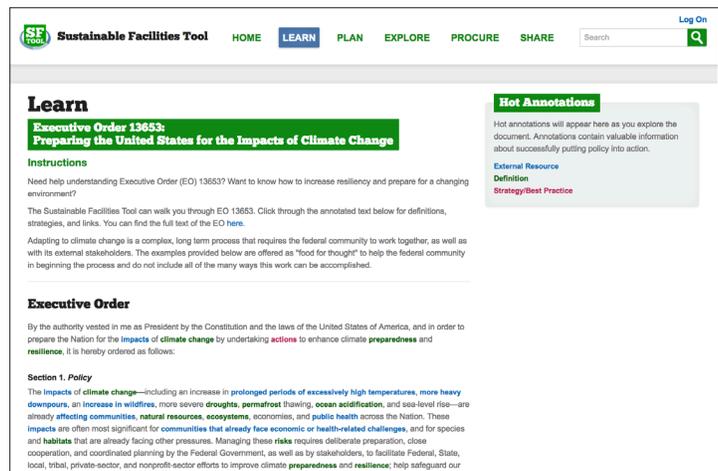
#### Highlight 11. Supporting Federal Climate Preparedness with Resources and Data

Under Executive Orders (EO) 13514<sup>9</sup> and 13653<sup>10</sup>, President Obama directed Federal agencies to evaluate and prepare for climate-related risks to ensure that they can continue to meet their missions and serve the American public as climate changes. A key component of USGCRP’s work to prepare the Nation for global change involves informing Federal preparedness and resilience efforts with resources built on sound scientific understanding.

To further support these efforts, USGCRP recently released an easy-to-access, web-based collection of resources to help Federal agencies plan and implement actions for adapting to climate change. This **Federal Adaptation Resources** collection includes executive orders and strategic plans, select technical reports on adaptation research, frameworks and tools to help agencies adapt their operations to changing climate conditions, and overview reports for higher-level decision makers, among other resources. Available through USGCRP’s newly redeployed website (*Highlight 17*) at <http://go.usa.gov/8VUT>, the collection will be updated as new information, data, and tools are developed and deployed.

The Federal Adaptation Resources collection houses information about and links to over 100 resources; a few examples include:

- **“Hot Annotated” EO 13653** (pictured right) – To help Federal agencies understand the requirements outlined in EO 13653, USGCRP and the General Services Administration (GSA) partnered to develop a version of the EO with “hot annotations”, or clickable terms. The



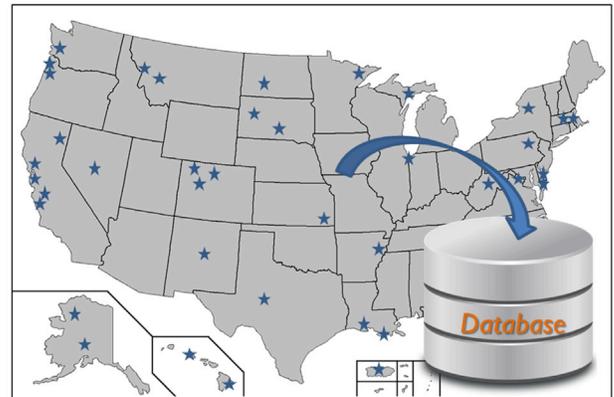
<sup>9</sup> Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance. 2009. <http://go.usa.gov/8Vv4>

<sup>10</sup> Executive Order 13653: Preparing the United States for the Impacts of Climate Change. 2013. <http://go.usa.gov/8Vvk>

annotations contain definitions, links to related Federal resources, and examples of strategies and best practices. To learn more, visit: <http://go.usa.gov/8Vf9>

- **Bibliography for Monitoring and Evaluating Adaptation Efforts** – Monitoring and evaluating the effectiveness of adaptation efforts can help the Federal Government progressively improve its response to climate change. To support program and project managers in their adaptation planning, monitoring, and evaluation in coastal regions, USGCRP identified a set of relevant products, peer-reviewed literature, and other resources in an annotated bibliography. To learn more, visit: <http://go.usa.gov/8V75>

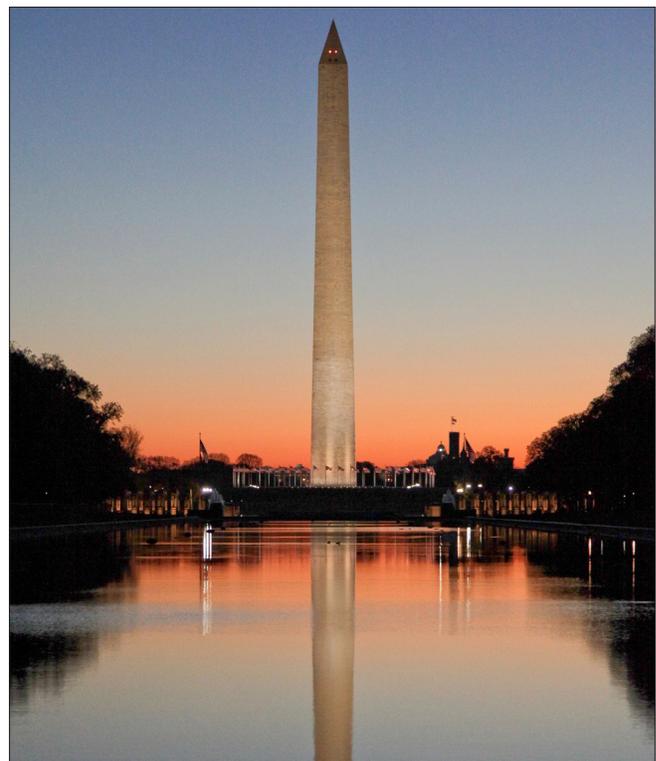
- **Vulnerability Assessment Registry Database** (pictured right; currently under development, slated to be launched and added to the Federal Adaptation Resources collection in FY 2014) – The USGS National Climate Change and Wildlife Science Center, with support from USDA-FS and other partners, is developing a searchable public registry on climate-change vulnerability assessments. This registry will cover assessments related to species and ecosystems, infrastructure, cultural resources, public health, and socioeconomic systems, with the goal of making information about vulnerability assessments more readily accessible so that resources can be most efficiently used. To learn more, visit: <http://go.usa.gov/8VHm> ♦



## Highlight 12. Building a Climate-Resilient National Capital Region

The Washington, DC metropolitan region holds a unique concentration of Federal buildings, irreplaceable cultural and historic resources, nationally significant monuments and landscapes, and diverse communities. This region is already experiencing the effects of climate change, including more frequent extreme weather events, rising temperatures, and recurring flooding. As these impacts intensify, they will affect residents and workers, real estate assets, businesses, government, and natural resources.

Federal, regional, and local organizations have an opportunity to work together, share technical information, and collaborate on climate adaptation strategies tailored to the U.S. national capital. Continuing the information sharing and partnership building activities that started in fall 2013 with a focus on infrastructure, the National Capital Planning Commission (NCPCC), the Metropolitan Washington Council of Governments (MWCOC), GSA, NASA, SI, and USGCRP sponsored a second series of free webinars and workshops for stakeholders. This second series focused on workforce, communities, and natural systems and is intended to enhance regional coordination and assist government agencies in planning for climate change. To learn more, visit: <http://goo.gl/wrjtfV> ♦



The Washington Monument in Washington, DC.

### 2.2.2. Sharing and Managing Information

As the breadth of global change information continues to expand and diversify, developing a systematic approach to consolidating and accessing this information is becoming increasingly important. To address this need, USGCRP has implemented the initial phase of a novel, comprehensive, web-based approach to information provision known as the Global Change Information System (GCIS). The GCIS, which launched in May 2014 and continues to develop and expand, is intended

to provide an efficient and curated gateway to global change information, publications, data, and metadata produced by USGCRP agencies (*Highlight 13*).

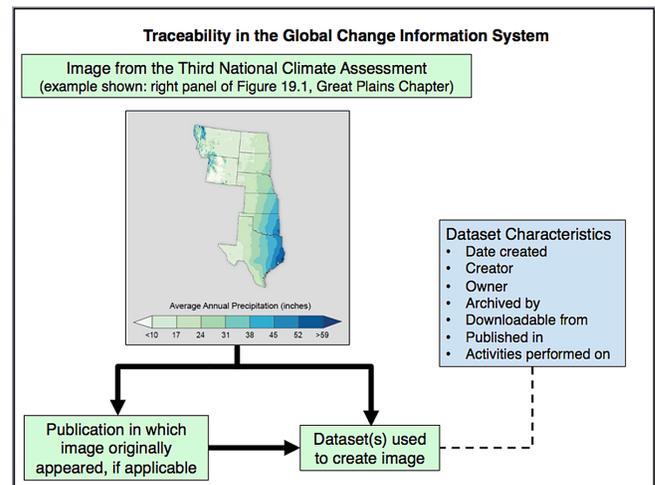
USGCRP also supports related and complementary Federal climate data-sharing initiatives, including the Climate Data Initiative and its associated web portal, [climate.data.gov](http://climate.data.gov), designed to support American communities and businesses in preparing for the impacts of climate change (*Highlight 14*).

### Recent Highlights

#### Highlight 13. Tracing Global Change Science Back to the Source

USGCRP’s novel Global Change Information System builds on prior agency investments and is designed to support traceability between multiple environmental data streams—such as observations from sensors and output from models—and the resulting scientific reports. This system creates an open environment for users to access machine-readable information and trace user-friendly products back to the supporting science. As an important first step and proof-of-concept, the GCIS provides this traceability and documentation for references in the Third National Climate Assessment (see related *Highlight 9*) and datasets used in the Assessment’s climate science chapter.

As a structured data server (SDS), the GCIS identifies and links various components of the Assessment, such as findings, graphics, and supporting data, to make its underpinnings accessible. This not only strengthens credibility, but also helps users to discover related resources. The long-term vision for the GCIS involves enhancing capabilities to support future assessments and growing into a unified information source for scientists, decision makers, and the interested public. The GCIS SDS is designed to serve data to various web platforms and has been released as open-source code, enabling others to use it in support of similar activities. To learn more, visit: [data.globalchange.gov](http://data.globalchange.gov) ♦



This diagram shows how, using the Global Change Information System, a user can trace an image from the Third National Climate Assessment back to its original source and supporting data. (Credit: Adapted from Goldstein et al., 2013<sup>11</sup>)

#### Highlight 14. Empowering the Nation with Climate Data

In March 2014, USGCRP helped support the launch of the Climate Data Initiative, a key component of the President’s Climate Action Plan. The Climate Data Initiative brings together open government data with commitments from the private and philanthropic sectors to develop data-driven tools that communities and businesses across America need to plan for the impacts of climate change.

