

NOAA Response to the SAB Report on Climate Information Needs for 5-10 Year Hazard Mitigation Cycles

Document Overview

This document serves as the response to the Science Advisory Board's (SAB) report on Climate Information Needs for 5-10 Year Hazard Mitigation Cycles. Provided in this document is NOAA's response to each of the SAB's recommendations on Drought, Flood, Extreme Heat, Wildfire, and the SAB's overarching recommendation. If additional information is required please contact Amanda McCarty (amanda.mccarty@noaa.gov).

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Recommendations On Drought

Drought 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.

NOAA's Response

NOAA concurs with this recommendation. In the near term, Drought.gov will onboard new capabilities in Climate Engine, which facilitate threshold analysis and summarization. This will allow answering questions, from any drought index or anomaly dataset, such as "how many times did each pixel/county/basin/state exceed a drought threshold within a selected period?" This general capability will allow the investigation of decadal trends in both longer-term and short-term, and flash drought timescales. The results will be available on Drought.gov for users to explore with interactive mapping tools or the download of data in cloud-ready GIS formats from NODD.

NOAA's NIDIS program has partnered with the Western Regional Climate Center (WRCC), the Desert Research Institute (DRI), UC Merced, and Google to develop Climate Engine, a cloud computing web application in which programmers and non-programmers alike can quickly and easily process and visualize satellite and climate data in an interactive User Interface (UI) and Application Programming Interface (API). Data storage, access, and on-demand processing and storage are accomplished using the Google Cloud Platform (GCP), and the massively parallel cloud computing platform Google Earth Engine. Common climatic operations, along with multiple modern drought indices, have been coded into Google Earth Engine and made available in the Climate Engine UI and API. NIDIS/Drought.gov now operates an operational version of the Climate Engine API, running within a NOAA Cloud environment, leveraging a NOAA contract with Google Earth Engine and the NOAA Open Data Dissemination (NODD) program. Drought.gov is using Climate Engine to produce hundreds of drought indices each day, based on multiple leading foundational datasets from NOAA, NASA, and other partners. These operational products are not only located on Drought.gov but also disseminated to partners through the NIDIS-led Regional Drought Early Warning Systems (DEWS). Vegetation Health Index (VHI) produced by LEO satellites provides critical inputs in drought monitoring within the USA and globally and is used extensively by USDA.

Drought 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.

NOAA's Response

NOAA agrees with part of this recommendation. NWS's Climate Prediction Center currently produces monthly and seasonal drought outlooks, as well as an experimental rapid-onset drought tool to identify areas of drought that may develop in the coming 2-3 weeks. NIDIS and NWS are collaborating to improve both reliability and usability of existing NWS Drought Outlook

products as well as develop experimental products. Improvement in precipitation prediction skill, and thus in drought prediction skill, will be necessary to enhance NOAA's suite of drought prediction products and expand to longer timescales.

NOAA is working to expand awareness of drought conditions and developing drought risks through modernized messaging and extensive regional coordination, in particular through NWS field offices and NIDIS regional Drought Early Warning Systems (DEWS). There is some limitation on reach because there is not currently full national geographical coverage of the regional DEWS networks due to NIDIS resource constraints.

Enhancing and expanding NOAA's forecasts will help to serve stakeholders across several sectors and geographic scales, to include infrastructure managers. However, managing drought mitigation infrastructure is outside of NOAA's mission.

Both NIDIS and the Weather Act are currently being considered for reauthorization by Congress, which may also provide opportunities to enhance and expand forecasting capabilities.

Drought 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.

NOAA's Response

NOAA concurs with this recommendation and recognizes that drought impacts reach beyond the economic impacts of just the agricultural sector and has initiatives that address both the need to inform climate mitigation planning as well as enhancing drought assessment.

NOAA/NIDIS led an effort earlier this year identified priority actions and outstanding research questions that would continue to advance drought assessment in a changing climate.

Addressing these needs will improve drought assessment so that it consistently accounts for non-stationarity which is vital given the role assessments play in supporting communities in preparing for, mitigating, and responding to drought.

