SAB PWR Report Response
Panelist Key Talking Points
Science Advisory Board Meeting
December 1, 2022

Please add your top 1-2 key messages within the document below. These points will be shared with the SAB for review prior to the meeting on December 1, 2022.

Panel 1: Activities that are the highest priority for "Immediate First Steps"

Ed Clark

- **NextGen Water Resources Modeling Framework** - Improve Continental Scale Hydrologic Modeling. NOAA has been working to develop a Next Generation Water Resources Modeling framework, designed to facilitate needed model interoperability and multi-model approaches, collaboration, and scientific evaluation. The Next Generation Water Resources Modeling framework leverages investments across the federal government and will allow NOAA and other agencies to run model configurations that support their respective operational and research applications. NOAA is also pursuing research to advance hydrologic process representation in earth system models and exploring the viability of multi-model hybrid dynamical/machine learning experimental hydrologic prediction systems.
- **NWM Version 3 -** The NWS has completed development of National Water Model (NWM) Version 3.0, which improves forecast accuracy and expands the NWM domain to portions of Alaska, as well as delivers Integrated Water Prediction (IWP) forecast along the Atlantic, Pacific, Gulf coasts to account for the combined flooding from freshwater and saltwater processes by coupling with both the Surge and Tide Operational Forecast System (STOFS) and Probabilistic Tropical Storm Surge (P-SURGE) capabilities from the National Ocean Service and National Hurricane Center, respectively. .
- **Hydrologic Ensemble Forecast Service (HEFS) -** NOAA is currently implementing the HEFS at approximately 3,400 locations by the close of Q3 of FY2023 (~2800 to date). HEFS accounts for both meteorological and hydrological uncertainty, and these forecasts are being used to inform risk based water resources decisions (e.g., FIRO). HEFS is replacing the legacy Ensemble Streamflow Prediction (ESP) with a target of providing characterization of uncertainty in streamflow predictions from hours to the full water supply year. HEFS locations are specific forecast points which are usually US Geological Survey stream gages or other points of measurements (e.g., inflow to reservoirs.)
- **Real time and Forecast Flood Inundation Mapping (FIM) -** With resources provided to NOAA under Provision 3 of Bipartisan Infrastructure Law, NOAA will revolutionize U.S. water prediction capabilities by disseminating, for the first time in history, real-time, high spatial resolution forecast flood inundation maps for 100% of the US population. This forecast information will provide communities with access to critical, detailed flood maps that facilitate proactive decision making before and during floods, and prevent loss of life

and property damage. These maps will depict when and what areas and infrastructure will be impacted, how deep the flood waters will be, and how long an area will be impacted by flooding. The National Weather Service is on track to operationally implement FIM services to 10% of the U.S. population by FY2023. This domain includes the Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) that participated in the FY18/19 and FY20/21 DOC APGs.

Mike Farrar

- NOAA structure, processes and resources have improved, but more work is needed in order to optimally align and coordinate research and R2O initiatives across NOAA
    - NOAA coordination has improved somewhat with the Earth System Innovation Board (formerly Weather, Water and Climate Board), but that structure would benefit from more 'teeth' in driving forward NOAA priorities
    - While NOAA processes have helped (e.g., Line Office Transition Managers Committee), R2O continues to be a challenge
    - Workforce development in the sciences needs to be better resourced and coordinated across NOAA, noting that NOAA is competing globally for new scientists and engineers, so we need to 'up our game' to recruit and retain.
- We have a golden opportunity to focus on some existing efforts that directly get after the recommendations from the PWR report. Two examples jump out to me:
    - Community modeling: NOAA's Unified Forecast System (UFS) and related efforts (e.g., Environmental Prediction Innovation Center/EPIC and Joint Center for Satellite Data Assimilation/JCSDA) should be stably resourced for the long-term.
    - The Precipitation Prediction Grand Challenge (PPGC) project is 'shovel ready' and well aligned with NOAA's greatest needs, so we should immediately move forward with PPGC as a strategic first step. I also note that PPGC directly addresses 8/11 of the PWR's Immediate Actions, to include the following:
        - "**Target water cycle extremes** and their cascading impacts to improve flood and drought prediction"
        - "**Accelerate development of an Earth system modeling (ESM)** to improve forecast accuracy and lead time
        - "**Target the understanding and prediction of high-impact weather (HIW)** to match the urgent need imposed by climate trends, population and infrastructure increases, and disproportionate impacts on vulnerable communities"
        - "Fully implement and rapidly expand the existing plans for **improved weather data dissemination**"

Jennifer Mahoney

- **FS3 - Research and Data Assimilation:** Advancement of NOAA's model depends heavily on a well-trained and educated workforce. One of the most significant gaps is access to scientists with the depth of knowledge and experience in data assimilation. One suggestion would be to invest in NOAA's Cooperative Science Centers to develop and grow the next generation workforce specifically trained in DA.

