U.S. Global Change
Research Program

OUR CHANGING PLANET

The U.S. Global Change Research Program for Fiscal Year 2020

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

A Supplement to the President's Budget for Fiscal Year 2020

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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 Fiscal Year 2020 edition of *Our Changing Planet* provides a summary of programmatic achievements, recent progress, and budgetary information for USGCRP. 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.

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INTRODUCTION

The U.S. Global Change Research Program (USGCRP) coordinates research across 13 federal agencies (Figure 1) to understand the human-induced and natural processes that influence the total Earth system: the atmosphere, oceans, land, water, ecosystems, and people. USGCRP emphasizes research that can be used to answer critical questions about large-scale forces of change in the Earth system, and how the United States and the world can respond to reduce exposure to climate-related risks, protect public health, and strengthen economic and community vitality. The Program was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990.[1]

What is global change?

The term "global change" means changes in the global environment (including alterations in climate, land productivity, oceans and other water resources, atmospheric chemistry, and ecological systems) that may alter Earth's capacity to sustain life.

USGCRP builds on a foundation of decades of federal investment in research and development to ensure that the United States is a world leader in global change research. Through USGCRP, member agencies work together to align research investments with national needs, maximize efficiencies in federal scientific programs, strengthen the nation's innovation base, and deliver products mandated by the GCRA, including the quadrennial National Climate Assessment. USGCRP's mandate also involves promoting international coordination on global change research, including providing support for activities relating to U.S. participation in international scientific assessments, and advancing U.S. leadership in global change science (see Supporting International Global Change Science).

The Fiscal Year (FY) 2020 edition of USGCRP's annual report to Congress, *Our Changing Planet*, presents highlights of the Program's recent achievements, as well as a summary of agency expenditures under USGCRP's budget crosscut (see Budgetary Information), as required by the GCRA. USGCRP's scope includes but is not limited to the range of agency programs implemented with funds included in the budget crosscut, and the efforts described in this document represent only a small subset of the overall accomplishments of the Program. The highlighted activities represent interagency collaborations that rely on coordinated investments of two or more member agencies. Note that single agency investments, including many that enable interagency accomplishments, are not typically covered in this annual report. See Appendix I. USGCRP Member Agencies for more detail on the principal focus areas related to global change research for each member agency.

Figure 1: U.S. Global Change Research Program Member Agencies

Department of Agriculture

Department of Commerce

Department of Defense

Department of Energy

Department of Health and Human Services

Department of the Interior

Department of State

Department of Transportation

Environmental Protection Agency

National Aeronautics and Space Administration

National Science Foundation

Smithsonian Institution

U.S. Agency for International Development

IMPLEMENTING THE 2012–2021 NATIONAL GLOBAL CHANGE RESEARCH PLAN

USGCRP's National Global Change Research Plan and its 2017 update provide the framework for advancing scientific understanding of the Earth system while strengthening capacity to answer questions critical to decision-making. The Program's four strategic goals, which align with its mandate under the GCRA, are to advance global change science, inform decisions, conduct sustained assessments, and engage key stakeholders and audiences in support of these goals, including internationally. This section highlights recent achievements that support implementation of USGCRP's goals and illustrate ongoing advances in the science of global change. Additional activities undertaken in the reporting period and in previous years are available at https://www.globalchange.gov/explore.

Advancing Science

Global change science covers a range of disciplines and methods, including Earth observations, Earth system modeling and predictability, understanding Earth system processes, and social science approaches to understanding the connection between human and natural systems. Data produced by USGCRP research efforts are made freely available for public use, and USGCRP and its member agencies have expanded their efforts to provide data in formats that are accessible and usable for decision-makers as well as scientists.

Integration across different topics and approaches, enabled by sustained interagency coordination through USGCRP, helps drive advances in understanding of the changing Earth system and ensure that federal science is able to inform decisions and actions in response to change. The research efforts highlighted in this section, drawn from diverse disciplines and methods within global change science, are advancing our ability to observe, understand, and model processes of change in the Earth system and inform efforts to build resilience to the impacts of global change.

Highlight 1. Unprecedented observations in the Southern Ocean help improve global climate models

The Southern Ocean surrounding Antarctica is the stormiest place on Earth, marked by heavy cloud cover that helps determine how much of the sun's energy reaches Earth's surface. Due in part to the scarcity of field data from the region, current climate models have difficulty reproducing the behavior of clouds over the Southern Ocean, which in turn affects how well they can simulate current and future climate. Motivated by these data limitations, an international multi-agency effort collected atmospheric and oceanographic data via ship-, aircraft-, and island-based instrumentation in a set of recent campaigns, revealing details about clouds, precipitation, and other atmospheric properties in the region that will help improve weather and climate modeling and forecasting capabilities across the globe.

Together, the NSF-funded Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES), the DOE-funded Macquarie Island Cloud Radiation Experiment (MICRE) and Measurements of Aerosols, Radiation and Clouds over the Southern Ocean (MARCUS) campaigns, and the Australian Clouds, Aerosols, Precipitation, Radiation, and Atmospheric Composition over the Southern Ocean (CAPRICORN) program captured extensive observations of cloud and aerosol properties and flows of energy between the atmosphere and ocean between 2016 and 2018.

Measurements taken by different instruments will be integrated to reveal details about the atmosphere from the surface up to about 6 miles (10 km), ultimately providing highly detailed data that can be used to improve model predictions.

In addition to these focused interagency field campaigns, research and operational satellites operated by NASA and NOAA, respectively, provide information on the broader environment in which clouds form beyond the limited time periods of the campaigns. Together, data from focused field campaigns and ongoing satellite operations inform the larger-scale models that simulate Earth's climate system.

A researcher launches a radiosonde instrument attached to a weather balloon to capture detailed atmospheric data. Credit: National Center for Atmospheric Research.