NOAA/NIDIS is developing a Climate Adaptive Drought Planning (CADP) platform prototype in partnership with other federal agencies, that will provide needed technical assistance for quantifying drought risk and vulnerability. This national platform will be hosted on Drought.gov and will expand capabilities for all communities to improve drought mitigation and adaptation. The CADP platform will be informed by previous NOAA-supported multi-sector research on the economic impacts of drought including the 2020–2021 Southwestern U.S. Drought Assessment. Improvements to drought risk assessments for current, seasonal, and future drought events

allow for prioritization of drought resilience strategies for adaptive water and land use management, which accounts for anticipated non-stationarity due to climate change. However, meaningfully quantifying economic losses from drought across different sectors will require additional resources and is a longer-term goal for NOAA/NIDIS, as the economic variables for drought impact vary by sector. Additional resources will also be needed to fully implement the CADP platform across all geographies and sectors.

NOAA is working with USACE, USBR, and other water resource management agencies on enhancing the application of Forecast Informed Reservoir Operations (FIRO) to support the development of adaptation strategies and sustainability policies to increase the resilience of existing water resources infrastructure to more effectively balance future changes in drought and flood risks. Funding as part of the 2022 Bipartisan Infrastructure Law (BIL) is supporting NOAA efforts to develop, demonstrate, and transition into operations improved predictions of too much water and too little water that can inform reservoir operations and water resources management decisions.

Many NOAA programs work on drought-related issues relevant to this recommendation. NOAA has recently established a cross-Line Office team, focused on drought, under the umbrella of Climate Ready Nation. The purpose of this team is to build on existing collaboration across NOAA, enhance awareness of drought-related activities across NOAA, and to expand opportunities for one-NOAA contributions to a drought-ready nation.

Recommendations On Flood

Flood 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.

NOAA's Response

NOAA concurs with this recommendation. NOAA's NWS and OAR are working on the next generation of precipitation frequency estimation through updates to the Atlas 15 volumes and through development of guidance for Probable Maximum Precipitation (PMP) in order to characterize extreme precipitation using climate prediction scenarios.

NOAA is recognized by the engineering and floodplain management communities as the authoritative source of precipitation frequency data and has a long history of generating these data that serve as the foundation for built infrastructure nationwide. NOAA engages with key partners such as the American Society of Civil Engineers and the Association of State Floodplain Managers on the requirements for precipitation frequency information and the cadency at which updates should be made.

The December 2022 [FLOODS Act](#) authorizes NOAA to establish a program, known as the *NOAA Precipitation Frequency Atlas of the United States*, to compile, estimate, analyze, and

communicate the frequency of precipitation in the United States. Also in December 2022, the [Precip Act](#) directs NOAA to improve federal precipitation estimation for the United States. Furthermore, with the 2022 Bipartisan Infrastructure Law (BIL), NOAA received funding to facilitate updating of Probable Maximum Precipitation (PMP) estimates that reflect climate change and uncertainty.

The BIL provided NWS with first-ever direct federal funding to update the NOAA Atlas 14 precipitation frequency standard for the entire U.S. and its territories, while accounting for climate change. These updated precipitation frequency estimates will be developed by the Office of Water Prediction as NOAA Atlas 15 and will be presented in two volumes. Volume 1 will account for non-stationary temporal trends in historical observations, and Volume 2 will use future climate model projections to generate adjustment factors for Volume 1. NOAA has developed a new methodology for Atlas 15, in partnership with the Federal Highway Administration and the academic community, as described in the "[Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates](#)" assessment report.

The Atlas 15 estimates will provide critical information on extreme precipitation to support flood mitigation planning and infrastructure design with information that considers multi-decadal climate projections, with volumes expected to be updated at least every 10 years.

Low Earth Orbit (LEO) data are now operationally used to create flood maps globally that are used by several agencies including FEMA within the US and other countries via the international disaster charter.

Flood 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.

NOAA's Response

NOAA concurs with this recommendation. A NOAA team is conducting a study on climate changes impacting western watersheds over the next 30 years and is developing a plan (currently unfunded) for further long-term studies.

As directed by the language accompanying the Consolidated Appropriations Act, 2022, Public Law 117-103, and as part of NOAA's focus on expanding climate services to inform climate adaptation efforts, NOAA is conducting a study of hydroclimatological changes in the major river basins of the Western United States over the next 30 years. In addition, Congress requested a report proposing a "plan to establish a long-term research and monitoring program to improve the understanding of the hydroclimatological changes in the major river basins of the Western United States."

