2023 ENVIRONMENTAL INFORMATION SERVICES WORKING GROUP (EISWG) REPORT TO CONGRESS

PRESENTED TO THE NOAA SCIENCE ADVISORY BOARD
BY THE ENVIRONMENTAL INFORMATION SERVICES WORKING GROUP (EISWG)

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2023 EISWG Report

to the United States Congress

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Environmental Information Services Working Group (EISWG)
(The EISWG is a Standing Working Group of the SAB)

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INTRODUCTION

This sixth report to the United States Congress from the National Oceanic and Atmospheric Administration (NOAA) Science Advisory Board (SAB) Environmental Information Services Working Group (EISWG) is made in accordance with Title IV, Sec. 401(c) of the Weather Research and Forecasting Innovation Act of 2017 (P.L. 115-25, signed 18 April 2017), and as amended (most recently by P.L. 115- 423, 7 January 2019) (hereafter, the "Weather Act"), which assigns EISWG the responsibility to prepare and transmit an annual report, along with specific follow-on actions, to be completed as follows:

> "ANNUAL REPORT.—Not less frequently than once each year, the Working Group shall transmit to the Science Advisory Board for submission to the Under Secretary a report on progress made by National Oceanic and Atmospheric Administration in adopting the Working Group's recommendations. The Science Advisory Board shall transmit this report to the Under Secretary. Within 30 days of receipt of such report, the Under Secretary shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a copy of such report."

The EISWG appreciates the Congressional interest in its work, and its members stand ready to meet with Congress to provide additional details regarding the contents of this report.

REPORT OVERVIEW

The 2023 EISWG Report to Congress (RtC) begins with a statement on the urgent need for NOAA's weather programs to meet rapidly increasing demands and the critical support provided by Congress. This is followed by four core report sections that focus on: (1) the assessment of NOAA progress in adopting previous EISWG recommendations (as required by The Weather Act); (2) a brief summary of new EISWG reports with findings and recommendations approved by the SAB within the last year and awaiting initial NOAA responses; (3) additional topic areas where findings and recommendations are currently in preparation by EISWG; and (4) the close relation of EISWG activities to the Priorities for Weather Research (PWR) report, its recommendations, and its potential impact on the 2024 EISWG Report to Congress. This closes with a brief summary of common needs and recommended immediate first steps. Five appendices collect, in a compact tabular form, the original SAB-approved EISWG recommendations and the corresponding initial NOAA responses to each. Links to the original NOAA reports, the EIWSG reviews with findings and recommendations, and the NOAA responses are included in each appendix.

URGENCY OF NOAA WEATHER PROGRAMS AND CONGRESSIONAL SUPPORT

Ensuring a Weather Ready Nation (WRN) has been a motivational call to action since its 2014 inception at the National Weather Service (NWS). Designed to help build preparedness and resilience to extreme weather, water, and climate events, this call to action is expanding to include a Climate Ready Nation. Over this period, the environmental information needs required to support a WRN have only grown. The demands for actionable weather forecasts with longer lead times have steadily increased based on the frequency, duration, and severity of high impact and extreme weather, water and climate events nationwide. Extreme-event information needs that previously could be accommodated by a short-term surge capacity have merged into a near-continuous demand for a higher level of NWS response. Examples include the need to respond to the increasing frequency of severe heat waves and heat domes, wildfires and unhealthy air quality, droughts and floods, hurricanes and tornadoes, winter storms and extreme cold, etc. As one quantifiable example, the figure below plots the average time between Billion Dollar [or greater] Weather and Climate Disasters derived from the NOAA National Centers for Environmental Information (NCEI) database. The average time of 90 to 130 days between billion-dollar damage exceedance events experienced in the 1980's has dramatically decreased to its current average of only 20 days, leaving little if any time to recover from one event before preparing for the next.

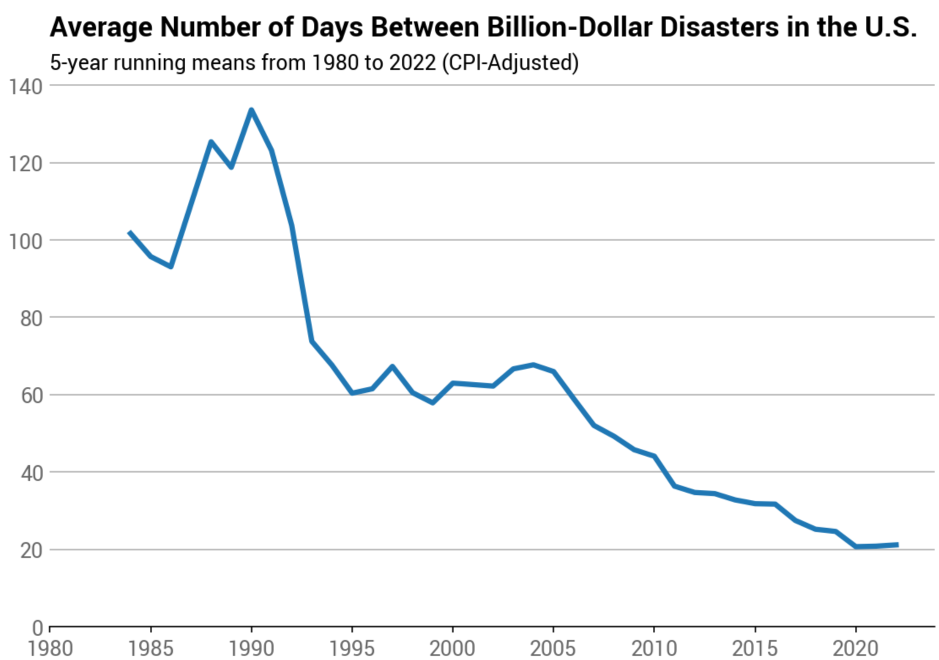

Figure 1: Five-year running means of the annual average number of days between the "Begin Dates" of Billion Dollar Weather and Climate Disaster "Events" documented in the NOAA NCEI database between 1980 and 2022.The steady decline in the number of days between major events is one illustration of the increasing demands on NOAA services.

The need to expand support for NOAA to respond to these growing demands for services has been recognized by the U.S. Congress. In 2020, Congress requested the NOAA SAB to respond within one year with the Priorities for Weather Research (PWR) report that identified investments required to produce true improvements in weather forecasting and dissemination. The SAB delivered the PWR report in 2021 with broad endorsement across the weather enterprise. NOAA has referenced it repeatedly in their subsequent budget requests and prioritizations. Congress has further recognized the need for urgent investment in NOAA through the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL). With full realization that these acts include unprecedented levels of new investments that include covering a backlog of NOAA needs, it is also clear from the increasing and ongoing demands of a Weather, Water, and Climate Ready Nation that sustained core funding for research and operations beyond short-term supplementals will still be required.

This EISWG 2023 Report to Congress will emphasize both the successes and the challenges in NOAA's response to EISWG recommendations. One shared challenge is associated with insufficient longer-term core implementation support. The Weather Act Reauthorization that Congress is currently developing is an opportunity to facilitate the required transformation. EISWG is ready to continue to organize and provide community expertise to inform this process. As noted in the PWR report, the benefits of a fully resourced weather and climate portfolio across the weather enterprise will be a more vibrant and equitable weather-informed economy, and a nation that is better able to respond, and is more resilient, to extreme weather. The Interagency Council on Advancing Meteorological Services (ICAMS), co-chaired by the Under Secretary of Commerce for Oceans and Atmosphere, can help coordination efforts across federal agencies in the weather enterprise to broadly advance EISWG recommendations with greatest efficacy.

SECTION 1. NOAA Progress in Adopting EISWG Recommendations

BACKGROUND AND MOTIVATION: The EISWG has approached this 2023 Report to Congress with an expanded scope based on the convergence of environmental urgency and Congressional action. A core responsibility of The Weather Act charge to the EISWG is to report to Congress on NOAA's progress in responding to EISWG recommendations. Past EISWG Reports to Congress have always provided an update on a topic-focused dialogue between the SAB and NOAA that followed a pre-set sequence of steps; namely, NOAA report, EISWG review, NOAA response, and dialogue. The past Reports to Congress stayed within the constraints of each topic's timeline through to a concluding NOAA response. Unfortunately, this is an encumbered process that can take multiple years given the long timelines associated with each step and the multi-level approval process. In addition, there had been no additional follow-on review of past recommendations. This

Report to Congress is the first to take on a more comprehensive retrospective look at NOAA's overall response to EISWG recommendations across multiple topics. As such, the EISWG placed an elevated priority in this report on completing a high-level review of past recommendations, NOAA's subsequent successes, and remaining challenges. Not only would the high level information alone provide the most useful context for the Congress, it would be more readily obtained and therefore, more up to date.

