

Opportunities for Expanding and Improving **CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC**





Office of Science and Technology Policy
National Oceanic and Atmospheric Administration
Federal Emergency Management Agency

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See page 25 for photo credits.



Table of Contents



Letter to America 4

Introduction 6

Principles for Advancing Climate Information and Services to Meet Societal Challenges 8

Our Vision 10

Recommendations on Expanding and Improving Climate Information and Services for the Public 11

Recommendation 1: Focus climate services on the challenges that pose the greatest risks and opportunities to society 11

Recommendation 2: Foster interagency coordination and strategic public-private partnerships to develop, deliver, and continually advance climate services 15

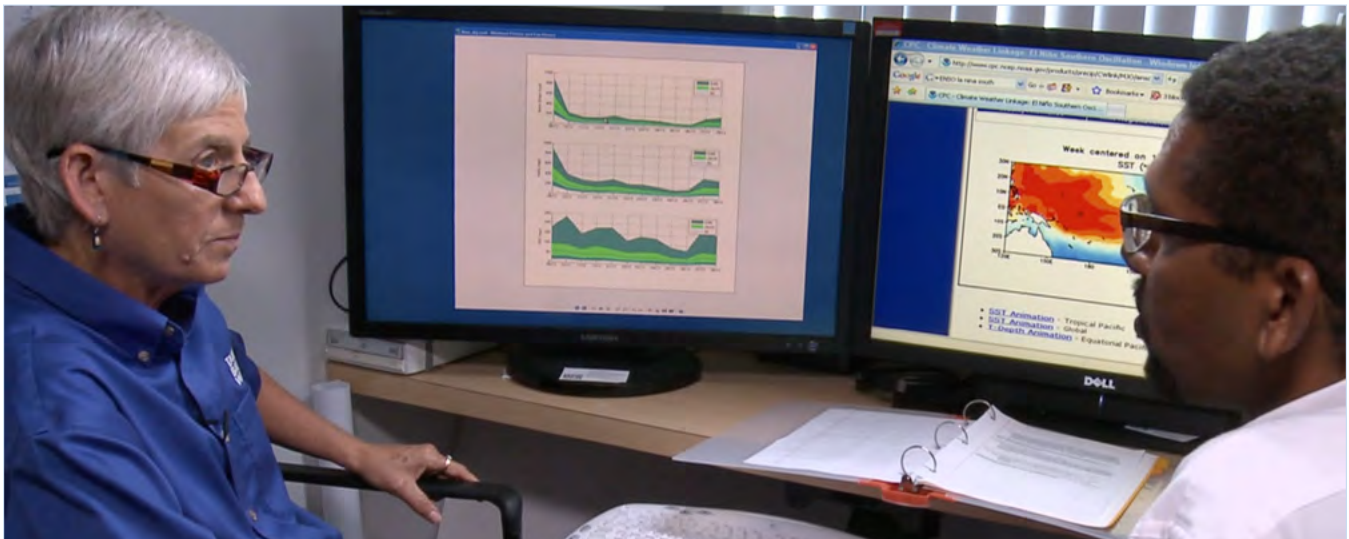
Recommendation 3: Enhance the usability, translation, and relevance of climate services to support use by all Americans 17

Recommendation 4: Strengthen core science capabilities needed to expand and improve climate services 20

Conclusion 23

References 24

Photo Credits 25



Letter to America

Climate change is impacting Americans—and the global community—every day. To tackle this crisis, President Biden issued a call to action in his Executive Order 14008.¹ Section 211(d) directs Federal agencies to develop a plan for expanding and improving climate forecasts and access to information products and services to assist agencies and State, local, Tribal, and territorial governments, communities, and businesses in preparing for and adapting to the impacts of climate change.

Past robust and sustained Federal investments in climate science have provided foundational knowledge that allows us to understand the changes currently underway and to anticipate those to come. However, the urgency of the climate crisis, summarized most recently by the Intergovernmental Panel on Climate Change (IPCC),² demands an even greater effort, both to deliver new knowledge about key unknowns and also to provide existing knowledge and information to the public and decision makers so they can put it to use to support planning, policies, and action. This latter goal depends upon the provision of what is called “climate services,” defined here as scientifically-based information and products that enhance users’ knowledge and understanding about the impacts of climate change on potential decisions and actions.³ These services are made most effective and useful through collaboration between information providers and users. The development and provision of usable climate services will enhance planning across timescales, from weeks to decades into the future, and inform and support both mitigation and adaptation actions.

The Nation urgently needs a suite of significantly enhanced, timely, authoritative, understandable, relevant, and actionable climate services. Federal agencies, whose missions and operations are being impacted by climate change, need better information to plan and to respond. Both public and private sectors need timely, easy-to-find, and understandable climate services at decision-relevant scales to assess vulnerability and inform actions to enhance resilience and reduce future climate change. Every community, especially those who have been historically underserved, needs this information. In this report, we propose actions to meet this challenge.

This report outlines a plan to work across agencies and with users and partners to:

- Develop the robust set of actionable climate services, which are science-based information and products that meet the needs of a diversity of users;
- Design and implement effective tools and equitable delivery mechanisms for climate services;

“The United States and the world face a profound climate crisis. We have a narrow moment to pursue action at home and abroad in order to avoid the most catastrophic impacts of that crisis and to seize the opportunity that tackling climate change presents. Domestic action must go hand in hand with United States international leadership, aimed at significantly enhancing global action. Together, we must listen to science and meet the moment.”

—Executive Order on Tackling the Climate Crisis at Home and Abroad

- Leverage the respective capabilities of Federal and private-sector partners to spur innovation to create climate services that reach all communities; and
- Implement ambitious science and technology initiatives to better understand key unknowns about climate change and how people use services to continually improve and expand knowledge, engagement, and education, bolstering the effectiveness of service capabilities.

Rising to this challenge will require sustained and coordinated engagement to ensure that Federal agencies and our partners develop climate services that are trusted, useful, and used by decision makers and the public.⁴

While accelerating action to reduce global emissions, and while preparing for and adapting to the current and future impacts of climate change to enhance the resilience of U.S. communities and the nation as a whole, we must also consciously and strategically improve and expand climate services to empower all Americans with the science that they need to take action.

Sincerely,



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Introduction

The impacts of climate change are being felt across the United States and around the world, as documented through robust and sustained science and felt through lived experiences. Because the pace of climate change has accelerated and the impacts can be devastating, an unprecedented effort is needed to better inform society's preparedness for, and resilience and response to, current and future changes. Meeting this challenge requires significant new scientific efforts, a whole-of-government approach, collaboration across science and mission agencies, partnerships with the private sector, and sustained engagement with diverse information users to align climate services with decision needs.

