NOAA SCIENCE ADVISORY BOARD REPORT ON CLIMATE INFORMATION NEEDS FOR 5-10 YEAR HAZARD MITIGATION PLANNING CYCLES

PRESENTED TO THE NOAA SCIENCE ADVISORY BOARD

BY THE SAB CLIMATE WORKING GROUP

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Climate Working Group Report

In support of the NOAA Science Advisory Board

Climate Information Needs for 5-10 Year Hazard Mitigation Planning Cycles

26 April 2023

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Introduction

After a decade or more of assessing impacts of climate change, communities and resource managers are turning their attention to mitigating emerging climate hazards and vulnerability in their health and well-being, infrastructure and ecosystems. The new FEMA (2022) guidance to the states for hazard mitigation planning states, “It is critical that the state plan include the effects of climate change on hazards, potential impacts, and strategies.”[1] With this shift in hazard planning objectives, decision makers need information to prioritize funding and implementation decisions on the 5-10 year time horizon while also continuing to look for more insights for enhancing operations at the subseasonal to seasonal timeframes.

NOAA is uniquely suited to support decision makers addressing emerging climate hazards and vulnerabilities through its research in understanding and prediction of changes in climate, weather, ocean and coasts; climate services which share that knowledge and information with others; and stewardship to conserve and manage coastal and marine ecosystems and resources. For decision-makers on the ground and other agencies with responsibilities to climate-sensitive sectors, groups, and regions, NOAA is the trusted source for this type of information. With its prediction mandate, NOAA is best placed to make critical decisions about how best to make climate projections which balance the state of the science with the pressing need for actionable information. While a central player for many issues, NOAA continues to face resource constraints that restrict the pace and scale of response. We recognize that meeting the full scope of emerging climate needs is dependent on resources allocated to the agency as well as continued efforts to leverage existing resources and create greater efficiencies in practice.

This report draws on the expertise of Climate Working Group Members and interviews with over 30 individuals including NOAA staff and others leading major hazard mitigation initiatives (see Appendix A). We sought out innovative decision makers at the cutting edge of integrating climate into hazard management to identify emerging needs to draw insights from their pioneering efforts. NOAA staff generously shared their time and provided briefings on work related to heat, flood, drought, and wildfire hazards. Climate Working Group members synthesized this information together with their professional knowledge in developing these recommendations.

This paper focuses on the issues that were of the highest priority for these “front-line” users supplemented by CWG member experience. This key informant interview

[1]FEMA.(2022). State Mitigation Planning Policy Guide. https://www.fema.gov/sites/default/files/documents/fema_state-mitigation-planning-policy-guide_042022.pdf.

approach captures emerging challenges being encountered by organizations leading in the pursuit of climate adaptation/hazard mitigation and raises clear themes for NOAA consideration in fostering a climate ready nation. Ancillary data show a growing number of hazard mitigation projects receiving federal funding (Figure 1), and each dollar spent on hazard mitigation yields relatively high values of benefits (Figure 2).