<sup>11</sup> Goldstein, J. et al. 2013. Provenance of Figures in the Global Change Information System. *Research Data Access and Preservation Summit*: Baltimore, Maryland.

With the launch of the Climate Data Initiative, data from USGCRP agencies—including NOAA, NASA, USGS, and DOD—and other Federal entities are accessible on [climate.data.gov](http://climate.data.gov). The pilot theme of the site focused on data and tools related to coastal flooding and sea level rise—including the recently updated Sea Level Rise Tool for Sandy Recovery, developed through a partnership among USGCRP agencies, other Federal entities, and local institutions in the aftermath of Hurricane Sandy (to learn more, visit: <http://go.usa.gov/8VuV>). The recently released second theme concentrates on food resilience, and future themes will incorporate risks to public health and energy infrastructure.

By taking the extensive data sets regularly collected by NASA, NOAA, and other agencies and applying the ingenuity, creativity, and expertise of technologists and entrepreneurs, the Climate Data Initiative will help to create easy-to-use tools for regional planners, farmers, hospitals, and businesses across the country—and empower America's communities to prepare themselves for the future. To learn more, visit: [climate.data.gov](http://climate.data.gov) ♦

### 2.2.3. Educating, Engaging, and Communicating with Stakeholders

As the leading Federal authority on global change science, USGCRP and its member agencies play a key role in engaging and educating citizens about global change and related societal issues. USGCRP helps to develop the scientific workforce of the future by building capacity in the United States (*Highlight 15*) and internationally (see *Section 3.3*) and fosters greater public understanding of climate and global change through the dissemination of timely, credible, and accessible information (*Highlights 16, 17*; see also related *Highlights 9, 13*).

USGCRP also uses engagement and dialogue to gain greater understanding of the public's science and

information needs. For instance, the National Climate Assessment (NCA) program employs an engagement strategy that leverages scientific capacity throughout the United States, while ensuring that the assessment process and products are accessible and useful to stakeholders and the general public. A key part of this strategy is NCAnet, a continually evolving network of more than 150 organizations working with the NCA program to engage producers and users of climate assessment information (to learn more, visit [ncanet.usgcrp.gov](http://ncanet.usgcrp.gov)). As a direct outcome of this engagement approach, organizations and individuals across the country contributed input for consideration in the NCA process and significantly extended the reach of the Third National Climate Assessment report, released in May 2014 (see related *Highlight 9*).

## Recent Highlights

### Highlight 15. Building Capacity Among Climate-Change Interpreters

Informal education settings such as zoos, aquariums, and parks play an essential part in conveying science to broad public audiences. USGCRP agencies work together to support initiatives that build capacity for communicating the science and impacts of climate change among interpreters in these important educational environments. For example, the National Network for Ocean and Climate Change Interpretation (NNOCCI), funded by NSF and led by the New England Aquarium (NEAQ), comprises a partnership of aquariums, zoos, parks, academic institutions, and other non-profit organizations across the country. Members with expertise in ocean and climate science, communications, and cultural sciences build and share knowledge through workshops and six-month study circles that target specific interpretative skills. To learn more, visit: <http://goo.gl/1G0rRs>



An interpreter talks to aquarium visitors. (Credit: NNOCCI)

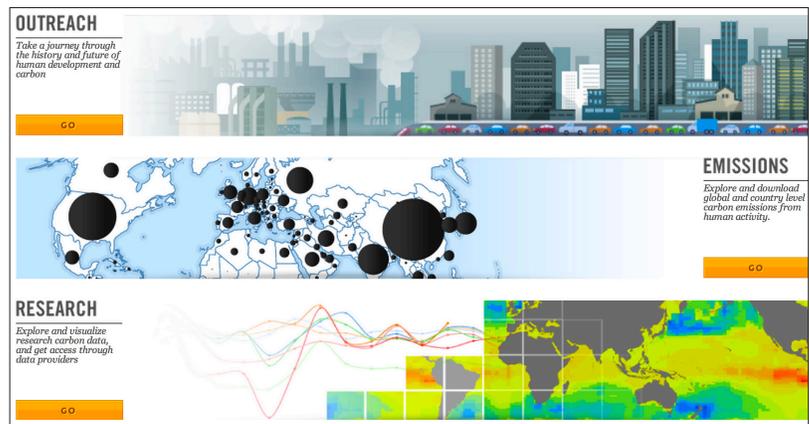
In a related effort, NEAQ is collaborating with other aquariums on Visualizing Change, a project that integrates NOAA datasets and visualizations with strategic communications tools for interpreters based on the best available social and cognitive science. Through this and other interconnected projects supported by NOAA, NSF, and the Institute of Museum and Library Services, NEAQ and its partners aim to 1) enhance interpreter training and collaboration nationwide, and 2) connect audiences to climate issues through their personal values and emotional connections with marine life, thereby motivating them to embrace effective solutions. To learn more, visit: <http://goo.gl/lk6Vdi>

Earth to Sky (ETS)—a partnership between NASA, NOAA, the National Park Service, the U.S. Fish and Wildlife Service, and the University of California, Berkeley—encourages interpreters and other informal educators to use relevant Federal science, data, and educational products in their work. ETS, which has provided professional development opportunities for climate-change interpreters since 2008, will launch new, regionally focused courses on climate-change communication in 2015: distance-learning sessions will focus on climate science, followed by face-to-face sessions during which participants will examine the impacts of climate change in the geographic area in which they work. To learn more, visit: <http://goo.gl/L1yfsJ> ♦

**Highlight 16. A Global Carbon Atlas for Educators, Policymakers, and the Public**

The Global Carbon Atlas, released in late 2013, is an interactive web-based platform designed to communicate information about the global carbon cycle to educators, policy makers, non-governmental organizations, the general public, and the scientific community. The Atlas allows users to explore, visualize, and interpret global and regional carbon data related to human activities and natural processes, with the goal of sharing knowledge and supporting decisions to limit and cope with human-induced climate change.

The Global Carbon Atlas was made possible by the measurements, models, and interpretative skills of research institutions and individual scientists around the world. It was produced by the Global Carbon Project, which is supported in part by USGCRP’s funding of international programs within the Earth System Science Partnership (ESSP). USGCRP’s U.S. Carbon Cycle Science Program is an affiliate office of the Project. To learn more, visit: <http://goo.gl/KSvcJu> ♦

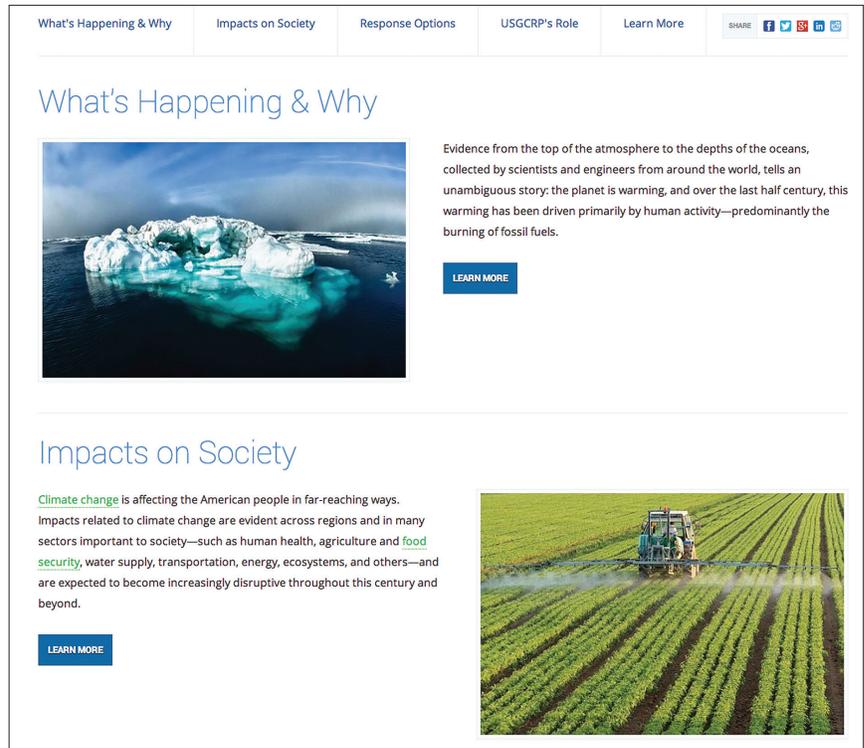


The Global Carbon Atlas.

**Highlight 17. GlobalChange.gov Reloaded: USGCRP’s New Website**

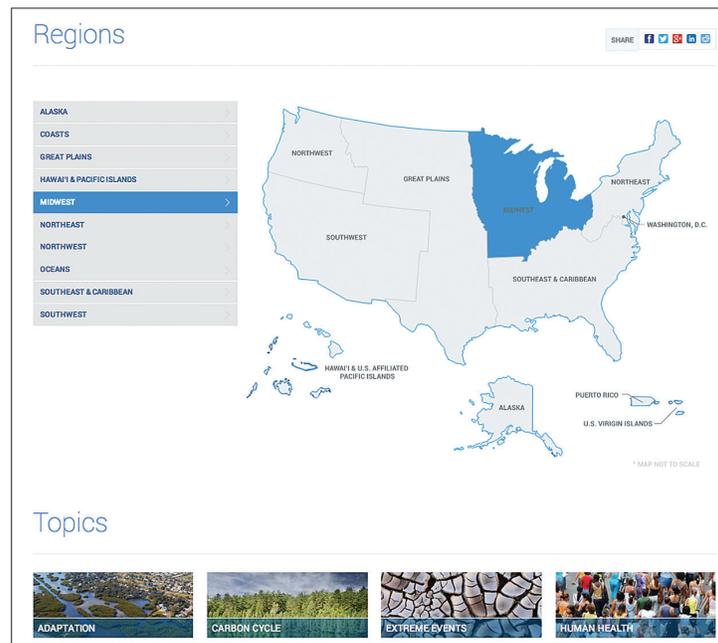
With the release of the Third National Climate Assessment (see related *Highlight 9*) came a spike in public demand for information about climate change, its impacts on America, and USGCRP. The Program met this press of interest with a new user-friendly, public-oriented website that launched concurrently with the report’s release. The site deploys the Third National Climate Assessment in an interactive, shareable format. It also provides a dynamic suite of resources and information spanning the breadth of USGCRP and serving user groups including scientists, decision makers, educators, and the general public.