This report responds to President Biden's January 2021 Executive Order 14008, Section 211(d) part one: *"To assist agencies and State, local, Tribal, and territorial governments, communities, and businesses in preparing for and adapting to the impacts of climate change, the Secretary of Commerce, through the Administrator of the National Oceanic and Atmospheric Administration, the Secretary of Homeland Security, through the Administrator of the Federal Emergency Management Agency, and the Director of the Office of Science and Technology Policy, in coordination with the heads of other agencies, as appropriate, shall provide to the [National Climate] Task Force a report on ways to expand and improve climate forecast capabilities and information products for the public."*¹

The Executive Order also calls for a report, in Section 211(d) part two, on the potential development of a consolidated Federal geographic mapping service to facilitate public access to climate-related information in support of resilience planning. [The companion "part two" report](#) was developed by the Federal Geographic Data Committee (FGDC) and outlines a plan to facilitate increased public access to the Federal portfolio of climate-related geospatial information and services. This includes climate-related information provided through the GeoPlatform, which helps Federal agencies make their key datasets broadly available in open GIS formats to support geospatial mapping and analysis. These two reports, and their authoring communities, are aligned in their goals of strengthening climate science, climate data, and the discovery and open-access delivery of climate tools and services.

The National Oceanic and Atmospheric Administration (NOAA), the Federal Emergency Management Agency (FEMA), and the White House Office of Science and Technology Policy (OSTP) developed this "part one" report with input from a number of Federal experts with extensive knowledge of the needs and opportunities to respond to the President's directive.

The Executive Order articulates the need for "information products for the public," and here we define those as "climate services," which are scientifically-based, usable information and products that enhance knowledge and understanding about the impacts of climate change on potential decisions and actions.³ The Executive Order also calls for "expanded and improved climate forecast capabilities," and this report interprets that language to mean a broad suite of climate-science capabilities, from observations, to research, to predictions (descriptions of future climate typically ranging from months to years) and projections (descriptions of future climate typically ranging from decades to centuries), to assessments, that support the development of "climate services." Developing usable climate services depends on a strong foundation of climate science made useful at timescales and spatial scales relevant to decision makers looking to prepare for and respond to climate change.

Climate services are made most effective through collaboration between information providers and users.³ The successful development and use of climate services depends on working with communities to identify climate-related vulnerabilities and incorporating social-science knowledge and the experience of practitioners to develop and implement effective methods of engagement, translation, and shared learning. For the purposes of this report, we focus on opportunities for the U.S. Government to advance

climate services that the public needs, as well as the science needed to support the development and use of climate services.

The report draws on the strengths of NOAA as an agency that serves as an authoritative provider of climate science and services, FEMA as an agency working to enhance preparedness for, response to, and recovery from climate-related hazards, and OSTP as the White House office that coordinates broad interagency science and technology initiatives and associated policies. The report also draws on capabilities and examples from across the U.S. Government—from the Federal climate-science agencies that provide valuable information to the agencies who apply this information as they work on the ground with stakeholders to address climate-related threats.

The recommendations in this report identify opportunities for the U.S. Government to make rapid progress on expanding and improving climate services to better address societal challenges:

Recommendation 1: Focus climate services on the challenges that pose the greatest risks and opportunities to society.

Recommendation 2: Foster interagency coordination and strategic public-private partnerships to develop, deliver, and continually advance climate services.

Recommendation 3: Enhance the usability, translation, and relevance of climate services to support use by all Americans.

Recommendation 4: Strengthen core science capabilities needed to expand and improve climate services.

Addressing these recommendations will require increased coordination across multiple Federal agencies to accelerate the development of new knowledge and more actionable services, and to deliver those services effectively and efficiently with a user-driven approach. Recent climate-related weather disasters in the United States and around the world demonstrate the need for better and more timely information to support preparedness, response, and recovery; anticipated future impacts lend additional urgency.



Decision makers and the public look to the U.S. Government for authoritative information. A seamless spectrum of climate services, spanning different decision-relevant spatial scales and timescales, is needed to support preparedness for the next disaster and resilience to long-term climate-related impacts. There is also a need to improve the accessibility and utility of U.S. Government climate information, which can be difficult to navigate and is not always designed at the scale or in a format that enables effective decisions. Climate services should be based on the best-available science, developed in a way that is understandable, actionable, credible, relevant, and communicated clearly. These services should be focused on the challenges that pose the greatest risks and opportunities to society.

Filling current gaps in climate science and technology will help to rapidly advance and expand climate services, making significant leaps in capabilities. For example, developing improved services will depend on improving the resolution and accuracy of climate projections, expanding the types of projections that are provided, and enhancing monitoring and assessment of climate impacts, as well as the effects of different mitigation and adaptation activities. Partnerships will be key to the development and enhanced utility of climate information for addressing decision needs. Non-governmental, State, local, Tribal, and territorial leaders, academic experts, and private-sector entities can help advance scientific understanding, support the development of climate services, and bridge and translate U.S. Government information for specific users.

Growing more sustained relationships of trust between climate-science providers and users will be critical to ensuring that climate information meets user needs. In particular, there is an immediate need to prioritize and engage with communities who have historically been underserved,⁸ and are often on the front lines of climate impacts. Ensuring that climate-service providers and mission agencies work alongside *all* communities, prioritizing those most vulnerable to the effects of a changing climate on their lives and livelihoods, will empower communities with information and technical assistance to help them plan and act.

Principles for Advancing Climate Information and Services to Meet Societal Challenges

Every day, Americans make decisions that are relevant to their current and future resilience to climate change. How much water will their crops or livestock need this year? How high should a bridge be built to withstand future flooding over the next 50 to 100 years? Where should they purchase a home without worrying about the risks of wildfire or storm surge to their property? Should they contact their child's football coach about policies for keeping players cool on extremely hot days? For how many years into the future will sea ice be safe to hunt on? Where should solar and wind energy infrastructure be sited so as to maximize production while minimizing wildlife conflicts?

Having access to climate services that are more useful will enable individuals, governments, businesses, and organizations to make decisions based on sound science. Advancing the development, communication, and accessibility of climate services will require a whole-of-government approach, with increased collaborations between science providers and agencies who work closely with communities. Ensuring that these services are useful will require sustained communication and active listening, providing feedback on what is needed. And addressing climate-related challenges, such as those associated with drought, wildfire, flooding, coastal resilience, and extreme heat can provide timely opportunities for engagement and progress.

Tackling the climate crisis requires a commitment to support all communities, including those that have been historically underserved, so that they are able to adapt and respond. In pursuing the Administration's goal of expanding and improving climate services for the Nation, this report uses the following principles to guide U.S. Government approaches toward addressing the recommendations. The principles are not in priority order; all are equally important.