Highlight 2. Scientists investigate the effects of carbon emissions from thawing permafrost soils

Long-frozen northern soils known as permafrost contain one of the world's largest stores of organic carbon. This reservoir is stable while frozen, but as permafrost thaws, decomposition of biomass by microbes produces the heat-trapping gases carbon dioxide and methane, returning soil carbon to the atmosphere where it contributes to climate change. Permafrost carbon stores are expected to be increasingly vulnerable to decomposition as the climate continues to change, leading to a feedback cycle of further warming and permafrost thaw.[2]

Earth system models have recently begun to account for the effects of carbon emissions from gradual, surface-level permafrost thaw in their estimates of future climate change. However, carbon emissions from processes of deeper, abrupt thawing that occur beneath thermokarst lakes—shallow ponds that form in permafrost terrain as soils thaw—are not yet accounted for in models. To help address this gap, researchers funded by NASA, NSF, and DOE used model output, supported by USGS-NASA satellite data and field measurements, to investigate the impacts of carbon emissions from thermokarst lakes on future climate change.[3]

By comparing estimates of Arctic-wide permafrost carbon emissions from surface thaw alone with estimates that include abrupt thaw beneath thermokarst lakes, researchers found that accounting for emissions from abrupt thaw more than doubles previous estimates of warming caused by northern permafrost thaw this century. These findings demonstrate the need to incorporate abrupt permafrost thaw in Earth system models for a more comprehensive understanding of the rate of climate change throughout the 21st century.

Methane emitted from thawing permafrost below an Arctic thermokarst lake is trapped in bubbles of many different sizes and shapes as the ice grows during the winter. Credit: Katey Walter Anthony/University of Alaska Fairbanks.

Highlight 3. Researchers reconstruct a new history of ocean warming

Globally, average sea level has risen over the past several decades as ocean waters have warmed. While the ocean as a whole has absorbed a huge amount of heat from the warming atmosphere, ocean currents transport that heat differently across regions, contributing to significant regional variations in the amount of sea level change. Understanding changes in ocean heat content and the role of currents in shaping patterns of warming is critical to assessing current and future global and regional climate change, sea level rise, and coastal flooding risk.[4]

Before the 1990s, however, most ocean temperature measurements were limited to the upper ocean (above 700m), presenting an incomplete picture of past ocean heat content. To help address this gap, researchers funded in part by NASA combined NOAA and NASA satellite and field data with a model of heat transport within the ocean to reconstruct patterns of ocean warming over the industrial era. Their method provides a global, full-depth estimate of ocean warming dating back to 1871.[5]

The study also demonstrates that changes in heat transport by ocean circulation have produced significant regional variations in ocean heat content, and consequently, sea level rise. In particular, a stronger convergence of warm ocean currents in the Atlantic Ocean has contributed to the accelerated warming observed in the region over the past six decades. These findings show that analyses of ocean dynamics and circulation can help explain trends in ocean warming and sea level rise and yield clues about future climate and regional sea level change.

Highlight 4. New data infrastructure helps build a virtual ecosystem of Earth science information

The ability to archive and share datasets generated by field, experimental, and modeling activities is a critical component of Earth system and global change research. Several recent interagency efforts aim to support advances in global change data access, synthesis, and use.

DOE recently launched the Environmental Systems Science Data Infrastructure for a Virtual Ecosystem (ESS-DIVE), a publicly accessible archive of Earth and environmental science data generated by DOE-supported ecosystems research. ESS-DIVE enables the user community to easily access the datasets underlying research results, review results that have already been published, and use data for new analyses.

ESS-DIVE is a partner in the NSF-funded Data Observation for Earth Network (DataONE), which enables free and open sharing of scientific data across a platform of networked federal and non-federal data portals. DataONE supports enhanced search and discovery of Earth and environmental data across a number of repositories managed by its members, meaning that ESS-DIVE's data contents will be discoverable by a broader user base.

Together, these efforts broaden existing initiatives to help users efficiently access data that is easy to interpret, integrate, and analyze, enabling researchers to tackle critical global change research questions from a multi-disciplinary perspective.

Highlight 5. A collaboration identifies pathways to enhance social science integration in federal global change research

Through its Social Science Coordinating Committee (SSCC), USGCRP works to integrate social science methods, findings, and disciplinary perspectives into federal global change research programs. The social, behavioral, and economic sciences provide critical insights on the drivers and impacts of global change and inform mitigation, adaptation, and resilience decisions.

In February 2019, in collaboration with the National Academies of Sciences, Engineering, and Medicine's Board on Environmental Change and Society, the SSCC convened a seminar entitled "Climate Resilience Pathways and Social Science Research Actions." Building on a March 2017 workshop examining social science perspectives on climate change and the subsequent publications, the seminar brought together over 200 participants from academia, federal agencies, and diverse state, local, and civil society stakeholders. Participants discussed opportunities to advance interdisciplinary research in federal programs,

and the use of social science research and insights for societal transformation to meet global change and sustainability challenges.

The seminar presented recent interdisciplinary social science syntheses for understanding societal drivers of and vulnerability to climate change, and effective responses that consider a variety of socio-cultural and historic contexts. Academic researchers and federal agency and international program managers discussed the successes and challenges of social science integration and interdisciplinary and transdisciplinary approaches in global change research and decision support. The seminar and subsequent discussions identified areas for potential future work, including enhancing institutional infrastructure to foster federal and academic interdisciplinary collaboration, and connecting social science research with the environmental justice community and decision-making.
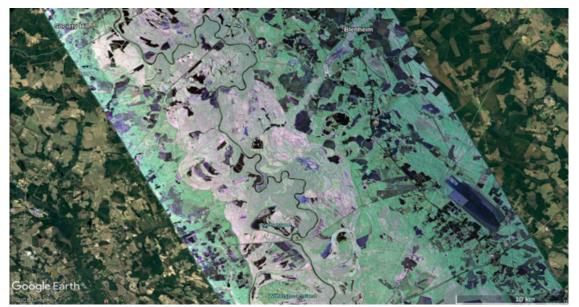
Informing Decisions

USGCRP coordinates and integrates efforts across the Federal Government to provide access to authoritative, freely available assessments, datasets, and tools that inform decisions related to all aspects of global change. Interagency science contributes to the development of information tools for responding to climate-related risks and opportunities, including the provision of information at regional scales useful for decision-making.