The site opens with a primer section on climate change, its impacts on society, America’s response options, and how USGCRP research fits in. Through a clickable map and a series of icons, users can explore region- and topic-specific resources aggregated from the Assessment and other Federal sources. Users searching for in-depth information can access relevant reports and datasets from the U.S. Government and other authoritative scientific bodies, along with tools targeted to specific groups, such as Federal agencies preparing for climate change (see related *Highlight 11*), data users interested in global change (see related *Highlight 13*), and educators teaching climate. The site also provides a central, curated source of news about Federal global change research and activities, as well as a portal to public engagement opportunities and resources developed by USGCRP and external partners.



The “Understand Climate Change” section of GlobalChange.gov.

In its first week, the website—including the Third National Climate Assessment pages—received over 300,000 visits, 850,000 page views, and a strongly positive reception from the digital media community. Going forward, the site will expand to include broader and more in-depth topical information and will become integrated more fully with other digital Federal resources. To learn more, visit: [www.globalchange.gov](http://www.globalchange.gov) ♦



The “Explore Regions & Topics” section of GlobalChange.gov.



# 3 Leveraging Global Change Research for Societal Needs

The President’s Climate Action Plan invokes the pivotal role of USGCRP in generating sound science to manage the impacts of climate change. USGCRP activities support the Climate Action Plan in a wide range of ways, including through the release of the Third National Climate Assessment (see related *Highlight 9*), support for the Climate Data Initiative (see related *Highlight 14*), and others. This section highlights select activities supporting three of the Plan’s components: Identifying Vulnerabilities of Key Sectors to Climate Change, Developing Actionable Climate Science, and Strengthening Global Resilience to Climate Change.

## 3.1. Identifying Vulnerabilities of Key Sectors to Climate Change

Climate change is affecting nearly every sector of our society and economy, from transportation and infrastructure to food and water supplies. Identifying and assessing the vulnerabilities of these sectors to climate change is a critical first step in preparing for and increasing resilience to future impacts. The following highlights focus on vulnerabilities in the agriculture (*Highlight 18*), ecosystem services (*Highlight 19*), and public health (*Highlight 20*) sectors.

### Recent Highlights

#### Highlight 18. Modeling Climate Impacts on Agriculture and Adaptation by the Agro-Economy

Agricultural production is a critical sector of the domestic and global economy that is affected directly by climate change. The Agricultural Model Intercomparison and Improvement Project (AgMIP)—supported in part by DOE, NASA, USAID, and USDA—is a major international effort linking the climate, crop, and economic modeling communities to produce improved projections of climate impacts on the agricultural sector, thereby enhancing capacity to prepare for and respond to these climate-driven changes. To learn more about AgMIP, visit: <http://goo.gl/ZmU82S>

As part of AgMIP, a group of researchers used a suite of global agro-economic models to simulate potential economic responses to future climate change and crop growth scenarios from the IPCC Fifth Assessment Report (see related *Highlight 10*). For the scenarios studied, which assumed a high greenhouse gas emissions pathway to the year 2050, they found that climate-driven reductions in the global productivity of major field crops will likely drive changes in crop yield, cropland area, and location of production. International trade could reduce variation in productivity levels to a much narrower range of changes in global crop consumption. However, maintaining crop consumption could come at a cost: all nine economic models in this study projected an increase in the inflation-adjusted price of crops (see graph on next page). ♦



This graph shows projected impacts of climate change on crop productivity (darker blue) and related agricultural and economic responses. Black dots indicate the average percent change in each variable by 2050, relative to no climate change; the height of each column shows the range of results across climate, crop, and economic models. These results represent global averages for major field crops including wheat, rice, coarse grains, and oil seeds. (Credit: Adapted from Nelson et al., 2014<sup>12</sup>)

### Highlight 19. Assessing Risks to Freshwater Fish

Trout and salmon are economically and ecologically important stream-dwelling species. Researchers from USGS, NOAA, and the University of Montana are working together to assess the effects of current and future climate change on these species' freshwater habitats throughout the Pacific Northwest, with the goal of providing tools to help managers predict and respond to potential climate impacts on habitats, populations, and the economy.

Research to date indicate that increasing stream water temperatures may lead to fragmentation of suitable habitat for migratory trout and salmon, causing a loss of genetic diversity and a decrease in some vulnerable populations. Though this project focuses on the upper Flathead River watershed in the United States and Canada, its modeling framework can be applied to assess vulnerabilities, support management decisions, and inform conservation efforts across a range of freshwater ecosystems. To learn more, visit: <http://go.usa.gov/8prH> ♦



The Transboundary Flathead River Watershed, home to key trout and salmon species, extends from British Columbia into Montana. (Credit: G. Lenz, USGS)

### Highlight 20. Linking Climate Change to Health Impacts

Climate change threatens human health in a variety of ways, including through increased heat waves, worsened air quality, changing ranges of food-, water-, and insect-borne diseases, and other effects. These impacts are already affecting the health of Americans and are expected to intensify as climate change progresses. To better understand and meet the public health challenges posed by climate change, USGCRP—through leadership by EPA, NOAA, and HHS's Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH)—is developing a new assessment of the impacts of climate change on health in the United States. This assessment will synthesize current scientific literature—addressing the need for a more quantitative understanding of climate–health impacts, as called for by the President's Climate Action Plan—and will support the sustained National Climate Assessment process (see Section 2.1.4).

<sup>12</sup> Nelson, G.C. et al. 2014. Climate change effects on agriculture: Economic responses to biophysical shocks. *Proceedings of the National Academy of Sciences* 111 (9): 3274-3279. <http://goo.gl/Xd8V29>

The assessment report, entitled *Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, is expected to be released in 2016. It is intended to inform public health officials, urban planners, decision makers, and other stakeholders at multiple levels of government who are interested in better understanding the risks climate change presents to human health. Though the report will not include policy recommendations, it will present authoritative scientific evidence that could be used to support adaptation and other strategic decisions in the public health sector. Improved understanding of health risks and uncertainties will support hazard identification and allow for better-coordinated responses to climate impacts.

Public input and engagement have informed and will continue to inform the assessment's development. In spring 2014, a public call was issued for scientists and stakeholders to submit supporting literature, comment on the draft prospectus, and nominate report authors. In addition, USGCRP held a forum to gather input from subject matter experts and the public on proposed plans for scoping, drafting, and producing the report. The forum attracted over 100 participants representing government, academia, the private sector, and non-governmental organizations. Additional opportunities for input will occur during a public review of the draft report, to be held in 2015. To learn more, visit: <http://go.usa.gov/8pYG> ♦

### 3.2. Developing Actionable Climate Science

Scientific data and insights produced by USGCRP agencies are essential to helping public officials, resource managers, and communities better understand and manage the risks associated with climate change. From

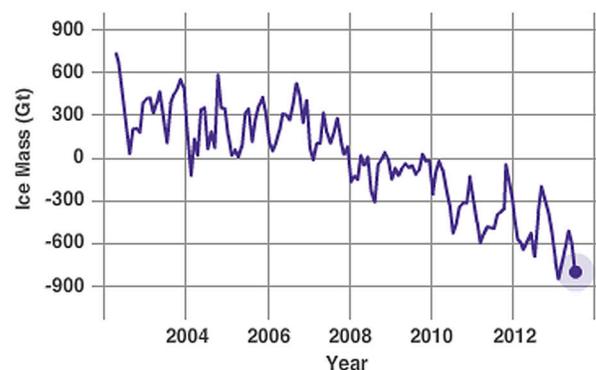
developing a set of national climate-change indicators for decision support (*Highlight 21*), to improving the monitoring and prediction of extreme weather and climate events (*Highlight 22*), to using climate scenarios to protect taxpayer investments in Federal assets (*Highlight 23*), USGCRP is deploying science and tools to help the Nation take action on global change.

#### Recent Highlights

#### Highlight 21. Tracking Climate Change with Indicators

"Indicators" are variables that can be used to measure the status or trend of a system. Indicators of climate-related global change—whether ecological, physical, or societal—can be used to track and communicate key aspects of the changing environment, point out vulnerabilities, and inform decision making at local, state, and national levels.

A pilot set of climate indicators is being developed collaboratively by USGCRP agencies including NASA, NOAA, EPA, USDA, DOE, DOD's U.S. Army Corps of Engineers (USACE), CDC, and DOI. The pilot set is expected to launch in 2014 on [www.globalchange.gov](http://www.globalchange.gov), with data served through USGCRP's Global Change Information System (see related *Highlight 13*). A proposal for a larger network encompassing a broader set of indicators is under evaluation. This proposed network would provide streamlined access to climate data and trends for use in the next quadrennial National Climate Assessment (see *Section 2.1.4*) and would be intended to inform climate-smart decisions in management and research across the public and private sectors. It would leverage and build on existing activities by integrating data from Federal agencies and the broader scientific community in a single unified system with shared data quality standards. As a contribution to this effort, NASA funded 14 projects to develop and test new indicators that will support the sustained National Climate Assessment process; these projects are slated to be completed in FY 2015. To learn more about indicators, visit: <http://go.usa.gov/8pBk>; to see interactive examples, visit: <http://go.usa.gov/PpZQ> ♦

