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Before the
United States House of Representatives
Committee on Science, Space and Technology
Subcommittee on Environment

April 21, 2021

Good morning. Thank you, Chairwoman Sherrill, Ranking Member Bice, and Members of the committee. I appreciate the opportunity to appear before you today to discuss the role of the federal government and other entities in a national climate information system and the relationship of such a system to the issue of climate equity.

My name is Richard Moss and I am a Senior Scientist at the Joint Global Change Research Institute (JGCRI), a collaboration between the Pacific Northwest National Laboratory (PNNL), a Department of Energy (DOE) national laboratory, and the University of Maryland. I am also a non-resident fellow of the Andlinger Center for Energy and the Environment at Princeton University. Particularly relevant to the topic of today's hearing, I currently serve as the Chair of the convening board of the Science for Climate Action Network (SCAN), a network of individuals and organizations committed to improving the use of science to identify and implement effective responses to climate change.

My testimony today draws on my work at JCGRI, while a fellow at Princeton, and my role serving as Chair of the SCAN convening board. It does not represent the views of DOE.

Previously, I served as the Director of the US Global Change Research Program (USGCRP) Office during the Clinton and G.W. Bush administrations and for this service was awarded the Department of Energy's Distinguished Associate Award by Secretary Abraham Spencer. I have chaired and served on boards and committees of the National Academies of Science, Engineering and Medicine (NASEM), including several charged with providing advice to USGCRP and other federal programs. I have had extensive experience in climate change assessments at international, national, and local levels through the Intergovernmental Panel on Climate Change (IPCC), the US National Climate Assessment (NCA), and the New York City Panel on Climate Change (NPCC). I chaired the Federal Advisory Committee on the Sustained National Climate Assessment which was established by NOAA Administrator Kathleen Sullivan and Presidential Science Advisor John Holdren in 2016.

I would like to acknowledge multiple colleagues whose work is reflected in this statement. First, the members of the Independent Advisory Committee on Applied Climate Assessment (IAC)

who served as co-authors of a report on providing authoritative information on climate science to inform and implement adaptation and mitigation strategies (their names appear as the authors of this publication, which is appended to this statement). Second, I would like to thank the members of the SCAN board of conveners, especially Katharine Jacobs, who directs the Center for Climate Adaptation Science and Solutions at the University of Arizona. Third, I wish to thank the many friends and colleagues in federal service with whom I worked over my career. And finally, I wish to acknowledge the Andlinger Center for Energy and the Environment at Princeton University for hosting me as a visiting fellow.

I will focus my remarks today on the urgent need for a federally supported national system or framework for climate information that establishes leadership, coordination, and accountability across the whole federal government and additional non-federal actors to provide users with accessible and authoritative information and responsive technical assistance. Additional federal action is needed to provide leadership and coordination across many federal and non-federal actors involved in climate services because users' needs are not being met today. But first I will begin with a working definition of climate services.

Climate services include a diverse set of products and technical support activities that range from customized climatological data to economic data to mediation and engagement.

The objective of climate services is to help potential users access and apply information about past and projected future changes in climate, the potential impacts of these changes, and the characteristics and tradeoffs among various response options. Definitions of climate services provided by groups such as the American Meteorological Society, The World Meteorological Organization's Global Framework for Climate Services, and European Commission's Climate Services Roadmap all note the importance of putting climate information in the context of use and incorporating engagement of users in the process of service design and provision.

My statement today will consider "climate services" as "the transformation of climate-related data – together with other relevant information – into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large" (European Commission 2015).

Actors across all sectors and regions of the United States face myriad challenges in trying to respond to climate change. In the additional background information below, I discuss some of these challenges in greater detail. Perhaps the one mentioned most frequently is confusion about what data to use for different types of problems and which of the many portals and systems can provide it (sometimes referred to as the "practitioners' dilemma"). But there are other problems too, and these have implications for the kind of capacities needed in a national system of climate services. One is using climate science to adjust existing policies, plans, environmental standards, public health measures, operating rules, and budget structures. These may include capital improvement plans, hazard mitigation plans, zoning ordinances, regulations for maintain air and

water quality, building codes, and other public documents that can lead to decisions that avoid or reduce impacts and, it is hoped, foster resilience.

