Report
HIGHLIGHTS
February 2017

Accomplishments of the U.S. Global Change Research Program

The U.S. Global Research Program (USGCRP) is the nation's principal contribution to the worldwide effort to understand our changing planet. Growing out of interagency planning under the Reagan and H. W. Bush administrations, USGRCP was established by Congress in the 1990 Global Change Research Act. At that time, it was clear that global environmental change was important, but the many forces altering the ocean and atmosphere—affecting the climate, ecosystems, freshwater systems, agricultural systems and more—were not well understood. Information needs have also grown as global changes are increasingly visible in our everyday affairs, from droughts and extreme storms to the acidifying ocean.

From its inception, USGCRP has consistently focused on building scientific knowledge and making it useful. For example, the Program has documented substantial increases in heavy downpours in most regions of the United States over the past 50 years, which can cause flooding that overwhelms the existing infrastructure of sewers and roads. Awareness of such trends can help governments, businesses, and citizens plan accordingly in a number of realms, including agriculture, conservation, and human health.

This report highlights advances in global change science in the quarter century the USGCRP has been in existence, and documents some of its contributions to that growth. Accomplishments are discussed in terms of the two primary functions of USGCRP: (1) strategic planning and coordination of global change research efforts in 13 participating federal agencies and departments (see Box 1); and (2) high-level synthesis of global change research results presented in assessments and other products that are shared with decision makers and the American public.

What is Global Change?
Global change refers to changes in the Earth's environment that may alter the capacity of the Earth to sustain life. Processes of global change include climate variability and change, but also ecosystem changes that can have substantial effects on the supply of natural resources, on the economy, and on human well-being.

MAJOR CONTRIBUTIONS TO UNDERSTANDING GLOBAL CHANGE

Looking back over a quarter century, the USGCRP has made notable accomplishments in its mission of scientific research to advance the national interest. This report identifies the following four examples of notable contributions.

Development of Global Observation Systems Earth system science is an observational science in which the whole planet is the laboratory. Aside from a few early datasets on global processes—such as the record of atmospheric CO_2 measured at Mauna Loa—no truly global datasets were available in the late 1980s and few had been measured for a long enough time to measure global change.

One of the major contributions of the USGCRP is the collection of consistent data sets, at levels of spatial resolution from global down to specific watersheds and neighborhoods. Working with NASA's Earth Observing System (EOS), which also got its start from Congress in 1990, USGCRP instituted objectives and associated critical measurements designed to

address understanding of global change with space-based observations.

One early success of the global space-based observing system was a greatly improved understanding of land-cover change. For example, Landsat data together with new methods for analysis produced the first consistent, replicable measurement of loss of humid tropical forest in the Amazon basin. Today, the ability to calculate terrestrial global processes, such as changes in the length of the growing season, can only be accomplished with the global-satellite data record initiated by the USGCRP.

As global Earth observations from space were expanding, some of the same USGCRP agencies, and others as well, planned and implemented airborne, ground, and ocean-based observing systems. The Tropical Ocean-Global Atmosphere (TOGA) Array in the western Pacific, the expansion of the ocean Argo floats, the development of AmeriFlux for terrestrial CO_2 fluxes, and the creation of a nationally consistent archive of temperature observations are prime examples.

Through its Integrated Observations Interagency Working Group, USGCRP continues to coordinate a large and growing portfolio of observations, both satellite and *in situ*. More than 30 instruments are currently operating in near-Earth orbit, which measure or allow the calculation of a wide suite of variables, including wind speeds and circulation patterns, atmospheric concentrations of CO_2 and aerosols, land-cover change, ice sheets, cloud properties, ocean salinity, sea ice, and the biosphere's net primary productivity on both land and ocean.

Earth System Modeling Earth system models, which mathematically represent the physical, chemical, and biological processes across the planet, are indispensable tools for understanding global change and generating information needed by decision makers. In 1990, most models focused only on the atmosphere component of the Earth system, with crude representation of clouds and radiation processes and little representation of interactions with the ocean and land surfaces. While useful for studying large-scale responses to changes, such as increases in greenhouse gases, those models were not useful for smaller-scale features, such as tropical storms, hurricanes, or sharply defined warm and cold fronts.

Significant investments by several USGCRP agencies have addressed many of those limitations. Today's models represent multiple interacting components at increasingly higher resolutions. It is now possible to simulate realistic past conditions that can be compared with both satellite and *in situ* observations. This advance is critical to advancing scientific knowledge, making more accurate forecasts of near-term risks such as drought, informing maps of coastal flood risk, and many other practical applications.