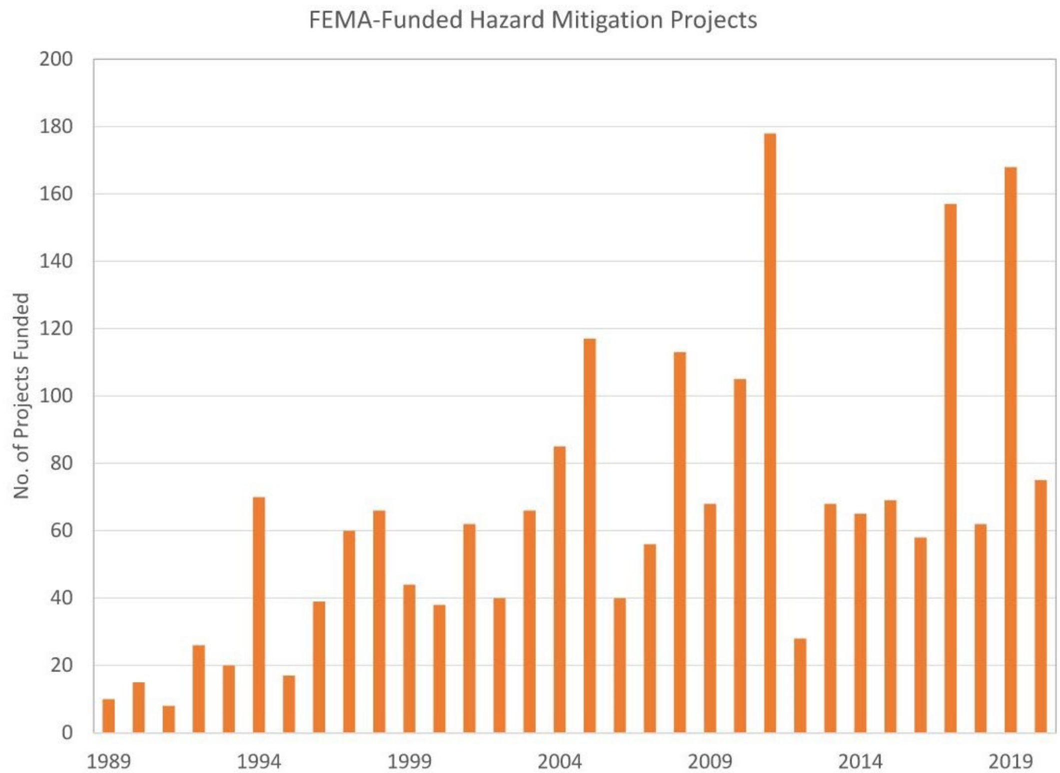

Figure 1: The number of hazard mitigation projects funded by FEMA each year. (Source: OpenFEMA Dataset: Hazard Mitigation Assistance Projects - v2).

National Institute of BUILDING SCIENCES	ADOPT CODE	ABOVE CODE	BUILDING RETROFIT	LIFELINE RETROFIT	FEDERAL GRANTS
Overall Benefit-Cost Ratio	11:1	4:1	4:1	4:1	6:1
Cost ($ billion)	$1/year	$4/year	$520	$0.6	$27
Benefit ($ billion)	$13/year	$16/year	$2200	$2.5	$160
Riverine Flood	6:1	5:1	6:1	8:1	7:1
Hurricane Surge	not applicable	7:1	not applicable	not applicable	not applicable
Wind	10:1	5:1	6:1	7:1	5:1
Earthquake	12:1	4:1	13:1	3:1	3:1
Wildland-Urban Interface Fire	not applicable	4:1	2:1	not applicable	3:1

Figure 2: Nationwide average benefit-cost ratio by hazard and mitigation measures. (Source: National Institute of Building Science, 2019, Natural Hazard Mitigation Saves report).

This white paper includes four sections synthesizing recent changes in the characteristics of drought, flood, extreme heat, and wildfire hazards, respectively. Under each section, the types of hazard mitigation measures being proposed and initiated by implementation agencies are described. A set of recommendations are presented under each hazard, which identify opportunities for NOAA to enhance delivery of climate information needed for implementation and operating hazard mitigation solutions.

Drought Hazards

Motivation

A warming world is driving changes to weather and climate dynamics, potentially leading to a greater frequency of rapidly onsetting and intensifying droughts. At critical times in agricultural or rangeland development, these conditions can lead to catastrophic losses or necessitate faster and greater intervention or response measures. Over the past decade, the use of the term “flash drought” has become more common to describe this phenomenon. In addition, warmer temperatures and greater extremes (duration and magnitude) of precipitation deficits lead to long-term drought consequences (tree mortality) that are not alleviated when precipitation returns.

1. Develop nationally-available products to track decadal changes in drought patterns

Findings: The National Integrated Drought Information System (NIDIS) Act of 2006 mandates NOAA to improve drought monitoring and forecasting capabilities through timely collection, integration and dissemination of drought early warning information. NIDIS and related programs such as the National Drought Monitor routinely generate a number of information products for effective monitoring of drought in near-real time. However, closing in on two decades of implementation, NIDIS is still not nationwide and current informatics have missed critical condition onset necessary for drought early warning. There is limited information on long term characteristics of drought such as recurrence intervals, event durations, area impacted, and how event characteristics are changing with continued warming. Gaps still exist in information and resources available to local, state, and federal agencies for drought planning and development of adaptation strategies for responding to changing drought conditions as the world continues to warm.