Another challenge all actors face is in securing funding for climate adaptation and mitigation actions. Much of this funding will need to be provided through federal grants and low interest loans, especially to communities disadvantaged by structural inequities and injustice. The rest is likely to come from municipal/state operating budgets and investments and thus be evaluated with benefit-cost analysis and various financial risk analytics. Using climate information for these purposes will not only require different climate variables and analyses than are typically used in research to evaluate models, it will also require new analytic and decision support methods that climate services need to develop and provide. Finally, these data and methods will need to be tailored for local adaptation.

Capacity for engagement with users and sufficient resources to enable underserved communities to access needed services are critical to effective climate services.

Engagement with users is incredibly important when considering climate services. Given the complexity of climate action, engagement is far more than "outreach" to communicate results or gather information needs, it must also involve facilitation, engagement, and capacity building. Many adaptation and mitigation options will need to be implemented at the community or larger scale and will thus involve navigating collective action and social dilemmas. Existing institutions and governance processes will likely be strained to manage the competing values and preferences of different stakeholders, and climate services should include capacity to provide this support. Climate services can have unintended impacts on these processes and careful facilitation is needed to not disadvantage stakeholder groups who lack access to information.

Provision of climate services must be equitable, ensuring all communities can access these essential resources *irrespective of their ability to pay*. Increasingly, private sector climate services firms are providing sophisticated risk analytics for users who can afford them. A national climate information system must provide comparable services to underserved communities to avoid worsening existing inequalities. Many low income and minority communities have been driven to settle in locations that are more vulnerable to climate threats. Simultaneously they face financial, legal, educational, health challenges exacerbated by histories of redlining, proximity to industrial facilities, and public health services that are more difficult to access and of lower quality. Developing resilience will be even more challenging for those living in these circumstances.

In summary, climate services involve far more than providing climatological data and must also include engagement with end users, information on adaptation strategies, technical support, and capacity building, among other functions. A national climate information system must be given authority, staffing, and resources for coordinating across the whole of government, NGO, university, and private sector providers, and it should be held accountable for its performance.

To meet the needs of users, additional federal actions are needed to provide leadership and coordination across the many federal and non-federal actors.

With growing risks to human, economic, and natural systems associated with climate change, there is a need for more effective leadership and coordination of climate services. In the United States today, climate services are provided by a diverse set of federal agencies/programs, NGOs, and private sector firms. There are a number of strengths in our current highly distributed approach, including:

- serving a broad range of decision makers in systems they are already accustomed to working in;
- offering high degrees of customization;
- maintaining momentum in adaptation by building on existing provider-user relationships; and
- having a diversity of approaches for developing new types of information, model evaluation methods, decision support tools, and facilitation approaches.

Many private sector and NGO groups (too many to name individually here) supply different types of climate services, generally at the scale of a city or community. Some of these are structured around supplying available observations and projections related to impacts. Others occupy niches in different parts of the climate services value chain such as customization, risk analytics, technical support, or capacity building. An indicative, if not comprehensive list is provided in the background at the end of this statement. However, it is critical to note that these groups are not collectively capable of providing services at the pace that will be required to manage escalating climate-related risks. A coordinated approach for providing climate information is missing across the many sources, types, and applications of climate information. As a result of this lack of coordination, the needs of users are not being met.

It is critical to note that federal science investments are and will continue to be the *foundation* for our understanding of climate and global change, and thus for climate services. Even though local knowledge and university-based contributions are expanding, growing this investment is becoming more essential over time. A second benefit of maintaining a diverse and high level of federal engagement across multiple agencies and programs is that federal agencies do much more than research: in fact for many, research is subordinate to their primary missions of facilitating growth and problem-solving in different areas of the economy and civil society. Each agency has accrued knowledge and trusted relationships that can help with the challenge of integrating assessment of climate risk into our nation's economy and civic life. The agencies themselves need to manage risk to their facilities, their employees, and their missions.

A 2016 Government Accountability Office (GAO) report focused on the supply of climate information and reported that current efforts across federal and non-federal sources "do not fully meet the climate information needs of federal, state, local, and private sector decision makers." GAO concluded that "climate information exists in an uncoordinated confederation of networks and institutions. The federal government's climate information—composed of observational

records from satellites and weather monitoring stations, projections from complex climate models, and other tools—is fragmented across many individual agencies that use the information in different ways to meet their respective missions". It cites other reports and the results of interviews with climate services stakeholders (both providers and users) that identify a number of barriers to accessing climate services including silos among and within federal agencies that lead to fragmentation of information, missed opportunities for data sharing and learning, and provision of information that vastly underserves decision makers.