Principle 1: Foster sustained engagement with information users

In the past, a number of efforts to advance climate services were conducted by scientists, without consultation and communication with desired end users of the information or without input from social scientists who have knowledge about how to build and sustain effective collaborations. This resulted in mismatches between the information provided and the decisions that individuals and organizations

were trying to make. Through decades of improvement, there is now better awareness of the need to continuously engage users across Federal, State, local, Tribal, and territorial governments, communities, non-governmental organizations, and businesses to co-develop climate information and services. This sustained and iterative engagement can advance co-production of knowledge and help to ensure that climate services are useful, usable, and used.⁴

Principle 2: Empower all communities to prepare and respond

Many communities lack the resources and technical expertise to be able to access, tailor, and apply climate services. Many low-income communities and communities of color live in areas of high risk to flooding, heat, air pollution, or other climate-related threats.^{5,6,7} Particular attention should be given to the identification and support of communities that have been historically underserved, defined in President Biden’s Executive Order 13985 as “populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life.”⁸ Research and lived experience show that historically underserved communities suffer disproportionately from disasters and climate change.⁷ These communities may have specialized needs and may also face more limited options for adapting than communities in lower-risk areas or with more technical or financial resources. There must be a concerted effort to ensure that relevant, accurate, and authoritative climate information and services reach everyone, with particular attention to community issues such as health, housing, and transportation. Collaboratively communicating about and addressing climate risks will require building relationships of respect, listening, and trust so that climate-science providers are deeply versed in community needs.

Principle 3: Strengthen public-private partnerships

The U.S. Government does not have the capacity to provide tailored climate information and services for every potential information user. Scaling up the pace and extent of climate-service delivery will require partnerships with other governmental entities, businesses, non-governmental organizations, and university experts. This provides an

opportunity for innovation and customization, through active listening and co-production, developing information and services as a collaborative effort between the science producers and the users of that science. Importance should be placed on aligning the development and deployment of climate services at a cadence that is most useful and relevant for informing decisions. In alignment with Principle 2, increasing partnerships between Federal agencies and the private sector should not mean that climate products and services are only available to those best able to pay, as this would exacerbate inequities and risk by decreasing the availability of information for historically underserved populations who are likely least able to pay for services.



Principle 4: Continuously ground climate services in sound science

Climate services need to not only meet the needs of today, but to evolve and improve as new knowledge becomes available and as evaluation of existing tools and delivery mechanisms guides their improvement. Iterative learning and improvement will be essential. This will entail continuously integrating the evolving underlying science, including new observational and monitoring data, modeling information, research, and feedback from analyses of the effectiveness of existing climate service tools and modes of service delivery. Continuous refinement of climate services should also reflect and align with planning, policy development, investment, and other decision needs related to climate adaptation and mitigation. The science to support decision making will need to be integrated across disciplines—including physical, geospatial, biological, ecological, and social sciences, as relevant. Accountability and verification measures, and transparency and traceability, must characterize new climate information and services. Authoritative, publicly-available climate data and information from the U.S. Government, shared in a user-friendly way, will facilitate integration with other risk and opportunity information used by planners, engineers, developers, and emergency managers.

Our Vision

We envision a future in which every American, every community, and every business has access to usable climate services that empower them to prepare, respond, and be resilient to climate change.

We understand that meeting this challenge will require a significant, concerted, whole-of-government approach, across agencies and with partners outside of government. This will also require sustained, iterative engagement with information users to provide enhanced “customer service” and build relationships to raise mutual awareness of information needs and capabilities. Underpinning this effort is a need for advances in science, coupled with improved methods for service development, to quickly connect communities with the information they need to act.



Recommendations on Expanding and Improving Climate Information and Services for the Public

The impacts of climate change are being experienced across the Nation and around the world, with effects on all regions and economic sectors.^{1,5} Warming of ocean basins is altering storms and weather patterns and impacting biological resources, including a number of commercial and recreational fish species and coral reefs. Rising sea levels threaten coastal populations, drinking water, agriculture, and infrastructure through flooding, salt water intrusion, and storm damage. Increasing air temperature and changes in precipitation patterns impact human health, community resilience, agricultural productivity, natural resources, and fire weather. The Arctic is changing rapidly and dramatically, threatening the ways of life of Indigenous Americans and other residents, and impacting natural resources, energy, and national-security infrastructure.^{9,10} These impacts are disproportionately felt by low-income communities and communities of color, as well as those who work in climate-dependent industries, such as agriculture, fisheries, recreation, and tourism. Accelerating the development and use of climate services will enable Americans to better understand and address their climate-related risks, and will empower other parts of the U.S. Government to address climate-risk management through their missions and operations. Together, we will work inside and outside of government to enhance national resilience and tackle the climate crisis. The following recommendations provide priority areas to advance this goal.

Recommendation 1: Focus climate services on the challenges that pose the greatest risks and opportunities to society

In the development of climate services, priority should be given to the challenges, risks, and opportunities facing society—now and in the future. The National Climate Task Force, created under [Executive Order 14008](#), has to date established five new interagency working groups to enhance climate resilience: Drought Resilience, Flood Resilience, Coastal Resilience, Extreme Heat, and Wildfire Resilience. These working groups provide an opportunity to bring together agencies that produce science with those that use science to support their missions and operations. A number of Federal agencies are advancing information and services to build resilience across these five climate impacts as well as others. This report highlights some of the existing and emerging efforts underway.

Inform drought preparedness and response: Drought is having severe impacts on the United States, particularly in the West. The Drought Resilience Interagency Working Group, co-chaired by the U.S. Department of Agriculture (USDA) and the Department of the Interior, was established to facilitate interagency coordination on drought relief for affected communities and businesses. Many economic sectors, such as agriculture and ranching, are sensitive to regional changes in water availability. These water-dependent sectors are reliant on actionable climate information and services.

A number of Federal agencies are advancing the development and sharing of drought information through climate services to better address these needs. For example, the [U.S. Drought Monitor](#) is a weekly map of drought conditions produced jointly by USDA, NOAA, and the National Drought Mitigation Center. The U.S. Drought Monitor supports many decision needs, from USDA decisions around disaster declarations and eligibility for low-interest loans, to Farm Service Agency determinations of eligibility for their Livestock Forage Program, to State, local, Tribal, territorial, and basin-level decisions around drought response. The National Aeronautics and Space Administration (NASA) is integrating satellite and other weather data and open-source models into their [OpenET platform](#); this system makes data on evapotranspiration available to farmers, ranchers, and water managers at the scale of individual fields and farms. The interagency [National](#)

[Drought Resilience Partnership](#) is bringing together climate-science agencies with climate-information users, to advance understanding of, preparedness for, and response to drought. These partnerships provide important platforms for science and services coordination.

Inform decision making around current and future flood risks: U.S. and global communities are increasingly experiencing the impacts of flooding from changes in precipitation, water level, sea-level rise, and coastal inundation during storms. For example, extreme rainfall events and associated flash flooding have been overwhelming municipal infrastructure. These impacts highlight the need to address increases in flooding, both those that are already underway and those expected to come. Understanding the effects of climate change on flooding, as well as solutions for enhancing resilience, will enable communities to better assess their risks and prepare. President Biden's [Executive Order 14030](#) reinstated the Federal Flood Risk Management Standard (Flood Standard), a policy to improve the resilience of the Nation's communities and Federal assets against current and future flooding.