- To truly realize a seamless convective-resolving high-resolution rapidly-updating global model that can better predict high-impact weather, high performance computing is absolutely critical. With the increase in funding through the Bipartisan Infrastructure Law and the Inflation Reduction Act, NOAA has the opportunity to make a substantial increase in HPC to advance our scientific objectives. However, long-term sustainable funding is needed to maintain, grow, and to continue to advance NOAA's computing infrastructure that will enable new developments in NOAA's science and modeling efforts.

Mitch Goldberg

- **FS3 - Research on Data Assimilation:** There is a shortage of data assimilation scientists which NOAA must address.   We have been discussing approaches on how to accomplish this by developing a stronger recruiting pipeline with our Cooperative Institutes as well as developing a training program for candidates interested in NOAA's mission and a strong background in math and computer science.
- **FS7 - Impacts - Reanalysis and Forecasting:** Reanalysis is a high priority at ECMWF and likewise should be at NOAA. ECMWF spends considerable time ensuring significant historical data are quality controlled and assimilated.. For satellite observations, the satellites data records need to be reprocessed. NESDIS is working to re-establish its program to reprocess satellite climate records to support climate change studies, and to support reanalysis and reforecasts, and to incorporate socio-economic data with the long term climate data records to improve mitigation of extreme events by understanding impacts of past events.

Frank Indiviglio

- **Research & Development High Performance Computing -** NOAA is working to increase its R&D HPC infrastructure to effectively implement world-class research innovations in addressing the Grand Challenges of modeling the Earth system. These challenges require unprecedented levels of HPC capability with a strong and resilient workforce that effectively coordinates across Federal, academic, and scientific communities. The FY22 DRSA, FY22 BIL and IRA, and base funding will allow NOAA to increase its HPC. A portion of the supplemental resources will also increase investment in the software engineering skills needed to improve code efficiency and use next-generation computational architectures.
- HPC usage continues to grow across NOAA, this growth will continue to support a number of focus areas(Genomics, AI, EPIC, Uxs, cloud) and is essential to others such as our Data and Citizen Science. Cloud resources allow testing on a plethora of technologies that could then be scaled on future NOAA architecture. An important goal for the NOAA HPCC program is to provide an enterprise-wide capability where from the user perspective, the HPC resources available appear and are managed as one large environment including cloud and partnership capacity. This goal will require greatly increasing the commonality between HPC systems, software stacks, container development, bridging technologies and architectures solutions, and enterprise workload management.

Ariel Stein

- Aerosols and trace gases change the solar/terrestrial energy balance and cloud physics, impacting meteorology and climate on various timescales.Poor air quality has significant societal impacts, including degraded human health and visibility.
- NOAA has numerous legislative, interagency, and international mandates for its research and operational predictions of atmospheric composition.As NOAA consolidates its many operational systems into the UFS, NOAA has a unique opportunity to bring together its Atmospheric Composition modeling capabilities and increase the predictive power of the UFS.

Panel 2: Activities that are the highest priority for the longer term

V. Ramaswamy

- Advancing fundamental physics, chemistry, and dynamics to characterize, quantify, and reduce the biases in the mathematical modeling of the Earth System, and improve the ensemble-based forecasts. The enhancement in the treatment of the basic processes, especially those linked to convection-microphysics-radiation, is expected to lead to improved quantification of the interactions between the atmosphere, oceans, land, and ice components across timescales.
- Augmentation of HPC resources is particularly critical for the accurate predictions of the hydrologic cycle, especially under climate change (IPCC, 2021) and on local (e.g., county) scales. Urgent concerns for society in the context of Earth's increasing energy imbalance include high-spatial-resolution forecasts of the frequency and intensity of severe precipitation activity (excess and deficit), including spatial shifts of the precipitation belts. A better linkage of the physics of energy and water cycles causing weather extremes under the action of climate forcers will be an important element in NOAA's new generation of Earth System Models. The management and dissemination of the high-volume prediction datasets to societal sectors will complement the science.