Highlight 6. Interagency data products and research inform hurricane response and recovery in the Carolinas

Hurricane Florence struck the Carolinas on September 14, 2018, causing widespread flooding and damage. In the aftermath of the storm, NASA deployed airborne radar to map floodwaters threatening the region, supplying federal, state, and local agencies with information critical to disaster response efforts.

Airborne radar is able to "see" through cloud cover to image the ground below during day and night and can map flooding occurring under vegetation, which is especially valuable in heavily vegetated areas such as the Carolinas. Scientists rapidly mapped the extent and depth of flooding, helping local authorities identify potential damage to and blockage of infrastructure such as roadways and levees and prioritize recovery efforts as flood waters receded.

NASA worked closely with and leveraged the expertise of state, federal, and other partners to provide analysis of satellite imagery, data products, and other decision-support aids, including the states of North Carolina and South Carolina, the Federal Emergency Management Agency, Federal Aviation Administration, U.S. National Guard, U.S. Geological Survey, NOAA, USDA-Forest Service, the University of South Carolina, and the University of Florida.

Following the immediate focus on response and recovery, satellite and airborne observations are helping scientists update streamflow and flood models. In particular, measurements of flood level change will assist NOAA and NASA hydrologists in updating flood prediction models.
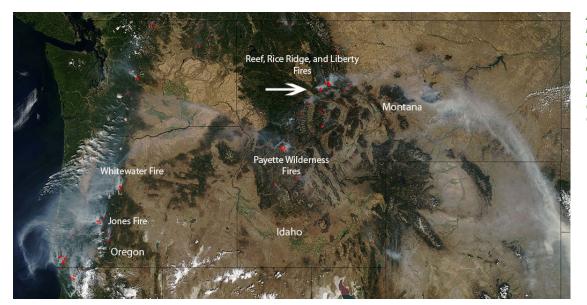
Highlight 7. Drought and wildfire research supports adaptation planning in the western United States

Wildfires affect communities throughout the United States each year, threatening lives, property and infrastructure, and ecosystems.[6] Understanding how climatic conditions influence wildfire patterns can improve our ability to predict the occurrence and severity of future wildfires, and ultimately support the development of effective adaptation strategies.

In response to this need, multiple programs within the U.S. Geological Survey (USGS) and the Department of the Interior's Climate Adaptation Science Centers (CASC) are collaborating with the USDA Forest Service (FS) and other partners to deliver the data needed to understand and plan for changes in wildfire risk. Several papers published in 2018 describe results from efforts funded by the Alaska CASC that included use of climate model data supported by DOE, NOAA, and DOI, and wildfire data from USDA-FS and DOI.

Researchers supported by USGS and USDA-FS investigated how future changes in climate might affect area burned in different types of ecosystems in the western United States, producing data at scales relevant for watershed and landscape management.[7] While results suggest that area burned will continue to increase on a regional level, outcomes for individual landscape types vary. Area burned is expected to grow in forests and some areas with a mix of forests and non-forest vegetation, but decrease in some (though not necessarily all) drier non-forested ecosystems with limited fuel. However, because of changes in other factors that influence wildfire (such as land use, fire suppression practices, or invasive species) that can be difficult to anticipate, these projections do not represent long-term forecasts.

In another project, a USGS researcher examined the current understanding of the relationship between wildfire and drought, and recommended key research directions aimed at increasing the usefulness of that knowledge for managing fire risk.[8] Information on how climate conditions and drought influence wildfire over different timescales, along with a greater understanding of how people affect and respond to wildfires in the longer term, could ultimately result in predictions of the timing and size of future wildfires for use in regional planning.
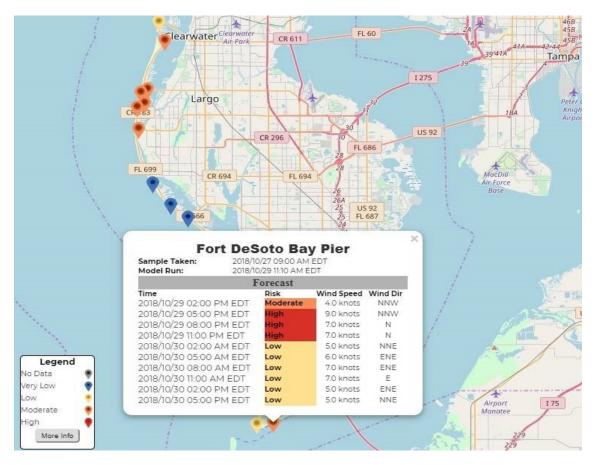
Highlight 8. A new forecast tool helps the public avoid toxic algal blooms

In the Gulf of Mexico, toxic algal bloom outbreaks (or red tides) occur primarily during the late summer and early fall, and can be harmful to people and ecosystems. One of the most severe red tide outbreaks in a decade hit Florida's Gulf Coast throughout the summer and early fall of 2018, with widespread adverse impacts that prompted the governor to declare a State of Emergency in mid-August.

In October 2018, a new pilot smartphone-based information resource developed by NASA, NOAA, and state and local partners began alerting users to red tide risks around St. Petersburg and Pinellas County, Florida. The new 24-hour Experimental Red Tide Respiratory Forecast is updated every three hours and allows the public to see which beaches are currently impacted by red tide and which ones may be impacted over the next day. The forecast system uses satellite data to identify and map the spatial extent of algal blooms, as well as water sampling to test for the presence of toxic blooms.