Adapting Stormwater Infrastructure to Increasing Precipitation Intensity. Camden County Municipal Utilities Authority (CCMUA) in New Jersey has experienced sewer flooding during intense rain events due to the age of their system and the lack of available funding for infrastructure replacement. Realizing that climate change is expected to increase the frequency and intensity of storms, CCMUA's utility operators decided to learn more about the utility's current and future vulnerability. Working with the Environmental Protection Agency (EPA), CCMUA used the Climate Ready Evaluation and Awareness Tool (CREAT) to learn more about the magnitude of its Combined Sewer Overflow (CSO) and other vulnerabilities and to identify potential adaptation strategies. The CCMUA partnership with the state environmental protection agency, the local university, and local non-profits enabled the municipality to integrate water conservation and promote a comprehensive network of green infrastructure programs and projects that will help Camden adapt to future conditions.¹¹

FEMA, the White House Office of Management and Budget (OMB), and the Council on Environmental Quality (CEQ), are co-leading the Flood Resilience Interagency Working Group to advance the implementation of the Flood Standard. A whole-of-government approach to this task requires easily accessible and usable climate information and services. For example, OSTP is initiating a Science Sub-group to connect agencies with climate information to support implementation of the Flood Standard. Federal agencies such as FEMA are also working to better integrate climate information and risk into their grant programs, as well as into products such as FEMA's [National Risk Index](#) and flood maps developed through [Risk MAP](#), to better represent current and future flood risk across a broader range of flooding scenarios. Historically underrepresented, underserved, and under-resourced communities suffer disproportionately from disasters, including flooding.⁷ FEMA, the Department of Housing and Urban Development (HUD; e.g., through their Community Development Block Grants), EPA, and other agencies are actively working to ensure that these communities have equitable access to funding and support before, during, and after disasters and that such assistance neither reinforces nor exacerbates existing inequalities.

Improve coastal resilience to inundation and hazards: Coastal regions are being affected by sea-level rise, stronger and more frequent storms, increased flooding, and other climate-related impacts. America's coasts concentrate almost 40% of the population on only 10% of the country's land mass. Approximately 40% of U.S. coastal residents fall into an elevated coastal hazard risk category, and these residents include children, the elderly, households where English isn't the primary language, and those in poverty.¹² Coastal communities are actively looking to apply climate information to reduce their risks to current and future change.

Recognizing the need to address current and future coastal change, the Coastal Resilience Interagency Working Group, co-chaired by NOAA and CEQ, is working to: align major Federal involvement and programs in coastal resilience, develop effective and equitable grant-making strategies, and facilitate use of Federal data sharing and mapping resources to improve coastal resilience investment decision making. This provides an important opportunity for groups like the National Science and Technology Council's Subcommittee on Ocean Science & Technology and the U.S. Global Change Research Program, a consortium of 13 Federal climate-science agencies, to support coastal resilience through identifying coastal climate information, tools, services, and addressing research needs. Efforts to enhance usable information and services for decision making in coastal regions can build off of existing information platforms, such as NOAA's [Digital Coast](#) and NASA's [Sea Level Change Portal](#).

Improve understanding of, and resilience to, extreme heat: As global temperatures rise, extreme-heat effects are being experienced with higher frequency and severity, and are often associated with impacts on air quality. The Extreme Heat Interagency Working Group, co-chaired by the Department of Health and Human Services (HHS), the Environmental Protection Agency (EPA), and NOAA, is bringing together science, environmental, health, and response agencies to advance short- and long-term strategies to reduce the impacts of extreme heat on vulnerable communities, including low-income communities, homeless populations, and outdoor workers.

Predicting extreme heat and informing societal response depends on actionable climate information, maps, tools, and services. The U.S. Global Change Research Program's Interagency Crosscutting Group on Climate Change and Human Health and other experts are working with the Extreme Heat Interagency Working Group to ensure that advances are made in climate information to support the understanding of and preparedness for heat-related health impacts. Addressing the risks of extreme heat requires close collaboration with the healthcare sector (such as HHS and EPA), emergency management officials, natural resource agencies that provide cooling green infrastructure (such as the U.S. Forest Service [USFS]), and other users of climate information, to anticipate and respond to information needs. The [National Integrated Heat Health Information System](#) (NIHHIS), jointly developed by the Centers for Disease Control and Prevention (CDC) and NOAA, provides actionable, science-based information to help decision makers reduce exposure and manage their risks.

Integrating Climate Information into FEMA Grant Programs. FEMA's Hazard Mitigation Assistance grant programs, which include the Building Resilient Infrastructure and Communities (BRIC) grant program, encourage innovative mitigation projects (i.e., sustained actions taken to reduce or eliminate long-term risk to life and property from a hazard event) that can assist communities in adapting to climate change while realizing related benefits for sustainability and other community priorities. Mitigation is any sustained action taken to reduce or eliminate long-term risk to life and property from a hazard event. FEMA encourages communities to consider a system-wide planning approach to mitigation to help build community-wide resilience to natural hazards exacerbated by climate change. With easier access to the latest climate data, communities will be able to develop more robust and accurate community hazard mitigation plans, which will guide community decision making and aid in scoping and prioritizing mitigation projects to reduce risks. BRIC supports use of future conditions data in project design through the award of additional qualitative points for projects that: (1) enhance climate adaptation, (2) detail how the project is being responsive to the effects of climate change (such as sea-level rise), (3) detail how the project is being responsive to the effects of other future conditions (population/demographic, land use, etc.), and (4) cite data sources, assumptions, and models. Increasing FEMA's access to and understanding of climate data and information can also inform FEMA's future year Benefit-Cost Analysis (BCA) methodology for Hazard Mitigation Assistance grants. FEMA regularly reviews its BCA tools and guidance to ensure that they capture all appropriate sources of benefits of mitigation activities. Increasing access to and use of climate information and services could also help FEMA grant applicants more accurately capture the benefits of performing mitigation actions, as compared to the costs of future damages.¹³

Enhance the resilience of the United States

to wildfires: Wildfires are a growing hazard in the United States, as evidenced by an increasing number of large blazes and prolonged seasons. Extreme heat and drought are exacerbating this challenge. Given the rapid growth in the scope and intensity of wildfires, there is renewed urgency in increasing the resilience of forests and grasslands by using prescribed fire, mechanical thinning, and other techniques to reduce hazardous fuel loadings. Post-fire tree replanting efforts and other restoration activities are also getting top priority. The Wildfire Resilience Interagency Working Group, co-chaired by DOI, USDA, and OMB, has been formed to facilitate this important, longer-term resilience work. The Interagency Working Group will build on the highly-successful [National Interagency Fire Center](#) model of collaboration, which coordinates wildfire response efforts the Bureau of Indian Affairs, Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, USFS, along with partners from the National Association of State Foresters, the FEMA U.S. Fire Administration, the Department of Defense, and the National Weather Service. The Wildfire Resilience Interagency Working Group will include focus on sharing best practices across landscapes and ecosystem types and applying science to assist in mapping wildfire risk areas and associated fuel-reduction targets. The Interagency Working Group will be looking for new information resources to help accomplish these tasks, in much the same way as individuals and communities threatened by wildfire use tools (e.g., [AirNow Fire and Smoke Map](#) developed by the EPA, CDC, and the USFS) to avoid dangerous wildfire smoke exposure. Climate-science agencies will be at the table, to help provide information (e.g., predictions and long-term trends) and understand needs associated with this longer-term wildfire resilience work.