METHODOLOGY: The EISWG took an approach that was designed to stay high level and focused on only identifying notable successes and ongoing significant challenges. This allowed EISWG to obtain the targeted information and avoid making this retrospective review another prolonged and resource intensive effort.

To accomplish this objective, the EISWG first reviewed the original documents, including the EISWG report recommendations and the NOAA response, plus any subsequent back and forth exchanges (See appendices). The outcome of this review was a set of questions, topics and ideas that warranted follow-up with NOAA. Once these topics were identified, the SAB staff worked with the EISWG NOAA Liaisons to identify a few NOAA subject matter experts (SMEs) who could provide the EISWG updates on the related efforts. The EISWG then met with the NOAA and other external SMEs to collect the targeted high-level updates on successes and challenges.

This approach provided an excellent balance of efficiency and information transfer of the targeted high-level information on the set of selected report topics. Equally, it did not require extensive preparation or target in depth details.

1.A. NWS Data Dissemination

Motivation: NOAA's core data distribution program is widely acknowledged and enjoys strong bipartisan support. The distribution of foundational weather data and severe weather warnings is one of the most important services of the National Weather Service (NWS) and is the basis for the NOAA Environmental Data Partnership Agreement with emergency management agencies, companies in the United States weather industry (including broadcast/cable media outlets), and the academic/research community. These data are the foundation of an invaluable private weather industry in the USA.

Successes: In June, 2021, the EISWG recognized a serious ongoing issue with reliability, scalability and timeliness of critical NOAA foundational data, and proactively authored a comprehensive whitepaper that recommended NOAA take four different steps to both address the immediate urgent needs and to explore new technology as part of an updated and comprehensive Information Delivery Plan (IDP).

Over the past two years NOAA has collaborated several times with the EISWG on its recommendations and marked several technical successes that have eased the strain on their system and stabilized their services to their stakeholders. For example, NOAA implemented emergency network bandwidth upgrades that have resulted in monthly uptime statistics near the 97% target since July of 2022. Additional hardware has been ordered through increased IDP base funding and BIL one-time funding to achieve a higher uptime target as products continue to be migrated to the cloud.

Efforts are underway to further enhance reliability by implementing additional redundancy measures and work is ongoing to achieve full backup capabilities, although complete redundancy across all systems is not yet achieved. The rate usage limits that were needed to manage the lagging system several years ago have been relaxed as the result of the improved performance.

Greater use of Content Delivery Networks (CDNs), one of the key recommendations of the EISWG report, have now emerged as an integral component of NOAA's program. Furthermore, NOAA is actively pursuing collaboration with cloud providers, recognizing the potential benefits they offer. Several other significant successes can be reported, including the shift to Slack for NWSChat, which should immediately provide the capacity and bandwidth needed for major weather events, and potentially introduce new collaboration capabilities. Also, the current collaboration with cloud providers under various CRADAs has resulted in a wide variety of NOAA foundational data assets including real-time radar, forecast models and other products being made available on cloud providers for anyone interested in consuming the data in this way – easily transformed and integrated into existing tools and workflows in the cloud environment leading to innovative application development.

Challenges: NOAA does face several ongoing challenges in data distribution. One of the main challenges is the need for additional resources to achieve a targeted >99% data distribution rate. While NOAA strives to disseminate its data to the public and various stakeholders, limited resources can hinder their efforts. By allocating more resources toward data distribution infrastructure, such as advanced servers, robust networks, strong migration to the cloud, and efficient data management systems, NOAA can improve its data dissemination capabilities and increase the accessibility of critical information.

Another challenge NOAA must be prepared for relates to managing through multiple simultaneous hazards without putting their data distribution at risk. As an organization responsible for providing accurate and timely weather, climate, and environmental data, NOAA must ensure uninterrupted data availability even during times of multiple hazards. Natural disasters like hurricanes, wildfires, and severe storms can strain the data distribution infrastructure, causing disruptions and delays. To overcome this challenge, NOAA needs to invest in resilient systems that can handle concurrent hazards, implement redundancy measures, and establish contingency plans to maintain data dissemination operations even in the face of adverse conditions. By addressing these challenges, NOAA can enhance its data distribution capabilities and continue to serve as a reliable source of information for the public and decision-makers. Using the success of the initial CRADA programs, NOAA should accelerate last-mile data delivery of foundational data on an equal opportunity and no cost basis to end users through the cloud providers.

1.B. Hurricane Forecast Improvement Program (HFIP)

Motivation: Hurricanes have caused the U.S. over $1.3 Trillion (CPI adjusted) in economic losses since 1980, more than all other Billion-Dollar Weather and Climate Disasters combined (NOAA NCEI Summary Statistics). Central to NOAA's mission of saving lives and property from devastating hurricanes is an information value chain (e.g., PWR Fig. 5) that includes: (a) a diverse network of satellite, atmosphere and ocean observing systems that provide essential hurricane data to operational centers and the public; (b) NOAA's Environmental Modeling Center (EMC), where operational data-assimilative forecast models are run to provide human forecasters the most advanced numerical guidance products; and (c) the National Hurricane Center (NHC), where the official hurricane track, intensity and storm surge forecasts and warnings are generated and communicated to the public. This full information value chain is supported by NOAA's Hurricane Forecast Improvement Program (HFIP), which for 14 years has rapidly transitioned advanced readiness level Research to Operations (R2O) that has saved countless lives and prevented even greater economic losses.

Successes: We are now approaching the final year of the third HFIP 5-year Strategic Plan. NOAA, and the broader scientific community engaged in the HFIP process, can be commended for the significant progress achieved. Most notably, the new coupled atmosphere-ocean-wave Hurricane Analysis and Forecast System (HAFS) was recently transitioned to operations at EMC. This milestone marks years of scientific investment in research and testing by NOAA and the broader community within NOAA's Unified Forecast System (UFS). This core transition is supported by: (a) advances in coordinated atmosphere/ocean observing system demonstrations including uncrewed systems; (b) growing collaborations with the Navy as encouraged by the CENOTE Act; (c) new warning products informed by Social, Behavioral and Economic Sciences (SBES) research; and (d) an expanded Hurricane and Ocean Testbed (HOT) where innovations can be evaluated for impact in a near-operational environment.

Challenges: As documented in the original EISWG Review, the NOAA Response, and in the 2022 EISWG Report to Congress, full implementation of the HFIP 5-Year Strategic Plan has been limited by a funding profile hovering near the 60% level, about $8 Million below what is required annually for full scale implementation. As a result, significant implementation gaps persist, particularly in the area of storm surge research, and in Social, Behavioral and Economic Sciences (SBES). Support for hurricane storm surge research was transferred from HFIP to the COASTAL Act (see NOAA response, page 2), but COASTAL Act support for a cohesive hub of hurricane-focused research has not materialized. Similarly, NOAA concurs with many EISWG and PWR recommendations for long-term SBES research promoting improved communication of forecasts and warnings, but much has been deferred pending future support. Intermittent short-term support has been provided by Congress through Disaster Supplementals or by NOAA through limited Weather Program Office (WPO) research funds, leading to promising initial results and the definition of new priority areas for longer-term early readiness level investments.

In spite of significant advances in HFIP, damage from hurricanes continues to be devastating (e.g. Hurricane Ian), and the need to continue to improve forecast skill and delivery persists. This is in part due to insufficient funding to act on the HFIP strategy, but it is also a need to keep pace with advances in technology on the one hand, and the complications of forecasting while ocean, atmosphere and coastal systems continue to change on the other. As a specific example, new uncrewed atmospheric, ocean surface, and ocean subsurface observing systems that have demonstrated their value through intermittent Disaster Supplementals lack sustained operational support to prevent observation gaps like those experienced in Hurricane Ian before its devastating 2022 landfall in Florida. To take full advantage of the advanced coupled Earth System Model (ESM) features of HAFS, sustained observational datasets that span the area both above and below the air-sea interface are required.

1.C. Earth Prediction Innovation Center (EPIC)

Motivation: High Impact Weather (HIW) events are increasing in frequency, intensity and duration across the U.S., accelerating public demand for actionable forecasts and warnings with longer lead times covering a greater diversity of extreme weather events. This demand is supported by the three pillars of the weather information value chain (PWR Fig. 5) from fundamental observations and data assimilation, to core numerical modeling and forecasting, and continuing across the last critical mile of information delivery to the public. The Earth Prediction Innovation Center (EPIC) supports the central core of this value chain with the goal of “enabling the most accurate and reliable operational numerical weather prediction system in the world” © 2022 EPIC. The EPIC approach is to foster community involvement in the rapid transition of innovative research to operations within the Unified Forecast System (UFS).