The tool was developed by NOAA's National Centers for Coastal Ocean Science in partnership with the Gulf of Mexico Coastal Ocean Observing System, the Florida Fish and Wildlife Conservation Commission, and Pinellas County Environmental Management, through funding from NASA. It builds on NOAA's Harmful Algal Bloom Forecast System and the Near Real-Time Integrated Red Tide Information System from the University of South Florida, both of which use NASA satellite data from the Terra and Aqua spacecrafts.

An image from a new pilot smartphone-based information tool that alerts users in Florida's central Gulf Coast to potential respiratory hazards from toxic algal blooms. Credit: Gulf of Mexico Coastal Ocean Observing System.

Highlight 9. Flood mapping helps planners visualize the future of California's coast

U.S. coastal communities are increasingly vulnerable to sea level rise, tidal flooding, higher storm surge, coastal erosion, and other climate-related impacts.[9] To help communities in southern California plan for rising water levels, a NASA DEVELOP team collaborated with the U.S. Geological Survey's (USGS) Pacific Coastal and Marine Science Center, in partnership with the California Coastal Commission, to create detailed projections of flooding from sea level rise and coastal storms along the central and southern California coastline that can inform planning to reduce climate-related risks to future development.

The team updated USGS's online coastal flood prediction tool, the Coastal Storm Modeling System (CoSMoS), using data collected via aircraft and satellite (including the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) mounted on NASA aircraft and the Landsat 8 satellite) to create more detailed flood projections for the central and southern Cal-

ifornia coastline. The team focused on very high tide events, known as king tides, that already cause regular flooding in some low-lying communities in southern California, offering a preview of events that communities can expect to occur more frequently as sea level continues to rise. The updated data allowed the project team to see details from particular king tide events and generate a new baseline for the impacts of future king tides along the southern California coastline.

Using the new satellite and aircraft data, USGS plans to assess the accuracy of and update flood simulations provided by CoSMoS, which, in turn, will provide better flood hazard forecasts for southern California communities. The updated data are among the resources the California Coastal Commission will use as a guide for identifying areas likely to be affected by flooding and erosion as sea level continues to rise.

A king tide flooded parts of Imperial Beach, California in December 2018. Credit: California King Tides Project.

Conducting Sustained Assessments

As required by the Global Change Research Act, USGCRP produces a quadrennial National Climate Assessment (NCA) that synthesizes understanding of present and future climate change processes and the ongoing and potential impacts on society in the United States. Since the release of the NCA3 in 2014, USGCRP has transitioned towards a sustained assessment process that supports ongoing assessment and engagement processes, culminating in a quadrennial assessment, the most recent of which was completed in 2018 (Highlight 10). Through sustained assessment efforts, agency and interagency assessment products provide valuable inputs to the NCA, including the *Second State of the Carbon Cycle Report* released in 2018 (Highlight 11), and serve individual agency and interagency constituencies.

Highlight 10. Assessment products outline climate-related risks and response actions

USGCRP completed the Fourth National Climate Assessment (NCA4) in November 2018 with the release of NCA4 Volume II (*Impacts, Risks, and Adaptation in the United States*). Building on an assessment of observed and projected changes in the physical climate system released as Volume I of NCA4 (*Climate Science Special Report*) in 2017, Volume II focuses on climate-related risks to systems that support our well-being and economy.

A number of ongoing assessment products and efforts undertaken by USGCRP's member agencies and interagency groups provided valuable inputs to NCA4 Volume II. USGCRP led the development of two major sustained assessment products that served as inputs to the report: *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* and the *Second State of the Carbon Cycle Report* (see Highlight 11). A number of USGCRP agency-led products also improved the thoroughness of the assessment, including the USDA-led assessment on *Climate Change, Global Food Security, and the U.S. Food System* conducted on behalf of USGCRP, and *Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis*; NOAA's Climate Resilience Toolkit, Climate Explorer, and State Climate Summaries; and EPA's updated economic impacts of climate change report. In addition, a variety of USGCRP indicators and scenario products supported the evaluation of climate-related risks throughout the report's regional and sectoral chapters, and the report's Overview chapter featured an interactive graphic on climate-relevant indicators based on data collected around the United States.

Both volumes of NCA4 are supported by the Global Change Information System (GCIS), a freely accessible database linking together all the information used in USGCRP assessments. GCIS acts as an advanced, multifaceted bibliography for the more than 6,000 unique references cited across the 29 chapters of Volume II, maintaining easy-to-find records of the sources of all scientific information in the report and providing access to the original data and research. This includes analysis and visualization processes for figures, enabling reproducibility and transparency of results. GCIS also supports other USGCRP sustained assessment products.

NCA4 Volume II was authored by more than 300 federal and non-federal experts, including individuals from federal, state, and local governments; tribes and indigenous communities; national laboratories; universities; and the private sector. The entire process was informed by engagement with hundreds of external stakeholders, including a series of regional workshops that reached more than 1,000 individuals in over 40 cities. Listening sessions, webinars, and public comment periods also provided valuable input to the authors. The report underwent an extensive, multi-phase process of review—involving the submission of and response to nearly 10,000 review comments—received from USGCRP federal agency experts, the general public, and a panel of experts from the National Academies of Sciences, Engineering, and Medicine.

NCA4 Volume II is available at nca2018.globalchange.gov.