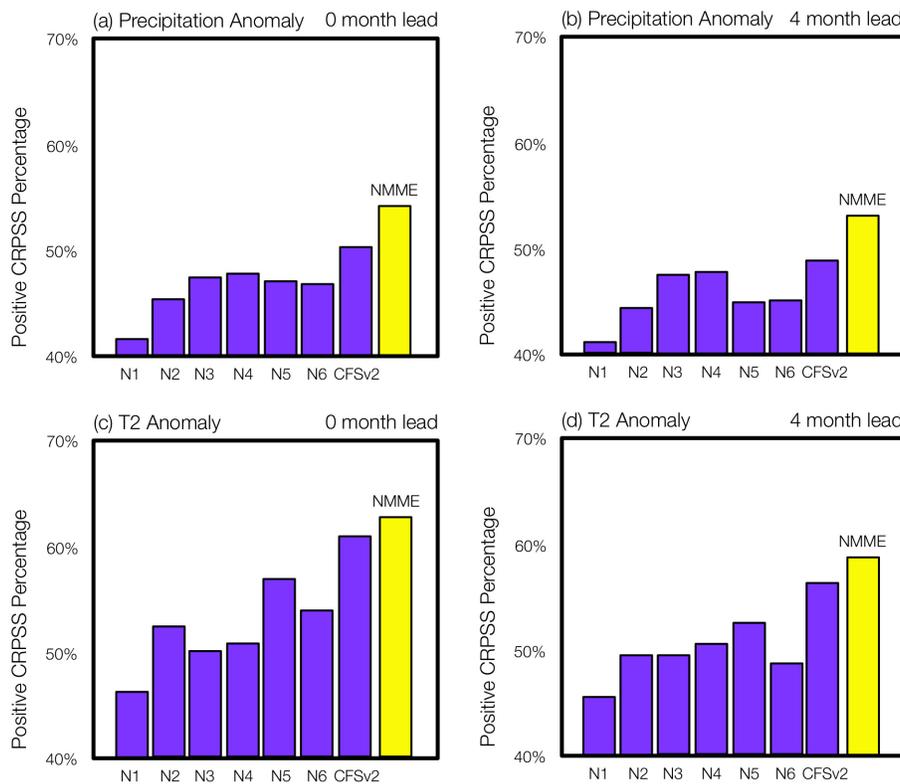


An example of a climate change indicator: variation in Antarctic land ice mass over time. (Credit: NASA)

## Highlight 22. Drought Research to Support Management and Preparedness

Drought is a significant hazard for the United States, with potentially severe and long-lasting impacts on the Nation’s economy and food and water supplies. USGCRP agencies are advancing our understanding of the causes and consequences of drought, an FY 2015 interagency research priority (see *Section 4*). They are also collaborating in efforts to support drought preparedness and recovery, such as the National Drought Resilience Partnership (a deliverable of the President’s Climate Action Plan) and the National Integrated Drought Information System (NIDIS). NIDIS is a partnership among several Federal entities (including USGCRP agencies DOE, DOI, DOT, NASA, DOC, NSF, HHS, EPA, USACE, and USDA) and academic research institutions that focuses on improving drought monitoring, understanding, and prediction. A recent report produced by NIDIS and the NOAA Drought Task Force analyzed the 2012 drought in the central Great Plains—a drought that continued to impact the U.S. economy into 2014—and identified improvements that could be made to enhance our national prediction capabilities going forward. To learn more, visit: <http://go.usa.gov/8pKW>

An interagency research effort that is currently advancing U.S. drought prediction capabilities is the North American Multi Model Ensemble (NMME), led by NOAA in partnership with DOE, NSF, NASA, and U.S. and Canadian research institutions. The NMME coordinates models from across major national modeling centers to generate near-term climate predictions. This approach harnesses the unique capabilities of each individual model to produce a cumulative climate prediction that is, as a whole, more accurate than what an individual model could produce. Although the NMME was developed as a research experiment, its demonstrated prediction capabilities are improving our ability to forecast climate conditions—including drought—anywhere from months to seasons in advance. To learn more, visit: <http://go.usa.gov/8pKd> ♦



The NMME (yellow column) is a seasonal forecasting system that combines individual models (purple columns N1-N6) to produce more accurate predictions of climate. In forecasts of precipitation (top two panels) and temperature (bottom two panels)—key factors for predicting drought—the NMME performs better than any of the individual models. The NMME’s better performance is indicated by the heights of the bars, which show performance relative to a reference forecast. (Credit: Adapted from results by E. Wood, Princeton University)

### Highlight 23. Using the National Climate Assessment to Help Protect Federal Assets

GSA owns or leases 9,624 assets, maintains workspace for 1.1 million Federal employees, preserves more than 481 historic properties, and procures more than \$60 billion in products and services for the Federal Government. Climate change has the potential to impact the ability of GSA and other Federal agencies to fulfill their missions, operate their facilities, and maintain their services. With its region-by-region breakdown of climate data and projections, the Third National Climate Assessment (see related *Highlight 9*) and its supporting regional climate scenarios provide a robust scientific basis for Federal adaptation planning.

In 2013, through a set of full-day “scenario sessions,” the USGCRP National Coordination Office and member agencies NOAA, NASA, EPA, and USDA helped GSA to prepare for the impacts of climate change. The collaborating agencies harnessed regional climate scenarios developed in support of the Third National Climate Assessment to begin planning for climate-related risks to Federal facility and supply chain assets managed by GSA’s Washington, DC and Kansas City, MO offices. The GSA team developed detailed storylines describing how climate change might affect assets in Washington and Kansas City 50 years in the future. Two-page summary versions of USGCRP’s Regional Climate Trends and Scenarios played an especially important role in developing these storylines, enabling the GSA team to quickly identify and prioritize region-specific climate risks. In post-session surveys, participants resoundingly affirmed a sense of increased organizational readiness and confidence in preparing for climate-related risks. To learn more about the Regional Climate Trends and Scenarios, which were produced by NOAA in collaboration with other agencies, visit: <http://go.usa.gov/8pkT>

In 2014, USGCRP led the translation of National Climate Assessment and IPCC findings into a read-ahead “playbook” for the interagency Climate Change Adaptation Planning Workshop, part of the Federal Government’s Climate Change Preparedness and Resilience Exercise Series. Held on May 7—the day after the Assessment’s release—this workshop marked the first use of the report itself to support Federal adaptation planning. Findings from the Assessment, the supporting Regional Climate Trends and Scenarios, and the associated Global Sea Level Rise Scenarios (also developed in support of the Assessment with leadership by NOAA; <http://go.usa.gov/5h5G>) informed modules on climate impacts in the South-west, the Mid-Atlantic and Southeast, the Arctic, and nationwide. Participants from 27 Federal agencies and departments used this information in building capacity for planning to reduce climate-related risk and increase resilience. ♦

### 3.3. Strengthening Global Resilience to Climate Change

Countries around the world are experiencing adverse socioeconomic and environmental impacts from extreme weather and climate events like floods, drought, heat waves, and tropical storms—many of which are projected to intensify or become more frequent in a warmer world.<sup>13</sup> USGCRP and its member agencies are leveraging the results of international scientific investments and responding to the needs of decision makers worldwide by connecting research with tools, resources, and projects that enhance the ability of the global community to manage climate risks. DOS,

NOAA, and HHS, for instance, are supporting the prioritization of human health in the Nairobi Work Programme, part of a United Nations Framework Convention on Climate Change (UNFCCC) initiative to build capacity for climate adaptation in developing countries. USGCRP agencies also contribute to international resilience-building efforts that target vulnerable settings such as urban environments (*Highlight 24*), coastal zones (*Highlight 25*), and regions with agriculture-based economies (*Highlight 26*).

<sup>13</sup> Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 2013. Stocker, T.F. et al., Eds. Cambridge University Press. <http://goo.gl/QZ66v8>

## Recent Highlights

### Highlight 24. Understanding Global Urbanization and Environmental Change

With more than half the world's population living in cities, urban areas are at the core of many global environmental change issues and their solutions. Through its funding of the International Human Dimensions Programme (IHDP), USGCRP supports the Urbanization and Global Environmental Change (UGEC) project, an international leader in research on the interactions and feedbacks between environmental change and urbanization at the local, regional, and global scales. UGEC provides a multidisciplinary forum for researchers to share expertise and address knowledge gaps, and emphasizes training and networking opportunities for early-career scholars and practitioners.

In 2013, UGEC contributed to the United Nations' recent State of the World's Cities report, which contended that urban prosperity could be enhanced by a stronger emphasis on environmental sustainability (among other factors), rather than maintaining a narrow focus on economic growth. Other UGEC efforts focused on specific countries and regions: for instance, UGEC researchers found that agricultural expansion associated with continued urbanization in China is likely to pressure the country's land resources,<sup>14</sup> while in Africa, urban greening is less advanced than in other regions but has the potential to address long-standing development, quality of life, environmental, and sustainability issues.<sup>15</sup> UGEC's coordination of urbanization and environmental change research represents an unparalleled platform for continuing to advance the understanding of these interconnected, policy-relevant global issues. To learn more, visit: <http://goo.gl/eP6ONX> ♦

### Highlight 25. Supporting Sustainability and Resilience in Coastal Zones

Coastal zones are central to socioeconomic development and are estimated to provide more than half of all global ecosystem goods and services. These narrow, marginal, often low-lying areas are subject to intense population pressure—with over a billion inhabitants—and are highly vulnerable to extreme weather and natural hazards associated with climate change. USGCRP supports efforts to understand and prepare for climate impacts in coastal zones worldwide through its member agency activities in the United States and its funding for IHDP, IGBP, and the Global Change System for Analysis, Research, and Training (START).

IHDP and IGBP sponsor the Land-Ocean Interactions in the Coastal Zone (LOICZ) project, an international, interdisciplinary research initiative that brings together experts from a range of fields and countries to explore the drivers and impacts of global change in coastal environments. In 2013, LOICZ researchers assessed coastal changes ranging from the breakup of ice in Arctic deltas to the state of ecosystem services in West African coastal watersheds. They developed geomorphic classifications for small tropical islands as a physical basis for coastal adaptation strategies, and created a classification index for coastal sediment cells for improved shoreline management in India. To learn more, visit: <http://goo.gl/Ek3CCF>

Jakarta, the capital of Indonesia, is already experiencing the impacts of sea level rise, floods, and saltwater intrusion into aquifers. These climate-related hazards, combined with other pressures like rapid population growth and poverty, imperil the socioeconomic, environmental, and human security of this coastal megacity's 9.6 million residents. To support the development of coastal adaptation strategies for Jakarta, START and Jakarta-based partners connected research with planning to produce a risk management and adaptation plan for the



Flooding in Jakarta in 2013. (Credit: U.S. Embassy in Indonesia)

<sup>14</sup> Jiang, L., Deng, X.Z., and Seto, K.C. 2013. The impact of urban expansion on agricultural land use intensity in China. *Land Use Policy* 35: 33–39. <http://goo.gl/gS5fm2>

<sup>15</sup> Simon, D. 2013. Climate and environmental change and the potential for greening African cities. *Local Economy (Special Issue: Resurgent African Cities?)* 28 (2): 203–217. <http://goo.gl/pj14tY>

city's most flood-prone areas and provide recommendations for urban design. This collaborative effort promoted networking between researchers, planners, city officials, and affected communities, fostering a process of robust decision making involving incentives and trade-offs to manage climate hazards and enhance resilience. To learn more, visit: <http://goo.gl/v1kikW>

**Highlight 26. Informing Risk Management and Agricultural Decisions in the Caribbean**

In the Caribbean, the economic importance of agriculture and tourism—combined with rural poverty and widespread vulnerability to climate-related hazards like hurricanes and drought—makes planning for climate impacts an urgent necessity. USAID and NOAA are working together on multiple fronts to connect climate research with risk management, climate-resilient development, and adaptation challenges in this region.