Successes: The initial operating capability for EPIC has been established in NOAA's Weather Program Office (WPO). The WPO engages the full weather enterprise by funding research that improves weather forecasts and promotes a Weather Ready Nation, and is a logical home for EPIC's more specific mission. Raytheon Intelligence and Space (RI&S) has been established as the primary contractor to support software development, advanced user support and community engagement within EPIC. With the Unified Forecast System (UFS) continuing to advance, EPIC has focused initially on the Global Forecast System (GFS) mid-range forecasts, the Rapid Refresh Forecast System (RRFS) short-range forecasts, and future versions of the Hurricane Analysis and Forecast System (HAFS); with future plans for coastal modeling and fire weather applications. Support for some initial research projects is now available to the external community through training, tutorial and workshop events (e.g., the FY23 WPO Innovations for Community Modeling Funding Opportunity, and the FY23 WPO Innovation for Next Generation (WINGS) Dissertation Fellowship awards, see EPIC.NOAA.gov).

Challenges: EPIC is working toward a fundamentally new open-science open-development approach to entrain the external community and foster collaborative research activities that develop, test and transition innovations within the Unified Forecast System (UFS). Fostering a focused but still new community-based approach on innovations that improve operational forecasts takes time and investment to fully succeed. HFIP, with its 14-year history briefly noted above, contains many components of what a successful community-involved rapid-transition program can include. Successful implementation of the full EPIC vision will lead to more rapid transitions of community innovations into NOAA operations.

EPIC supports the UFS through an open-development model that enables the broader community to contribute improvements and innovations into the forecast system and advance the nation's forecasting capabilities. Some major elements, including the Joint Effort for Data assimilation Integration (JEDI) system, are open for the community to use, but not to change or co-develop, focusing community attention directly on the forecast models specifically. NOAA's Environmental Modeling Center (EMC), where many of the nation's operational forecast models are run, is providing support to EPIC, but many EMC high priority needs are beyond EPIC's currently supported scope. Raytheon Intelligence and Space (RI&S) is under contract to build the software engineering infrastructure to facilitate community access to the UFS models, but similar infrastructure to facilitate the return flow of innovation back into the UFS, including model diagnostics and evaluation software, remains to be built. The WPO is funding external research in priority areas for medium- and short-range weather forecasting, but requires broader external funding for expanding scope, and a much greater availability of High Performance Computing (HPC) resources dedicated to research and development. Sustained research support for the external community consistent with the level of need is not available, limiting the people involved and the targeted opportunities for innovation. An education and outreach campaign on what is available and how access is facilitated through EPIC can contribute to building community participation. With an informed community, funding for R&D, and the HPC to advance its collaborative work, the UFS will then need a governance system, potentially established within the Community Modeling Board, to adjudicate candidate contributions and their eventual transition to operations.

1.D. Tornado Warning Improvement and Extension Plan (TWIEP)

Motivation: Tornado research is of paramount importance due to its urgent nature and the potential for devastating consequences. Recent examples of tornado outbreaks highlight the need for a deeper understanding of these phenomena to enhance preparedness and minimize impacts. In addition to meteorological studies, social and behavioral sciences play a critical role in mitigating the impacts of tornadoes. It is well known that human behavior and decision-making during tornado threats significantly influence public safety outcomes. Research in this domain helps identify patterns and barriers that affect how individuals respond to tornado warnings, seek shelter, and communicate vital information. By incorporating social behavioral insights into emergency preparedness plans, policymakers, emergency managers, and meteorologists can develop more effective strategies to disseminate warnings, enhance public understanding, and encourage proactive response behaviors.

Successes: NOAA has achieved some successes in improving tornado forecast accuracy through a variety of initiatives. Notably, they have employed machine learning and deep learning techniques to develop prototype algorithms and applications that outperform similar production systems. This research has been conducted in collaboration with the National Severe Storms Laboratory (NSSL), resulting in valuable advancements aligned with recommended practices.

The integration of artificial intelligence techniques into the Multi-Radar Multi-Sensor (MRMS) system has received positive attention in the Hazardous Weather Testbed (HWT) and has been incorporated into the Advanced Weather Interactive Processing System (AWIPS). NOAA has also acknowledged the importance of social and behavioral sciences, forging partnerships with the Social, Behavioral and Economic Sciences (SBES) program based at NWS headquarters. By distinguishing between stronger and longer-lived tornadoes (those responsible for the vast majority of damage and deaths) and weaker and shorter-lived tornadoes, NOAA has been able to enhance their understanding and forecasting capabilities. However, challenges persist in accurately predicting the weaker EF0 and EF1 tornado-producing storms.

The HWT continues to serve as a premier platform for collaboration, although transitioning successful research outcomes into operational production remains challenging. Furthermore, NOAA has made gradual progress in increasing the observation capabilities of radars to lower elevation angles to observe the lower structure of storms at a greater range. These endeavors have contributed to the overall improvement of tornado forecasting.

Challenges: Despite the successes, NOAA still faces a range of challenges in improving tornado forecasts. An important obstacle is the complicated transition of the Tornado Warning Improvement and Extension Program (TWIEP) to VORTEX-USA, and its relationship to the pre-existing VORTEX-SE. This has complicated the research priorities and resulted in a mismatch in funding compared to what is demanded in the legislation. Additionally, efforts to enhance tornado forecasts suffer from a lack of coordination across NOAA, and a clear directive, which continues to hamper progress.

There is a strong need for a well-established conduit between research and operations to ensure that the research findings inform operational practices effectively. Unfortunately, this connection is not well established, and it remains unclear to what extent research is influencing operations with new approaches and capabilities. Some advances are left in a beta testing configuration or in ongoing collaborations. For example, the Threats in Motion initiative has not yet transitioned into full operations mode, posing a challenge to its effectiveness.

Recent advancements, such as ensemble-supported tornado risk products, struggle to become integrated into the existing operational systems. They are more typically delivered through web pages and single-use applications hindering their impact on field forecasters - ultimately undercutting their operational value. The same issue arises with experimental radar algorithm development activities for the automated detection of tornadic threats.

Verification is a critical foundation to prioritizing and advancing relevant research, yet the verification metrics currently being used are not well aligned with the services, making it difficult to accurately assess the effectiveness of tornado forecasts. Despite these challenges, teams dedicated to improving tornado forecasts do strive for a continuous flow of research advances toward operational improvements, unfortunately at a slower pace and with limited funding. The unwavering commitment of these teams keeps the progress going, despite the obstacles they face.

1.E. Observing System Simulation Experiments (OSSE)

Motivation: Observing System Simulation Experiments (OSSE) are of significant importance, particularly for NOAA due to their potential to improve decision-making processes. By simulating the observations that could be obtained from hypothetical new instruments or platforms, OSSEs enable NOAA and its collaborators to assess the potential benefits and cost-effectiveness of investing in new observing technologies. This aids in strategic planning and prioritization of resources for future operational observing systems. Moreover, OSSEs facilitate the optimization of data assimilation techniques, by evaluating the relative enhancements to the accuracy of weather models by assimilating the simulated observations. Through OSSEs, NOAA can refine its observational strategies, enhance forecast skill, and ultimately provide more reliable and timely information to protect lives, property, and the environment.

Successes: The Weather Research and Forecasting Innovation Act of 2017 specifically mandates NOAA to perform OSSEs to quantitatively assess the relative value and benefits of observing capabilities and systems. Much of the specific work mandated in the Act was completed successfully within the Quantitative Observing System Assessment Program (QOSAP) at the Atlantic Oceanographic and Meteorological Laboratory (AOML).

In addition to completing the Weather Act required studies, the Quantitative Observing System Assessment Program (QOSAP) within NOAA has achieved notable successes in its OSSE endeavors. QOSAP has demonstrated strong engagement and increased visibility, fostering interaction across multiple NOAA line offices. While OSSEs were originally focused on atmospheric analysis, the QOSAP has expanded its scope to include the ocean domain, and there is growing consideration for ecosystem-related research; indeed, the QOSAP's growth has been particularly significant in the field of ecosystem forecasting and ocean-related assessments.

Within NOAA, the QOSAP operates under the oversight of the Observing Systems Committee (OSC), which is part of the NOAA Observing Systems Council (NOSC). The committee provides regular check-ins and reports to the NOSC, while day-to-day operations, budgets, and execution fall outside the NOSC's purview. One key strength of the QOSAP rests in its ability to assess the value of potential investments through OSSEs, adding a valuable layer of analysis to the lines of information used to make informed decisions on whether to proceed or not. These OSSE-based evaluations have served as valuable tools for making several crucial yes/no determinations within NOAA and have contributed to its overall success.