Recommendation 1: Develop operational products to measure the timing (frequency), pace (how fast onset and development occurs), magnitude of deficits and impacts, and spatial resolution of drought events in a way that can track changes in metrics by decade in response to continued warming. Ensure that all capabilities are employed nationwide via the NIDIS program.

2. Enhance investments in forecasting emerging drought hazards

Findings: Existing drought risk maps from the FEMA National Risk Index and the NOAA NCEI’s Billion-Dollar Disaster Program are based on information from past drought events. These are inadequate for planning, design, and operations of new drought mitigation infrastructure such as Managed Aquifer Recharge facilities. Infrastructure planners require projections of future drought risks, emerging compounding hazards, and prioritizing areas of highest long-term risk of droughts. Additional resources may be required.

Recommendation 2: Continue to enhance and expand forecasting across timescales from weather to seasonal timescales to enable a greater awareness of emerging and developing drought risks and for managing emerging drought mitigation infrastructure.

3. Enhance tools to support local drought mitigation planning

Findings: A significant portion of NOAA's existing drought monitoring resources are expended on maintaining existing drought products and supporting the existing user base. This leaves few resources to expand the product portfolio to address emerging drought hazards and new user needs. The focus of drought management practice by state and local partners is shifting from regional hazard assessments to helping local entities such as farms and water agencies implement drought mitigation measures and developing adaptation strategies. Clear communication about the uncertainties in drought indicators and predictions will be important for such assessments.

Recommendation 3: Enhance tools and information delivery to support coordination across drought mitigation planning, drought assessment (including the expansion of the measurement of the economic losses from drought to include loss of job opportunities, energy losses, and agency revenue losses), and possible adaptation pathways to accommodate anticipated changes in drought characteristics with climate change. Ensure that all capabilities are employed nationwide via the NIDIS with emphasis on research to practice.

Flood Hazards

Motivation

Climate changes are creating an environment where rainfall events are becoming more extreme and pose challenges to current infrastructure capabilities and design standards. Traditionally, periodic updates to products informing infrastructure design have been made using historical observations under the assumption that periodic updates would capture any changes in precipitation characteristics. This approach will not likely keep pace with the anticipated acceleration of change in the coming decades.

1. Develop decadal projections for flood mitigation planning

Findings: Flood resilience planners are investing substantial resources to plan and implement a range of solutions to adapt to changing hydrologic patterns and hazards. NOAA Precipitation Frequency Atlas 14 is the primary source of peer-reviewed nationwide information for characterizing extreme precipitation in the planning and design of flood control infrastructure. However, NOAA Atlas 14 is composed of 11 regional volumes developed or revised over two decades using funding from ad hoc opportunities. Shortening the product development and update cycle to provide users with standard tools and guidance for performing intermediate updates nationwide will require sustained funding, technological innovations, and program support for the NOAA Atlas team. Furthermore, the Atlas 14s are backward-looking, that is, they are based on historical observations. How best to incorporate information about uncertain future precipitation extremes as they may respond to a warming climate remains a topic of research, but yet is of critical importance for project planning with multidecadal lead times. Planners in some states have access to customized climate projections and information products developed by state agencies while others don't have access to state-provided datasets. This disparity at the state level sets up a very uneven field for local communities seeking to characterize local hazards and secure federal grants for hazard mitigation.

Recommendation 1: Explore opportunities to routinely update characteristics of extreme precipitation and flood events with decadal climate predictions in support of forward-looking flood mitigation planning and infrastructure design.

2. Provide guidance for decadal projection of future hydrology

Findings: NOAA science and applications programs, laboratories, and community of researchers have developed numerous climate models, projections and experimental products with varying degrees of accuracy and uncertainty. Different climate products may be better suited for different applications, geographic and climatic settings. It is currently extremely difficult for end users with no direct involvement in the research programs to determine which of the resulting products are best suited to their specific application needs. For long range prediction, the Coupled Model Intercomparison Project (CMIP) has assembled simulations from multiple climate models to facilitate intercomparison and comparison to observations. However, each model has a very different performance when simulating different variables in different geographic regions and under different climate states. The choice of global climate models influences the prediction results, and users currently receive no guidance from NOAA on how to choose models for specific applications. In addition, the spatial scale of the global models is often too coarse to support regional applications. There is a need for spatially downscaled climate information usable at the regional and local scale. One example is the State of California's Cal-Adapt enterprise, which currently provides access to data based on high-resolution downscaled CMIP5 and CMIP6 projections.

