

**NOAA Response to the  
Science Advisory Board's  
REPORT CONCERNING  
THE NOAA REPORT TO CONGRESS: SUBSEASONAL AND SEASONAL (S2S)  
FORECASTING INNOVATION: PLANS FOR THE TWENTY-FIRST CENTURY**

**July 2023**

## EXECUTIVE SUMMARY

### REPORT CONCERNING THE NOAA REPORT TO CONGRESS: SUBSEASONAL AND SEASONAL (S2S) FORECASTING INNOVATION: PLANS FOR THE TWENTY-FIRST CENTURY

The Environmental Information Services Working Group (EISWG), an advisory working group reporting to the National Oceanic and Atmospheric Administration (NOAA) Science Advisory Board (SAB), was charged to review NOAA's October 2020 Report to Congress in "Subseasonal and Seasonal Forecasting Innovation: Plans for the Twenty-First Century" (hereafter NOAA S2S Report). In response, the EISWG formed a review team that included EISWG members as well as supporting members from the SAB Climate Working Group (CWG) given the influence of climate conditions and knowledge in S2S timeframes as defined in the Weather Research and Forecasting Innovation Act of 2017, Public Law 115-25 (Apr. 18, 2017) (hereafter, The Weather Act), Title II, Section 201 to be between two weeks and two years. The report provided recommendations related to the overall S2S Program (Section I), and specific recommendations aligned with the NOAA S2S Report sections, which include the current subseasonal and seasonal (S2S) products and services (Section II), current plans (Section III) and longer term requirements (Section IV) for improving S2S products and services.

This document provides NOAA's response to the [REPORT CONCERNING THE NOAA REPORT TO CONGRESS: SUBSEASONAL AND SEASONAL \(S2S\) FORECASTING INNOVATION: PLANS FOR THE TWENTY-FIRST CENTURY](#). NOAA is grateful to the EISWG and CWG members for providing their detailed recommendations. For each recommendation, current actions being undertaken along with planned activities by NOAA that address the recommendation are described. As can be seen in the individual responses, NOAA largely concurs with the recommendations. In some instances, additional resources need to be made available in order to adequately address the recommendations.

### **NOAA Responses to Specific Findings and Recommendations**

#### **1. Summary Recommendations**

1.1. Recommendation 1: NOAA should make the S2S supplement report publicly available for download alongside the official report. Language should also be included on the download site that describes the relationship between the two reports. Annotating the reports with dates on which they were published would also be beneficial, especially in referencing the reports.

NOAA Response: NOAA concurs with this recommendation. The summary report does not accurately portray the amount of the effort, in breadth and depth, that NOAA has put forth in addressing climate at S2S time scales. NOAA will annotate the reports as

suggested and provide the context for and relationship between the two documents. Language in the supplemental document may need to be modified for public audiences.

1.2. Recommendation 2: NOAA should develop, publish, and maintain a standardized index of the various definitions that exist (nationally and internationally) for the terms subseasonal, seasonal, S2S, interannual, decadal, short range, medium range, long range, etc., to help eliminate potential confusion around these widely used terms.

NOAA Response: NOAA concurs with this recommendation. NOAA will publish online a list of standardized definitions of suggested terms, consistent with Congressional language where necessary. The index will also include a definition of the term “climate” developed in coordination with the World Meteorological Organization (WMO), professional organizations, and stakeholders from public and private institutions, and also the additional definition and use preference for the term “monthly”.

1.3. Recommendation 3: NOAA should ensure consistency in its use of “S2S” and associated/related terminology across all products, services, programs, projects, budget requests, correspondence, etc.

NOAA Response: NOAA concurs with this recommendation. The NOAA National Weather Service (NWS) Climate Services Program will work to ensure usage of consistent and clear terminology throughout guidance documents, training of NOAA staff, and collaborations with NOAA line offices and external partners producing climate services. This terminology will be informed by the standard index of definitions from Recommendation 2.

1.4. Recommendation 4: NOAA should adapt the vision from the NAS (2016) S2S Report: “S2S forecasts of environmental conditions will be as widely used a decade from now as weather forecasts are today” (or a similar vision) to develop a strategic, time-bound goal (or goals) for its S2S overall program that encompasses the entire Earth System and all associated offices.

NOAA Response: NOAA concurs with the idea behind this recommendation to adapt the vision from the National Academy of Sciences (NAS) S2S Report, but notes that this vision statement as written may not be realistic given real constraints on predictability and available resources. NOAA supports the idea of developing strategic, time-bound goals. To this end, the [Weather, Water, and Climate Strategy for FY23-FY27](#) identifies many outputs that are relevant to the S2S program:

- Extreme Heat and Cold - Extreme Events & Cascading Hazards Outputs 1, 2
- Floods - Extreme Events & Cascading Hazards Output 6
- Drought - Extreme Events & Cascading Hazards Outputs 7,8
- Wildfire - Extreme Events & Cascading Hazards Output 11
- Precipitation Extremes - Extreme Events & Cascading Hazards Outputs 17,19

- Coastal Storms - Extreme Events & Cascading Hazards Output 21
- Marine Heatwaves - Extreme Events & Cascading Hazards Output 27
- Cascading Hazards - Extreme Events & Cascading Hazards Outputs 29, 30
- Consistent Coastal Water Level Variability Predictions - Coastal Resilience Output 4
- Hydrological Ensemble Forecast Services - Water Availability, Quality, and Risk Output 6
- Subseasonal and Annual Integrated Water Capabilities - Water Availability, Quality, and Risk Output 10
- Subseasonal to Decadal Integrated Water Capabilities - Water Availability, Quality, and Risk Output 11

It is difficult to ascertain the appropriate level of skill required for the large variety of applications/uses of S2S predictions. Uncertainty ranges will be larger and predictions more probabilistic in S2S than present weather forecasts due to nature of climate predictability, with significant differences between 2-3 week forecasts and 18-24 month forecasts. Some specific variables (e.g., mean temperature) in specific regions may reach the level of skill required for useful applications but many (e.g., storms, coastal inundation) likely will not.