The proposed program plan under development would include methodological evaluation and probabilistic modeling of future changes in the volumes of water naturally available and natural water cycle in the different regions of the West. The report's proposed activities would serve to improve collective understanding of model uncertainties and inform future monitoring, model development, and prediction/projection activities. The report's proposed program has four goals: monitor and assess real time and historical hydroclimate to support present day decision making; improve predictions and projections of future hydroclimate conditions; adopt standards to advance community water resources modeling; and develop "best-estimate" assessments of future hydroclimate conditions for investments supporting climate adaptation. If funded, the program and resulting actions will result in guidance materials for using climate projections for multi-decadal decision making and infrastructure planning.

Flood 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.

NOAA's Response

NOAA concurs with this recommendation. The NWS River Forecast Centers are expanding use of ensemble forecasts in operations, though development resource challenges and RFC staffing demands constrain the degree of long-range planning that is provided. Furthermore, the NWS Water program is expanding research into climate resilience, which will inform future technical approaches for resilience planning.

Considerable community engagement is performed by NWS field offices, including River Forecast Centers (RFC) and also Weather Forecast Offices (WFO), in supporting near-term and extended-range needs through climate, flood prediction, and water supply forecasts and outlooks. Much of the information is presented as probabilistic ensembles representing forecast uncertainty. This includes information useful for mitigating long-range impacts from the RFC Hydrologic Ensemble Forecasting System (HEFS), which provides forecasts that account for both meteorological and hydrologic uncertainties. HEFS is the core capability informing the Forecast Informed Reservoir Operations (FIRO), which is used by water resources managers to optimally balance flood control and water supply demands. RFCs also provide specialized, custom information for local projects and studies supporting long-range mitigation and climate resilience. WFOs provide modernized WFO Drought Information Statements that characterize hydrologic, agricultural, meteorological, and socioeconomic drought conditions, and support local community needs. Furthermore, a series of previous and ongoing social science studies continue to provide clarity on requirements for the water prediction community.

The Cooperative Institute for Research to Operations in Hydrology (CIROH) established in April 2022 provides a structure for expanding research and development for water prediction across all time scales, including projects supporting climate-focused topics. CIROH will promote expansion of support for long range needs regarding information used for mitigation and

resilience. Stronger connections between RFCs and NOAA-managed research and development activities will enhance RFC service levels by fully informing the research based on RFC operations experience.

Flood 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.

NOAA's Response

NOAA concurs with this recommendation. A new generation of NWS total water level forecast delivery is being implemented, and coastal communities are the subject of a proposal for a robust framework for resilience planning.

NOAA continues to support congressional direction from Title III of the Coordinated Ocean Observations and Research Act of 2020, [Public Law No: 116-271](#) to collaborate with and provide decision support regarding total water prediction. The most recent version of the National Water Model (NWM version 3.0) provides first-time Total Water Level (TWL) guidance for coastal areas of the CONUS, Hawaii, Puerto Rico, and the U.S. Virgin Islands by coupling the National Ocean Service (NOS) and National Hurricane Center (NHC) coastal models leveraging the NWM, SCHISM, STOfS, and PSURGE forecast suite. Future services expansion includes the provision of flood inundation mapping (FIM) in the coastal zone for analysis and forecast timeframes, and case studies of historic storm events. These maturing operational capabilities for TWL information will support response and resilience planning for coastal communities.

The NOAA whitepaper report "[Coastal Flooding and Inundation Information and Services at Climate Timescales to Reduce Risk and Improve Resilience](#)" enumerates a multi-step vision to provide a suite of coastal inundation service at climate timescales. This report proposes a centralized, integrated, operational framework for coastal information and services. Other coastal inundation processes to consider are flooding related to sea ice changes in the Arctic.

Recommendations On Extreme Heat

Extreme Heat 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 crossagency collaborations and deepening engagement with state and local government officials who coordinate heat planning and emergency response.

NOAA's Response

NOAA concurs with these recommendations. Pending capacity, we anticipate making some enhancements in time for the 2024 Heat Season.

NOAA National Weather Service (NWS) local Weather Forecast Offices (WFOs) continue to strengthen partnerships with local, county, and state governments, including public health officials, to document and understand local public health impacts. These partners regularly receive Impact-based Decision Support Services (IDSS) and briefings ahead of potential extreme heat events. Thresholds of NWS Excessive Heat Watches, Warnings, and Heat Advisories are assessed at the local level to ensure thresholds reflect local impacts based on partner input.