Recommendation 2: Develop externally-focused guidance materials that synthesize current scientific knowledge and best practices for using climate projections to characterize future hydrology supporting decadal-scale decision making and infrastructure planning applications.

3. Enhance climate extension to the flood mitigation community

Findings: NOAA's River Forecast Centers (RFCs) use operational hydrology models to generate daily flood forecasts which are widely used by the emergency management community. Subseasonal hydrologic predictions are also being generated using NOAA's National Water Model which computes full natural flow for a dense network of river locations around the nation at time scales ranging from the most recent 28-hour period to predictions for 10-day and 30-day outlook periods. However, climate change is altering the characteristics of flood hazards as precipitation regimes change and land cover impacts such as wildfire alter landscapes and increase debris flows. In addition, several Western States have begun shifting the flood policy focus away from managing floods as a nuisance to capturing and storing flood waters for use during future drought periods. The changes include structural solutions such as retrofitting existing levees and buildings, non-structural solutions such as Forecast Informed Reservoir Operations (FIRO) programs, and hybrid solutions such as Flood-Managed Aquifer Recharge (Flood-MAR) programs, conjunctive use programs, and temporary appropriation laws which permit diversion of flood flows to groundwater storage when river levels exceed set thresholds. Design and operation of structural, non-structural and hybrid solutions require new hydrologic products that are not currently included in the existing suite of climate prediction products. NOAA River Forecast Centers could serve as the primary interface between NOAA and state and local flood management agencies who are developing flood mitigation infrastructure and climate resilience plans, and adapting operations to changing climate conditions.

Congress recently passed the bipartisan “Flood Level Observation, Operations, and Decision Support Act” (FLOODS) Act, which includes a provision for formation of a National Flood Information System, which among other things requires development of an improved flood early warning system. The FLOODS Act also provides for establishment of positions of Service Coordination Hydrologists at each of the ten NWS River Forecast Centers, who would be responsible for increasing impact-based decision support services via improved interactions with users and developers of flood forecast products (Flood Level Observation, Operations, and Decision Support Act, 15 USC § 9704 (2022)). The Act specifies activities which go beyond flood forecasting to include aspects of water management. These activities are likely to be infeasible without addressing the role of changing precipitation and temperature extremes on flood frequency and severity, and the overall seasonal water supply forecasts.

Recommendation 3: Enhance engagement of the River Forecast Centers in supporting long-range flood mitigation and climate resilience planning in the flood management user community through regional climate extension activities.

4. Integrate predictions of riverine and coastal flooding

Findings: The forecast regions for NOAA’s River Forecast Centers end at points where tidal influences begin to influence river water levels. As a result, there are currently no river forecasts in coastal watersheds and areas at risk of flooding from a combination of riverine flooding and coastal flooding. The inundation hazards in these areas are projected to increase in coming decades with changing precipitation regimes and sea level rise.

Recommendation 4: Develop operational capabilities to forecast combined riverine and tidal/storm surge supporting emergency response and resilience planning for coastal communities dealing with sea level rise.

Extreme Heat Hazards

Motivation

Heat is of increasing concern to community planners and resilience officers due to impacts of extreme events as well as chronic stress due to longer and more intense heat seasons in some regions of the country. Communities at the forefront of developing heat mitigation plans are continuing to learn about their needs as they delve more deeply into how best to protect their residents from the growing risk of negative heat-related impacts. In developing recommendations around the user-needs for forward-looking information on heat-hazards, the CWG conducted a series of interviews with heat officers in major urban areas as well a discussion with the leads of *National Integrated Heat Health Information System* (NIHHIS), and NOAA scientists leading efforts to make large-scale decadal predictions of heat (See Appendix A).