In recognition of the need to coordinate the nation's diverse and decentralized modeling efforts, the USGCRP set up the Interagency Group on Integrative Modeling (IGIM) in 2011. USGCRP agencies also play a role in international modeling efforts, specifically the Coupled Model Intercomparison Project (CMIP) established in 1995, which uses standardized specifications of model inputs and outputs established by an international committee.

Carbon-Cycle Science Carbon-cycling research has been a focus for USGCRP agencies because of the role carbon plays as a major regulator of Earth's climate and as a key factor in controlling the acidity of the global oceans. In order to assess and predict change, both carbon fluxes to the atmosphere (sources) and carbon sequestration in land and ocean ecosystems (sinks) need to be understood and quantified.

The USGCRP agencies have championed strategic planning activities and promoted and coordinated core observations and process studies on global carbon sources and sinks. In 1998, the Carbon Cycle Interagency

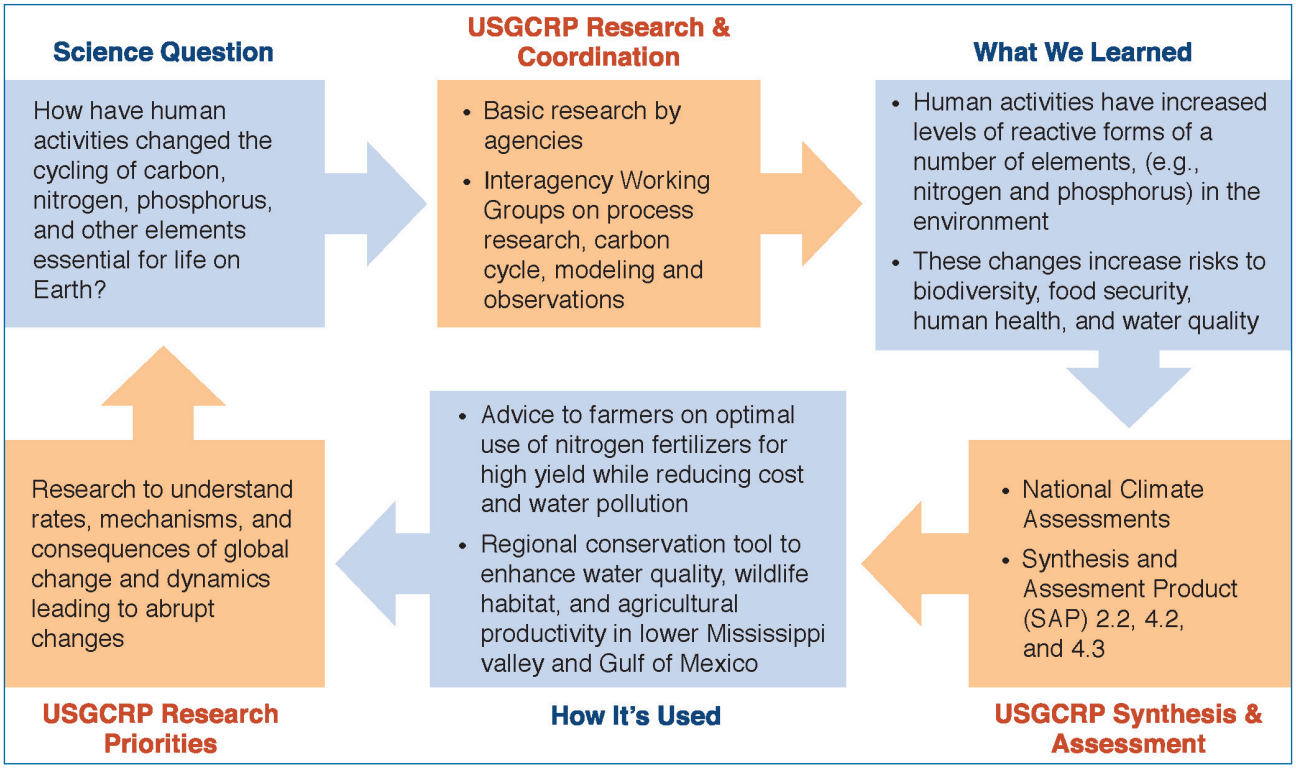
Box 1. Current Participating Agencies and Departments in the USGCRP

- National Science Foundation
- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration
- Environmental Protection Agency
- Department of Energy
- Department of State
- Department of Defense
- Department of the Interior
- Department of Agriculture
- Department of Transportation
- Department of Health and Human Services
- U.S. Agency for International Development
- Smithsonian Institution

USGCRP in the International Context

In global change science, U.S. government agencies make a major contribution to the necessarily global enterprise of research, data development, and analysis. The effectiveness of U.S. efforts is enhanced by dialogue and coordination with other nations, catalyzing scientific understanding while reducing duplication of efforts. The need for effective coordination of U.S. agencies with international activities seems likely to increase in the future, and the USGCRP, with its unique overview of diverse U.S. global change research activities, plays an important role in this process in three useful areas: joint research, global observation, and international assessment.