Increasing heavy rains are leading to more soil erosion and nutrient loss on midwestern cropland. Integrating strips of native prairie vegetation into row crops has been shown to reduce soil and nutrient loss while improving biodiversity. The inset shows a close-up example of a prairie vegetation strip. Source: Figure 21.2, Ch. 21: Midwest, NCA4 Volume II (Photo credits: [main photo] Lynn Betts; [inset] Farnaz Kordbacheh).
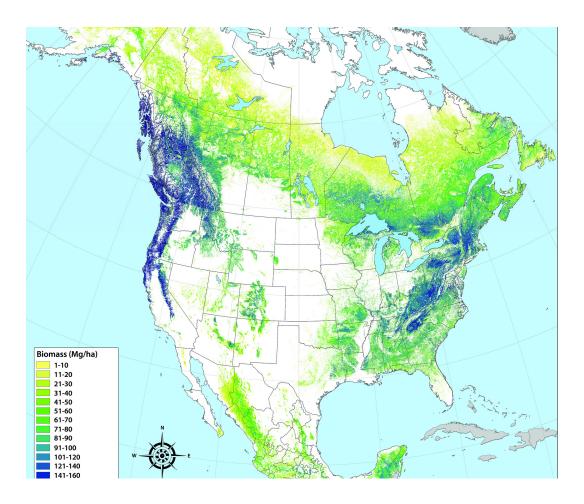
Highlight 11. A major interagency assessment evaluates carbon cycle science and impacts on society

The *Second State of the Carbon Cycle Report* (SOCCR2), released by USGCRP in November 2018, is a state-of-the-science assessment of the carbon cycle in North America and its connection to climate and society. Authored by more than 200 experts from the United States, Canada, and Mexico, SOCCR2 focuses on U.S. and North American carbon cycle processes and their interactions with global-scale carbon budgets and climate change impacts over the last decade.

The report includes an assessment of carbon source, sinks, and flows across atmospheric, aquatic, and terrestrial systems, including natural and managed ecosystems and human systems such as agricultural production. Responding to the needs of stakeholder groups such as natural resource managers, it con-

siders relevant carbon management science perspectives and science-based tools for supporting and informing decisions in the context of a changing climate. SOCCR2 also evaluates the status of and emerging opportunities for improving measurements, observations, and projections of carbon cycle change in North America.

SOCCR2 underwent an extensive, multi-phase process of internal and external review from federal agency experts, the general public, and a panel of experts from the National Academies of Sciences, Engineering, and Medicine.

SOCCR2 is available at carbon2018.globalchange.gov.

This image shows the distribution of aboveground forest biomass across North America, measured as milligrams of biomass per hectare (mg/ha). One hectare is equivalent to about 2.5 acres. This map combines four independently developed maps of biomass for Canada, Alaska, the conterminous United States, and Mexico. Source: SOCCR2, Figure 9.1.

Supporting International Global Change Science

As part of its mandate under the Global Change Research Act, USGCRP works to improve coordination of U.S. activities with the programs of other nations and international organizations in order to promote international cooperation on global change research and build global change research capacity in developing countries. To advance these goals, USGCRP develops international partnerships that support the priorities and objectives of the USGCRP community, link to USGCRP's program areas, and build on existing agency investments and resources. The partnerships and related activities highlighted this year support activities that align with USGCRP's strategic goals and help to maintain U.S. influence and leadership in the international research community.

Highlight 12. A new collaboration on data and decision-making supports sustainability in the Amazon Basin

SERVIR is a joint initiative between NASA and USAID that develops demand-driven services, tools, and training for decision-makers in more than 50 countries. By connecting USAID's development network with NASA's science, geospatial technologies, and extensive satellite data, SERVIR helps strengthen local capacity to integrate science and technology into decision-making.

Since 2004, SERVIR has collaborated with leading regional organizations in the developing world to help people and institutions track environmental changes, evaluate climate threats, and respond rapidly to natural disasters. In March 2019, USAID and NASA initiated activities for SERVIR-Amazonia, a five-year effort that will address environmental and development challenges in the Amazon Basin, home to the world's largest tropical rainforest. SERVIR-Amazonia will be one of five SERVIR regional hubs currently operating around the world, and will be implemented through a network of local and international partners serving the Amazon region.

Highlight 13. Interagency efforts help lead a new international climate and health research initiative

USGCRP agencies and interagency groups played a leading role in the development of a Belmont Forum international Collaborative Research Action (CRA) launched in April 2019, focused on issues at the intersection of climate, environment, and human health.

In addition to an international scoping workshop organized by the Interagency Crosscutting Group on Climate Change and Human Health (CCHHG) and International Activities Interagency Working Group (IAIWG) in April 2018, USGCRP member agencies (including the National Institutes of Health (NIH), NOAA, and NSF) participated in a year-long, international drafting process for a final research call. USGCRP member agencies (including NIH, NOAA, NSF, and USDA) also partnered on the CRA by providing funding or in-kind contributions to support

eligible U.S. researchers. Following the Belmont Forum model, U.S. resources would directly support only U.S. researchers as part of this action. However, this opportunity allows U.S. agencies to leverage the contributions of other international partners and promote scientific collaboration.

The CRA will support international research teams of natural, health, and social scientists and stakeholders, working together to understand how climate variability and change influence human health and well-being, and to support effective responses. The initiative aims to generate scientific evidence and tools to support policy and decision-making that can enhance health system resilience to climate impacts and provide significant public health benefits.

Highlight 14. USGCRP supports major international global change assessments

USGCRP coordinates and supports the engagement of the U.S. science community in major international assessments on global change science, including those conducted by the Arctic Monitoring and Assessment Programme, the Intergovernmental Panel on Climate Change (IPCC), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), as well as science panels informing the Montreal Protocol on Substances that Deplete the Ozone Layer process.

International assessment reports provide policymakers with regular updates on the state of knowledge, current and future risks, and potential response options to climate change, biodiversity loss, and other drivers of global environmental change. Scientists affiliated with and supported by USGCRP are key contributors to major assessments as authors and reviewers, providing technical support and scientific expertise.

In collaboration with the State Department, USGCRP provides support for U.S. author participation in and U.S. government review processes for these assessments. In addition, USGCRP

member agencies support scientific observations and model projections that serve as key inputs into assessment deliverables. In 2019, IPBES published a major global assessment, and IPCC released two Special Reports requested by governments as part of the Sixth Assessment Report cycle.