Federal action is urgently needed to provide leadership and coordination, including identifying and filling data and service gaps, providing guidelines for authoritative data and decision support, and making it easier for users to find and access authoritative information and services that are fit for purpose.

The federal government could improve the current uncoordinated approach to climate services in the United States by creating a national system for climate information that establishes leadership, coordination, and accountability across the whole federal government, works with diverse non-federal actors, and provides users with accessible and authoritative information and responsive technical assistance.

Strong national leadership and coordination needs to be created in the federal government to better meet the needs of government and civil society users of climate services. As discussed, climate services today involve a diverse group across the federal government and many non-federal entities. This distributed system is a strength because it accurately reflects the diversity of local, regional, sectoral, and institutional contexts where climate action needs to be taken. To make these diverse activities and sources of information come together, a national system must start from user needs and define specific requirements for meeting these needs effectively.

Building on prior studies and reports and my experience across federal and non-federal sectors, there are three high-level needs that a national system of climate services must provide: (1) data and information that are findable, accessible, authoritative, and usable; (2) technical assistance that is responsive, trusted, and quality assured; engagement; and (3) governance to provide leadership, coordination, and accountability (see table 1). I will briefly discuss these needs, indicative requirements to make them effective, and the implications for the design of the federal component of climate services.

Needed from a national climate services/information system	**Requirements**	**Implications for federal component of national climate information system**
Governance (leadership, coordination, accountability)	Leadership and effective coordination	Influential secretariat with embedded agency staff; authority over budget w/ gap filling; cross-cut process
	Addresses equity	Strong federal role to backstop NGOs and private sector

	Provides resources	Steady funding to support research, development, and implementation of adaptation
Data and information	Findable and accessible	Adequate resources to create intuitive interfaces to find, access, and integrate needed data
	Authoritative and representative of the state of science	Reflects state of science; assessment function to establish good practice standards; ongoing interactions between research programs and services
	Relevant and used	Sustained engagement to support "fitness for use"
Technical assistance and engagement	Responsive and trusted	Multi-agency/actor—build on existing trust relationships
	Quality assured	Certification processes through professional associations (e.g., ASCE, APA, APH, ASAP)

Table 1.

Governance (leadership, coordination, accountability)

A stated purpose of this hearing is to explore improved Federal investment and coordination of Federal climate risk information and climate services, potentially through a centralized "Federal Climate Service." This is an institutional challenge in the sense that it requires improving mechanisms for structured decision making among diverse agencies, allocation of resources, and input from a standing advisory body to represent users and non-federal providers.

Prior legislation and proposals have attempted to establish variants of a Federal Climate Service. A number of reports including the GAO study cited previously have examined how to improve the US climate services landscape. One may also draw on international experiences, including the design of services in other countries and the Global Framework for Climate Services established by the World Meteorological Organization. The 2016 GAO study in particular explored options for creating a national system with both federal and non-federal components. It concludes that "a national climate information system with defined roles for federal agencies and nonfederal entities could emphasize the strengths and deemphasize the limitations of these different options." My personal view (and that of the large number of adaptation professionals we have engaged in the context of writing the IAC report) is consistent with this conclusion. Efforts to establish a climate service primarily as a federal activity have the potential to be disruptive for multiple reasons, including a "top-down" mentality that could disrupt trusted relationships between existing providers and users who are already working together. It is unlikely that any single institution or program will be able to meet all user needs.

However, strong leadership and coordination is needed across the federal government. Whatever structure is developed, it will be advantageous to build on the strengths of the current distributed system for climate services, including the three well-known and trusted federal climate science networks (the NOAA Regional Integrated Sciences and Assessments program; the Climate Adaptation Science Centers; and the USDA Climate Hubs). Non-federal entities including professional organizations, private sector firms, centers at universities, NGOs, and other groups are well placed to apply complementary expertise to provide customized information and technical support appropriate to each subject and context.