Build partnerships between science providers and users: These challenges and emerging efforts to enhance cross-governmental coordination should serve as a near-term opportunity for building partnerships between science providers and information users. These partnerships will ensure that decision makers have access to information that they need to understand their vulnerabilities to climate-related impacts and to develop solutions that address them. In addition, social science directed at a greater understanding of community values, preferences, and the nature of compound risks involving a changing climate will help to support solution-oriented strategies.

Significant advances in climate science and services are needed for other climate-related threats in addition to the above-noted drought, flood, coastal resilience, extreme heat, and wildfire challenges. Climate change

Applying Climate Information and Tools to Address Coastal Flooding. The City of Hallandale Beach is a 4.6 square-mile-wide city in Broward County, Florida that is vulnerable to coastal flooding, requiring actions such as elevating bridges and improving stormwater management. To support and prioritize that work, Hallandale Beach requires local data and information, because many Federal datasets are not usable at the local level, and well-known products offered by the private sector have skipped their zip code. Consequently, Hallandale Beach has relied on a mix of Federal and non-Federal products, such as: U.S. Census and tide-gauge data, the NOAA Coastal Flood Exposure Mapper, the NOAA Sea-level Rise Viewer, and the Coastal Resilience Mapping Tool; information downscaled by the [Southeast Florida Regional Climate Change Compact](#); and information products offered by the Urban Sustainability Directors Network. This mix-and-match approach is necessary because no single product serves Hallandale Beach well. In addition, Hallandale Beach was awarded funding through [FEMA's Hazard Mitigation Grant Program](#) to construct an expanded drainage system to better address future flooding. This system proved effective when Category 4 Hurricane Irma battered the City in 2017, and the pump stations helped to control floodwaters and reduce impacts to properties. Ensuring that Hallandale Beach and other communities have trusted and useful climate information and services, as well as support needed for implementation, is key to enhancing coastal resilience.¹⁴

also poses threats to public health (e.g., through emerging disease risk and air pollution); safety and longevity of infrastructure (e.g., through flooding, worsened storms, and more severe wildfires); fisheries, aquaculture, and other ocean sectors (e.g., through ocean acidification, warming, and deoxygenation); community livelihoods (e.g., through climate-related impacts on ecosystems and community infrastructure and associated cultural disruption from displacement of traditional communities, resources, or customary practices); ecosystem health (e.g., through climate-related increases in invasive species and loss of biodiversity), and more. In addition, potential tipping points in the climate system—ranging from melting permafrost to melting ice caps and glaciers, from ocean circulation to rapid changes in forest carbon sinks—would have dramatic changes on many of the above climate-related challenges. Consequently, significant advances in climate science (see Recommendation 4), but especially, continued interaction between climate scientists developing services and those affected by these impacts, are imperative.

Recommendation 2: Foster interagency coordination and strategic public-private partnerships to develop, deliver, and continually advance climate services

Communities, economic sectors, and organizations have unique needs in terms of the nature, location, content, and form of the information they need to prepare for and respond to the changes, based on the risks and realities that they face. They look to a diverse range of Federal agencies as trusted sources of credible, science-based information. Advancing climate services at actionable scales and with useful content will require a more cohesive and collaborative, whole-of-government approach that leverages the expertise and trusted relationships of Federal agencies with communities, while enhancing coordination on underlying fundamental information.

The United States currently coordinates Federal research investments in climate, weather, ocean, and resilience science, modeling, and observations through organizations such as the relevant subcommittees of the National Science and Technology Council (including the Subcommittee on Global Change Research/[U.S. Global Change Research Program](#) [USGCRP], Subcommittee on Ocean Science and Technology [SOST], Subcommittee on Resilience Science and Technology [SRST], [U.S. Group on Earth Observations](#) [USGEO], and the [Interagency Arctic Research Policy Committee](#) [IARPC]), as well as the recently established [Interagency Council for Advancing Meteorological Services](#) (ICAMS). In addition, as noted above, the National Climate Task Force has created a number of Interagency Working Groups to address Drought Resilience, Extreme Heat, Wildfire Resilience, Coastal Resilience, and Flood Resilience. To develop and deliver state-of-the-art climate services, however, will require much greater and more strategic alignment and coordination of existing efforts that respect, empower, and leverage existing missions and mandates across Federal agencies and also identify areas where new mechanisms might be considered. The goal of this recommendation is to leverage the best assets of individual agencies and entities to facilitate much more effective integration and uptake of the climate information and services that are needed.

Provide information that can be customized to accelerate service delivery: While the U.S. Government provides core climate information and services, Federal agencies do not have the capacity to engage individually with each community and organization that wants tailored climate services. Information users also have varying levels of familiarity with climate information and different decision needs. As a result, the U.S. Government often relies on non-Federal entities, such as State, local, Tribal, and territorial governments, academic institutions, non-governmental organizations, and the private sector, to work with specific information users and customize and translate Federal climate information and services, accelerating the pace, scale, and footprint of locally-relevant and useful climate information. This diversity of needs provides an opportunity for an emerging climate services industry that is spurring innovation and job growth, while also supporting and accelerating actions that enhance local resilience. Working through partnerships also improves understanding of the needs of consumers, provides feedback

to Federal climate science and service providers to inform prioritization, and helps to build collaborative networks of scientists and practitioners working together to address climate change.

Advance a coordinated set of climate services:

Advancing a coordinated set of climate services will enable ready access to consistent, authoritative information at decision-relevant scales to assist Federal, State, local, Tribal, and territorial governments in resilience activities. The path to coordination should leverage existing, trusted relationships with Federal agencies accountable for ensuring use-inspired services and information dissemination, such as FEMA for emergency management, HUD for housing and community development, USDA for agriculture and forests, and the CDC for public health. Other primary relationships include universities that advance knowledge relevant to State and local services; professional associations that leverage sector-specific audiences; and the private sector, which will continue to expand products and services.

Improve the navigability of U.S. Government climate information and services, and advance an integrated information system:

Many information users, from city officials to individual homeowners, have indicated that they find the U.S. Government's climate information and services to be difficult to access. They don't know where to go to find what they are looking for, as the volume of information and products is overwhelming and can be challenging to navigate without familiarity with each Federal agency. There is a need to improve the discoverability, integration, and transparency of the U.S. Government's climate information and services, so that there is a "no-wrong-door" approach for those trying to access and use information.

Streamlining access to information can enable users to enter from multiple sources and channels and seamlessly and consistently receive the information they need.

Providing a coordinated entry point for existing Federal information resources is an important step to improving access. USGCRP agencies are currently planning for just such an online information system, building off of efforts like the [U.S. Climate Resilience Toolkit](#). The vision for this system is to provide easy access to:

- Projections of physical climate information (e.g., temperature, precipitation) at best-available model resolution (i.e., 100 to as low as 25 kilometers);
- Downscaled projections that enhance that resolution to scales useful for local decision makers;

Enhancing Tribal Resilience to Climate Change.