At the national level, NWS is experimentally expanding the Western Region HeatRisk prototype across the contiguous United States, which combines climatologically based heat information with CDC heat-health data sets to provide a forecast of the potential level of risk for heat-related impacts.

NWS is a founding member and co-lead of the NIHHIS program along with OAR/CPO and CDC. Recent efforts by NOAA and other NIHHIS agencies include multiple federal heat safety social media campaigns per year, health informed heat safety infographics, and a federal heat safety summer campaign. In collaboration with NIHHIS, the NOAA Regional Coordination Teams and the NOAA Regional Climate Service Directors organized and facilitated Heat Equity Tabletop Exercises in Las Vegas, Phoenix, Charleston, and Miami to stress test federal-state-local heat plans and identify gaps (with NWS WFO representatives and local EMs involved in each exercise). Future heat tabletop exercises are proposed for FY24 pending capacity. Best practices from the tabletops, as well as the Heat Equity pilots more broadly, have been developed and will be posted to Heat.gov.

NIHHIS and NWS/CPC are also working to expand use of NOAA's products for heat decision-making, on expanded timescales, such as making improvements to the CDC Heat and Health Tracker, which was piloted by OAR/CPO and CDC through the USGCRP. This tool uses the CPC 1-month outlook to characterize future heat exposure potential (as well as using NWS HeatRisk thresholds). Heat.gov is in discussions with NWS (WPC, CPC) on how to improve the products and services available through Heat.gov for the public. NIHHIS is also working with Forrester on a Heat.gov user assessment to develop requirements for enhancements. Pending capacity, we anticipate making some enhancements in time for the 2024 Heat Season.

Extreme Heat 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.

NOAA's Response

NOAA concurs with this recommendation with modifications. NOAA suggests extending these services beyond urban environments, to also provide heat information at decision-relevant scales for State, Local, Tribal, and Territorial decision-makers.

NOAA, as a contribution to NIHHIS, has supported over 70 communities in conducting [citizen science urban heat island \(UHI\) mapping campaigns](#), the results of which include high-resolution air temperature and humidity datasets, reports, and interactive maps that are free and open source. In FY24, thanks to the IRA supplemental, NIHHIS is running two competitions (worth a combined total of \$5M) to establish 2 heat-focused Centers of Excellence that have at their core a requirement to develop and deploy open data, tools, and other outcomes to mitigate community-scale heat impacts. These centers will build on the success of the UHI mapping campaigns.

NOAA already supports the development, deployment, and use of numerous datasets such as via the [Extreme Heat Vulnerability Mapping Tool](#), the [Heat Equity mapper](#) (developed by NESDIS Viz Lab) and the [Virtual Reality Urban Heat Island \(UHI\) experience](#) (developed by the NESDIS Viz Lab and Office of Education SOS team). The OAR-funded, NESDIS-collaborating Applied Research Center also developed a new [Analysis Ready Climate Health Dataset](#) to support community-based research. NCEI's Climate at a Glance tool is a user-friendly way to access temperature climatologies at the city scale.

In FY21, NIHHIS also funded 5 applied research projects that developed new free and open tools and other resources for communities to build resilience to heat. For example the [Plan Integration for Resilience Scorecard for Heat \(PIRS for Heat\)](#) as well as a new American Planning Association [guide on urban heat resilience](#) for planners.

Extreme Heat 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.

NOAA's Response

NOAA concurs with the recommendations to coordinate activities across relevant NOAA offices to develop an inclusive plan that will improve access to authoritative information for decision makers.

As the lead of the Climate Ready Nation (CRN): Heat focus, NIHHIS can play a pivotal role in integrating heat services across the agency as well as in tailoring them for decision-makers.

NWS, NESDIS, and OAR all have critical roles to play in *producing* and *maintaining* this information. The NIHHIS/CRN:Heat team plans to conduct a NOAA Heat Summit in FY24 to begin to explore alignment on heat activities across LOs.

NOAA's National Centers for Environmental Information (NCEI) is responsible for placing NOAA's environmental data into historical context, and for providing NOAA authoritative climate data records. NCEI is responsible for ongoing and reliable hosting of NOAA environmental datasets, and for making data-products easily findable and accessible to improve utility for decision-makers. NCEI regularly engages regionally via the Regional Climate Service Directors and Regional Climate Centers to understand needs and support co-development for climate information and services, modeling service delivery across NOAA.