Planning for climate impacts is crucial to protecting the Caribbean's agriculture- and tourism-based economy. (Credit: K. Helmer, USAID)

For example, the USAID- and NOAA-supported International Research and Applications Project (IRAP; to learn more, visit: <http://goo.gl/XqmehJ>) is linking physical climate data—including USGCRP agencies' monitoring and prediction capabilities—with applied research on impacts, vulnerabilities, and decision making throughout the Caribbean. To this end, IRAP works with academic institutions, development programs, and resource management organizations to translate climate information, develop applications and tools for decision support, and build adaptive capacity among decision and policy makers. Additionally, through their support for the Climate Services Partnership, USAID and NOAA recently helped Jamaica's Meteorological Service and Rural Agricultural Development Authority (RADA) create a climate information tool for farmers. The tool, supported by additional technical input from Columbia University, provides seasonal forecasts and early warnings, including seasonal drought projections. RADA uses this information to guide farmers in their agricultural practices—for instance, recommending seed varieties and pest management techniques that are most likely to succeed under projected climate conditions. To learn more, visit: <http://go.usa.gov/8pRY>

Finally, USAID and NOAA are working with partners in the Caribbean on enhancing the availability of climate information for decision makers through the Caribbean Regional Climate Outlook Forum and the development of a Caribbean Regional Climate Center. All of these activities serve as significant contributions by the U.S. Government to the WMO's Global Framework for Climate Services. To learn more, visit: <http://goo.gl/SPsVNJ> ♦



# 4 A Look Ahead: Interagency Research Priorities for FY 2015

In fulfilling the 2012–2021 Strategic Plan, USGCRP continues to build on its core interagency research capabilities with investments in science, tools, and data. Building on this strong scientific foundation, USGCRP agencies are making the necessary long-term investments to inform responses to high-priority societal impacts of global change, such as those related to changing patterns of weather extremes and potential thresholds and tipping points in human and natural systems.

USGCRP’s vision is to help the Nation successfully meet the challenges of climate and global change. To fulfill this vision, USGCRP agencies will continue to support scientific research needed to advance our understanding of Earth system processes, to characterize past and current climate and global change, and to identify, understand, and better project associated impacts and risks. Moving forward, the Program is developing enhanced capacity and tools to help decision makers anticipate and better manage those risks. The FY 2015 priorities build on those of FY 2014, using long-term scientific progress to address challenges of societal concern. They are organized within four areas:

1. **Predictions:** Predict seasonal to multi-decadal interactions among physical, biological, and human systems on local to global spatial scales.
2. **Drought:** Improve understanding of the causes and consequences of drought in a changing climate.
3. **Arctic Research:** Understand the impacts of global change on the Arctic regions and their effects on global climate, including sea level rise and methane release to the atmosphere.

4. **Actionable Science:** Provide actionable climate and global change science to support policy making and management for adaptation and mitigation.

Applying scientific knowledge and information to practical, risk-based decisions requires the integration and translation of science into information that can be used by a diverse array of decision makers. In implementing its FY 2015 priorities, USGCRP will emphasize integration that connects science and research products to specific societal needs, as part of its commitment to strengthening foundational capabilities for reaching decisions makers. These investments in global change research will support implementation of the actions laid out in the President’s Climate Action Plan.



## 5 Budget Information

The FY 2015 requested budget for USGCRP research programs is approximately \$2.5 billion. This request represents a commitment by the Administration to ensure that USGCRP can fulfill its responsibilities under the law. Over the past five years, USGCRP’s annual budget crosscut has averaged about \$2.5 billion.

The budget crosscut table (Table 1) represents the funds self-identified by USGCRP agencies as their contributions to USGCRP research. The budget crosscut does not

include the costs of many agency investments that are directly relevant and necessary to the ability of USGCRP to address national objectives related to climate and global change (for example, many of the observing networks and satellite systems that are critical to documenting trends were originally implemented by their sponsoring agencies for current operational purposes, and those typically are not included in the budget crosscut). DOD does not report activities or funding through the USGCRP budget crosscut.

Table 1. FY 2013–2015 USGCRP Budget Crosscut by Agency

Agency	FY 2013 Budget Operating (\$M)	FY 2014 Budget Enacted (\$M)	FY 2015 Budget Requested (\$M)
Department of Agriculture (USDA)	107	111	88
Department of Commerce (DOC)	301	329	348
Department of Energy (DOE)	209	217	246
Department of Health and Human Services (HHS)	10	8	8
Department of the Interior (DOI)	55	54	72
Department of Transportation (DOT)	1	1	1
Environmental Protection Agency (EPA)	17	18	20
National Aeronautics and Space Administration (NASA)	1355	1431	1392
National Science Foundation (NSF)	316	313	318
Smithsonian Institution (SI)	8	8	8
<b>TOTALS</b>	<b>2379</b>	<b>2489</b>	<b>2501</b>
Non-Add Agency	FY 2013 Budget Operating (\$M)	FY 2014 Budget Enacted (\$M)	FY 2015 Budget Requested (\$M)
Department of State (DOS)*	3	3	3
U.S. Agency for International Development (USAID)*	11	11	8

\* USAID and DOS funding supports USGCRP and the Climate Change International Assistance effort. In the past, some of this funding was counted under both categories. These efforts do not add to the USGCRP total.



# 6 Appendices

## 6.1. About USGCRP

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “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.”

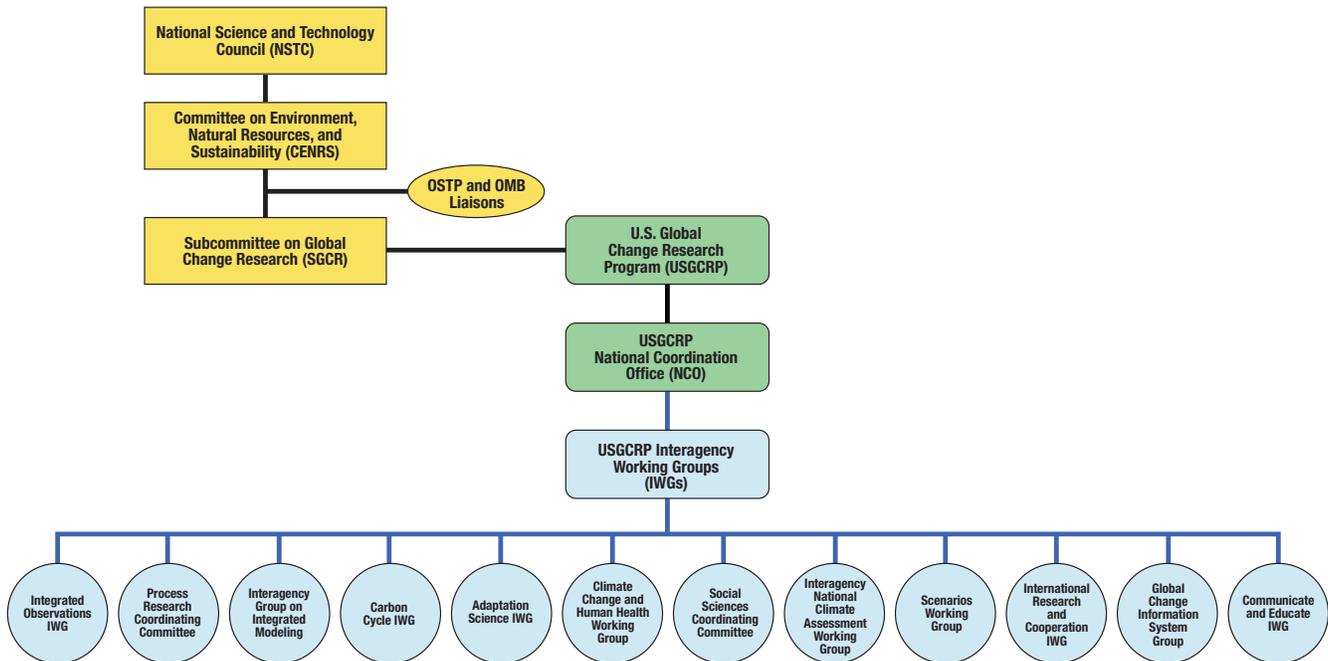
USGCRP coordinates and integrates global change research across 13 Federal agencies (*Box 1; Section 6.2*) to most effectively and efficiently serve the Nation and the world. Through interagency partnerships and collaborations with leading experts, USGCRP advances

climate science and improves our understanding of how global change is impacting society, both today and into the future.

As mandated by Congress, USGCRP develops a new strategic research plan every ten years, with triennial revisions and updates. The 2012–2021 Strategic Plan (*Section 1; Box 1*) is being implemented by the collective efforts of USGCRP’s 13 member agencies.

USGCRP is steered by the Subcommittee on Global Change Research (SGCR) of the National Science and Technology Council’s (NSTC’s) Committee on Environment, Natural Resources, and Sustainability (CENRS), and overseen by the White House Office of Science and Technology Policy (OSTP). The SGCR, whose

USGCRP’s organizational structure. Blue lines indicate NCO coordination.



membership is listed on page ii, oversees interagency activities through the USGCRP National Coordination Office (NCO) and interagency working groups (IWGs).

IWGs are the primary USGCRP vehicles for implementing and coordinating global change research activities within and across agencies. These groups are critical to integrating and assessing progress throughout the Program. The IWGs span a wide range of interconnected climate and global change issues and address major components of the Earth’s environmental and human systems, as well as cross-disciplinary approaches for addressing these issues.