The Sacramento Mountains—home of the Mescalero Apache Tribe in southern New Mexico—are experiencing a shift to a warmer and drier climate. Local meteorological records reveal that 3 of the area's worst 10 droughts, and some of the highest temperatures ever recorded in the region, have all occurred since 2011. Trends show that the monsoon season is arriving later in the year, and the average duration and frequency of monsoon rains is decreasing. Additionally, the average duration and intensity of winter snowfall has decreased, reducing the Tribe's water supply and negatively impacting the Tribe's Ski Apache ski resort. Recognizing the threats of a changing climate, Tribal government leaders and managers are working with a range of Federal, State, and local government agencies and academia to maintain ecosystem health and resiliency and promote local, healthy foods. The Tribe's Forest Plan features reducing forest fuel loads, monitoring forest and ecosystem health, and managing invasive species. Their active forest management plan has promoted recovery from the 2012 Little Bear Fire, which devastated surrounding communities. Through the U.S. Fish and Wildlife Service's Tribal Wildlife Grant Program, the Tribe is working with academic and State partners to determine the potential influences of a changing climate on the native range of cutthroat trout. With funding from several Bureau of Indian Affairs programs, supplemented with assistance from the EPA, the Tribe is improving water quality in its fish hatchery to prevent higher contaminant loading as climate change decreases the frequency of flushing streamflows. Collectively, these actions are enabling the Tribe to enhance their resilience by using their knowledge of climate change to adapt.¹⁵

- Derived products that translate these physical parameters into projections of future flood and wildfire risk, as well as sea-level rise; and
- Indicators of observed and projected changes in societally-relevant factors, such as extreme heat (for emergency responders, athletes, and outdoor workers) or sea-ice coverage (for Indigenous communities, the shipping industry, and national security).

This consolidated climate information system is intended to be readily accessible to anyone looking to understand and address future climate impacts, including those communities most vulnerable to climate change and with the fewest resources to prepare and respond. Once established, such a climate information system would solicit and respond to feedback from users to improve the system and provide information to the Federal research programs that produce the underlying information. Close coordination and communication would be needed with a diversity of potential information users to identify and address any barriers to access and use. An analysis of the Federal Government’s ecosystem of climate data, information, and tools from the perspective of the end-user, such as a local adaptation practitioner, would help to inform this effort and ensure that it is designed and implemented in a way that maximizes accessibility and usability.

Geospatial information and maps often serve as a backbone for the many types of climate information products and services discussed in this report. The Federal Geographic Data Committee (FGDC) plays a key role in coordinating Federal geospatial activities among agencies that are using GIS maps to help develop and provide information products for a wide variety of user groups on multiple climate-related topics. Enhancing Federal geospatial capabilities, as described in the [FGDC’s companion report](#) to this document, can advance the overall success of the information products and mapping enterprise.

Recommendation 3: Enhance the usability, translation, and relevance of climate services to support use by all Americans

Advancing the use of climate services will require communication, engagement, and partnerships to build shared awareness. Social scientists and those skilled in science translation and engagement will have a key role to play in helping inform each of those aspects. Online climate services alone will be insufficient for supporting use. For example, many potential consumers are not familiar with the language, process, or limitations of climate projections. Community planners or mission agencies may have difficulty assessing which data, information, and tools are most relevant for their decision needs. They may not know what information the science can (or cannot) provide them. And many science providers are not aware of the specific and often complex decisions that climate services are intended to support, or what other factors are being integrated into decision making.



Growing the cadre of individuals skilled at this type of engagement between science providers and users, through pathways such as fellowships, the emerging Civilian Climate Corps,¹ agency training opportunities, and extension services, will be key to improving uptake, use, and utility of climate information. Professional planners, such as urban and regional planners, and agency planning officials, also play a critical role as information users and translators, working to prepare for a more sustainable future. In these efforts,

priority should be given to communities who have been historically underserved and left behind, including those that are among the most vulnerable to the impacts of climate change and that currently lack access to information and technical and financial resources to support their planning.

Enhancing climate resilience requires multiple steps: exploring hazards, assessing vulnerability and risk, investigating options, prioritizing and planning, and taking action.¹⁶ Linking this capacity to existing programs and trusted relationships is critical to ensuring that public investments across this spectrum consider a changing climate in specific places and for specific decision needs. The U.S. Government supports a number of organizations that connect climate science to decision makers on the ground; for example:

- The U.S. Department of the Interior’s network of [Landscape Conservation Cooperatives](#) bring together land, water, and wildlife managers who identify climate vulnerabilities and develop regional adaptation approaches that are informed, in turn, by applied science research that is conducted by [U.S. Geological Survey’s National and Regional Climate Adaptation Science Centers \(CASCs\)](#).
- The [U.S. Department of Agriculture’s Climate Hubs](#) develop and deliver science-based, region-specific information and technologies to agricultural and natural resource managers to enable climate-informed decision making, and they provide assistance in implementation of those decisions.
- [NOAA’s Regional Integrated Sciences and Assessments \(RISA\)](#) program supports interdisciplinary research teams (of physical, natural, and social scientists) that expand and build the Nation’s capacity to prepare for and adapt to climate change impacts. RISA teams work with public and private user communities to advance partnerships, support knowledge to action networks, and innovate services, products, and tools to enhance the use of science in decision making.

These are just a few of the many U.S. Government programs that support the provision of climate services on the ground, including through partnerships with non-Federal entities.

Expand sustained engagement with information users:

Expanding on successful models of engagement, and building sustained relationships, including with communities who have been historically underserved, will be key to advancing usable climate services. Networks that connect science providers and users must be bidirectional in nature, with consumers influencing the provision of information and services, and the Federal Government using that input to not only improve the information resources, but also to influence the research and development activities in the government that are producing the underlying information. OMB and OSTP released research and development priorities for the Fiscal Year (FY) 2023 budget to Federal agencies, which included: “prioritizing efforts to connect science and decision making through meaningful engagement

Empowering Global Communities with Climate Data and Information.

A joint initiative of the National Aeronautics and Space Administration (NASA) and United States Agency for International Development (USAID), and leading geospatial organizations in Asia, Africa, and Latin America, SERVIR works with countries and organizations in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality. Using satellite data and geospatial technology, SERVIR co-develops innovative solutions through a network of regional hubs to improve resilience and sustainable resource management at local, national and regional scales. SERVIR increases awareness and access to information and supports analysis to help people in these regions make a range of decisions that can increase resilience to climate change and reduce emissions from land use through early action and the use of Earth observation information, Earth science, and technology. With activities in more than 50 countries, SERVIR has already improved the capacity to develop local solutions by developing over 40 custom services, collaborating with over 600 institutions, and training more than 10,000 individuals. SERVIR relies on partnerships with other agencies, including NOAA, EPA, USDA, including the U.S. Forest Service, and the U.S. Geological Survey, with expertise in scientific research and international development.¹⁷

with climate information users, including through the application of user-friendly climate tools and services.”¹⁸ The U.S. Global Change Research Program can play an important leadership role by coordinating across climate-science agencies to inform and support these efforts, including through connecting the National Climate Task Force’s Interagency Working Groups with relevant science and services, and through providing relevant science-based information that supports agencies’ efforts to implement climate action plans.