An effective Federal climate service will need to be well-integrated with the Federal agencies that produce and use climate data. But more importantly, it must provide engagement, leadership, coordination, and accountability across the US. This is a dramatic challenge – engaging across 50 states and territories, almost 600 Indian tribes, an array of private sector interests, and literally thousands of communities is no small task. Table 1 suggests four requirements for effective governance: leadership and effective coordination; addresses equity issues; continuity of effort across changes in national leadership; and accountability to users. While not a comprehensive list, these qualities are necessary if the Federal government is to support a distributed national system of climate services that makes relevant and authoritative information findable and usable, and that delivers this information with needed technical support in an equitable fashion.

In this context, federal leadership should include establishing an overarching strategy that includes a vision, mission, goals, and lays out programs to achieve those aims. It will also require substantial additional funding. Strategy development should include extensive engagement with relevant agencies as well as expert and public input. Coordination will require assigning clear roles and responsibilities across Federal agencies, and based on assessment of gaps and needs, identifying broad potential roles and opportunities for non-federal actors with competitive funding organized through "statements of need." Such a coordination mechanism is included in the 1990 Global Change Research Act (Public Law 101-606(11/16/90), 104 Stat. 3096-3104), and in my experience, worked effectively with strong leadership from the White House Offices of Management and Budget (OMB) and Science and Technology Policy (OSTP). A new or existing interagency entity needs to apportion responsibility for performing specific tasks and must include a mechanism with authority sufficient to coordinate agency efforts including developing a cross-walked budget and reallocating resources across agencies if necessary.

In creating a national system, it is important to consider the inequitable impacts of climate change on the most vulnerable communities, whether in rural or urban settings. Addressing equity will require providing universal access to data, information, and technical support irrespective of ability to pay.

Accountability for performance is especially important because of the distributed structure of climate service providers. A standing advisory body will be needed to integrate input from the

system's stakeholders, non-federal climate service providers, and members of the research community and other experts developing new data and tools.

Data and information

As described throughout this statement, multiple types of data and information are crucial to users across all levels of government and sectors and regions of the nation. Climate services need to provide this information in a fashion that leads to better decisions. Table 1 lists three indicative requirements for data and information. I briefly discuss these.

Many reports on climate services and policy statements from user groups request that data be *authoritative.* I understand this to mean data and information that have been determined by experts (and/or those with authority over their work) to be the "best available data" for use by decision makers in their situation. This requirement also exists in many federal agencies, particularly where there are strong command hierarchies, in professional settings such as engineering where there is a tradition of best practice standards, in business, and when large public infrastructure projects are under consideration. But what are the criteria for designating something "authoritative" or "best available"? And are these even the right criteria? A more appropriate framing may be "fit for purpose" to identify information provided at the level of precision *actually needed* to inform a specific type of decision.

No single data set or method is "best available" across all regions of the US or for all relevant variables for complex reasons. The selection of what can be treated as authoritative will depend on the level of accuracy that may be required and the current state of science in modeling a particular phenomenon or variable. In some locations with lower natural variability (e.g., parts of the Southwest), Earth system models may be able to provide information to guide adaptation decisions, but in others where variability is greater (e.g., the Pacific Northwest) these models are not fit for those purposes. Additional research and assessments are needed to evaluate climate model data and methods for local assessments of climate hazards, e.g., future flood risks, catastrophic wildfires, extended heat waves, or persistent drought conditions.

It is not helpful and in fact can be harmful to designate a data set or method "authoritative" because it has other desired characteristics such as high spatial or temporal resolution. For example, recent analysis of the adaptation plans of nearly 90 large US cities explored the sources and methods for obtaining climate information for local resilience planning. Despite the availability of multiple potentially valid data sets and approaches for estimating future rainfall extremes, cities centered resilience planning around a single data set that they judged to be appropriate to their needs. The use of another data set or approach could have resulted in different decisions and outcomes.

An effective national climate information system must prioritize a scientifically rigorous approach for engaging scientific experts and users to work towards defining what information can be treated as "authoritative" or "fit" for different purposes. This assessment process could identify specific designated data sets and/or the characteristics of appropriate methods to

customize and apply climate information that are consistent with the current state of science, as well as the local conditions and the decision context in which it will be used. The IAC report appended to this testimony includes discussion of an approach to incorporate such evaluations into sustained climate assessment.