IWGs are designed to bring agencies together to plan, develop, and implement coordinated activities, and to identify and fill gaps in the Program’s plans. They allow public officials to communicate with each other on emerging directions within their agencies, their stakeholder needs, and best practices learned from agency activities. Together, these functions allow the agencies to work in a more coordinated and effective manner.

USGCRP comprises the following working groups:

- Integrated Observations Interagency Working Group
- Process Research Coordinating Committee—coordinates interagency research on the nitrogen cycle; biodiversity and ecosystems; clouds, chemistry, and aerosol processes; and the terrestrial water cycle and land-atmosphere interactions
- Interagency Group on Integrated Modeling
- Social Sciences Coordinating Committee
- Carbon Cycle Interagency Working Group
- Adaptation Science Interagency Working Group
- Interagency National Climate Assessment Working Group
- Communication and Education Interagency Working Group
- International Research and Cooperation Interagency Working Group

- Global Change Information System Interagency Coordination
- Interagency Crosscutting Group on Climate Change and Human Health
- Scenarios Working Group

To learn more about each of the IWGs, visit: <http://go.usa.gov/N7A9>

## 6.2. Member Agencies

This section summarizes the principal focus areas related to global change research for each USGCRP member agency.

### Department of Agriculture

The United States Department of Agriculture (USDA) global change research program empowers land managers, policy makers, and Federal agencies with science-based knowledge to manage the risks and opportunities posed by climate change; reduce GHG emissions; and enhance carbon sequestration. USDA’s global change research program includes contributions from the Agricultural Research Service (ARS), the National Institute of Food and Agriculture (NIFA), the Forest Service (USDA-FS), Natural Resources Conservation Service (NRCS), National Agricultural Statistics Service (NASS), and Economic Research Service (ERS). These USDA entities ensure sustained food security for the Nation and the world. They maintain and enhance the health of U.S. forests and natural resources while identifying risks to agricultural production ranging from temperature and precipitation changes to the changing biology of pests, invasive species, and diseases.

Specifically, USDA develops GHG inventories and conducts assessments and projections of climate-change impacts on the natural and economic systems associated with agricultural production. USDA also develops cultivars, cropping systems, and management practices to improve drought tolerance and build resilience to climate variability. USDA promotes integration of USGCRP research findings into farm and natural resource man-

agement, and helps build resiliency to climate-change by developing and deploying decision support. USDA maintains critical long-term data collection and observation networks, including the Long-Term Agro-ecosystem Research (LTAR) Network, the Snowpack Telemetry (SNOTEL) network, the Soil Climate Analysis Network (SCAN), the National Resources Inventory (NRI), and the Forest Inventory and Assessment (FIA). USDA has instituted 7 Regional Hubs for Risk Adaptation and Mitigation to Climate Change to develop and deliver science-based region-specific information and technology. Finally, USDA engages in communication, outreach, and education through multiple forums, including its vast network of agricultural extension services.

### Department of Commerce

NOAA and the National Institute of Standards and Technology (NIST) comprise the Department of Commerce's (DOC's) participation in USGCRP.

NOAA's strategic climate goal is "an informed society anticipating and responding to climate and its impacts." NOAA's overall objective is to provide decision makers with a predictive understanding of the climate and to communicate climate information so that people can make more informed decisions in their lives, businesses, and communities. These outcomes are pursued by implementing a global observing system, conducting research to understand climate processes, developing improved modeling capabilities, and developing and deploying climate educational programs and information services. NOAA aims to achieve its climate goal through the following strategic objectives:

- Improved scientific understanding of the changing climate system and its impacts;
- Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions;
- Mitigation and adaptation efforts supported by sustained, reliable, and timely climate services; and
- A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions.

NIST works with other Federal agencies to develop or extend internationally accepted traceable measurement standards, methodologies, and technologies that enhance measurement capabilities for science-based GHG emission inventories and measurements critical to advancing climate science research. NIST provides measurements and standards that support accurate, comparable, and reliable climate observations and provides calibrations and special tests to improve the accuracy of a wide range of instruments and techniques used in climate research and monitoring. In FY 2009, NIST was included as a discrete element of USGCRP's budget crosscut to provide specific measurements and standards of direct relevance to the program.

### Department of Defense

The Department of Defense (DOD)—while not supporting a formal mission dedicated to global change research—is developing policies and plans to manage and respond to the effects of climate change on DOD missions, assets, and the operational environment. Various research agencies within DOD sponsor and undertake basic research activities that concurrently satisfy both national security requirements as well as the strategic goals of USGCRP. These include 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). When applicable, the research activities of these agencies are coordinated with other Federally sponsored research via USGCRP and other entities.

Because the performance of DOD systems and platforms are influenced by environmental conditions, understanding the variability of the Earth's environment and the potential for change is of great interest to the Department. DOD is responsible for the environmental stewardship of hundreds of installations throughout the U.S., and must continue incorporating geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes. 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 and to identify the environmental variables that must be forecast with sufficient lead time to facilitate appropriate adaptive responses. Each service agency within DOD incorporates the potential impact of global change into their long-range strategic plans. For example, the Navy's Task Force Climate Change (TFCC) assists in the development of science-based recommendations, plans, and actions to adapt to climate change. The USACE Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL) also actively investigates the impacts of climate trends for 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.

### Department of Energy

The Department of Energy's (DOE) Office of Science supports fundamental research to understand the energy-environment-climate connection and its implications for energy production, use, sustainability, and security—with particular emphasis on the potential impact of increased anthropogenic emissions. The ultimate goal is to advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges.

Two DOE research areas focus on areas of uncertainty in Earth systems models: Atmospheric System Research (science of aerosols, clouds, and radiative transfer); and Terrestrial Ecosystem Science (role of terrestrial ecosystems and carbon cycle observations). DOE also collaborates with NSF to develop the widely used Community Earth System Model, supports methods to obtain regional climate information, integrates analysis of climate-change impacts, and analyzes and distributes large climate datasets through the Program for Climate Model Diagnosis and Intercomparison and the Earth System Grid. The Department also supports the ARM Climate Research Facility, a scientific user facility that provides the research community with unmatched measurements permitting the most detailed high-resolution,

three-dimensional documentation of evolving cloud, aerosol, and precipitation characteristics in climate sensitive sites around the world.

Finally, DOE also conducts applied climate-related research, which is centered in DOE's Office of Energy Policy and Systems Analysis and Office of Policy and International Affairs. These programs develop and utilizes energy-economic models, including integrated assessment models, to evaluate policies and programs that enable cost-effective GHG reductions and accelerate the development and deployment of clean energy technologies. This includes supporting work to characterize climate-change impacts for use in policy analysis, vulnerability, and adaptation assessment and agency rulemakings. DOE also conducts assessments of climate change on electric grid stability, water availability for energy production, and site selection of the next generation of renewable energy infrastructure.

### Department of Health and Human Services

The U.S. Department of Health and Human Services (HHS) supports a broad portfolio of research and decision support initiatives related to environmental health and the health effects of global climate change, primarily through the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC). Research focuses on the need to better understand the vulnerabilities of individuals and communities to climate-related changes in health risks such as heat-related morbidity and mortality, respiratory effects of altered air contaminants, changes in transmission of infectious diseases, and impacts in the aftermath of severe weather events, among many others. Research efforts also seek to assess the effectiveness of various public health adaptation strategies to reduce climate vulnerability, as well as the potential health effects of interventions to reduce GHG emissions.

Specifically, HHS supports USGCRP by conducting fundamental and applied research on linkages between climate change and health, translating scientific advances into decision support tools for public health professionals, conducting ongoing monitoring and surveillance

of climate-related health outcomes, and engaging the public health community in two-way communication about climate change.

### **Department of the Interior**

The U.S. Geological Survey (USGS) conducts global change research for the Department of the Interior (DOI) and comprises DOI's formal participation in USGCRP.

USGS scientists work with other agencies to provide policy makers and resource managers with scientifically valid information and predictive understanding of global change and its effects with the ultimate goal of helping the Nation understand, adapt to, and mitigate global change.

Specifically, the USGS Climate and Land Use Change Research and Development Program supports research to understand processes controlling Earth system responses to global change and model impacts of climate and land-cover change on natural resources. USGS geographic analyses and land remote-sensing programs (such as the Landsat satellite mission and the National Land Cover Database) provide data that is used to assess changes in land use, land cover, ecosystems, and water resources resulting from the interactions between human activities and natural systems. The science products and data sets from these programs are essential for conducting quantitative studies of carbon storage and GHG flux in the Nation's ecosystems.

USGS is also leading the establishment of regional DOI Climate Science Centers that will provide science and technical support to region-based partners dealing with the impacts of climate change on fish, wildlife, and ecological processes.

### **Department of State**

Through the Department of State (DOS) annual funding, the U.S. is the world's leading financial contributor to the United Nations Framework Convention on Climate Change (UNFCCC) and to the IPCC—the prin-

cipal 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.

### **Department of Transportation**

The Department of Transportation (DOT) conducts research to examine potential climate-change impacts on transportation, methods for increasing transportation efficiency, and methods for reducing emissions that contribute to climate change. DOT's Center for Climate Change and Environmental Forecasting coordinates transportation and climate-change research, policies, and actions within DOT and promotes comprehensive approaches to reduce emissions, address climate-change impacts, and develop adaptation strategies. DOT also contributes directly to USGCRP's National Climate Assessment through focused research such as the Center's Gulf Coast Studies.

The Federal Aviation Administration (FAA) works closely with USGCRP and its participating agencies to identify and address key scientific gaps regarding aviation climate impacts and to inform mitigation solutions. Other DOT initiatives to address climate change and improve the sustainability of the U.S. transportation sector follow:

- FAA, the Federal Transit Administration (FTA), and other DOT agencies are undertaking climate impact and adaptation studies (including vulnerability and risk assessments), working with science agencies to develop regional climate data and projections, conducting methodological research, supporting pilot programs, and providing assistance to transportation stakeholders including state and local agencies.

- The FAA manages the Continuous Lower Energy, Emissions, and Noise (CLEEN) program as a government–industry consortium to develop technologies for energy efficiency, noise and emissions reduction, and sustainable alternative jet fuel. FAA also participates in the Commercial Aviation Alternative Fuels Initiative (CAAFI), a public–private coalition to encourage the development of sustainable alternative jet fuel.
- The multi-modal Intelligent Transportation Systems Joint Program Office is leading the Applications for the Environment: Real-Time Information Synthesis (AERIS) program, seeking to generate and acquire environmentally relevant real-time surface transportation data, and to use these data to reduce some of the negative environmental impacts of surface transportation.