Integrate robust engagement into climate

assessments: Climate assessments, which provide integrated information on current and projected climate impacts, are frequently used by decision makers and serve as an important opportunity for engagement. Efforts such as the [National Climate Assessment](#), the [Intergovernmental Panel on Climate Change](#), the [State of the Climate Report](#), and the [Arctic Report Card](#) depend upon continuous user engagement and the full cycle of assessment capabilities. To expand and improve these capabilities, assessments should provide information that can support the creation of tailored information products that address sector-specific and local decision needs. Assessments should include more in-depth engagement with local communities and underrepresented groups to incorporate more diverse knowledge sources. For example, the Arctic Report Card has been made more robust with engagement with Indigenous experts and content from traditional knowledge.

Listen and learn through experience:

Approaches to providing and sharing climate information, tools, and services should be informed by the realization that it is difficult to do this well, and that capabilities will improve as experience is gained. This means that approaches should have built-in opportunities for evaluation, learning, and refinement. Additionally, the need for learning means that mechanisms need to be put into place so that the needs of stakeholders and decision makers inform the U.S. Government’s climate-science agenda. The U.S. Government and non-Federal partners can also help share lessons learned and build communities of practice across information users with similar decision needs (e.g., coastal municipalities experiencing nuisance flooding due to sea-level rise). Information users also need assistance designing and implementing solutions to advance adaptation and mitigation, and both Federal and non-Federal case studies and other sources of information can help them to understand and assess options.

Addressing Climate Risks to the Department

of Defense. The Department of Defense (DoD) has identified climate change as a critical national security threat and has taken steps at DoD installations to address vulnerabilities from climate change, beginning with a high-level screening of exposure of installations to climate hazards. These hazards include heat, drought, coastal and riverine flooding, wildfire, secondary impacts (land degradation and energy demand), and historic extreme weather. There are approximately 5,000 DoD locations worldwide, each facing unique climate change risk factors. To better understand and manage these risks, DoD has adopted and expanded a climate change tool designed by the U.S. Army Corps of Engineers to project the effects of climate change on almost 1,400 of these locations to date. The DoD Climate Assessment Tool, or DCAT, enables personnel at all levels of the Department—from installation planners to leadership—to understand each location’s exposure to climate-related hazards using historical data and future climate projections. By providing installation managers with knowledge about the range of future climate conditions, DCAT helps managers determine major climate hazards and whether additional in-depth analyses are necessary. Both the screening-level insight from DCAT and local knowledge of sensitivity and adaptive capacity are needed to identify appropriate climate adaptation steps. A “multiple lines of defense” approach can include a mix of management, temporary, structural, nature-based, and nonstructural measures to enhance performance and resilience over the intended project lifecycle.¹⁹

Enhance climate literacy and grow a next-generation workforce: Advancing climate information and services requires a well-trained and diverse workforce. The Biden-Harris Administration is working to reinforce the Federal workforce and protect scientific integrity.²⁰ Federal agencies are growing the climate literacy of their existing workforces through education and training. They also are advancing the development of climate information resources for educators and students, across ages and career stages, to advance understanding of the climate challenge and encourage interest in these fields. In their efforts to educate, train, recruit, and retain a next-generation workforce, agencies should ensure that this workforce is enriched by all forms of diversity, from expertise, to gender, to race and ethnicity. Providing education, training, and experience around translating climate science and working with information users to understand and address their needs can grow these important skills. The OMB-OSTP memorandum with research and development priorities for the FY 2023 budget notes that facilitating public access to climate-related information will need to be coupled with “capacity building and training to increase access to and support the use of data, information, and climate services.”¹⁸ Having a workforce that better reflects the diversity of America and is trained in connecting science and decision making will enable improved identification of needs across a diversity of communities and ensure that the development and expansion of climate services are designed in a way that is inclusive, with robust and sustained stakeholder engagement.

Recommendation 4: Strengthen core science capabilities needed to expand and improve climate services

While decades of research have resulted in great progress in understanding the causes and consequences of climate change, additional scientific advancements are needed to produce more reliable, actionable information and inform the development of usable climate services.

The Biden-Harris Administration has articulated climate research and development priorities for FY 2023,¹⁸ including: research to advance understanding of the societal and economic impacts of climate change (e.g., human and ecosystem health, wildlife, and fisheries); improving observational networks to create carbon inventories and baselines; improving modeling capabilities for local-scale, regional climate, and related extreme-weather events; and disaster attribution science, including research in potential tipping points in physical, natural, and human systems. Priorities also include catalyzing research and innovation for high-fidelity, high-resolution modeling and simulation to address critical challenges in public health, climate science, and disaster resilience.¹⁸ Examples of research needs that align with these priorities and the need to advance climate services include:

- **Understanding the fuller socioeconomic consequences of climate change.** In addition to the immediate consequences of climate change on human health, food and water availability, and other societal impacts, there needs to be improved understanding of cascading impacts, such as triggers inducing the potential displacement of communities.
- **Understanding the impacts of climate change on ecosystems.** Ecosystems and the benefits they provide to society are impacted by climate change, but they are often inadequately characterized to support effective management decisions.
- **Improving simulation of climate and weather extremes,** including heat, drought, extreme precipitation, flood, wildfire, storm surge, and more. There may be opportunities for rapid progress, for example in modeling wildfire smoke and associated public-health consequences.
- **Improving simulations of local- and regional-scale climate,** including through models having finer spatial resolution and improved representation of processes. Impacts and decisions happen at the local scale, yet simulating phenomena at this scale is a weakness of current models.

- **Anticipating potential tipping points** by advancing understanding of feedbacks that could lead to rapid and irreversible changes in our planet, such as those related to the changes in the carbon cycle, rapid ice-sheet melt, or thawing of permafrost.
- **Projecting compound environmental extremes**, such as droughts and wildfires, as well as their interactions with natural and human systems (including behavior).
- **Improving the quantification of uncertainty** in climate projections, and advancing clear communication around that uncertainty.
- **Advancing effective engagement and knowledge-sharing methods**, including those that use social sciences to improve development, delivery, and usability of climate services.
- **Maintaining and improving the monitoring** of changes in the Earth system at high spatial and temporal resolution. These observations, across physical, natural, and human systems, provide foundational understanding to inform the development of next-generation models.
- **Understanding and advancing predictability** to improve seasonal-to-interannual timescale climate predictions.²¹ Predictions on these time horizons presently are limited by skill; improvements in skill would be valuable to the development and provision of decision-relevant climate services.
- **Advancing geospatial tools and data** to improve understanding and visualization of weather and climate impacts to inform preparedness and response.
- **Improving computing technology and methods.** Improving computational power and leveraging expertise and technologies from software engineering, artificial intelligence, machine learning, and quantum computing can support rapid advances in climate simulation, information, and service development. Filling gaps in broadband coverage and access to basic computer technologies, which are barriers in more remote areas of the United States, such as rural areas, parts of Alaska, and many islands, will be important for connecting people to needed information. Access to computing should not be a barrier to protecting Americans from harmful impacts of extreme weather and climate change.
- **Advancing greenhouse gas monitoring.** Rapidly cutting emissions will reduce the amount of future changes to which society needs to adapt. Improved monitoring is needed of greenhouse gases, including through integration across different datasets (e.g., *in situ*, airborne, and satellite), filling observational gaps, integrating socioeconomic information, and monitoring the benefits of carbon sequestration from nature-based solutions, such as carbon sequestration and storage on agricultural lands, as well as from conservation and restoration in forests and the ocean. More robust information systems would help decision makers demonstrate the benefits and impacts of climate mitigation measures, from local to global scales.
- **Improved understanding of benefits and consequences of actions to address climate change**, including the actual and projected effects of different adaptation and mitigation actions.