For context, we note that although the charge of this working group was to develop recommendations on needs for forward-looking information on the 5-10 year time horizon, we found that in many cases (not all!) strict separation of planning and response time-scales (Figure 3) was not particularly useful for practitioners. This was because the development of adequate response plans is iterative, evolving, relatively nascent, and urgent. As such, response time-horizons tended to be top-of-mind for officers. We worked to balance this bias by explicitly prompting users to think about how NOAA products could support planning time-horizon needs.

The users that we spoke with were particularly attuned to heat as it relates to human health and we gathered less information about the impact of heat on building and transportation infrastructure. As this is a multi-faceted topic, there is certainly room for a more in-depth study of how NOAA can support the information-needs of practitioners who build and maintain physical infrastructure. Overall, we identified three core needs around i) forecasts and warning processes; ii) tools, products, and data to support response and planning processes; and iii) research needs.

Figure 3: The value of forward-looking heat information for decision support:

1. Tailoring heat warnings to human health and safety

Findings: NOAA already provides multiple tools to help individuals and planning officials assess the potential for heat stress in their communities[2]. These include the *HeatRisk prototype* forecast, the *Wet Bulb Globe Temperature* and *Heat Index* tools for evaluating the likelihood of heat health impacts. NOAA is also leading the *National Integrated Heat Health Information System* (NIHHIS) interagency effort[3], which is focused on

Investments in these tools and programs indicate that NOAA places a high value on meeting the health and safety needs of local communities who are in danger of experiencing heat extremes.

However, heat, health and safety officers indicate that there is a need for NOAA to continue to improve the efficacy of heat advisory forecasts, warnings, and thresholds to make them more relevant to the local health and safety outcomes for residents. For example, practitioners suggested that the use of variable warning and advisory thresholds based on geographic location, heat wave intensity and duration, overnight temperatures, and community characteristics including demographic (e.g., age and pre-existing health conditions), housing (e.g., homeless, poor access to air conditioning), and labor specifics (e.g., outdoor workers) in a community is necessary.

[2] https://www.weather.gov/safety/heat-index
[3] https://www.heat.gov/pages/about-heat-gov

It should be noted that, in some cases, emergency managers may be restricted in their authority to deploy heat-safety resources in the absence of NWS warnings/advisories. This makes it particularly important for the NWS to be responsive to the local context of their thresholds. This interaction between physical variables and the lived-experience of residents suggests that the involvement of social scientists and collaboration across agencies and government levels (federal, state, local, community) will be necessary. Officers also indicated that NOAA (specifically the NWS) should provide advance warnings to health and safety officials when NOAA forecasts (including those made from weather and/or earth system models) indicate any potential (even at a very low likelihood) for extremely anomalous heat events. There appears to be concern that NWS forecasters may be overly conservative in their communication to public officials. Finally, it was also brought to our attention that there is a relative paucity of research-based evidence for officials to rely on as they design local heat mitigation strategies and prescribe warning/advisory thresholds. NOAA may be able to support the bolstering of this evidence base through the NIHHIS program mandate.

Recommendation 1: Continue to improve NOAA heat advisory and warnings to make them more relevant to community and resident-specific health and safety outcomes. Develop formal channels for interaction between NOAA forecasters and local safety officers to ensure reliable communication of any *potential (even at low likelihood*) for extremely anomalous heat events. We recommend continued strengthening of the NIHHIS program, including the relevant cross-agency collaborations and deepening engagement with state and local government officials who coordinate heat planning and emergency response.

2. Support local planning, preparing, and response decisions in urban environments.

Findings: Urban planners who are working to manage, predict, and mitigate unsafe heat conditions at the street and block-level have an unmet need for tools, datasets, observations, and models that can aid in their decision and planning process. Within urban environments, there can be significant variations in heat extremes based on building design, the color and material of buildings and ground surfaces, and proximity to vegetation, shade, and water. It is clear that there is a need for improved mapping of community and neighborhood-level extremes, as the temperature and humidity experienced at a local level can significantly exceed what is forecast and monitored at official NWS stations.

Tools, resources, and strategies for managing these highly localized (street level and neighborhood level, as needed) spatial and temporal variations, both in current and future conditions could be developed, maintained, and disseminated through NOAA programs.