Another key consideration for climate data and information raised by many users is that it be *findable and accessible*. As discussed above, it is currently difficult for users to find the right data or information for their problem. These challenges exist for a variety of reasons, including the multiplicity of potential sources and a lack of guidance on how to choose. Many prior efforts have worked to develop solutions to the challenge of finding and accessing data/information across multiple providers. In the case of climate science, the challenge has an added dimension in that information is constantly improving and new data sets are added all the time. Users should be able to interact with information throughout its life cycle as it is added and updated.

Accessibility is often also a problem in another way: data and information are not provided in usable formats and/or accessing it requires expertise or resources that users do not have. Some communities and decision-makers have adequate financial resources to hire consultants to solve these problems, but many do not. Any national system for climate services must provide resources that enable access by traditionally underserved, poor, and otherwise disadvantaged communities to be aware of relevant information and data, to have technical assistance in determining how this information can be used, and to have support in accessing and using it.

Technical assistance and engagement

Climate science requires transformation and customization. Without additional analytics and technical support, it is not possible to understand how a given change in climate should affect the design of a bridge, dam, or airport runway, whether tiling will be needed to drain more frequently flooded low-lying fields, or how coastal zoning—whether urban, suburban, or rural—should be updated. As discussed previously, interdisciplinary teams of climate scientists, professionals, and other experts are developing new data, models, and analytic methods to provide this technical support. A key challenge for consumers of these types of technical support is assessing the quality of work proposed by potential providers. Established professional bodies (e.g., the American Society of Civil Engineers, the American Planning Association, the American Public Health Association, the American Institute of Architects) should be resoured to develop standards for practice in their domains. The adaptation field and organizations such as The American Society of Adaptation Professionals (ASAP), EcoAdapt, and others are evolving good practice standards to ensure resilience solutions are socially equitable, ecologically sound, and do not negatively affect efforts to reduce greenhouse gas emissions.

A national system for climate services should leverage existing efforts. A well-designed national approach to climate services will include technical support to those formulating and carrying out mitigation and adaptation strategies. There are decades of research in the social and sustainability sciences, public administration, decision making under deep uncertainty, and other areas which,

if tapped, can inform the design of constructive public dialogue, sustained engagement, and adaptive pathways.

Conclusion

In my statement before the Subcommittee, I have attempted to clearly define climate services and highlight the broad diversity of actors involved in these efforts in the United States. There is an urgent need for a federally supported national system or framework for climate information that establishes leadership, coordination, and accountability across diverse actors to provide users with accessible and authoritative information and responsive technical assistance. Such a system must address the diversity of needs for data and information that is fit for purpose, reflects the state of the science, and is findable and accessible, especially for underserved communities. A coordinated system, with leadership from the federal government, has the potential to enable those across our diverse geography and economy leverage the wealth of world-class climate science, available thanks largely to federal science investments, to better mitigate and adapt to the impacts of our changing climate.

Thank you again for the opportunity to testify on this important topic. I would be happy to answer any questions you may have.

Additional Background

This background section discusses 1) the challenges faced by all levels of government (including tribal) and civil society actors in responding to climate change; and 2) the potential role of a sustained, applied national climate assessment in meeting one of the key requirements for climate services: identifying authoritative data and quality-assured technical assistance and facilitation. This material and other sections of this statement are based on edited versions of the report of the Independent Advisory Committee on Applied Climate Assessment (IAC), mentioned above. The full articles are included as appendices to this statement.

Communities across the nation are affected by climate change

Damages and loss of life occurring across the United States from recent floods, wildfires, and heat waves demonstrate the growing risks associated with climate change. The impacts vary from place to place and across diverse communities with different vulnerabilities and capacities to respond. Media attention largely focuses on the costly impacts of more frequent and/or severe extreme events. But slower-onset changes in conditions such as higher nighttime temperatures, reduced snowpack, drought, and more frequent sunny-day “nuisance flooding” are also having substantial impacts, especially as they interact with other long-term trends such as subsidence of land in coastal areas, expansion of paved surfaces and human settlement, and degradation of ecosystems and vital natural resources. The disruption to communities and lives in both rural and urban areas is widespread, with a particular burden on indigenous nations, communities that have experienced racial discrimination, the young and the elderly, those whose livelihoods are directly

tied to natural resources, and others who lack adequate resources to adapt. Collectively all levels of government, the private sector, and individual citizens are spending 10s if not 100s of billions of dollars annually to recover from and implement measures to moderate future damages resulting from these interacting forces.