BUDGETARY INFORMATION

The budget crosscut represents the funds self-identified by USGCRP agencies as their contributions to USGCRP research activities. In addition, USGCRP leverages other agency activities not represented in the budget crosscut to accomplish its mission. For example, many of the satellite systems and surface-based observing networks that are foundational to USGCRP research were originally implemented by their sponsoring agencies for operational purposes, and thus typically are not included in the research crosscut.

FY2020 USGCRP Budget Crosscut by Agency

Funding amounts are shown in millions of dollars ($M) and are rounded to the nearest millions (totals reflect the rounded sum of the unrounded agency amounts).

Agency	FY2018 Enacted ($M)	FY2019 Enacted ($M)	FY2020 President's Budget ($M)
Department of Agriculture (USDA)	103	101	96
Department of Commerce (DOC)	320	293	194
Department of Energy (DOE)	239	259	117
Department of Health and Human Services (HHS)	10	11	10
Department of the Interior (DOI)	25	25	13
Department of Transportation (DOT)	0	0	0
Environmental Protection Agency (EPA)	18	19	0
National Aeronautics and Space Administration (NASA)	1,499	1,484	1,286
National Science Foundation (NSF)	254	237	219
Smithsonian Institution (SI)	8	8	8
TOTAL (USGCRP)	2,477	2,436	1,943

APPENDIX I. USGCRP MEMBER AGENCIES

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

DEPARTMENT OF AGRICULTURE

Global change research at the U.S. Department of Agriculture (USDA) is conducted across multiple mission areas and 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 ranging from temperature and precipitation extremes to the changing infestation ranges and intensities of pests, invasive species, and diseases that result from shifting climatic conditions.

USDA assesses climate change effects on the natural and economic systems associated with productive lands. USDA 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 management and helps build resiliency through the development of information products and decision support tools. USDA maintains critical long-term data observation networks including the Long-Term Agro-ecosystem Research (LTAR) Network, the Snowpack Telemetry (SNOTEL) network, the Experimental Forests and Ranges, the Soil Climate Analysis Network (SCAN), the National Resources Inventory (NRI), and the Forest Inventory and Assessment (FIA). USDA's ten Regional Climate Hubs deliver timely and authoritative tools and information to natural resource management professionals, ensuring that the latest science is available to support decision-making. To that end, USDA engages in many communication, outreach, education, and extension efforts across multiple forums to ensure that decision makers, natural resource managers, and stakeholders have access to the most up-to-date scientific information for management decisions.

DEPARTMENT OF COMMERCE

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

NOAA's mission is to understand and predict changes in climate, weather, oceans and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources. From supercomputers and state-of-the-art models to observations and outlooks, NOAA provides data, tools, and information to help people understand and prepare for climate variability and change. NOAA's current priorities are (1) to reduce the impact of extreme weather and water events (Weather Act of 2017) and (2) to increase the sustainable economic contributions of our fishery and ocean resources (Blue Economy). NOAA aims to advance its goals and priorities through the following research and development vision areas:

- Reduced societal impacts from severe weather and other environmental phenomena;
- Sustainable use of coastal and ocean resources;
- A robust and effective research, development, and transition enterprise.

NIST works with other federal agencies to develop or extend internationally accepted traceable measurement standards, methodologies, and technologies that enhance measurement capabilities for greenhouse gas 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.

DEPARTMENT OF DEFENSE

The effects of certain global changes such as climate change are considered national security issues with potential impacts to Department of Defense (DoD) missions, operational plans, and installations. The 2018 National Defense Strategy prioritizes long-term strategic competition with great power competitors by focusing the Department's efforts and resources to: 1) build a more lethal force, 2) strengthen alliances and attract new partners, and 3) reform the Department's processes. To achieve these goals, DoD must be able to adapt current and future operations to address the impacts of a variety of threats and conditions, including those from weather, climate, and other natural events. To that end, DoD factors in the effects of global change into its mission planning and execution to build resilience.

DoD manages and executes research activities across the Services that while addressing specific national security requirements may also be leveraged to address the strategic goals of the USGCRP. The Navy, through the Office of Naval Research, sponsors basic and applied research in potentially relevant broad thrust areas of marine meteorology, physical oceanography, and arctic and global prediction. The Army, primarily through the Army Research Office (ARO) and the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) sponsor and execute basic and applied research in

relevant areas such as biogeochemical sciences, terrestrial science and phenomenology, and polar science and engineering. The Strategic Environmental Research and Development Program (SERDP), DoD's Joint environmental science and technology program, is planned and executed in partnership with DOE and EPA. SERDP invests in research aimed at enhancing DoD's resilience to a number of environmental threats and includes efforts to develop climate change assessment tools.

DEPARTMENT OF ENERGY

The Department of Energy's (DOE) Office of Science supports fundamental research to address key uncertainties in regional to global-scale Earth system change arising from the interactions and interdependencies of the atmospheric, terrestrial, cryospheric, oceanic, and human-energy components of the Earth system. DOE's research strives to understand and anticipate how environmental and compounding stressors can influence the pattern and magnitude of weather and other extremes, and how these in turn influence the robustness and resilience of U.S. energy infrastructures. Supporting its major role in Earth system prediction, DOE supports long-term field experiments to advance process and systems level understanding; scale-aware parameterizations that can be incorporated into multi-scale models; and advanced software tailored to models that can be ported to DOE's fastest supercomputers. DOE also invests novel machine learning and uncertainty quantification methodologies that allow model products to be more useful to DOE stakeholders. To assist the scientific community in carrying out research, DOE commits significant resources to archiving and management of extensive observed and model-generated data sets for easy retrieval and processing.

There are three areas of DOE research that contribute to the Department's efforts to advance the science of Earth system change: (a) Atmospheric System Research (science of aerosols, clouds, and radiative transfer); (b) Terrestrial Ecosystem Science (role of terrestrial ecosystems and coupled biogeochemical cycles); and (c) advanced modeling that combines development, simulation and analysis. DOE maintains its own suite of advanced modeling platforms, including the Energy Exascale Earth System Model (E3SM), which currently uses DOE's advanced high performance pre-exascale computers; DOE also collaborates with NSF to support the widely-used Community Earth System Model. Using the DOE-supported Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the Earth System Grid Federation, DOE analyzes and distributes large Earth System Model output, with data analytics capabilities available to researchers. The Department also supports the Atmospheric Radiation Measurement (ARM) Research Facility, a scientific user facility based on three permanent observatories and three mobile platforms that in turn 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.