NOAA is already recognized as the "official provider of forward-looking, quantitative, hazard information for heat hazards." With enhanced authority, resources, and interagency collaboration, NOAA could go further than hazard information, toward co-developing and providing information on exposure (in collaboration with Census population estimates), and providing integrated information to help characterize the *risk of impacts* due to heat hazards. While NOAA does not have in-house all of the datasets and expertise required for this (we cannot do this without engaging other agencies in their respective missions and mandates), we do have a system working toward this (NIHHIS), and we host the place where this outcome can come together for the public: Heat.gov.

NOAA provides a variety of heat-related products and services across timescales. NWS Public Weather Services Program and Climate Services Program oversee NWS heat related products and services such as seasonal and sub-seasonal temperature outlooks (at monthly and 3-month scales, going out one year), week 2 hazards charts, Day 3-7 hazards charts, text and graphical hazardous weather outlook, watches, warnings, and advisories all inclusive of heat. NWS also has tools providing deterministic and probabilistic heat forecast information. NOAA Physical Sciences Laboratory provides forecast information related to Marine Heatwaves.

NOAA OAR and NWS are also co-founders and co-leads of the National Integrated Heat Health Information System (NIHHIS), coordinating across federal agencies regarding heat products, services, messaging, and outreach - including in support of Heat.gov. The NWS Public Program is the NWS representative on NIHHIS, guiding strategy and goals, as well as leading the NIHHIS Communications Working Group.

NOAA Research (OAR) funds and conducts research and transitions outcomes into operations and applications with NWS, NESDIS, and external partners. For longer timescales, for example, GFDL is developing modeling capabilities at the decadal timescale, and they have an empirical statistical downscaling team that collaborates with NIHHIS and other parts of NOAA to develop high-resolution climate data that is in high demand by decision-makers. The Climate Program Office (MAPP, CVP, COM programs) supports a Rapid Attribution Team that is developing new climate attribution services, with a heat-focused pilot in discussion.

Recommendations On Wildfire

Wildfire 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.

NOAA's Response

NOAA can offer available climate scale forecasts to help develop a characterization of infrastructure and ecosystem risks but is not the lead agency to perform this task. NOAA would have to partner with other wildland fire management agencies or receive a Congressional mandate to translate environmental forecasts to ecosystem impacts involving burned areas. Characterizing risk to infrastructure is largely a FEMA activity. NOAA fire and fire programs coordinate with FEMA and the US Fire Administration to utilize community level risk assessments, and will work to inform these risk assessments with climate projections.

Similarly, risks to terrestrial ecosystem services are in the domain of partners in USGS and USDA. Currently, NOAA does not employ a framework for estimating past or potential future losses associated with damage to ecosystems (e.g., the Billion Dollar Disasters product does not take these impacts into account). Working with agency partners to develop these capabilities would be a valuable complement to the available suite of hazard risk assessment tools.

Wildfire 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.

NOAA's Response

Similar to Wildfire Recommendation #1, NOAA can offer available climate scale forecasts to help develop risk maps but is not the lead agency to perform this task. NOAA would have to partner with other wildland fire management agencies or receive a Congressional mandate to translate environmental forecasts to ecosystem impacts vegetative changes caused by burned areas. This is largely a research community and FEMA activity. NOAA fire and climate programs coordinate with FEMA and the US Fire Administration to utilize community level risk assessments, and will work to inform these risk assessments with climate projections. Also, wildfire risk maps already exist: <https://wildfirerisk.org/> and <https://hazards.fema.gov/nri/wildfire>.

An effort to characterize fire potential on timescales of 5-20 years would be uniquely valuable for community planning and hazard mitigation. NOAA is supporting projects to improve climate

projections at these time scales (e.g., [MAPP Climate Futures](#), [Climate Variability and Predictability Program](#)). However, it remains a challenge to generate actionable projections of regional hydroclimate and drought on these time scales, let alone fire potential. This challenge is exacerbated by difficulty in modeling vegetation characteristics on these time scales, as well as human development patterns that determine community exposure.

Wildfire 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.

NOAA's Response

NOAA concurs with this recommendation. NOAA/NWS is taking positive steps currently by expanding staff (an increase of 5 positions) at NIFC for the continued interagency coordination and development of fire environment integrated services, including climate. NOAA actively participates on the National Wildfire Coordinating Group, Predictive Services Oversight Group, White House Wildfire Resilience Interagency Working Group, and the Wildfire Commission (among other interagency fire related organizations). NOAA OAR is also developing, through DRSA and BIL funding, subseasonal-to-seasonal-to-decadal wildland fire risk information products to inform the likelihood of wildfire and the prepositioning of fire suppression and management efforts.