The Value Chain of Scientific Knowledge on Global Change



In addition to the new scientific knowledge produced by its coordinated research, the USGCRP provides the nation with a range of benefits resulting from use of this information. This **value chain** is illustrated above with research on the cycling of carbon, nitrogen, phosphorus, and other key elements, which have, among other things, led to advice to farmers on how to optimize fertilizer use. Another example is the use of knowledge about changes in the frequency, intensity, and duration of some extreme weather and climate events, which is being used to reduce their human and financial costs with the development of drought early warning systems and other aids to practical decisions. Yet another example is how research on the impacts of heat waves on human health led to the development of the National Integrated Heat Health Information System and heat-wave early warning systems that have reduced morbidity and mortality.

Working Group (CCIWG) was formally constituted to coordinate efforts that 12 U.S. government agencies and departments now lead as part of the U.S. Carbon Cycle Science Program.

During the past 25 years, research organized and supported in part by the USGCRP has greatly increased our understanding of the processes involved in, for example, the potential for enhanced decomposition of soil carbon as the climate warms, and the processes influencing CO_2 uptake in a warming ocean. Important components of this research are intensive, interagency coordinated field campaigns that unite *in situ,* airborne, and satellite-based observations.

Integrating Human Dimensions into Global Change Research The social forces shaping land and energy use and urbanization globally—including the behavior of individuals, organizations, and communities—are understood to be of basic importance in all aspects of global change research. Through its coordinating activities, the USGCRP has made important contributions to bringing together the natural and social sciences in global change research and encouraging member agencies to support fundamental social science.

Social science is also important in the efforts USGCRP has made to deliver actionable science in support of decision making, particularly at the regional scale. Regional decision support centers were established by the Department of the Interior (Climate Science Centers), NOAA (Regional Integrated Sciences and Assessments [RISA] program and Regional Climate Centers), and USDA (Climate Hubs), each targeted at the specific responsibilities of the sponsoring agency. These centers have served as testbeds for experimentation in informing decisions, effectively providing platforms for applied human dimensions research.

While progress is being made in advancing human dimensions research, challenges remain. In particular, many USGCRP agencies lack social science expertise and sustained social science data resources. These challenges will have to be overcome for further progress in incorporating the social sciences into the USGCRP, to provide the

information the nation needs to effectively and efficiently manage current and likely consequences of global environmental changes.

LOOKING AHEAD

Through interagency partnerships and collaborations with leading experts, the USGCRP has worked successfully since its inception to advance global change science and improve understanding of how global change affects society today and how it could affect society in the future. In the coming decades, as the impacts of global change become increasingly apparent, USGCRP will need to augment the knowledge base for exploring options to protect the nation's interests in the face of accelerating global changes. The Program should build on its accomplishments by sustaining, expanding, and coordinating observations of the Earth system and maintaining a balanced program of discovery-driven and use-inspired research to support the needs of the nation at local, regional, national, and global scales. The Program is well poised to tackle this task.

USGRCP Assessments and Other Products

USGCRP has prepared three National Climate Assessments (NCAs)—published in 2000, 2009, and 2014—and is in the process of preparing a fourth one. The NCAs are coordinated and produced by the USGCRP National Coordination Office. Dozens of supplementary reports have been produced by the Program and its participating agencies, often as input to the NCAs. Assessments and assessment products are critical components that connect the coordinated research and results with the decision makers and American public who use them.

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For More Information . . . This Report Highlights was prepared by the Board on Atmospheric Sciences and Climate and the Board on Environmental Change and Society based on the report *Accomplishments of the U.S. Global Change Research Program.* The study was sponsored by the National Aeronautics and Space Administration. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authoring committee and do not necessarily reflect those of the sponsor. Copies of the report are available from the National Academies Press, (800) 624-6242; **http://www.nap.edu**.

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