DOE also conducts related applied research involving energy technologies, energy analysis, and prototype infrastructures. The research and analyses undertaken by these offices often requires the development and application of companion models to those used in the Office of Science, e.g., models of energy systems and infrastructures; economics; technology impact; and risk assessment. The applied offices also maintain and update data sets to explore such topics as electric grid stability, water availability for energy production, and siting of 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 air contaminants affected by climate change, 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 greenhouse gas emissions.

Specifically, HHS supports USGCRP by conducting fundamental and applied research on linkages between climate variability and 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 constitutes DOI's formal participation in USGCRP.

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

Specifically, the USGS supports research to understand the physical, chemical, and biological components of the Earth system, the causes and consequences of climate and land use change, and the vulnerability and resilience of the Earth system

to such changes. The USGS Land Change Science and National Land Imaging 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 datasets from these programs are essential for DOI's biological carbon sequestration project (LandCarbon), which is conducting quantitative studies of carbon storage and GHG flux in the Nation's ecosystems.

USGS also leads the regional DOI Climate Adaptation Science Centers, which deliver science to help fish, wildlife, water, land, and people adapt to a changing climate.

DEPARTMENT OF STATE

The Department of State (DOS) contributes to the Intergovernmental Panel on Climate Change (IPCC), which assesses scientific, technical, and socioeconomic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. DOS, with the assistance of USGCRP, coordinates U.S. reviews of IPCC reports to ensure that the reports are a comprehensive, objective, and balanced assessment of the subject matter; nominates U.S. scientists to serve as authors; and represents the United States at IPCC meetings. DOS also works with other agencies in promoting international cooperation in a range of bilateral and multilateral science initiatives and partnerships.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation (DOT) coordinates with USGCRP and its participating agencies to inform transportation system mitigation and resilience solutions. DOT initiatives to improve the resilience of the U.S. transportation sector include:

- The Federal Highway Administration (FHWA) is working with states and metropolitan areas to increase the health and longevity of the Nation's highways through an ongoing program of assessing vulnerabilities; considering resilience in the transportation planning process; incorporating resilience in asset management plans; addressing resilience in project development and design; and optimizing operations and maintenance practices.

- The Maritime Administration (MARAD) Ports Team is scoping a framework for a proposed asset management tool called the Waterfront Asset Management Tool (WFAM) for domestic port planning. This proposed asset management tool would assist public and private ports with tools to establish risk-based asset management plans to prioritize maintenance dollars and provide justification for spending scarce funding for maintenance and/or resiliency priorities.

- The Office of the Assistant Secretary for Research and Technology (OST-R) is working in partnership with the FHWA and the OST Office of Intelligence, Security, and Emergency Response to ensure that the costs and benefits of resilience are incorporated into the transportation infrastructure planning process. The goal is to develop nationally-replicable modelling tools capable of estimating the regional-scale impacts of natural and man-made disasters on the transportation system. These tools will enhance pre-event planning and disaster recovery capabilities.

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 policy makers, stakeholders, 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 defining adaptation options to effectively prepare for and 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 and human health impacts of greenhouse gas emission reduction technologies and approaches to inform sustainable mitigation solutions. EPA Program Offices and Regions leverage this research to support mitigation and adaptation decisions, as well as inform communication with external stakeholders and the public.

EPA relies on USGCRP to develop high-quality scientific models, data, and assessments to advance understanding about physical, chemical, and biological changes to the global environment and their relation to drivers of global climate change. Satellite and other observational efforts conducted by USGCRP agencies are crucial to supporting EPA's efforts to understand how land use change, population change, climate change, and other global changes are affecting ecosystems and the services they provide. EPA's global change research applies and extends these results using regional and local air quality, hydrology, and sea level rise models to better understand the impacts of climate change to specific human health and ecosystem endpoints. These connections 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 and understanding about the connections between global change and impacts at local, regional, and national scales, as well as how mitigation and adaptation actions may influence global changes.

EPA's research informs approaches to prepare for, adapt to, and minimize the impacts of climate change, including extreme weather events, wildfire, and rising sea levels, and their impacts on human health and well-being and social and economic

systems. Other EPA activities include applying long-term datasets, analytical tools, and models to examine and communicate observed climate change indicators and project impacts and economic damages associated with global mitigation scenarios. EPA's technical assistance and analytical expertise supports state and local decision makers seeking to identify, prioritize, and implement adaptation work within their environmental programs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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 22 on-orbit missions (as of July 2019) measure numerous variables required to enhance understanding of Earth interactions. In 2018, NASA launched the Gravity Recovery and Climate Experiment Follow On (GRACE-FO) dual-satellite mission with its German partner GFZ (German Research Centre for Geosciences) to restart the record from the 2002–2017 GRACE satellite mission. GRACE-FO is now continuing the work of tracking Earth's water movement to monitor changes in underground water storage, the amount of water in large lakes and rivers, soil moisture, ice sheets and glaciers, and sea level caused by the addition of water to the ocean. The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument, launched to the International Space Station (ISS) in 2018, is now measuring the surface temperature of plants and using that information to better understand how much water plants need and how they respond to stress. The Ice, Cloud, and land Elevation Satellite (ICESat-2) and the Global Ecosystem Dynamics Investigation (GEDI) also launched in 2018. ICESat-2 is measuring the elevation of ice sheets, glaciers, and sea ice in unprecedented detail, continuing the record of ICESat and making coordinated measurements with Operation Ice Bridge under-flights. GEDI is measuring the structure of Earth's tropical and temperate forests in high resolution and three dimensions from the ISS. In 2019, the Orbiting Carbon Observatory 3 (OCO-3) launched to the ISS and is now adding to the record of global carbon dioxide (CO_2) measurements taken by OCO-2. OCO-3 focuses on understanding the regional sources and sinks of CO_2 from the unique vantage point of the ISS. Several small (U-Class) satellites (also known as CubeSats) deployed from the International Space Station in 2018 as part of NASA's Earth Science Technology InSpace Validation of Earth Science Technologies (InVEST) program and began taking their first measurements and sending data to the ground. Four new projects were also selected as part of the InVEST program: SNOO-PI: SigNals-Of-Opportunity P-band Investigation; Hyperspectral Thermal Imager (HyTI); Compact Total Irradiance Monitor Flight Demonstration; and, High-Resolution Trace-Gas Hyperspectral Imagers, with Agile On-board Processing.