Challenges: The OSSE (Observing System Simulation Experiment) efforts within NOAA face several challenges that need to be addressed for further progress. One prominent challenge is the limited visibility of these successful efforts, as they are currently housed within NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). To increase visibility and maximize impact across NOAA, it would be beneficial to locate QOSAP at a higher organizational level so that it can provide an umbrella capability across line offices. In addition, while QOSAP has a NASA member, and regularly communicates with OSSE scientists within NASA, it would benefit from more direct collaboration between NOAA and NASA. This would not only enhance recognition but also provide additional resources to support the OSSE initiatives. Another challenge lies in the predominant focus on future satellite observing systems. Given the large expenditures associated with building and launching new satellite missions, satellite OSSEs likely have the largest potential return on investment. However, a sole focus on satellite observations may restrict the use of OSSEs for other types of observations (e.g., in-situ land or ocean measurements). Additionally, performing OSSEs at a high resolution and over longer time periods through a coupled Earth system nature run would be highly beneficial. This is because higher resolution nature runs more realistically capture extreme weather processes, and forecast systems in the future are expected to be run at higher resolution than they are currently. Finally, it is important to recognize that numerical weather forecast OSSEs should not be the sole method for evaluating observing systems, as they rely on a forecast and data assimilation that is constantly evolving and improving. Other types of OSSEs that do not rely on a weather prediction system are already being used at NASA and at other agencies. A combination of forecast and non-forecast based OSSEs are necessary for a comprehensive observation impact assessment. Addressing these challenges will contribute to the advancement and effectiveness of OSSE efforts within NOAA.

SECTION 2. New EISWG Reports and Recommendations

2.A. Global Oscillation Network Group (GONG) and its Successor Data Source for Space Weather Operations. (SAB approved April 2023)

NOAA's Space Weather Prediction Center (SWPC), one of the nine National Centers for Environmental Prediction (NCEP) of the National Weather Service (NWS), is charged with nowcasting and forecasting space weather conditions. Geomagnetic storms and associated geomagnetic activity are important space weather phenomena that can impact GPS systems, electric power transmission, satellite communications, and satellite drag, and are considered to be hazardous events for the nation’s infrastructure. To forecast the solar drivers of these phenomena, SWPC employs continuous observations of the sun from the National Solar Observatory’s Global Oscillation Network Group (NSO GONG), a network of six observatories situated around the globe. NSO GONG provides a vital data source for space weather operations, and it is nearing end of life. Any replacement will take years to become operational. NSO's next generation GONG (ngGONG) project is the most straightforward option. It will maintain present operational capabilities, and provide observations for future requirements. NSO is requesting funds from the National Science Foundation for the design phase of ngGONG, but a contribution from an operational agency may be crucial for project selection. The time window to complete ngGONG prior to the demise of GONG is closing. We recommend that NOAA/NWS financially support the design phase for ngGONG, to ensure the initiation of the project.

2.B. Subseasonal And Seasonal (S2S) Forecasting Innovation: Plans for the Twenty-First Century. (SAB approved August 2022)

Subseasonal to Seasonal (S2S) forecasts are increasingly used by decision makers at every level of government and across the private sector. Recent S2S extremes of temperature and precipitation have amplified the demand for S2S products as well as the need for greater skill and effectiveness. EISWG concluded that overall, NOAA's S2S report was responsive to Congressional tasking, and NOAA's S2S programs and plans provide an excellent framework to continue advancing S2S forecast products and decision-support services. The EISWG review provided eight Summary Recommendations and thirteen Specific Review Results Recommendations. The Summary Recommendations included making the NOAA S2S Report Supplement publicly available, standardizing S2S definitions and terminology, developing S2S strategic goals, highlighting S2S as an Earth System effort, and encouraging interagency and international collaboration. The report also emphasized the need to further integrate Social, Behavioral and Economic Sciences (SBES) in the development of S2S products and services for specific stakeholder categories, and to develop the means to consistently measure and assess value to stakeholders.

SECTION 3. EISWG Topics in Development

Congress requires EISWG to maintain a large working group with broad expertise from across the Weather Enterprise, and encourages EISWG to divide into subpanels to conduct specific reviews, assemble findings, and formulate recommendations. In 2022, EISWG conducted an expertise needs assessment and sought nominations for new members to fill specific categories. The Working Group is back up to its target strength with 22 members covering the priority areas of expertise, and has established subpanels working on the following topics:

A. The Gaps in NEXRAD Radar Coverage subpanel is reviewing the NOAA report on this subject, integrating responses from the PWR report, and is considering complex terrain, underserved communities, and the role of the private sector in its recommendations.

B. The Radio Occultation subpanel is expanding to also address the optimal combination of government backbone and commercial assets in the NESDIS observing system architecture.
C. The Water and Drought subpanel is looking at the impacts of flood and drought events, the need for water resource management, and the National Water Center product suite to develop recommendations that take into account the recent PWR and The White House Office of Science and Technology Policy (OSTP) reports.
D. The Heat and Human Health plus Fire Weather subpanel will first focus on Heat and Human Health, a NWS priority, as the NOAA Fire Weather Testbed spins up.
E. The Systematic Forecast Errors subpanel is developing a plan for the best way for EISWG to contribute its expertise to this issue with diverse interagency interests.

SECTION 4: EISWG and the Priorities for Weather Research (PWR) Report

The U.S. Congress, in the December 2020 FY21 Omnibus Consolidated Appropriations Act, directed the NOAA SAB to prepare a report on the Priorities for Weather Research (PWR) that provides policymakers with the relevant information necessary to prioritize investments over the next ten years, and evaluates future potential Federal investments for all domestic users of weather information. The PWR report (link, DOI:10.25923/w9fg-g569) was completed by the SAB in December 2021. Taken as a whole, the recommendations contained in the PWR report are transformational. Over the last two years, the PWR report has been frequently referenced by NOAA, the external community, and Congress. For example, the Weather Program Strategic Plan (link) addresses 25 of the 33 PWR recommendations. Many EISWG members served on the PWR report preparation team of over 150 Subject Matter Experts, including the EISWG co-chairs serving as PWR co-leads. EISWG has referenced PWR findings and recommendations where appropriate within this 2023 Report to Congress.

The NOAA SAB amended the PWR charge at their 26-27 April meeting and continued the PWR Core Team through 31 Dec 2024 to: (a) document best practices established during the PWR report process so that they can be applied more broadly within the SAB; and (b) facilitate the ongoing discussion and application of the PWR report recommendations by NOAA. This extension enables the PWR Core Team to contribute to the dialogue around the PWR report to maximize the benefit of the PWR effort. This extension also lines up with the EISWG 2024 Report to Congress process, and is consistent with the Congressional interest in EISWG's insights as a broad and engaged SAB Working Group of well-informed Subject Matter Experts on NOAA's weather programs. We anticipate that the 2024 Report to Congress process will be even more aligned with evaluating both EISWG and PWR recommendations to better inform Congress of NOAA progress in critical areas. As 2024 will be three years into the decade-long scale of the PWR recommendations, the Immediate First Steps (Section 8) identified in the PWR report are especially relevant to EISWG recommendations in the upcoming 2024 Report to Congress.

SUMMARY

We are at a critical juncture of changing weather patterns, increasing demands for actionable environmental information, and the Congressionally recognized value of investing in NOAA, that demands an immediate and coordinated effort. EISWG contributes to this effort by reviewing NOAA responses to The Weather Research and Forecasting Innovation Act of 2017, assembling findings, and developing recommendations that will promote a vibrant and equitable weather informed economy, and a responsive and resilient Weather Ready Nation. EISWG recommendations that are approved by the SAB are forwarded to the NOAA Administrator for consideration. EISWG is required to submit an annual Report to Congress (RtC) describing NOAA progress on adopting EISWG recommendations.

EISWG developed a new process in 2023 of systematically pairing EISWG recommendations with initial NOAA responses (see Appendices) and then developing a concise set of questions to discuss with NOAA Subject Matter Experts on the relevant topics to assess progress. Results are summarized in Section 1 of this report. A consistent picture emerges. NOAA most often concurs with EISWG recommendations. Where core funds are available, or rapid transitions of high readiness level activities can be supported by short-term supplementals, significant progress and success can be reported.

Still much work that NOAA agrees is important is deferred due to a lack of support. This is especially true for the early readiness level long-term research needs, and for the transition to core operational support for proven observing, data assimilation and modeling technologies. Especially critical are the cross-cutting needs for Social, Behavioral and Economic Sciences (SBES) research that informs the last critical mile of forecast and warning communications, increased support for external partners to promote innovation through open science approaches, and significant increases and sustained support for High Performance Computing (HPC) and network communication capacities for both research and operations. These common threads are consistent with many of the PWR report's Immediate First Steps (IFS) (see PWR: Report in Brief, pp. 3-5). These include early readiness level research in Earth systems models (IFS-1), SBES data collection and research (IFS-2), and support of innovative research and workforce development in data assimilation (IFS-3), as well as infrastructure investments in data dissemination (IFS-4), HPC for operations and research (IFS-5), and gap-filling of existing Earth system observing networks (IFS-6) . The actions and impacts include reanalysis and reforecasting for improved Earth system models (IFS-7) supporting better understanding and prediction of High Impact Weather (IFS-8), and of water cycle extremes and their cascading impacts (IFS-9). IFS-10 recognizes the complexity but growing importance of developing more objective methods to estimate the relative value of NOAA investments.