Wildfire 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.

NOAA's Response

NOAA concurs with this recommendation. Sustained research grant funding through NOAA's Weather Program Office will help expand research and development on smoke hazards. NOAA NWS Fire and Public Weather Service programs coordinate with USFS, EPA, and NASA fire and air quality projects on smoke forecast products and services. Weather Forecast Offices around the country coordinate with public health partners on public messaging, wildfire mitigation, and smoke impacts.

NOAA's satellite observations are being used by operational weather models to [improve forecasts for smoke, and its impact on air quality](#). NOAA is improving predictive modeling systems that can be used to forecast the location and amount of smoke downstream of fires, which are used by the National Weather Service, EPA, and others to provide warnings to vulnerable communities.

Overarching Recommendation

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.

NOAA's Response

NOAA agrees with this recommendation. Investments in social, behavioral, and economic science allow for improved engagement with decision-makers to understand capabilities and gaps in climate-sensitive decision-making processes. There is an opportunity to improve the product life cycle from start to finish: understanding gaps, requirements development and adjudication, solution development, transition to operations, and successful service delivery. NOAA will commission the Service Delivery Team, part of the ESIB Coordination Team, to lead a cross-line office approach to define common terms and metrics for success of an integrated research-to-operations-to-service delivery (R2O2S) framework, while recognizing that the research-to-operations framework needs to be extended to include regional and local climate service delivery. NOAA agrees that this process will work toward two deliverables: a defined R2O2S process that optimizes continuous user engagement via a true process of co-production of climate services, and a living roadmap that serves as a common point for reference for users to access information on climate services delivery improvements at various stages of the product life cycle.

List of Acronyms and Abbreviations:

AAAAI	American Academy of Allergy, Asthma & Immunology
ABL	Atmospheric Boundary Layer
AC4	Atmospheric Chemistry, Carbon Cycle and Climate
ACRS	NSTC Air quality and Community Research Subcommittee
ACX	GeoXO Atmospheric Composition Instrument
AEROMMA	Atmospheric Emissions & Reactions Observed from Megacities to Marine Areas
AeRoNet	Aerosol Robotic Network
AGES	AEROMMA+CUPiDS, GOTHAAM, EPCAPE, and STAQS workshop
AM4VR	NOAA GFDL Variable-Resolution global Atmospheric chemistry-climate Model
AQ	Air Quality
ARL	Air Resources Laboratory (NOAA OAR ARL)
ARM	Atmospheric Radiation Measurement sites
ASHAQ	NASA Applied Sciences in Health and Air Quality
ATom	Atmospheric Tomography
BIL	Bipartisan Infrastructure Bill
C&GC	Climate & Global Change
CAMS	ECMWF Copernicus Atmosphere Monitoring Service
CAP	Climate Adaptation Partnership program (CAP/RISA)
CAPTEX	Cross APPalachian Tracer EXperiment
CARB	California Air Resources Board
CATChem	Configurable ATmospheric Chemistry
CRACMM	Community Regional Atmospheric Chemistry Multiphase Mechanism
CDC	Centers for Disease Control
CDR	Climate Data Record
CIRES	Cooperative Institute for Research in Environmental Sciences
CIROH	Cooperative Institute for Research to Operations in Hydrology
CMAQ	RRFS Community Multiscale Air Quality Modeling System
CMRA	NOAA Climate Mapping for Resilience and Adaptation
ConUS	Continental United States
CPASW	Climate Prediction Applications Science Workshop
CPO	Climate Program Office (NOAA OAR CPO)
CSI	CPO Climate and Society Interactions
CSL	Chemical Science Laboratory (NOAA OAR ESRL CSL)
CUPIDS	Coastal Urban Plume Dynamics Study
DOE	Department of Energy
GEMS	Geostationary Environmental Monitoring Spectrometer
EAN	European Aeroallergen Network
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
ECMWF	European Center for Medium-range Weather Forecasts
EDMF	MYNN Eddy Diffusivity-Mass Flux
EJ	Environmental Justice
EMC	Environmental Modeling Center (NOAA NWS NCEP EMC)
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ERB	Earth's Radiation Budget program
ESM	NOAA GFDL Earth System Model
ESRL	Earth System Research Laboratory (NOAA OAR ESRL)
FENGSHA	Wind-blown dust emission forecast model
FIREX-AQ	Fire Influence on Regional to Global Environments and Air Quality
FIRO	Forecast Informed Reservoir Operations