In August 2019, NASA announced that it selected a space-based instrument under its Earth Venture Instrument (EVI) portfolio that will make observations to improve our understanding of the biology, chemistry, and ecology of coastal waters to help protect ecosystem sustainability, improve resource management, and enhance economic activity. The selected Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR) instrument will provide unique observations the Gulf of Mexico, portions of the southeastern United States coastline, and the Amazon River plume—where the waters of the Amazon River enter the Atlantic Ocean. GLIMR will be integrated on a NASA-selected platform and launched in the 2026-2027 timeframe into a geosynchronous orbit where it will be able to monitor a wide area, centered on the Gulf of Mexico, up to seven times a day. This hyperspectral ocean color radiometer will measure the reflectance of sunlight from optically complex coastal waters in 141 narrow wavebands.

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 inter-comparisons. NASA also carries out observationally driven modeling projects that include data assimilation, reanalysis, process representation, initialization, and verification.

In 2018, the Long Island Sound Tropospheric Ozone Study (LISTOS) multi-agency (e.g., NOAA, EPA, and multiple state-level agencies) collaborative study focused on Long Island Sound and the surrounding coastlines that continue to suffer from poor air quality exacerbated by land/water circulations. The primary measurement operations took place between June-September 2018. Campaigns initiated in 2019 include the Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP2Ex) (conducted with the Naval Research Laboratory and Manila Observatory), which will investigate cloud formation in the western part of the Philippines, one of the world's most unpredictable geographic regions for weather and climate model, and the Fire Influence on Regional to Global Environments Experiment - Air Quality (FIREX-AQ) (conducted with NOAA). Fire emissions in the United States derive approximately half from Northwestern wildfires and half from prescribed fires that burn mostly in the Southeast U.S.; FIREX-AQ will investigate both wild and prescribed fires.

Five new NASA Earth science campaigns part of NASA's Earth Venture-class program, selected in 2018, will take to the field starting in 2020.

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, and are focused on such areas as water resources, health/air quality, and ecological forecasting. The Earth science technology program funds, develops and demonstrates a broad range of cutting-edge technologies—from new instruments and components to advanced modeling and information systems—to enable new 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's Global Earth Observatories, examining the dynamics of forests (ForestGEO, formerly SIGEO) and coastal marine habitats (MarineGEO) over decadal time frames.

The Smithsonian also brings together researchers from around the Institution to focus on joint programs aimed at estimating volcanic emissions, understanding and sustaining biodiversity, monitoring animal migrations, characterizing working landscapes and seascapes, or studying emerging infectious diseases in wildlife and humans. 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, the Anacostia Community Museum, the National Museum of African American History and Culture, 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 programs expand 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, education, and outreach programs on these topics.

U.S. Agency for International Development

The U.S. Agency for International Development (USAID) carries out climate change and development work in four main areas: energy, sustainable landscapes, climate resilience, and climate risk management. USAID supports global research and analysis and partners bilaterally with dozens of countries to build capacity, address governance, and create the legal and regulatory environment needed to address climate change and development. This work is integral to helping countries pursue economic growth, stability, and self-reliance.

Energy: USAID helps partner countries build strong energy sectors that can attract private investment and power global economic and social development. USAID's efforts support least-cost modern energy solutions. In many countries, renewable energy is now the least-cost solution that maximizes development impact.

Sustainable landscapes: USAID supports research on estimating and accounting for land-based carbon stocks and greenhouse gas fluxes, and on governance and finance in the land sector, all with a focus on developing countries. USAID also supports partner countries in meeting their commitments to reduce land-based greenhouse gas emissions, often through activities that promote conservation, restoration, and sustainable use of forests, agriculture, and other lands. By improving landscape management, USAID helps to curb destruction and degradation, improve livelihoods, and increase resilience.

Climate resilience: USAID works with partner countries to build climate resilience and disaster preparedness to weather and climate-related shocks and stresses such as droughts, floods, and shifting rainfall patterns. Improved weather and climate information, informed land use planning, and smart infrastructure design are some ways communities can prepare for these risks and avoid setbacks. Thinking ahead and proactively managing risks help sustain livelihoods and maintain critical services, reducing the need for costly disaster response.

Climate risk management (CRM): CRM is an internal USAID practice to assess, address and manage climate risk in new strategies, projects, and activities across USAID's development portfolio, safeguarding U.S. investments through informed decision-making.

With over seventy overseas missions, USAID enables decision makers to apply high-quality climate information to their decision making and enables countries to accelerate their transition to climate resilient, sustainable economic development. USAID achieves these objectives through direct programming and integration of climate change adaptation and mitigation activities into the broader development portfolio.

USAID leverages scientific and technical resources from across the U.S. Government, private sector partners, and nongovernmental organizations and science institutes to develop and implement low-emissions development strategies, creating policy frameworks for market-based approaches to emission reduction and energy sector reform, promoting sustainable management of agricultural lands and forests, protecting biodiversity, and mainstreaming adaptation into development activities in countries most at risk to advance resilient and sustainable development.

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