### Environmental Protection Agency

The core purpose of the Environmental Protection Agency’s (EPA’s) Global Change Research Program is to develop scientific information that supports stakeholders, policy makers, and society at large as they respond to climate change and associated impacts on human health, ecosystems, and socioeconomic systems. EPA’s research is driven by the Agency’s mission and statutory requirements, and includes: (1) improving scientific understanding of global change effects on air quality, water quality, ecosystems, and human health in the context of other stressors; (2) assessing and developing adaptation options to effectively respond to global change risks, increase resilience of human and natural systems, and promote their sustainability; and (3) developing an understanding of the potential environmental impacts and benefits of GHG emission reduction strategies to support sustainable mitigation solutions. This research is leveraged by EPA Program Offices and Regions to support mitigation and adaptation decisions and to promote communication with external stakeholders and the public.

EPA relies on USGCRP to develop high-quality scientific data and understanding about physical, chemical,

and biological changes to the global environment and their relation to drivers of global change. EPA’s Global Change Research Program connects these results to specific human and ecosystem health endpoints in ways that enable local, regional, and national decision makers to develop and implement strategies to protect human health and the environment. In turn, EPA’s research provides USGCRP agencies with information about the connections between global change and local impacts and how local actions influence global changes.

Research activities include efforts to connect continental-scale temperature and precipitation changes to regional and local air quality and hydrology models to better understand the impacts of climate change on air quality and water quality, and to examine how watersheds will respond to large-scale climate and other global changes to inform decisions about management of aquatic ecosystems and expand understanding of the impacts of global change. Satellite and other observational efforts conducted by USGCRP are crucial to supporting EPA’s efforts to understand how land use change, climate change, and other global changes are affecting watersheds and ecosystems, and the services they provide.

### National Aeronautics and Space Administration

As stated in the 2010 National Space Policy, the National Aeronautics and Space Administration (NASA) plays a crucial role in conducting global change research, ensuring sustained monitoring capabilities, and advancing scientific knowledge of the global integrated Earth system through satellite observations and satellite system development. As such, NASA fully supports USGCRP’s new National Global Change Research Plan 2012-2021 to advance science, inform decisions, conduct sustained assessments, and communicate and educate. NASA actively contributes to USGCRP’s National Climate Assessment and constitutes about half of the USGCRP budget.

NASA’s global change activities have four integrated foci: satellite observations, research and analysis, applications, and technology development. Satellites provide

critical global atmosphere, ocean, land, sea ice, and ecosystem measurements. NASA's seventeen on-orbit satellites measure numerous variables required to enhance understanding of Earth interactions. NASA is launching five Earth-observing missions within a 12-month period: Global Precipitation Measurement (GPM) and Orbiting Carbon Observatory-2 (OCO-2) launched in February and July 2014, respectively; RapidScat, Cloud-Aerosol Transport System (CATS), and Soil Moisture Active Passive (SMAP) are additional launches planned to occur by early 2015.

NASA's program advances observing technology and leads to new and enhanced space-based observation and information systems. The Earth science research program explores interactions among the major components of the Earth system—continents, oceans, atmosphere, ice, and life—to distinguish natural from human-induced causes of change and to understand and predict the consequences of change. NASA makes significant investments to assure the quality and integration of data through calibration and validation efforts that include satellite, surface, and airborne measurements, as well as data intercomparisons. NASA also carries out observationally driven modeling projects that include data assimilation, reanalysis, process representation, initialization, and verification. The airborne systems provide high-resolution observations of variables relevant to global change research, including polar seas and ice sheets, atmospheric composition, carbon storage and flux in the Arctic, hurricanes in the Atlantic Ocean, and root-zone soil moisture at different locales in North America. Applications projects extend the societal benefits of NASA's research, technology, and spaceflight programs to the broader U.S. public through the development and transition of user-defined tools for decision support. The Earth science technology program enables previously infeasible science investigations, improves existing measurement capabilities, and reduces the cost, risk, and/or development times for Earth science instruments.

### **National Science Foundation**

The National Science Foundation (NSF) addresses global change issues through investments that advance

frontiers of knowledge, provide state-of-the-art instrumentation and facilities, develop new analytical methods, and enable cross-disciplinary collaborations while also cultivating a diverse, highly trained workforce and developing educational resources. In particular, NSF global change programs support the research and related activities to advance fundamental understanding of physical, chemical, biological, and human systems and the interactions among them. The programs encourage interdisciplinary approaches to studying Earth system processes and the consequences of change, including how humans respond to changing environments and the impacts on ecosystems and the essential services they provide. NSF programs promote the development and enhancement of models to improve understanding of integrated Earth system processes and to advance predictive capability. NSF also supports fundamental research on the processes used by organizations and decision makers to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of a changing and variable environment. Long-term, continuous, and consistent observational records are essential for testing hypotheses quantitatively and are thus a cornerstone of global change research. NSF supports a variety of research observing networks that complement, and are dependent on, the climate monitoring systems maintained by its sister agencies.

NSF regularly collaborates with other USGCRP agencies to provide support for a range of multi-disciplinary research projects and is actively engaged in a number of international partnerships.

### **Smithsonian Institution**

Within the Smithsonian Institution (SI), global change research is primarily conducted at the National Air and Space Museum, the National Museum of Natural History, the National Zoological Park, the Smithsonian Astrophysical Observatory, the Smithsonian Environmental Research Center, and the Smithsonian Tropical Research Institute. Research is organized around themes of atmospheric processes, ecosystem dynamics, observing natural and anthropogenic environmental change on multiple 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. Most of these units participate in the Smithsonian Institution Global Earth Observatory (SIGEO), examining the dynamics of forests over decadal time frames.

The Smithsonian Grand Challenge Consortium for Understanding and Sustaining a Biodiverse Planet brings together researchers from around the Institution to focus on joint programs ranging from estimating volcanic emissions to ocean acidification measurement. Smithsonian paleontological research documents and interprets the history of terrestrial and marine ecosystems from 400 million years ago to the present. Other 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.

These activities are joined by related efforts in the areas of history and art, such as the Center for Folklife and Cultural History, the National Museum of the American Indian, and the Cooper Hewitt Museum of Design to examine human responses to global change, within communities, reflected in art and culture, food, and music. Finally, Smithsonian outreach and education expands our scientific and social understanding of processes of change and represents them in exhibits and programs, including at the history and art museums of the Smithsonian. USGCRP funding enables the Smithsonian to leverage private funds for additional research and education programs on these topics.

### U.S. Agency for International Development

The U.S. Agency for International Development (USAID) supports programs that enable decision makers to apply high-quality climate information to decision making. USAID's climate-change and development strategy calls for enabling countries to accelerate their transition to climate-resilient, low-emission sustainable economic development through direct programming and integrating climate-change adaptation and mitigation objectives

across the Agency's development portfolio. USAID is the lead contributor to bilateral assistance, with a focus on capacity building, civil society building, and governance programming, and creating the legal and regulatory environments needed to address climate change. USAID leverages scientific and technical resources from across the U.S. Government (e.g., NASA, NOAA, USDA, USGS) as it applies 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 agriculture 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 them to work together to develop shared priorities and implementation plans. USAID's engagement and expertise in agriculture, biodiversity, infrastructure, 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 where multilateral agencies cannot.

## 6.3. Glossary

### Adaptation

Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. *Related terms: adapt, adaptation science. See also definition in EO 13653: <http://go.usa.gov/8Vvk>*

### Adaptive capacity

The potential of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, and cope with the consequences.

### Aerosol

Aerosols are fine solid or liquid particles, produced by human activities or natural processes, that are suspended in the atmosphere. Aerosols can cause cooling

by scattering incoming radiation or by affecting cloud cover. Aerosols can also cause warming by absorbing radiation. *Related terms: aerosol effect, aerosols*

**Biodiversity**

The variety of life, including the number of plant and animal species, life forms, genetic types, habitats, and biomes (which are characteristic groupings of plant and animal species found in a particular climate).

**Biogeochemical cycles**

Fluxes, or flows, of chemical elements among different parts of the Earth: from living to non-living, from atmosphere to land to sea, from soils to plants.

**Biomass**

The mass of living organisms or material derived from organisms in a given area.

**Carbon cycle**

Circulation of carbon atoms through the Earth systems as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms, and return of the carbon to the atmosphere as carbon dioxide as a result of respiration, decay of organisms, and combustion of fossil fuels.

**Carbon sequestration**

Storage of carbon through natural or technological processes in biomass or in deep geological formations.

**Climate change**

Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system. *See also global change.*

**Climate variability**

Natural changes in climate that fall within the observed range of extremes for a particular region, as measured by temperature, precipitation, and frequency of events. Measurable drivers of climate variability include the

El Niño Southern Oscillation and other phenomena. *Related term: natural variability*

**Drought**

A period of abnormally dry weather marked by little or no rain that lasts long enough to cause water shortage for people and natural systems.

**Ecosystem**

All the living things in a particular area as well as components of the physical environment with which they interact, such as air, soil, water, and sunlight.

**Ecosystem services**

The benefits produced by ecosystems on which people depend, including, for example, fisheries, drinking water, fertile soils for growing crops, climate regulation, and aesthetic and cultural value.

**Extreme events**

A weather event that is rare at a particular place and time of year, including, for example, heat waves, cold waves, heavy rains, periods of drought and flooding, and severe storms. Extreme events are often associated with significant economic damages. *Related term: extreme weather*

**Feedback**

The process through which a system is controlled, changed, or modulated in response to its own output. Positive feedback results in amplification of the system output; negative feedback reduces the output of a system.

**Forcing**

Factors that affect the Earth's climate. For example, natural factors such as volcanoes and human factors such as the emission of heat-trapping gases and particles through fossil fuel combustion.

**Global change**

Changes in the global environment that may alter the capacity of the Earth to sustain life. Global change encompasses climate change, but it also includes other critical drivers of environmental change that may interact with climate change, such as land use change, the

alteration of the water cycle, changes in biogeochemical cycles, and biodiversity loss. *See also climate change.*

**Global warming**

The observed increase in average temperature near the Earth’s surface and in the lowest layer of the atmosphere. In common usage, “global warming” often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change; it can also lead to other changes in climate conditions, such as changes in precipitation patterns.