Most people have come to accept that climate is changing and will have serious consequences through their direct experience and reports such as the recent Fourth National Climate Assessment. NCA4 shows that extensive changes in climate have been observed in all regions of the country and that Americans are already struggling to recover from and prepare for impacts. NCA4 updates the prior NCAs (released in 2000, 2009, and 2014) and extensively documents these impacts. A key message states that climate change "creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth." A recurring finding in many of the sectoral and regional chapters is that among those most likely to suffer these impacts are society's most vulnerable populations. The report finds that without additional large reductions in emissions, "substantial net damage to the US economy [will occur] throughout this century, especially in the absence of increased adaptation efforts."

"Now what?" is the pressing question that many are asking. How can we avoid the worst damages? What can be done to prepare for the impacts we can no longer avoid? And when we do incur damages, how can we recover more quickly and resiliently? These questions point to many challenges that will require state/local/tribal governments and citizens to integrate science and community values in decision-making. And they highlight the need for additional research and assessment to improve options to support implementation. For many communities, the challenge is to incorporate information about climate change and policies into planning economic opportunities, improving social welfare, updating infrastructure, protecting water resources, or conserving natural environments. Others need to manage overt climate threats—reducing risks of calamitous wildfires, containing health threats, managing flooding from record rainfalls, and recouping depressed agricultural production—while navigating challenging legal, financial, and equity issues exacerbated by preexisting burdens such as histories of restrictive zoning, siting of industrial facilities, and inadequate public health infrastructure.

Significant responses are needed and underway

Significant efforts are already underway to both reduce human contributions to climate change ("mitigation") and to adjust systems and practices to withstand impacts that can no longer be avoided ("adaptation"). With respect to mitigation, US states, local governments, companies, and citizens are contributing to global efforts to reduce greenhouse-gas concentrations in the atmosphere. Attention and planning have focused heavily on efforts to reduce GHG emissions in the energy sector, transportation, residential and commercial buildings, industry, and agriculture. These efforts notwithstanding, multiple assessments have concluded that mitigation is not taking place nearly rapidly enough to stabilize atmospheric GHG concentrations and that policies must be strengthened to avoid unmanageable levels of climate change.

Because impacts occur across all sectors and regions, many types of adaptation will be needed to recover from damages that have already occurred and to prepare for projected impacts. Assessments of the state of adaptation have found that adaptation is progressing but not fast enough to prepare for the existing and projected impacts. A study conducted in 2017 found that "...communities across the US are experimenting with adaptation...aided by an ever-growing base of knowledge and a plethora of tools. Still, the field remains limited in scope and effectiveness...too many adaptation efforts are stalled at the planning stage." While much progress has been made since 2017 and the drafting of the IAC report, the situation is still challenging. Adaptation is not keeping pace for many reasons, one of which concerns failures in the current system of providing climate services.

Typical challenges in taking action

The IAC report describes at a high level some of the challenges that lead many adaptation efforts to stall. The report discusses the need for many types of data and information and the difficulty that people have finding data that can be considered authoritative and useful ("fit for purpose") for their issue. This is indeed a major difficulty that needs to be addressed in federal action on climate change: confusion about what data to use for different types of problems and which of the many portals and systems can provide it (sometimes referred to as the "practitioners' dilemma"). But there are other problems too, and these have implications for the kind of capacities needed in a national system of climate services. One major problem that restricts progress is obtaining funding to implement climate adaptation and mitigation. Among the specific needs and opportunities are developing methods to use climate and impacts science in evaluating costs and benefits of response options. Another is using climate science to adjust existing policies, plans, operations, and budget structures. Many existing plans, codes, and budgeting processes (e.g., master plans, capital improvement plans, hazard mitigation plans, zoning, building codes) need to be updated using climate science and information on risks. Still others include evaluating debt and investments to reflect changing climate hazards and benefits of resilience measures, identifying supply chain and other climate-related business risks, and incorporating climate risk in state, local, and regional financial analysis.