While large cities may have access to the resources to simulate local heat variables using urban heat island and microscale atmospheric models, most cities in the U.S. do not have the resources, capacity or training to conduct these analyses without additional support. Similarly, pilot projects to make in-situ (and remotely sensed) observations of neighborhood-level heat extremes tend to focus on larger, and more well-resourced urban centers. There is a need to use this information to develop more generalizable local-scale information for small and mid-sized cities.

Recommendation 2: **Support the development, deployment, and use of open-source tools, models and high-resolution datasets that can be used to indicate, prepare-for and mitigate the potential for neighborhood-level extreme heat in urban environments.**

3. Create a clear institutional mandate within NOAA for provisioning of forward-looking heat hazard information.

Findings: There is a need for well documented, commonly-accepted, accessible, and authoritative sources of information on the potential for extreme temperature (and other human-safety and infrastructure-relevant heat outcomes) that project over the next 5 to 20 years. This centralized source of near-term heat information would have value for response, preparation, and planning professionals (e.g. urban planners, engineering and design teams, insurance providers, small business owners, health and safety officers etc). Some planners identified a need for data that can be included in cost-benefit analyses to justify investments in heat preparedness. Others indicated that the lack of a commonly recognized and authoritative source of forward-looking heat-risk information can be a barrier for local governments looking to i) justify investments in heat-related resilience activities, ii) obtain state and federal funding to finance resilience programs and projects, iii) point to clear standards to engineering standards.

While NOAA's National Centers for Environmental Information (NCEI) has a mandate to preserve, monitor, assess, and provide public access to climate data and information, it does not currently provide forward-looking guidance on extreme hazards. In general, there is a lack of clarity where, within NOAA, users can look for access to authoritative, quantitative guidance on the near-term, forward-looking potential for dangerous and extreme heat conditions. It was expressed that a *forward-looking* NOAA product analogous to the Atlas 14 precipitation frequency data for heat (i.e., point estimates of temperature, duration, frequency) would be useful in this context. A data-source such as this could potentially be accessed through the NIHHIS website (heat.gov), but the underlying research to produce and maintain this data product may need to come through directly from other NOAA offices, with data hosting through (e.g.) NCEI.

Recommendation 3: **A program or office within NOAA should be granted the authority and resources to become the official provider of forward-looking, quantitative, hazard information for heat hazards. This program should coordinate across relevant NOAA offices to develop a plan for i) conducting and/or incorporating the necessary underlying research and documentation to support the design, generation and maintenance of the data product, ii) ongoing and reliable hosting of the dataset, iii) making the data-product easily findable and accessible and monitoring, improving its utility for decision-makers.**

Wildfire Hazards

Motivation

The impacts of intensifying drought cycles, wildfire events, and increasing temperatures are felt acutely throughout the western United States and other fire-prone regions. The region struggles to address decades of land management decisions that have resulted in excess fuels and tree mortality, while fire behavior continues to change due to a warming climate. This results in larger, more destructive wildland fires that threaten ecosystems, communities, and economies in the region. To mitigate these hazards requires substantial investment in fuel treatments (using fire, natural grazing, and mechanical methods); landscaping to create defensible spaces; smoke damage remediation; home hardening (new construction and retrofitting); critical infrastructure protection; spatial fire planning; post-fire erosion, flooding, and debris flow management; replanting using native and climate change-relevant species; smoke preparedness for homes and public spaces; advisors in business continuity planning for wildfire response and recovery planning; and mental health services related to wildfire and smoke impacts. Broader impacts of air quality are addressed separately in the white paper, “Air Quality in a Changing Climate: NOAA’s Role”, submitted to the SAB on April 26, 2023.

1. Enhance assessment and mapping of wildfire risk to infrastructure and ecosystems.

Findings: Fire detection services have improved tremendously over the past decade and capabilities for initial detection of ignitions are now adequate. Remote sensing of fire intensity and spread has also improved dramatically using a combination of satellites and aerial surveys, particularly using drones. However, there is limited actionable information available for reducing vulnerability of specific systems using a combination of site-specific information on likely fire characteristics and guidance on how to make different types of structures, systems or ecosystems at a site less susceptible to damage.