Congress has increased investments in NOAA significantly through the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL). These investments will enhance NOAA weather programs and services, and will further enable the broader Weather Enterprise. Some of these investments will support PWR and EISWG recommendations. In addition, Congress is currently considering The Weather Act reauthorization. Our nation's economy, and our people's safety, is increasingly weather dependent and will undoubtedly benefit from the activity a Congressional reauthorization will generate. The EISWG remains committed to supporting the SAB, NOAA and Congress in these critical endeavors, and looks forward to supporting future requests for information from Congress as needed.

APPENDICES: EISWG Recommendations and NOAA Response

Appendix 1. NWS Data Dissemination (DISS)

NOAA Report • EISWG Recommendations • NOAA Response to EISWG

EISWG Recommendations on DISS - June 2021	**NOAA/NWS Response** - December 2021
# 1. Design and implement an emergency response It is imperative the NWS legacy data dissemination systems and associated infrastructure be stabilized, with the immediate goal of providing robust, reliable capacity with backup capabilities that function without the need for data access limits. This will likely require additional critical infrastructure investments that serve primarily as a stopgap (and possibly independent of the Integrated Dissemination Program [IDP]) until longer-term solutions can be finalized and implemented. EISWG encourages NOAA leadership to explore and implement strategies that will lead to increased bandwidth and infrastructure modifications necessary to bring immediate short-term relief to this critical situation.	NWS agrees with this recommendation. In FY 2021 the NWS received an additional $1.5M to begin addressing the bandwidth issue. The NWS swiftly initiated three procurements to alleviate the restriction. First, the NWS procured an upgraded network card to enable the clustering of firewalls in Boulder to match College Park and enable increased bandwidth throughout. Second, NWS procured upgraded routers as the next step in updating the hardware to support a larger circuit between College Park and Boulder. Third, the NWS procured several load balancers to increase bandwidth by over 50% from 65G to 100G. By the end of Q2 FY22, NWS expects to have the new hardware in place at both IDP Data Centers. Also, by the end of Q3 FY22, the network bandwidth at both IDP Data Centers including the circuits between the two sites will be upgraded to 100G. These upgrades will lessen the current bandwidth constraints for external customers to access IDP services and data. NWS will manage access limits as an appropriate security measure to mitigate against abuse and service attacks. These approaches will be continually adjusted as new methodologies become available, and as resources allow to reduce impacts.

EISWG Recommendations on DISS - June 2021	**NOAA/NWS Response** - December 2021
# 2. Strengthen engagement with the broader Weather Enterprise: The value of NWS public engagement after the PNS was first announced was demonstrated by the reduced limits implemented in the SCN. NWS should expand the successful engagement with external partners in a public forum to identify immediate, short-term actions all parties can take to provide emergency improvements while the upgrading effort in (1) is underway. The EISWG membership includes representatives from across the Weather Enterprise that are informed of the issues and are engaged in finding solutions, and could co-sponsor or facilitate such a forum.	The NWS concurs that direct engagement with the Weather Enterprise has successfully improved our current IDP operations and our plans for the future. Numerous hands-on conversations between NWS leaders, SMEs and individual enterprise members resulted in discovering and removing problematic processes and barriers, to the benefit of NWS operations and all enterprise members. This new level of public-private sector engagement will be continued now and into the future as we work to expand IDP capacity while improving overall service to our external partners and customers. In line with the WRFIA Act of 2017, which states in Sec 401 (3) (B) that the, “EISWG should identify opportunities to improve communications and partnerships among the National Oceanic and Atmospheric Administration and the private and academic sectors,” we appreciate this comment and look forward to further engaging with EISWG in this area. NWS agrees that ongoing engagement with external partners is critical, and appreciates the offer from EISWG to co-sponsor or facilitate forums for this purpose. We further agree that engaging the Weather Enterprise in discussions about improving customer experience are worthwhile. In keeping with our NWS Partnership Strategy, the NWS holds regular Partner Engagement Meetings at least three times per year and routinely communicates with stakeholders at conferences and through emails, news releases, and other informal means. NWS also schedules more subjectspecific meetings or webinars as needed such as the June 30, 2021, NWS Partners Webinar focused on Leveraging the Cloud for Numerical Weather Prediction data. We have archived past partner webinars and meetings at: https://www.weather.gov/wrn/calendar

EISWG Recommendations on DISS - June 2021	**NOAA/NWS Response** - December 2021
# 3. Prioritize designing and moving to an appropriate scalable architecture: Given the dramatic overall growth in demand, and the intermittent, event-driven surges, it is critical that elements of the architecture be collaboratively designed to address these dynamic data delivery needs. The need for an adaptable, scalable architecture is critical because while future demand is expected to increase, the rate of increase is difficult to predict. The EISWG encourages exploring different options, including: **a. Leverage Content Delivery Networks:** A major rapid enhancement for the current data dissemination system may be found in the increased use of Content Delivery Networks (CDN) that can quickly enable greater scalability of the existing NWS data delivery system. Using CDN technology, data files that do not change once produced (bulk model data grids, as one of many examples) can be cached on the edge of the CDN. This removes the need for every user data request to hit the NWS origin servers, providing the potential to greatly reduce the throughput of requests going directly to NWS. Demand will only increase as new models and products are developed, including the just released new version of GFSv16.	**a. Leverage Content Delivery Networks:** The NWS recognizes the value of using cloud for data dissemination and has already leveraged Content Delivery Networks (CDN) successfully. The NWS has hosted most of our weather.gov traffic on a CDN which has enabled us to offload roughly 80% of the total internet bandwidth from these websites that would normally be served by NWS data centers. The National Hurricane Center website is also hosted on a CDN, allowing for surges in traffic during tropical events. In FY21 NWS has undertaken several initiatives that are utilizing the power of cloud computing and the associated CDN capabilities. GIS Viewer and HydroVIS platforms are planning to leverage load balanced and geolocation based caching; and measurable & resilient content delivery through CDN platforms. Selected NOMADS datasets have already been publicly available for dissemination on NOAA's Big Data platform (BDP), i.e. GFS datasets have been available since 2019, HRRR since 2020 with a formal data dissemination project launched in FY21. NWS is working closely with its user-base to ensure that making model data available via the BDP platform and Cloud Service Providers is done in a way that does not disrupt end-users' downstream processes. In parallel to exploring model data delivery via the BDP platform, based on requested funding in FY22, NWS will investigate expanding the use of a CDN provider to serve NOMADS and FTPPRD services to the edge, reducing impacts to IDP on-premise infrastructure. Lastly, NWS is ensuring an enduser/operations support model for any long-term solution delivering model data to the enterprise

EISWG Recommendations on DISS - June 2021	**NOAA/NWS Response** - December 2021
b. Accelerate the migration to commercial cloud networks: EISWG is fully supportive of the IDP, with particular focus on Phase 4, which will require new resources and considerable time. As such, NWS should strongly consider how it could accelerate the migration of their last mile of data dissemination services to secure commercial cloud networks; such networks have demonstrated the ability to facilitate effective and efficient data management, including largescale distribution. The NOAA Big Data Project, implemented in collaboration with Amazon, Google, and Microsoft web services, provides useful experiences. The last mile delivery of NWS foundational data through commercial cloud environments must also comply with long standing NOAA principles around equal access to all data at no cost and mechanisms to ensure that no entities receive preferential treatment in terms of data available, or speed of availability. In summary, the EISWG endorses the use of commercial cloud networks (identified in the NWS IDP as part of Phase 4) and encourages the NWS to strongly consider reprioritizing such efforts to more rapidly move foundational data to the cloud. This will facilitate increased data distribution and have the greatest impact on reducing data requests from end users to current NWS data systems.	**b. Accelerate the migration to commercial cloud networks:** The NWS appreciates the SAB recommendation and is committed to following the NOAA Cloud Strategy that aligns with the federal Cloud Smart strategy, and complying with the principles of free open and equal access to the public. To this end, NWS currently has several initiatives underway that utilize the NOAA Cloud Utility contract in addition to the BDP contract. GIS Viewer and HydroVIS projects are designed to establish a unified GIS platform on a commercial cloud (AWS) that will enable real-time Flood Inundation Mapping (FIM) data to be disseminated. The Damage Assessment Toolkit application that collects and disseminates post weather-event data is already live and operational on an AWS platform. As recommended, NWS is ready to accelerate its cloud migration and has already worked with Forrester to develop cost models for some of the cloud candidates such as NOMADS and MAG as far back as in 2019. However, NWS also recognizes the need to undertake this migration cautiously and deliberately to ensure that security, operational integrity and performance goals are met. NWS also recognized the legacy nature of some of its applications and realizes that a substantial amount of resources must be invested in re-architecting and modernizing. Lift and shift is not a prudent option for many of the legacy applications. We will embrace the SAB suggestions and will ensure a proper emphasis on Phase 4. Our plan is to move in parallel as we transition data access from on-prem to cloud and simultaneously refactor/rearchitect/ready applications for the cloud migration provided we have the additional resources. Based on the additional resources proposed in the FY22 President's Budget, the NWS will be able to begin moving to the public cloud in the timeframe referenced in the IDP Plan. However, to move foundational data any more rapidly, the NWS would face a similar trade off decision between increasing the speed of the move to the cloud or leaving some missionessential applications on the legacy hardware, which is beyond end of life and is not redundant (Phase 3 of the IDP).