Often not discussed in the academic literature on how to apply science to social dilemmas is the reality that structural inequalities, perverse incentives, and the mindsets people bring to working on climate change are at least as much of a problem as obtaining quantitative analysis of the implications of changed intensity or frequency of climate hazards for engineering requirements or financial risk analysis. People in communities who are dealing with climate impacts, however, do see these challenges frequently. The result is that governance institutions and processes intended to provide a level playing field for all stakeholders will be stretched to build political consensus for investments to transition public infrastructure, let alone to chart the social and economic transformations needed to improve resilience in society. It is important to realize that even though scientific data are apolitical, climate services are provided in a political context in which some stakeholders have more access than others. What data and information is used and how they are formatted and provided can inadvertently reinforce these dynamics. Individuals trained in skilled facilitation and intermediation are needed to help navigate these problems so

science-based information does not further tilt the landscape of governance. A well-designed national approach to climate services will include technical support to those formulating and carrying out mitigation and adaptation strategies. There are decades of research in the social and sustainability sciences which, if tapped, can be brought to bear by facilitators trained to advise on the design of constructive public dialogue, sustained engagement, and design of adaptive pathways. These approaches will enable users to accesses climate knowledge in a fair and flexible way that enables them to explore the tradeoffs (and hopefully synergies) of different potential responses.

Identification of authoritative information and quality control through "sustained" assessment
To better meet Americans' needs to increase preparedness and resilience in the face of climate change, in 2016 the National Oceanic and Atmospheric Administration (NOAA) and the Office of Science and Technology Policy (OSTP) convened a Federal Advisory Committee (FAC) to develop recommendations on how to accelerate establishment of a *sustained national climate assessment*. Unfortunately, the FAC was disbanded in August 2017 while in the process of gathering public input and preparing its report. In early 2018, with support from the New York State Energy Research and Development Agency, Columbia University, and the American Meteorological Society, most FAC members reconvened and joined with eight additional experts as the Independent Advisory Committee on Applied Climate Assessment (IAC). IAC members consulted broadly with user groups including state/local/tribal entities, non-governmental institutions (NGOs), professional societies, and the private sector, as well as with scientists and intermediaries. Additional input was provided by a "Science to Action" collaborative of some 100 organizations and individuals interested in maintaining access to federal scientific information and fostering better science-practice interactions. These insights informed development of specific, practical recommendations on the NCA sustained assessment.

A conventional understanding of the concept of a sustained NCA is the timely production of special reports and derived data in between those produced every four years, as required by Section 106 of the US Global Change Research Act (Public Law 101-606(11/16/90), 104 Stat. 3096-3104). While this can be one outcome of sustained assessment, the more significant aspect, as described in a special report developed as part of NCA3, is to *establish sustained engagement and enduring partnerships between users and producers of climate information* in order to make this information more relevant, trusted, and thus used. Currently, the USGCRP uses regional stakeholder meetings to identify information needs and present findings of the quadrennial NCAs. These engagements are extremely useful and should be made more frequent.

The IAC suggested expanding the concept of engagement to develop sustained interactions and enduring partnerships *organized around recurring climate impacts and solutions*, for example adapting to specific climate hazards (e.g., catastrophic wildfire, heat waves, drought, flooding), planning adaptation pathways for coastal areas, modernizing infrastructure and making it resilient to changing hazards, or using ecosystem-based adaptation. For example, an ongoing series of meetings could be organized to explore science and strategies for addressing the challenge of severe flooding. Representative stakeholders from a set of towns, cities, or counties

confronting how to manage more frequent and severe flooding would meet with scientists and professionals with expertise needed to identify at risk locations and evaluate different solutions, for example climate scientists and hydrologists, ecologists, engineers, spatial planners, and public health specialists.

Because individuals and organizations indicate that adaptation plans are stalling at the implementation stage, one approach for organizing sustained engagement could be to structure conversations around different stages of a project implementation cycle, for example assessing vulnerability, designing options, revising codes and standards, obtaining financing, or monitoring and evaluation. Participants could explore methods they have used and whether they were effective, for example: What kinds of climate and impacts information were used in flood risk assessment? Were stakeholders engaged and what approaches to facilitation were used? What options were considered (e.g., ecosystem-based approaches vs. hard structures) and how were they evaluated?