Addressing these research needs requires focused effort across a number of climate-science agencies. Building on successes in advancing basic understanding of global change, U.S. Government science agencies should pursue new initiatives aimed at producing actionable information, by addressing the research goals listed above. These initiatives could be strengthened through creative pathways, such as prizes and challenges, and new partnership mechanisms to spur innovation and broaden collaborations across the Federal Government and with the external community. As noted above, the needs of stakeholders must influence the research agenda for climate services to be optimally effective. This will not happen without concerted effort; mechanisms need to be put in place to ensure that research conducted by Federal

agencies reflect decision needs. Successful Federal programs that connect science and decision making can serve as a model for others.

The global change research community has historically focused on conducting basic research to improve understanding of how the climate system works. The immediacy of climate risks demand that the research community also focus intensively on the science that will empower communities and businesses to anticipate, prepare for, and mitigate those risks. Programs that exist to support capacity building in historically underserved communities, such as those related to job training, housing, or healthcare, are also in need of climate services that can help to ensure that their investments promote capacity to adapt and respond. This is use-inspired science²² at its best—research that delivers new, fundamental knowledge that is immediately relevant to society. Beyond advancing key science needs, which are substantial, many in the research community are keen to work more closely with users and decision makers to ensure that the science being developed meets users’ needs and is actionable and useful. Enhancing these relationships will enable practitioners across a variety of sectors, from public health, to architecture, to water utilities, to integrate climate information into their work. The challenges are great, but addressing information needs will be critical for enhancing national resilience.



Conclusion

The impacts of climate change are here, and America is underprepared. In addition to articulating bold actions to reduce emissions as rapidly as possible, President Biden's direction in Executive Order 14008 to advance climate information and services is both a challenge and an opportunity to ensure that Americans have the information that they need to take action. Bringing together science and knowledge providers with information users will advance the development and application of usable climate services and build trusted relationships and dialogue. Working directly with and in support of communities that are most vulnerable to climate impacts and have historically been underserved and marginalized should take high priority. Continually developing the new knowledge needed to produce and develop useful climate services is paramount.

The Federal government already has many of the building blocks to deliver on the above recommendations, including many individual agencies' capabilities and the interagency mechanisms noted above. Addressing the recommendations in this report will require new and strengthened strategic collaborations across agencies, interagency entities, and partners outside the Federal government. Harnessing the knowledge of social sciences to better inform design and delivery of climate services will be particularly important. Science-providing agencies, science-using agencies, and non-governmental partners can all prioritize service development on the strategic challenges of drought, wildfire, flooding, coastal inundation, and extreme heat.

This report provides a set of principles and recommendations to advance the development of improved and expanded climate services to assist agencies and State, local, Tribal, and territorial governments, communities, and businesses in preparing for and adapting to the impacts of climate change. The challenge of advancing climate services will foster innovation, job creation, and entrepreneurship. Having actionable information in hand will ensure that all communities understand and are better able to address their risks, to build a more resilient future.



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Front cover (clockwise from top right). Chris Lee (left), Indiana Natural Resources Conservation Service (NRCS) technical team leader, and Keith Williams, Indiana NRCS planning team leader, talk on a farm in Evansville, Indiana. Photo credit: [Brandon O'Connor, United States Department of Agriculture, Indiana Natural Resources Conservation Service](#). Public domain.

(bottom right) An aerial view of Tampa, Florida. Photo credit: Image licensed from Shutterstock.

(bottom left) The University of Colorado Boulder Drought Resilience Impact Platform (DRIP) has recently begun collaborating with the Ute Mountain Ute Tribe, installing sensors and collaborating on drought resilience. Photo credit: [University of Colorado Mortenson Center in Global Engineering](#). Used with permission.

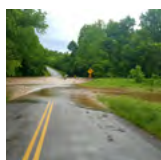
(top left) Firefighters applied foil wrap to protect General Sherman, a sequoia estimated to be around 2,300 to 2,700 years old. Photo credit: [Sequoia and Kings Canyon National Parks Fire Effects Crew, National Park Service](#). Used with permission.



Page 2. Coastal marshes at Blackwater National Wildlife Refuge in Maryland. Photo credit: [Jeffrey Brainard, Science Magazine](#). Used with permission.



Page 3. Dr. Alison Adams, manager of Tampa Bay Water (left) and Tirusew Asefa, a Resources Engineer for Tampa Bay Water (right), discuss the latest seasonal precipitation outlook and plan the water utility's operations. Photo credit: Kurt Mann, National Oceanic and Atmospheric Administration. Used with permission.



Page 5. Flash flood water rushes over a low-water bridge on a rural highway near Long Lane, Missouri. Image licensed from Shutterstock.



Page 7. Man on green grass examines a mobile device; symbols are overlaid on the image. Photo credit: Licensed from Adobe Stock Photos.



Page 9. Landscape architect Angie Milewski and floodplain administrator Marsha Hilmes-Robinson discuss the plans for development by Woodward, Inc. in a Fort Collins floodplain. Photo credit: Kurt Mann, National Oceanic and Atmospheric Administration. Used with permission.



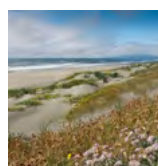
Page 10. Helitack crew member ready for flight on the Bureau of Land Management's Trout Springs Prescribed Fire in southwest Idaho. Photo credit: [Neal Herbert, Department of the Interior](#). Public domain.



Page 17. Sea-level rise information at Sarasota Beach, Florida. Photo credit: City of Sarasota, Florida. Used with permission.



Page 22. An aerial view of the damage Hurricane Ike inflicted upon Gilchrist, Texas. Photo credit: Jocelyn Augustino, Federal Emergency Management Agency. Image provided courtesy of [wikimediacommons.org](#); public domain.



Page 23. In Humboldt County, California, federal and state agencies, local governments, nonprofits, the Wiyot Tribe, private landowners, and other groups have teamed up to eradicate beachgrass, propagate native grasses and other species, and monitor results in the effort to build resilience to sea-level rise. Photo credit: [Andrea Pickart, U.S. Fish and Wildlife Service](#). Used with permission.

Opportunities for Expanding and Improving
**CLIMATE INFORMATION AND
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REPORT TO THE NATIONAL CLIMATE TASK FORCE • OCTOBER 2021



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