EISWG Recommendations on DISS - June 2021	**NOAA/NWS Response** - December 2021
# 4. Enhance user management, product availability announcements, and training programs Efforts are needed to reduce unnecessarily excessive demands placed on NWS infrastructure by outside entities. The NWS Office of Dissemination should strongly consider the development and distribution of a best practices document for data access. Inclusive to this would be a real-time notification system such as product availability announcements using widely available messaging. Users could then subscribe to receive announcements indicating availability of certain data products as opposed to continually requesting file lists from NWS servers in rapid succession to see if new files are available. To promote compliance with best practices, rather than continuing to allow data users to remain anonymous, it would be beneficial for the NWS to institute enhanced methods that would facilitate fast and definitive identification of individuals, organizations and institutions, to eliminate the challenges caused by their data acquisition methodologies. This capability would allow the NWS, with appropriate public notice to those entities, an opportunity to address and remediate concerns with individuals and organizations that put undue pressure on NWS infrastructure and provide users with ample notice to improve their code in accordance with NWS best practices.	The NWS agrees that reducing excessive demand is prudent given the current limitations of IDP. As an example, NWS managed demands during extreme weather events in the past year by distributing guidance on using NWSChat to ensure those who truly need to make use of the system will be able to do so. Similarly we have placed limits on some of the services to detect excessive usage patterns, and we regularly work with users to help them adjust their pattern of usage after being blocked. As for a real time notification system, the NWS is considering the use of a publish/subscribe system that would allow users to choose what information they would like to subscribe to for automatic updates. Additional research is required before the NWS can determine if this is a feasible path forward. Additionally, the NWS data is used across the globe by other federal agencies, national and international partners, educational institutions, and private enterprises. We agree there are merits to employing a real-time notification system and have been conducting some investigation in that area. We have recently employed SNS (Simple Notification Service) with the NOMADS datasets on the BDP. We are still collecting user feedback on this method of notification and whether it can feasibly be used for the global user community. We do realize that a key ingredient to implementing and maintaining the proactive, real-time user notifications and data-access requires enhanced user and operations support which needs upfront investment. To that end, NWS has requested funding in FY22 and hopes to start implementing it as soon as the funding becomes available. In the mean-time, NWS is implementing a cloud-version of its NWSChat process that allows for user subscriptions to alerts as enabled by the underlying COTS product. In the future, NWS plans to disseminate bulk data on the cloud platform where many of the content distribution and notification services are available for use without having to spend resources on developing them.

Appendix 2. Hurricane Forecast Improvement Program (HFIP)

NOAA Report • EISWG Recommendations • NOAA Response to EISWG

EISWG Recommendation on HFIP - October 2020	**NOAA Response** - December 2021
# 1. Overall Project Plan To address The Weather Act Title I, Sec. 104 (c), the expanded scope must be mapped to necessary resources and timelines.	NOAA base support (~$14M/year for FY19-FY22) and short-term supplemental projects under the Bipartisan Budget Act of 2018 (P.L.115-123) and the Additional Supplemental Appropriations for the Disaster Relief Act of 2019 (P.L.116-20) were used to accelerate four key strategies outlined in the 2019 HFIP Strategic Plan: 1. Development of the Hurricane Analysis and Forecast System (HAFS) to improve forecast guidance on track and intensity, including rapid intensity change; 2. Social Behavioral and Economic Science (SBES) Research to improve communication of risk; 3. Increased Research and Development High Performance Computing (RDHPC); and 4. Provide grants to broaden expertise and expand interaction with the external community. The budget reduction associated with the HFIP since FY15 slowed the rate of progress towards the 10-year HFIP goals by restricting the capacity to test and evaluate new research and delaying the transition of potential new analysis and forecast applications into operations. Reduced funding levels also hindered engagement with the academic community that dramatically slowed model improvements. The required annual budget for HFIP to address expanded scope is ~$22M. Disaster Supplemental resources from FY18 and FY19 provided one-time support of ~$20M over 3 years in hurricane focused research, of which ~60% went to Federal grants, and ~$25M for RDHPC. The follow-on FY22 Disaster Supplemental resources will provide $15M over 2 years to address some gaps. Hurricane research will have access to about one third of the $50M RDHPC resources available from FY22 Disaster Supplemental as well.
# 2. Rapid Intensification (RI) and Track Expand participation through dedicated science campaigns that cross the atmosphere-ocean interface to improve model physics and data assimilation, and increase the use of probabilistic forecasts to quantify uncertainty. Continue HAFS development and entrain more external researchers.	HAFS development is leveraging the advancements in the Unified Forecast System (UFS) and Joint Effort for Data Assimilation (JEDI) systems through Disaster Supplemental, UFS R2O, Earth Prediction Innovation Center (EPIC), and Federal grants, which also serve as touchpoints with broader community efforts. HFIP developed collaborations with Office of Naval Research (ONR) on Tropical Cyclone Rapid Intensification (TCRI) initiative (2020-22) and OAR/Global Ocean Monitoring and Observing (GOMO) and NOS/ Integrated Ocean Observing System (IOOS) on use of ocean observations to improve RI guidance (2021-2022).

EISWG Recommendation on HFIP - October 2020	**NOAA Response** - December 2021
# 3. Forecast and Communication of Storm Surges Communicating storm-surge risk should be prioritized, account for uncertainty from multiple sources, and address diversities of human perception, behavior, and needs. Evaluation and improvement of operational storm surge models should also be prioritized.	Owing to the budget reduction, storm surge research and development is now largely being supported by the Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act and UFS. Any budget reduction to the COASTAL Act Program budget will impact work leveraged to the HFIP Program. Current storm surge modeling activities are now coordinated under UFS through the Marine and Land Working Groups. The Disaster supplemental and COASTAL Act supported extension of storm surge forecast lead times to 3 days with the same skill as 2-day and the OCONUS development of storm surge guidance for Puerto Rico, U.S. Virgin Islands, Hawaii, and Guam. UFS is setting up a testbed to compare community coupled atmosphere- wave-ocean-hydrology models to assess their relative performance.
# 4. Risk Communication Research for Watch/Warning Products Watch and warning products need to address risk from multiple threats. Developing a strategic plan for SBES research with milestones and metrics should be a high priority to ensure forecasts and forecast products address diverse societal needs and impacts.	HFIP Strategic Plan Appendix A.2.4 outlines goals and metrics for SBES research to improve hazard guidance and communications of risk for all hazards. Due to budget reduction, HFIP is not able to support social science research at the levels planned or desired. Disaster Supplementals provided ~$3M over 3 years for this research (FY19-22) to support 6 projects. Additionally, the Office of Oceanic and Atmospheric Research (OAR) Weather Program Office (WPO) and National Weather Service (NWS) Science Technology and Integration (OSTI) budget portfolios are providing ~$1.5M over 2 years (FY20-21) to support an additional 5 SBES projects for research, testing, and evaluation of hurricane hazard services.
# 5. Expanding Partnerships and Collaboration Increase internal coordination across OAR, NWS and National Ocean Service (NOS), and expand science and technology partnerships to achieve Weather Act goals.	Enhanced collaboration across OAR, NWS, and NOS is occurring through the UFS R2O project, NOAA Modeling Board, Disaster Supplemental, Storm Surge, GOMO's Extreme Events Ocean Observing Task Team (EEOOTT), and COASTAL Act. For overall hurricane research to operation enhancement, we integrate more with NOAA testbeds such as the Joint Hurricane Testbed (JHT), Developmental Testbed Center (DTC), Joint Center for Satellite Data Assimilation (JCSDA), and Hazardous Weather Testbed (HWT).