The *proximate outcomes* of these sustained interactions would be to support the participants and help them build capacity. By selecting challenges that recur in multiple locations and enabling the participants in these sustained engagements to compare and evaluate experience. Over time, the participants could contribute to producing products that would serve *wider and scalable objectives*, for example developing principles and good practices that could serve as a starting point for customization by climate service providers, inform development of standards, capacity building, and quality assurance for climate services. Relevant professional bodies (e.g., engineering, public health and other professional associations) and other groups (e.g., bond rating agencies and other financial services) that are developing initial methods to incorporate climate change into their work could be included. This would enable the engagement process to provide missing opportunities for dialogue among climate scientists, professional practitioners, and stakeholders to learn from initial efforts to develop standards and best practices.

In conclusion, a sustained NCA can provide inputs for quality assurance of climate services by providing a process to evaluate science, decision support tools, communication and facilitation techniques, and other methods used in planning and implementing adaptation. Good practice standards developed through the assessment could then be used by climate service providers to ensure their products and processes were consistent with good practices, as well as by potential customers or users to identify criteria for evaluating proposals from climate services providers. Good practice standards for analysis and application of observations and projections could help produce information that could with confidence be treated as authoritative.

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An indicative (not comprehensive) list of categories and examples of groups that have a role to play in climate services in the US

- Federal agencies: Most agencies have ongoing programs relevant to climate services or are quickly standing them up. Prominent examples include

    - Research programs focused on Earth system science, impacts, and other areas of modeling (all of the agencies participating in the USGCRP). Many of these agencies have multiple portals with observations and projections of climate, hydrological, land use, socioeconomic, and other conditions related to their mission areas.
    - Additional programs not primarily focused on climate but with relevant data, analytic tools, and other materials, e.g., USDA's Cooperative Extension programs at land grant institutions, the National Sea Grant program, National Estuarine programs, and NOAA's National Coastal Zone Management Program.
    - FFRDCs including laboratory systems at the Departments of Commerce (NOAA), Defense, Energy, Homeland Security, as well as NASA and NSF
    - Regional climate centers: the 11 NOAA RISAs, 8 DOI Climate Adaptation Science Centers, and 8 USDA Climate Hubs (note that these are partnerships based at universities)
- Interagency programs: The research and activities of the USGCRP, especially including the NCA, are universally understood to be the bedrock for climate services. USGCRP coordinates agency program budgets, synthesizes the results of these programs related to impacts in the NCA, shares knowledge with decision across the country, and coordinates US participation in a number of international programs, among other activities (USGCRP 2020).
- International activities: The World Climate Research Programme and Future Earth serve as umbrella programs for a number of relevant research activities focused on Earth systems science, interactions of human and natural systems, sustainability, and other topics. Results of these programs include relevant data and information. The Coupled Model Intercomparison Project (CMIP), now in its 6th phase, identifies shared experiments, standards, coordination, infrastructure, and documentation for producing climate model runs that underpin scientific progress, assessments including the IPCC, NCA, and other national assessments. These results are also critical to development of many types of climate data and information.
- NGOs: The American Geophysical Union, the American Association for the Advancement of Science, the World Resources Institute, the Natural Resources Defense Council, The Nature Conservancy, Union of Concerned Scientists, and many other NGOs are involved in climate adaptation and mitigation actions and develop specialized data on climate and related conditions, as well as decision support tools. Many participate in the NCA and provide climate services.
- Academic centers and partnerships: There are multiple science, research, and engagement networks within and across universities whose work is relevant to climate services. Some provide observations and projections, often tailored to local or regional needs, and others provide decision support partnerships and tools or track climate adaptation or mitigation (e.g., Georgetown Climate Center)
- Professional associations: Many professional associations have climate programs/activities focused on developing climate resilience guidelines or incorporating climate change practice into their profession's codes and standards, e.g., ASCE, the

American Planning Association, the American Public Health Association, the American Institute of Architects. A relatively new professional association that is playing an increasingly important role in the field of adaptation is The American Society of Adaptation Professionals (ASAP). ASAP and EcoAdapt are each examples of nonprofits supporting the emerging field of climate adaptation.

- Private sector firms: Many private sector firms will be users of climate services as they are required to assess and disclose supply chain and financial vulnerabilities to climate change. A much smaller number of firms are offering facilitation and intermediation as well as data and risk analytics.