David DeWitt

- **Meeting User Needs for Actionable Sub-Seasonal to Seasonal (S2S) Climate Predictions:** Every stakeholder has a risk tolerance, and every prediction product has a skill profile. Stakeholders will generally use products that meet their risk tolerance. For example, water resource managers in the western United States generally can't use seasonal precipitation predictions due to the low skill level, but they can use one week forecasts to dynamically manage reservoirs, which is known as Forecast Informed Reservoir Operations (FIRO). We need to develop interactive tools that allow stakeholders to understand the skill profile and forecast uncertainty associated with our products so that they can make informed decisions regarding which products meet their needs.
- **Understanding S2S Predictability Limits and the Root Cause of Model Systematic Errors:** Coupled dynamical models exhibit systematic errors that have remained nearly the same in magnitude and distribution since the late 1990s. These errors represent missing or misrepresented physical processes and their interaction and limit forecast

skill. In order to reduce these errors and improve forecast skill, we need to invest in deep-dive diagnostics that allow us to evaluate the fidelity of the representation of physical processes in our models. We also need to exploit empirical and statistical prediction tools such as artificial intelligence and machine learning (AI/ML) and linear inverse models (LIM) to help us understand predictability limits and to provide targets for potential improvement of dynamical models.

Molly Baringer

- **Ocean/Atmosphere Interactions** - Research continues to show improvements in short and long-range weather predictions when including ocean observations and ocean-atmospheric coupling in numerical models. NOAA has recently tested new innovative ocean observing technologies to collect subsurface ocean observations and ocean marine boundary layer observations and assimilated these observations to produce improved numerical weather predictions.
- **Subseasonal to Seasonal Prediction of High Impact Weather** - The collection of key ocean observations and improved understanding of S2S processes is leading to promising research on generating skillful subseasonal to seasonal outlooks of high-impact weather.

David Michaud

- **Weather and Climate Operational Supercomputer (WCOSS)** - In June 2020, NOAA nearly tripled its operational supercomputing capacity moving from 4.2 PF per site (8.4 Total) to 12.1 PF per site (24.2 PF Total). NOAA is currently in the process of increasing the current WCOSS compute capacity by 20% moving from 12.1 PF per site (24.2 PF Total) to 14.5 PF per site (29 PF Total) with expected availability to users by July 2023. NOAA is beginning the process of requirements development and market research for the next phase of systems under the WCOSS contract from 2025-2030.
- **Advanced Weather Interactive Processing System (AWIPS)** - AWIPS is a critical component of NWS infrastructure which allows forecasters to directly interact with the model guidance and observational data to generate critical warnings, watches, and information for Impact-Based Decision Support. The NWS is working to transform AWIPS to operate using cloud technologies converging its data and processing environments. This will allow NWS forecasters to provide IDSS at an Emergency Operations Center, at the scene of a disaster, on the front lines of a hazard, or at a safe location in a continuity of operations capacity all with the same tools as back at the office. This will break down existing data distribution bottlenecks enabling NWS forecaster access to more robust data from WCOSS.

Robert Webb

- **Pursue high resolution ESM and machine learning methods to advance strategies to reduce tropical model error and biases** that are known to stem from under-resolved (sub-grid) processes related to clouds and rainfall. As high-resolution ESM capabilities develop, tropical errors and biases should be partially reduced with improved representation of circulation feedbacks related to deep convection. However, key processes related to clouds and rainfall, for example, surface fluxes and shallow convection that remain under-resolved in the foreseeable future can be addressed through ML strategies

- **Develop a sustained ongoing capability to generate global coupled earth-system reanalyses and reforecasts** to initialize operational forecasts, to bias correct and calibrate operational forecasts, to support ESM evaluation and improvement, to characterize extremes to inform risk assessments, provide training datasets for artificial intelligence.
- **Pursue innovative approaches to better characterize sub-grid scale variability of land surface processes such as soil moisture and snow depth** that can be integrated into forecast models to improve prediction of water availability and extremes by bridging the gap between *in situ*/point measurements and satellite measurements to inform the model parameterization of coupled land surface processes and assimilation of these data through testbeds to evaluate modeling innovations,