Appendix 3. Earth Prediction Innovation Center (EPIC)

EISWG Recommendations • NOAA Response to EISWG

EISWG Recommendations on EPIC - September 2019	**NOAA Response** - January 2020
# 1. NOAA should implement EPIC's governance structure and processes as soon as possible, with a focus on the managing institution, leadership team, and advisory boards, and providing the community clear statements of the EPIC vision, mission, and values.	We agree, and we are developing and tuning our path of governance to achieve the vision of EPIC and to ensure the smooth transition of useful contributions to the operational weather forecast. NOAA decision and control will increase as products intended for the operational weather model move forward, whereas the ideas of how to make improvements on the areas NOAA identifies will largely left to the imagination of the community participants. NOAA should focus on the lessons learned over the past 5-7 years in our own internal improvements of Research to Operations, and Operations to Research, in which the presumed recipient of the new technology is closely aligned and well informed early to the research advances as they proceed. This process cannot exist in complete independence, or transition will be frustrated and put EPIC at risk.
# 2. NOAA should work with the broader community to develop inclusive community engagement processes, and to anticipate and articulate the appropriate roles NOAA and other entities will play in EPIC.	Yes, we have been active in promoting community engagement by hosting workshops, industry day, requests for information and open sessions at professional conferences. The community cannot develop the EPIC program; NOAA must. We have taken much input to our benefit and all of our plans are well informed by the community.

EISWG Recommendations on EPIC - September 2019	**NOAA Response** - January 2020
# 3. Early and direct efforts should be made to welcome into the Unified Forecast System (UFS) research and development sandbox contributions from other dynamic cores, physical parameterization schemes, Earth-system observation strategies and data assimilation techniques (atmosphere and ocean) and models (e.g., MPAS, UKMO Unified Model).	NOAA agrees with this recommendation. The UFS is a community modeling framework that will allow contributions that may not result in direct operational benefits. As long as operational standards are met with respect to unit tests and regression tests, and success metrics are evaluated; the UFS framework will allow contributions to earth system model development. NOAA's Next Generation Global Prediction System (NGGPS) program selected the FV3 model as the dynamic core of the future through an evidence-based evaluation. The UFS will need to undergo a similar process for additional modeling components in the future. NOAA understands the possibility of the UFS accommodating other dynamic cores, but as NOAA has selected the FV3, we are not investing in or funding work on other cores. NOAA signed a Memorandum of Agreement (MoA) with the National Center for Atmospheric Research (NCAR) in 2017 that will allow for development of different model components within a common infrastructure to advance research and development efforts across organizations. EPIC will provide a consistent code base and framework for multiple dynamic cores and physics options, but providing a common code base for additional options and supporting those options are distinct differences that NOAA is keenly aware of in establishing EPIC. It is important that EPIC remain aligned to operational outcomes for effective management and acceleration of the R2O process.
# 4. NOAA should initiate a multi-agency R&D partnership program into which NOAA and other agencies contribute significant multi-year resources.	NOAA concurs with this recommendation. To address this, NOAA is engaging all partners to explain the role of EPIC and the importance of the UFS as a capability that integrates labs/centers/academia/private sectors/agencies as they conduct Earth-system model development to improve forecast skill. NOAA will continue to seek multi-agency R&D partnerships that will leverage resources and advance our collective missions.

EISWG Recommendations on EPIC - September 2019	**NOAA Response** - January 2020
# 5. NOAA should organize its Cooperative Institutes that have existing capabilities in NWP and related areas into a nascent, distributed EPIC co-laboratory charged with quickly carrying out one or two narrowly focused R & D thrusts that have potential for near-term success.	NOAA will take the recommendation under consideration. NOAA is seeking quick wins by releasing a version of the UFS v1.0 in early 2020, which will leverage existing resources as mandated by the Weather Research and Forecasting Innovation Act of 2017. We are gradually transitioning all of our operational modeling codes to Github in an effort to fully realize the concept of open source development. The CIs maintain a vital role in NWP development at NOAA, and we will determine through proper planning the distribution of EPIC resources to gain near-term success.
# 6. NOAA should immediately invest in and execute a Cloud implementation plan to promote community engagement and in support of research-to-operations.	NOAA concurs with this recommendation. To address this, EPIC plans to transition research and development of the UFS to a Cloud environment to dramatically improve Research to Operations (R2O) contributions from the community.

Appendix 4. Tornado Warning Improvement and Extension Program Plan (TWIEP)

NOAA Report • EISWG Recommendations • NOAA Response to EISWG

EISWG Recommendations on TWIEP - July 2019	**NOAA Response -** December 2019
#1. In its development of Warn on Forecast (WoF) procedures, NOAA should include pattern recognition and artificial intelligence algorithms that take into account and adapt for the various known shortcomings in explicit computer model forecasts.	NOAA agrees with this recommendation and notes that the agency is already doing this in a research and development environment. The WoF research program uses statistical techniques to pull probabilistic information out of model ensembles (rather than using explicit/deterministic model forecasts). The ensemble forecast output provides a range of possible outcomes based on variations in model physics and initial conditions that represent the variability of the atmosphere. The resultant probabilistic information can provide forecasters with a better understanding of the potential for severe weather, given that storms develop within the area. Output from the WoF research program have been tested and evaluated in the NOAA Hazardous Weather Testbed and have shown promising capability to assist forecasters with advance notifications to the public. In addition, NOAA is actively researching the use of machine learning methods as a way of post-processing the ensemble output from the WoF system and hopes to test these forecaster tools from the new methods in the Hazardous Weather Testbed with forecasters within the next several years.
# 2. NOAA should focus more strongly on reducing the false alarm rate (FAR) and other metrics of skill in current generation tornado warnings. Polygon-based warnings challenge the way FAR is determined and so demand new methods to quantify true positive, false positive, true negative, and false negative for precision, recall, and accuracy. As warning polygons are now updated as severe storms evolve, FAR measures will need to be assessed over space and time. The ways these metrics are computed should be transparent. National metrics are nearly meaningless by themselves; NOAA should compute and release metrics by Forecast Office. Importantly, while the focus should be on reducing the FAR, such reductions cannot come at the expense of affecting negatively other tornado warning-based metrics, such as the probability of detection.	NOAA agrees with this recommendation, and we are already working to revise how FARs are calculated. We disagree, however, that "… national metrics are nearly meaningless by themselves." They provide the national perspective on warning performance. Also, the NOAA National Weather Service (NWS) Performance Management website already provides warning statistics for each Workforce Management Office (WFO), multiple WFOs, NWS Regions, and nationally. NOAA concurs that FAR needs to be improved without negatively impacting POD. NOAA is continuing its research and development activities to better understand the tendencies that lead to FAR and how to address them.

EISWG Recommendations on TWIEP - July 2019	**NOAA Response** - December 2019
#3. As a means for obtaining greater low-level radar coverage of nonsupercell tornadic circulations and so significantly aiding in the warning of tornadoes, NOAA should consider … **a) …** reducing the lowest allowable elevation angle on all NEXRAD/WSR88D radars to the minimum possible value, consistent with ground clutter and local environmental considerations, and **b) …** adding one or two tower sections to selected existing NEXRAD to reduce ground clutter, increase the radar horizon, and allow better overall coverage.	**a)** NOAA notes that we have done this already in several locations; however, it is not practical in all locations due to terrain blockage and other environmental impacts. NOAA has lowered the angle for the Next Generation Weather Radar (NEXRAD) at 10 sites so far – Langley Hill, Washington; Monterey, California; Cedar City, Utah; Medford, Oregon; Buffalo, New York; Minot, North Dakota; Greenville-Spartanburg, South Carolina; Raleigh, North Carolina; Jackson, Mississippi; and Shreveport, Louisiana. The NWS Regions are prioritizing NEXRAD sites where lowering the angle will provide maximum benefits. Lowering the angle costs about $100,000 per site to conduct the environmental assessment and make the software changes in the NEXRAD unit and also to the WFO's Advanced Weather Interactive Processing System (AWIPS) to be able to use the data from the lower angles. **b)** NOAA disagrees with the recommendation. While increasing radar height could reduce blockage from nearby terrain, trees, and buildings, it will further extend the range of ground clutter. Furthermore, it is very expensive to raise the tower, and benefits are limited except in very few locations. NOAA considers raising the tower as a last resort when beam blockage has increased since the radars were installed, and lowest angles of data are no longer available. To date, we have raised the tower at only one site. Furthermore, the maximum height of the radar is 30 meters. It is not feasible to raise the tower greater than 30 meters due to the resultant degraded data quality related to distance between the feedhorn and signal processor, as well as the increased potential for high wind damage.