**Greenhouse gases**

Gases that absorb heat in the atmosphere near the Earth’s surface, preventing it from escaping into space. If the atmospheric concentrations of these gases rise, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the greenhouse effect. Greenhouse gases include, for example, carbon dioxide, water vapor, and methane. *Related term: heat-trapping gases*

**Heat wave**

A period of abnormally hot weather lasting days to weeks.

**Heavy [or extreme] rains**

An episode of abnormally high rain. The definition of “extreme” is a statistical concept that varies depending on location, season, and length of the historical record. *Related term: heavy downpours*

**Indicator**

An observation or calculation that allows scientists, analysts, decision-makers, and others to track environmental trends, understand key factors that influence the environment, and identify effects on ecosystems and society.

**Land cover**

The physical characteristics of the land surface, such as crops, trees, or concrete.

**Land use**

Activities taking place on land, such as growing food, cutting trees, or building cities.

**Mitigation**

Measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere.

**Ocean acidification**

The process by which ocean waters have become more acidic due to the absorption of human-produced carbon dioxide, which interacts with ocean water to form carbonic acid and lower the ocean’s pH. Acidity reduces the capacity of key plankton species and shelled animals to form and maintain shells.

**Ozone**

A colorless gas consisting of three atoms of oxygen, readily reacting with many other substances. Ozone in the upper atmosphere protects the Earth from harmful levels of ultraviolet radiation from the Sun. In the lower atmosphere ozone is an air pollutant with harmful effects on human health.

**Paleoclimate**

The climate that existed during the period before modern record-keeping. Paleoclimate can be measured with “natural thermometers” such as ice cores or tree rings.

**Permafrost**

Ground that remains at or below freezing for at least two consecutive years.

**Preparedness**

Actions taken to build, apply, and sustain the capabilities necessary to prevent, protect against, and ameliorate negative effects. *See also definition in EO 13653: <http://go.usa.gov/8Vvk>*

**Proxies**

A proxy is a way to indirectly measure aspects of climate. Biological or physical records from ice cores, tree rings, and soil boreholes are good examples of proxy data.

**Resilience**

A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with

minimum damage to social well-being, the economy, and the environment. *See also definition in EO 13653:* <http://go.usa.gov/8Vvk>

**Risk assessment**

Studies that estimate the likelihood of specific sets of events occurring and their potential positive or negative consequences.

**Risk management**

Planning to manage the effects of climate change to increase positive impacts and decrease negative impacts.

**Risk-based framing**

Planning based on the pros and cons of a given set of possibilities; includes assessment of a risk in terms of the likelihood of its occurrence and the magnitude of the impact associated with the risk.

**Scenario**

Sets of assumptions used to help understand potential future conditions such as temperature change, population growth, land use, and sea level rise. Scenarios are neither predictions nor forecasts. Scenarios are commonly used for planning purposes.

**Sink**

A natural or technological process that removes carbon from the atmosphere and stores it. *Related term: carbon sink*

**Stakeholder**

An individual or group that is directly or indirectly affected by or interested in the outcomes of decisions.

**Storm surge**

The sea height during storms such as hurricanes that is above the normal level expected at that time and place based on the tides alone.

**Stressor**

Something that has an effect on people and on natural, managed, and socioeconomic systems. Multiple stressors

can have compounded effects, such as when economic or market stress combines with drought to negatively impact farmers.

**Tipping point**

The point at which a change in the climate triggers a significant environmental event, which may be permanent on human time scales, such as the melting and collapse of very large ice sheets. *Related term: threshold*

**Uncertainty**

An expression of the degree to which future conditions (such as climate) are unknown. Uncertainty about the future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make. There is also uncertainty about how climate change, in combination with other stressors, will affect people and natural systems.

**Urbanization**

The concentration of human populations into discrete areas, leading to transformation of land for residential, commercial, industrial, and transportation purposes.

**Vulnerability**

The degree to which physical, biological, and socio-economic systems are susceptible to and unable to cope with adverse impacts of climate change.

**Vulnerability assessment**

An analysis of the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change. *Related term: vulnerability analysis*

For a more comprehensive global change glossary, visit: <http://go.usa.gov/NcEH>

## 6.4. Acronyms

<b>AACA</b>	Adaptation Actions in a Changing Arctic	<b>DYNAMO</b>	Dynamics of the Madden Julian Oscillation
<b>ACCRI</b>	Aviation Climate Change Research Initiative	<b>EBV</b>	Essential Biodiversity Variables
<b>AERIS</b>	Applications for the Environment: Real-Time Information Synthesis	<b>EO</b>	Executive Order
<b>AFOSR</b>	Air Force Office of Scientific Research	<b>EPA</b>	Environmental Protection Agency
<b>AgMIP</b>	Agricultural Model Intercomparison and Improvement Project	<b>ERDC</b>	Engineer Research and Development Center
<b>AMAP</b>	Arctic Monitoring and Assessment Programme	<b>ERS</b>	Economic Research Service
<b>AR5</b>	IPCC Fifth Assessment Report	<b>ESSP</b>	Earth System Science Partnership
<b>ARM</b>	Atmospheric Radiation Measurement Program	<b>ETS</b>	Earth to Sky Program
<b>ARO</b>	Army Research Office	<b>FAA</b>	Federal Aviation Administration
<b>ARS</b>	Agricultural Research Service	<b>FIA</b>	Forest Inventory and Assessment
<b>BON</b>	Biodiversity Observation Network	<b>FTA</b>	Federal Transit Authority
<b>CAAFI</b>	Commercial Aviation Alternative Fuels Initiative	<b>FY</b>	Fiscal Year
<b>CATS</b>	Cloud-Aerosol Transport System	<b>GCIS</b>	Global Change Information System
<b>CDC</b>	Centers for Disease Control and Prevention	<b>GCRA</b>	Global Change Research Act
<b>CENRS</b>	Committee on Environment, Natural Resources, and Sustainability	<b>GEO</b>	Group on Earth Observations
<b>CLEEN</b>	Continuous Lower Energy, Emissions, and Noise	<b>GHG</b>	Greenhouse Gas
<b>CMIP5</b>	Fifth-phase Coupled Model Intercomparison Project	<b>GPM</b>	Global Precipitation Measurement
<b>CRREL</b>	Cold Regions Research and Engineering Laboratory	<b>GSA</b>	General Services Administration
<b>DARPA</b>	Defense Advanced Research Projects Agency	<b>HHS</b>	Department of Health and Human Services
<b>DOD</b>	Department of Defense	<b>IARPC</b>	Interagency Arctic Research Policy Committee
<b>DOE</b>	Department of Energy	<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>DOI</b>	Department of the Interior	<b>IGBP</b>	International Geosphere-Biosphere Program
<b>DOS</b>	Department of State	<b>IHDP</b>	International Human Dimensions Programme
<b>DOT</b>	Department of Transportation	<b>IRAP</b>	International Research and Applications Project
		<b>ISCN</b>	International Soil Carbon Network
		<b>JAXA</b>	Japan Aerospace Exploration Agency
		<b>LTAR</b>	Long-Term Agro-ecosystem Research network

<b>LOICZ</b>	Land-Ocean Interactions in the Coastal Zone	<b>RISA</b>	Regional Integrated Sciences and Assessments
<b>MJO</b>	Madden Julian Oscillation	<b>SCAN</b>	Soil Climate Analysis Network
<b>MWCOG</b>	Metropolitan Washington Council of Governments	<b>SDS</b>	Structured Data Server
<b>MODIS</b>	Moderate Resolution Imaging Spectroradiometer	<b>SERDP</b>	Strategic Environmental Research and Development Program
<b>NASA</b>	National Aeronautics and Space Administration	<b>SGCR</b>	Subcommittee for Global Change Research
<b>NASS</b>	National Agricultural Statistics Service	<b>SIGEO</b>	Smithsonian Institution Group on Earth Observations
<b>NCA</b>	National Climate Assessment	<b>SMAP</b>	Soil Moisture Active Passive mission
<b>NCO</b>	National Coordination Office	<b>SNOTEL</b>	Snowpack Telemetry network
<b>NCPC</b>	National Capital Planning Commission	<b>START</b>	Global Change SysTem for Analysis, Research, and Training
<b>NEAQ</b>	New England Aquarium	<b>TFCC</b>	Navy’s Task Force Climate Change
<b>NIFA</b>	National Institute of Food and Agriculture	<b>TRMM</b>	Tropical Rainfall Measuring Mission
<b>NIH</b>	National Institutes of Health	<b>UGEC</b>	Urbanization and Global Environmental Change project
<b>NIST</b>	National Institute of Standards and Technology	<b>UN</b>	United Nations
<b>NMME</b>	North American Multi-Model Ensemble	<b>UN-REDD</b>	UN Reducing Emissions from Deforestation and Forest Degradation Programme
<b>NNOCCI</b>	National Network for Ocean and Climate Change Interpretation	<b>UNEP</b>	UN Environment Programme
<b>NOAA</b>	National Oceanic and Atmospheric Administration	<b>UNFCCC</b>	UN Framework Convention on Climate Change
<b>NRCS</b>	Natural Resources Conservation Service	<b>USACE</b>	U.S. Army Corps of Engineers
<b>NRI</b>	National Resources Inventory	<b>USAID</b>	U.S. Agency for International Development
<b>NSF</b>	National Science Foundation	<b>USDA</b>	U.S. Department of Agriculture
<b>NSTC</b>	National Science and Technology Council	<b>USDA-FS</b>	U.S. Forest Service
<b>OCO-2</b>	Orbiting Carbon Observatory-2	<b>USGCRP</b>	U.S. Global Change Research Program
<b>ONR</b>	Office of Naval Research	<b>USGEO</b>	U.S. Group on Earth Observations
<b>OSTP</b>	Office of Science and Technology Policy	<b>USGS</b>	U.S. Geological Survey
<b>OMB</b>	Office of Management and Budget	<b>WMO</b>	World Meteorological Organization
<b>PAGES</b>	Past Global Changes project		
<b>RADA</b>	Jamaica’s Rural Agricultural Development Authority		



# U.S. Global Change Research Program



The U.S. Global Change Research Program  
1717 Pennsylvania Avenue NW • Suite 250 • Washington, D.C. 20006 USA  
+1.202.223.6262 (voice) • +1.202.223.3065 (fax)  
[GlobalChange.gov](http://GlobalChange.gov)