Tony LaVoi

- NOAA is pursuing a multi-pronged approach to increase the accessibility, interoperability, and dissemination of its data, as outlined in the NOAA Data Strategy and Action Plan. These efforts are led by the NOAA Data Governance Committee, formerly the Environmental Data Management Committee, in close coordination with other NOAA councils and committees. Priority efforts include the development of a suite of Data Dissemination Recommendations for system owners, creation of a Analysis/AI-Ready Data Standard for use by the earth systems data community, development of Commercial Data Buy Guidance, identification of key cloud-native data types that enhance the usability of NOAA's data in cloud and hybrid systems, and deployment of a new NOAA data catalog.
- NOAA continues to build the NOAA Open Data Dissemination (NODD) Program, a public-private partnership with the commercial cloud community, to enhance access to NOAA's open data. Leveraging cloud platforms to support open environmental data access at scale has given NODD unique insights into how these data are used through engagements between public and private partners in industry, government, and academia. These relationships have driven development of NODD and have fostered broader discussions around future priorities in facilitating access to open environmental data. A key focus that has arisen in discussion over the past year is on interoperability. With more and more environmental data being made publicly available, linking these data in accessible, performant formats is becoming a challenge.

Panel 3: Activities that are highest priority where the community can help (government, academia, private sector)

Brian Gross

- **NWS is committed to leveraging community-based models for its operational systems.** These will be based on the Unified Forecast System, which engages other Federal agencies, academic institutions, and the private sector, in the open development of UFS applications, whose code resides in open github repositories. These applications are all ensemble-based, share common Data Assimilation software (the Joint Effort for Data assimilation Integration, or JEDI) from the Joint Center for Satellite Data Assimilation (in support of Recommendation OD-4), use ensembles to quantify uncertainty and support probabilistic forecasts, and are backed by a reanalysis and set of reforecasts for calibration (Recommendations OD-5, FO-3). Testing and evaluation are supported in the multi-agency Developmental Test Center and other NOAA testbeds. NOAA's Earth Prediction Innovation Center (EPIC) facilitates the integration of community innovation into UFS applications and the operational systems that derive from them, toward meeting Recommendation FO-2. Gaps, which the SAB could help expose and for which the SAB could promote potential solutions, exist in
    - Establishing a set of community-based metrics for model evaluation, which would address multiple Recommendations (e.g., FO-1, FO-2, etc)
    - NOAA's ability to evaluate new observing systems (lacking a robust OSE/OSSE capability), with which the weather enterprise can help (Recommendation OD-2.3).
    - The data assimilation workforce (Recommendation OD-3). Support for collaborative development of a workforce skilled in data assimilation science can be achieved, for example, through a university consortium and establishing communities of DA practitioners that can provide in situ experience to that workforce.
    - Precipitation prediction. Further development of UFS-based applications are needed to meet the goals of the Precipitation Prediction Grand Challenge, which addresses Recommendation FO-4, among others.
- NOAA's hunger for **additional HPC** is not satisfied. UFS applications are all ensemble-based, which requires factors of 10 increases in capacity. The reanalysis and reforecasts for each of the UFS-based applications form a high-capacity, limited duration requirement for HPC, ideally suited for the Cloud, for which NOAA lacks sufficient resources. A capability for regular, sustained reanalysis and reforecasts (Recommendation FO-3) is required for timely implementations. NWS is already compromising on the configuration of the ensemble-based UFS systems planned for operations over the next few years, based on limits to WCOSS capacity even after its recent upgrade. The availability of funding for R&D HPC through FY 2022 supplemental bills is encouraging, but the O&M tail for the acquired resources is sorely needed. Easier access to exascale computing systems, such as those hosted by the Dept. of Energy, would help NOAA with its capacity limits. Recommendations FE-6 and FE-7 support NOAA's quest for additional HPC capability.

Michelle Mainelli

- **NWS Integrated Dissemination Program (IDP) Infrastructure:** With increased FY22 base appropriations to sustain, enhance, and upgrade the NWS IDP infrastructure along

with favorable FY23 PB, House, and Senate Marks, NWS is poised to advance our dissemination value chain in a manner that is nimble, flexible, mobile and most importantly reliable and accessible when it is needed the most. Aligned with the Future Needs of IDP report, over the next 2-5 years, NWS data delivery services will be transformed with a hybrid-cloud approach taking advantage of cloud technologies that enable other government agencies, academia, and the private weather enterprise to enhance, amplify, and grow (in support of Recommendation ID-2).
- Success in transforming NWS dissemination services will only be possible if we involve our external stakeholders - our partners - every step of the way. As new methods to access products and services get deployed into operations, older unsupportable delivery services and websites will need to be sunsetted. Support of these efforts, productive feedback, as well as an open collaborative dialogue are essential.