Recommendation 1: Develop characterization of infrastructure and ecosystem risks–including loss of ecosystem services from compounded climate risks–to fully assess full impacts and support the development of climate-ready, fire adapted, communities.

2. Develop decadal projection maps of wildfire hazards, outcomes and emission.

Findings: Existing burn probability maps are largely developed from historical information from past fires, but these do not reflect the recent intensification of fires that has been observed in the West. A wide range of stakeholders including local governments, tribes, community groups, and private companies are trying to understand and manage the synergy between community protection, infrastructure damage, smoke exposure, and risks to water resources and forest resources, such as timber. Local agencies have begun to develop structured near-term risk analyses which compute the probability and intensity of fire, probable impacts on infrastructure, and potential mitigation strategies. Federal, state and local agencies and utilities partnering to prepare 2- to 5-year budgets and action plans need climate and wildfire projections to estimate and plan for the scope of needed future wildfire response and mitigation activities.

Recommendation 2: **Develop wildfire risk maps which integrate wildfire hazard potential, existing infrastructure and ecosystem vulnerabilities, antecedent and projected vegetation changes, and decadal climate projections to support decision making and adaptation actions in short (5-10 years) and mid (10-20) range planning efforts that support developing fire-adapted economies across the western U.S. and other fire-prone regions.**

3. Expand climate data services for wildfire mitigation planning.

Findings: Climate impacts such as changing weather distributions (e.g., wind and lightning), seasonal and periodic droughts and extreme precipitation events, have implications for vegetation and fuel distributions, likelihood of onset of wildfire, and fire behavior. These impacts may be compounded or mitigated by ongoing or planned fuels treatments across a multitude of state and federal land management agencies, public utilities, forestry operations, and other private land-owners.

Recommendation 3: **Expand development of climate data services for existing decision support tools for wildfire mitigation and planning and land management**

through engagement with existing multi-agency and partner initiatives such as the Wildland Fire Leadership Council (WFLC) and National Interagency Fire Center (NIFC) Predictive Services.

4. Expand prediction services for wildfire smoke exposure.

Findings: Increasing frequency, duration, size, and severity of large wildfires all contribute to increased emissions of particulate pollution, which impact the health of a far larger population than that directly exposed to the fires themselves. Aggressively expanding fuels treatments to mitigate fire risks necessarily implies trading exposure to particulate pollution during extreme wildfire events and seasons for more chronic exposure to pollution from large scale application of prescribed fire and wildland fire use to manage fuel loads. These tradeoffs and their health implications are still poorly quantified. Better quantifying when and where emissions from wildfires, prescribed fires and managed fires may result in harmful exposures for large populations will aid in targeting and managing planned fuels treatments, as well as justifying investments in smoke preparedness.

Recommendation 4: **Expand research and development of products for characterizing smoke hazards from wildfire and integrating health impacts of chronic smoke exposure into wildfire mitigation and public health response planning activities.**

Overarching Recommendation

Some common themes emerged in the review of opportunities for NOAA to enhance support for drought, flood, extreme heat, and wildfire hazard mitigation efforts. Many foundational pieces to address these planning needs are in place within NOAA. The NESDIS National Centers for Environmental Information (NCEI) routinely generates a set of climate products based on recommendations from its regional centers and customer service centers. In addition, NOAA research centers and funded research programs such as the Climate Adaptation Partnerships (CAP) / Regional Integrated Sciences and Assessments (RISA) program are continually engaging with stakeholders to develop conceptual climate products. However, there is no established process for transitioning these products to operations at the conclusion of the product development and validation phase.

A clearly defined pathway process is required to document the process of engaging with decision-makers to identify the characteristics of needed climate products and transitioning conceptual climate products from research to operations. This pathway would include a process outlining key decision points and the role of research, product development, and data services teams. The process should be accompanied by a roadmap which is periodically updated to report climate research products that are successfully transitioned to operations, climate products in development, and to prioritize products for transition to operations.