EISWG Recommendations on TWIEP - July 2019	**NOAA Response** - December 2019
#4. To aid in the warning of short-lived tornadoes, NOAA should build on the experiences in south-central Oklahoma and across the multicounty Dallas-Fort Worth metropolitan area and include networked X- or C-band as gap-filling radars to obtain greater low-level coverage of non-supercell circulations and strong winds.	NOAA notes that this is technically feasible, but not cost effective at this time. The proven benefits of such systems have not been categorically demonstrated to have a significant impact on NWS warnings. In the Dallas-Fort Worth area, the NEXRAD coverage is excellent. Via the National Mesonet program, NWS provides support to Collaborative Adaptive Sensing of the Atmosphere (CASA), a network of commercial X-band radars supplementing NEXRAD coverage in the DFW region. Given the NEXRAD coverage, the CASA data are supplemental and most useful in determining where to conduct post-storm surveys, rather than to warn for tornadoes. Forecasters appreciate having the CASA data, but still rely predominantly on the NEXRAD for issuing warnings in the Dallas-Fort Worth area. The real challenge remains to better understand these short-lived tornadoes and be able to warn before they form.
# 5. The NEXRAD processing software used to detect mesocyclone and tornado vortex signatures should be modernized/upgraded to reflect the best science now available. An example is provided by the Mesocyclone Detection Algorithm (MDA), which currently uses only a portion of the available shear information. A modernization of this key algorithm might allow circulations of (weak) intensity levels 1 and 2 to be detected sooner and utilized with some confidence. This could make possible earlier (by several minutes, or equivalently two or three volume scans) detection of the earliest stages of formation of long- lived tornadoes, and allow tracking of at least a portion of the life cycle of short-lived tornadoes.	In regards to NEXRAD software, NOAA is currently working to update both the Mesocyclone Detection Algorithm (MDA) and the Tornado Detection Algorithm (TDA), the latter of which identifies the Tornado Vortex Signature. NOAA is researching advanced algorithm technologies to track storm-scale circulation features of all intensities. These Rotation Track products are implemented on the Multi-Radar Multi-Sensor system which is available to forecasters. Additionally, new MDA and TDA are being developed that also includes dual polarization variables as well as shear estimates. The new TDA will be evaluated in the Hazardous Weather Testbed in spring 2020.
#6. Given the limited number of federal social science positions within the agency, NOAA should utilize its set of joint and cooperative institutes to access social science expertise in the national university community.	NOAA concurs with this recommendation and is beginning discussions to implement this action with the cooperative institutes. For example, NWS is working with the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) and the Center for Risk and Crisis Management (CRCS) on the conveyance of uncertainty and probabilistic forecasts.

EISWG Recommendations on TWIEP - July 2019	**NOAA Response** - December 2019
#7. NOAA should have social science programs charged with investigating questions such as the following: Will people take action more than a few minutes in advance, even if given warnings an hour in advance? Where is the balance between lead-time and good decision-making? If actions are taken based upon lead times an hour or longer than at present, will this include fleeing and, if so, will road infrastructure and traffic management suffice? Will the public take action based upon probabilistic tornado warnings? How should the public best receive such warnings? Will the public be responsive to repeatedly updated warnings (N.B., The Report (see Attachment 1), p. 7 suggests that such warnings could be updated every 2 minutes), or simply confused by such frequent updates, and so waiting until the last minute to attempt to take action?	NOAA agrees with this recommendation and notes that we are doing this now, however, expanding these efforts merits additional consideration. As an example, the National Weather Service is working with CIMMS and CRCS on the conveyance of uncertainty and probabilistic forecasts. Both WoF and the Forecasting a Continuum of Environmental Threats (FACET) programs have social science based research initiatives focused on the public response to these new warning techniques.
# 8. To reduce impacts in terms of minimizing property losses (as well as improve life safety measures), it will be necessary to implement stronger building codes. NOAA should develop and implement - in partnership with NIST, universities such as Texas Tech, and entities such as the Institute for Business and Home Safety - a weather-ready home certification program as an extension of its StormReady community and Weather-Ready Nation program,. This could encourage in-home shelters, hurricane clips to hold on roofs, etc.	While this may be beyond the scope of the agency's mission, it is a good idea and NOAA will continue to build partnerships with other Federal agencies, nongovernmental organizations, and industry to marry weather, water, and climate information from NOAA with structural information to help save lives and protect property. For example, NOAA works with NIST as they are the lead agency for the National Windstorm Impact Reduction Act. The NIST National Windstorm Impact Reduction Program was created to improve the understanding of windstorms and their impacts and to develop measures to reduce the damage they cause. In various storm areas (i.e., Great Plains, Southeast U.S.), or within regions associated with land-falling hurricanes, NOAA has deployed mobile observation platforms to better understand the winds embedded within the tornadoes.

Appendix 5. Observation System Simulation Experiments (OSSE)

EISWG Recommendations • NOAA Response to EISWG

EISWG Recommendations on OSSE - April 2019	**NOAA Response** - December 2019
# 1. OSSE, OSE, FSO, EFSO research efforts should be coordinated nationally (e.g., sharing of software tools) to avoid duplication of effort (e.g., via the QOSAP program). These methods each have their pros and cons, and should all be used to assess the relative benefit of different observing systems. Besides full-scale OSSE experiments, simple experiments could also be very powerful (e.g., for sampling strategies and data value evaluation).	NOAA concurs with this recommendation and will work through appropriate mechanisms to avoid duplication.
# 2. The OSSE development for earth system models (e.g., for sea ice prediction) needs to be accelerated. Furthermore, global 5 km (and preferably 3 km) Nature Run based on earth system models should be developed as the basis for a variety of OSSEs. This may require the purchase of new high-performance computers or the partnership with other agencies.	NOAA concurs with the recommendation to accelerate OSSE development and increasing the Nature Run resolution to 5 km. However, the agency notes that this activity will be well suited for cloud computing and may not require adding additional high performance computing capacity to existing NOAA assets.
# 3. NCEP data assimilation and prediction system will continue to improve. OSSEs are used to evaluate the observational network likely decades ahead. Therefore, the choice of observations and investment decisions based on OSSEs need to explicitly consider the potential impact of deficiencies in the current data assimilation and prediction system.	NOAA concurs with this recommendation.
# 4. Besides existing OSSE activities at NOAA, OSSEs should also be used to: ● assess the value of NOAA partnership in satellite remote sensing with foreign agencies (e.g., India) and the private sector (e.g., purchasing data from privately-launched satellites), ● assist the exploration of strategies for the most effective and efficient way to do sea ice prediction (observations, models, data assimilation). Should NOAA request ice-breakers? How many? ● compare the value of (polar, geostationary, small/cube) satellite network strategy (e.g., small number of large satellites versus large number of small and cube satellites) for weather and climate prediction, and ● do a gap analysis in NOAA; i.e., what are the greatest new observational needs? What combination of old and new systems will work best?	NOAA agrees with this recommendation

EISWG Recommendations on OSSE - April 2019	**NOAA Response** - December 2019
# 5.OSSEs have been primarily used to evaluate the impacts of observing systems and/or observation denial on forecast performance per se, that is, on the physical parameters, and treating all forecast locations, times, and circumstances as equal. But this idea should be extended to societal impacts, whether monetizable, or in terms of lives at stake, etc. In other words, there are national priorities (e.g., saving human race) where money does not matter, and there are priorities depending upon the constraint of financial resources. This could be a possible additional avenue of research. In an Earth system model where social systems and the built environment are included, one can imagine collecting human data or propagating just the physical earth system information through the social systems as well. Indeed, while OSSEs provide quantitative analyses of future observing system impacts for a specific model, the effects on products that rely on that model can only be estimated qualitatively. The NOAA/NESDIS Technology, Planning and Integration for Observation (TPIO) division has developed a qualitative tool for assessing supporting investment decisions, called the NOAA Observing System Integrated Analysis (NOSIA-II), also known as NOAA's Value Tree. This Value Tree is based on a survey of subject matter experts across all NOAA Line Offices to gauge the impacts of Earth observation investments on NOAA's key products and services. Therefore the aforementioned OSSE, OSE, FSO, EFSO and PQC tools should be used in concert with the current NOSIA-II system to determine NOAA's future observing needs.	As the EISWG report states, an OSSE modeling experiment is used to evaluate the impact of new observing systems on operational forecasts when actual observational data are not available. While NOAA acknowledges the value of OSSEs as a quantitative analysis tool, there are certain assumptions made when using a simulated dataset, and the agency is concerned that extending this tool to also evaluate societal impacts could potentially compound any assumptions or errors in the simulated dataset. However, observing system investments can be assessed by combining Observing System Experiments (OSE)/OSSE results with NOSIA model data to assess mission service impacts such as hurricane warnings and fisheries stock assessments. Using OSE/OSSE and NOSIA data in concert facilitates decision making before acquiring substantial observing systems to minimize risk, manage costs, and maximize impact. Additionally, economists have used NOSIA mission service impacts to estimate the return-on-investment from NOAA observing systems.