Allison Allen

- Effective partnerships with federal, state, local, private, and academic sector partners are fundamental to ensuring the most accurate and timely weather forecasts and warnings. There are a multitude of examples of past and existing collaborations, and how they have advanced modeling, forecasting, warning, and communication related to all types of weather. These partnerships are increasingly collaborative, rather than transactional, and span the entire R2O value chain. They will be increasingly necessary in tackling future forecast and warning challenges, including communicating probabilistic warning information and reaching historically underserved and vulnerable communities.
- Federal partnerships, such as the National Integrated Heat-Health Information System, National Wildfire Coordinating Group, and Space Weather Advisory Group are playing an increasing role in prioritizing, sponsoring, and conducting critical weather research. The makeup, roles, and implementation of these teams, and how they engage with private enterprise is critical to their effectiveness.

Dorothy Koch

- **NOAA's NWP community embraces open science and open data**. The UFS codes are open-development, and OAR Labs and EPIC, OCIO Open Data Dissemination Program are working to find solutions that will provide secure access to the UFS code and related data to the broad community outside the NOAA firewall. For this open data paradigm to succeed, partners across sectors are needed – the academic, public and private sector should engage in the nascent Community Modeling Board; agencies and centers that share model components with the UFS should engage in UFS working groups and activities (e.g. MOM6, CICE, FV3, microphysics, GOCART, Noah-MP); the private sector should benefit from but also contribute back to the UFS by engaging in CRADA's with NOAA.
- **To advance NOAA's new Society Data Insights Initiative (SDII)**, which will collect and analyze event-specific social science data, NOAA will need our academic partners to embrace the open data OSTP guidelines and look more toward data and instrument publication. NOAA is committed to partnering with the academic community to address concerns. NOAA will also need the private sector to provide data about people and

communities, data integration and cloud services. We will be interested in societal insight data CRADA's.
- The PWR has many recommendations that include/require partnerships particularly across government to succeed. For example, OD-6 develop a national boundary layer, soil moisture and data assimilation system; OD-7 observe the ocean, its boundary layer, and ocean-atmosphere feedbacks; OD-8 leverage and expand atmospheric river; FO-5 advance predictive capabilities for fire weather and air quality; FO-4 enhance prediction of Earth's water cycle extremes to achieve integrated water cycle modeling. NOAA has a carefully crafted partnership with EPA on air quality forecasting, based on extensive discussions and an MOA signed by the NOAA administrator that clarifies roles and responsibilities. For each of the recommended "grand challenge" data observation networks, scientific advances, and prediction improvements, a similar level of effort and mutual commitment of partner agencies will be required. We are working on some of these areas, for example on hydroclimatology and fire-weather, but to be effective we may need to focus and of course willing committed partners are key.

Ajay Mehta

- There continues to be observational gaps in data-sparse areas that will not be addressed by government systems only. While NOAA-managed systems will continue to be the backbone of our observational network, the ability to leverage partner and commercial sources will help to fill data gaps. This requires communication networks and systems to quickly ingest and process observations.
- In parallel to OAR's plans for a Phased Array Radar test article, the NWS will have to begin plans to acquire a follow-on radar to the current NEXRAD program, which is completing a Service Life Extension Program (SLEP). As part of the follow-on program, NWS will have to evaluate combining data from multiple sources/radars to expand coverage and build resiliency.

DaNa Carlis

- The PWR report and the responses from NOAA require significant collaboration and partnership with academia, private sector, and other federal agencies. Ensuring that those entities external to NOAA are familiar with the report and where they can engage will be key to successfully implementing the actions provided by the SAB. For instance, NOAA is tied to the success of JCSDA and is a primary funding source for them. However, there are many organizations such as NASA, USAF, and UKMET Office that are dependent on JCSDA's success and ensuring that these organizations are familiar with the PWR report and NOAA's responses will be part of the critical path for successful implementation.
- Successful engagement from the community requires the UFS community and EPIC to work synonymously to support innovation and interoperability of the UFS modeling framework as an R&D platform for the academic and private sector. Ensuring that the UFS modeling framework works on many systems outside of the NOAA boundary and that the community has the computing necessary to conduct R&D is also critical. HPC within NOAA is still very limited for R&D and providing resources to the community isn't

NOAA’s responsibility and with a good portion of the PWR report related to Earth System Modeling the need for R&D HPC inside and outside of NOAA for collaboration is extremely critical.