Appendix A

Table of Guest Speakers

Hazard	Speaker	Title/Affiliation	Reason for choosing
Drought	Joel Lisonbee	NIDIS Regional Drought Information Coordinator, Intermountain West and Southern Plains DEWS	National Integrated Drought Information System (NIDIS)
	Meredith Muth	NIDIS Regional Drought Information Coordinator, Southeast DEWS	
	Mark Svoboda	Director of National Drought Mitigation Center	U.S. Drought Monitor, drought prediction and mitigation planning.
	Tom Delworth	Senior Scientist, GFDL, and Leader of the GFDL Seasonal to Decadal Variability and Predictability Division	State of decadal prediction science and practice
Flood	Reem Zoun	Director of Flooding Planning, Texas Water Development Board	Development of first-ever State Flood Plan for regions in Texas. Major recent flood events including Hurricane Harvey (2017) and Tropical Storm Allison (2021).
	James Bronikowski	Manager of Regional Flood Planning, Texas Water Development Board	
	Matt Nelson	Deputy Executive Administrator for Planning, Texas Water Development Board	
	Robert Hartman	Consultant, Robert K Hartman Consulting Services Formerly: Hydrologist-in-Charge California-Nevada River Forecast Center, National Weather Service	Flood forecasting Operations. Forecast-Informed Reservoir Operations (FIRO).
	Fernando Salas	Director of the Geo-Intelligence Division in the Office of Water Prediction at NOAA's National Water Center (NWC)	NOAA Atlas 14 Precipitation Frequency Estimates
	Sandra Pavlovic	Earth System Science Interdisciplinary Center at NWC	
	Tom Graziano	Director, NWS Office of Water Prediction	
Heat	Jane Gilbert	Miami-Dade County Chief Heat Officer	Works to address impact of extreme heat across departments and partners

	Kathleen Ave	Sacramento Municipal Utilities District (SMUD), CA	Leading regional initiatives to address extreme heat
	Brendon Haggerty	Program Supervisor (interim) at Multnomah County Health Department, Portland, OR	Leading Portland's response to the Pacific NW heat dome of 2021
	Vivek Shandas	Founder of CAPA Strategies and Professor, Portland State University	Communicating heat hazards and social impacts.
	Lara Whitely Binder	Climate Preparedness Program Manager for King County	Heat hazard mitigation planning in King County, WA. Response to recent events including the Pacific NW heat dome of 2021.
	Addison Houston	Climate Adaptation Lead at King County Climate & Health Initiative	
	Julie West	Public Health Environmental Health Division, manage Healthy Community Planning and Partnerships group	
	Jared Schneider	King County Office of Emergency Management Hazard Mitigation Program Manager	
	Jamie Emert	Emergency Medical Services Division of King County, lead data analysis team within EMS	
	Juli Trtanj	Climate and Heat Health Lead, Climate Program Office, NOAA	National Integrated Heat Health Information System (NIHHIS), NOAA.
	Hunter Jones	NIHHIS Program Manager, Climate Program Office, NOAA	
Wildfire	Mary Mullusky	Chief, NWS Forecast Services Division, Analyze, Forecast & Support Office (AFSO)	Wildfire prediction and coordination activities within NOAA/National Weather Service.
	Stephen Bieda III	Science & Operations Officer, NWS Weather Forecast Office	
	Robyn Heffernan	Meteorologist, NWS National Fire Weather Science and Dissemination	
	Heath Hockenberry	National Fire Weather Program Manager, AFSO	
	Dave Sapsis	Research Supervisor/Fire Scientist, California Fire and Resource Assessment Program	Wildfire risk assessments, alternative management policy, and mitigation planning
NOAA Data	Ko Barrett	NOAA Senior Advisor for Climate	NOAA's Climate Ready Nation Initiative

Services	Benjamin DeAngelo	Deputy Director, NOAA Climate Program Office	NOAA's climate applications research
	Jin Huang	Division Chief, Earth System Science and Modeling Division (ESSM), NOAA Climate Program Office	
	Dan Barrie	Program Manager, Modeling, Analysis, Predictions & Projections (MAPP) NOAA Climate Program Office	
	Deke Arndt	Chief, Climatic Science and Services Division, NOAA National Centers for Environmental Information (NCEI)	NOAA's climate data services