FMC	Financial Management Center
GEFS-Aerosols	Global Ensemble Forecast System Aerosol component
GEO	Geostationary Earth Orbit
GeoXO	NOAA Geostationary eXtended Observations mission
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA OAR GFDL)
GHG	GreenHouse Gas
GML	Global Monitoring Laboratory (NOAA OAR ESRL GML)
GOES	NOAA Geostationary Operational Environmental Satellite
GOTHAAM	Greater New York Oxidant Trace gas Halogen and Aerosol Airborne Mission
GRAAPES	GRGreenhouse gas And Air Pollutant Emissions System
GSL	Global Systems Laboratory (NOAA OAR ESRL GSL)
HEFS	Hydrologic Ensemble Forecast System
HRRR	NOAA High-Resolution Rapid Refresh model
HYSPLIT	NOAA ARL Hybrid Single-Particle Lagrangian Integrated Trajectory model
ICAMS	Interagency Council for Advancing Meteorological Services
IDSS	Impact-Based Decision Support Services
IMPROVE	EPA Interagency Monitoring of PROtected Visual Environments
ISD	NOAA NCEI Integrated Surface Database
JPSS	NOAA Joint Polar Satellite System
LEO	Low Earth Orbit
MJO	Madden-Julian Oscillation
MoA	Memorandum of Agreement
MYNN	Mellor–Yamada–Nakanishi–Niino scheme
NAQFC	National Air Quality Forecast Capability
NASA	National Aeronautics and Space Administration
NWM	National Water Model
NWS	National Weather Service
NCEI	National Center for Environmental Information (NOAA NCEI)
NCEP	National Centers for Environmental Prediction (NOAA NWS NCEP)
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA NESDIS)
NGO	Non-Governmental Organization
NIDIS	National Integrated Drought Information System
NIH	National Institutes of Health
NIHHIS	NOAA & CDC National Integrated Heat Health Information System
NIST	National Institute of Standards and Technology
NMME	North American Multi-Model Ensemble
NSF	National Science Foundation
NSTC	National Science & Technology Council
NURPACS	NOAA User Readiness Plan for Atmospheric Composition from Space
NWP	Numerical Weather Prediction models
NWS	National Weather Service (NOAA NWS)
OAR	Oceanic and Atmospheric Research (NOAA OAR)
OFCM	Office of the Federal Coordinating Meteorologist
OSTP	Office of Science and Technology Policy
PI	Principal Investigator
PM2.5	Fine Particulate Matter (2.5 microns or less in diameter)
PMEL	Pacific Marine Environmental Laboratory
PMP	Probable Maximum Precipitation
POES	NOAA Polar Orbiting Environmental Satellites
R&D	Research & Development
RAP-Chem	Rapid-Refresh Model Coupled to Chemistry

RFC	River Forecast Center (NWS)
RISA	Regional Integrated Sciences Assessments program
RRFS	NOAA Rapid Refresh Forecast System
RRFS-SD	Smoke / Dust
S2S	Subseasonal to Seasonal
SAB	NOAA Science Advisory Board
SABRE	Stratospheric Aerosol processes, Budget and Radiative Effects
SC-ACIS	Subcommittee on Atmospheric Composition and Information Services
WG-AQ	Working Group on Air Quality
WG-ATD	Working Group on Air Transport and Dispersion
WG-FWS	Working Group on Fire Weather Services
WG-VA	Working Group on Volcanic Ash
SONGNEX	NOAA CSL Shale Oil and Natural Gas Nexus
STAQS	Synergistic TEMPO Air Quality Science
sUAS	NOAA small Uncrewed Aircraft Systems
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TOAR	Tropospheric Ozone Assessment Report
TWL	Total Water Level
UAS	Uncrewed Aircraft Systems
UFS	Unified Forecast System (-Chem, -Aerosols)
USDA	US Department of Agriculture
WFO	Weather Forecast Office (WFO)
WMO	World Meteorological Organization
WPO	Weather Program Office (NOAA OAR WPO)