1.5. Recommendation 5: NOAA should highlight S2S as a true Earth System effort with correspondingly cross-office approaches in NOAA's strategic planning, prioritization, and budgeting efforts to include regional offices.

NOAA Response: NOAA concurs with this recommendation. Current strategic goals within the FY23-FY27 Weather, Water, and Climate Strategy require a cross-office approach that is coordinated through NOAA's Earth Systems Integration Board (ESIB). As an example, the NWS Office of Science and Technology Integration (OSTI) and the NOAA Office of Oceanic and Atmospheric Research (OAR) Weather Program Office (WPO) are jointly sponsoring the development of the first Unified Forecast System (UFS)-based Seasonal Forecast System (SFS) that is composed of six Earth System components (atmosphere, land, ocean, sea ice, waves and aerosols) as a replacement of the operational Climate Forecast System version 2 (CFSv2) implemented in 2011. In addition, WPO is reaching across labs, programs, and line offices to build high-level tools for visualizing work being done and its maturity, to help inform priorities. This effort should more strongly leverage the existing Earth System modeling capabilities developed for many decades at the OAR Geophysical Fluid Dynamics Laboratory (GFDL). This could rapidly accelerate operational Earth System prediction.

Also, we are increasingly connecting to affected trust resources (ecosystems, fisheries, habitat, protected species) through cross-Line Office (LO) programs like the Climate, Ecosystems, and Fisheries Initiative (CEFI). However, S2S research and operations surrounding coastal inundation and general impacts specifically to coastal regions from already included processes (storm tracks, intensity, atmospheric circulation, coupled

modeling, data assimilation) seem to be largely left out and could be integrated into an Earth-system effort. “Coastal inundation” is specifically mentioned in The Weather Act. The NOAA National Ocean Service (NOS) has previously included S2S in their white papers and strategic plans, and both the Fifth National Climate Assessment (NCA5, Coastal Effects chapter) and the U.S. Climate Variability and Predictability (CLIVAR, Climate at the Coastal Research Challenge) have noted the importance and need for S2S forecasts in the coastal regions.

1.6. Recommendation 6: NOAA should emphasize S2S predictions in projects that are solicited and funded under NOAA’s Earth Prediction Innovation Center (EPIC) program.

NOAA Response: NOAA partially agrees. This recommendation as written implies that funding from various LOs and programs would be funneled through the EPIC program, which is not staffed to manage this. Current S2S prediction projects are largely funded by OAR/WPO Programs including S2S, Climate Testbed, Joint Technology Transfer Initiative through Notice of Funding Opportunities (NOFO) and NWS/OSTI modeling programs Next Generation Global Prediction System (NGGPS) Weeks 3-4, and FY23 SFS appropriations through internally funded projects. EPIC will facilitate and support S2S prediction projects by enabling community access to S2S modeling systems and ensure capability of running S2S modeling systems efficiently on High Performance Computing (HPC) platforms (including cloud platforms), and also assist NWS in the transition from research to operations. In addition, NOAA can promote and draw attention to S2S prediction projects that are solicited in conjunction with or leveraging the EPIC program.

1.7. Recommendation 7: NOAA should use the co-leadership role of NOAA in ICAMS, prioritize S2S-related interagency collaboration, including the initiatives under National Earth System Prediction Capability (ESPC).

NOAA Response: NOAA concurs with this recommendation. NOAA can use its co-leadership role to emphasize the need for broad agency participation in the Interagency Council for Advancing Meteorological Services (ICAMS). NOAA notes that there are other interagency hydroclimate coordinating bodies that are relevant to the S2S program, including the National Drought Resilience Partnership and the U.S. Global Energy and Water Cycle Experiment (GEWEX), coordinated by the US Global Change Research Program (USGCRP), to advance predictive capability and service delivery practices.

1.8. Recommendation 8: NOAA should capitalize on the Interagency Council for Advancing Meteorological Services (ICAMS) objective to “coordinate, help prioritize, and execute activities for U.S. global leadership in meteorological services” to cohere and increase overall international engagement and program support in areas related to S2S forecasting.

NOAA Response: NOAA concurs with the use of ICAMS as a coordinating body to cohere and increase international engagement and program support related to S2S forecasting, to the extent that ICAMS member-agency international partnerships can be leveraged and in close coordination with NOAA International Affairs offices. Recently the Fast Track Action Committee (FTAC) of the National Science and Technology Council (NSTC) has [proposed](#) to “Direct USGCRP to facilitate coordination among agencies specifically regarding climate service development, delivery, and use” and reduce the scope of ICAMS climate subcommittees to focus on high-impact weather and S2S prediction consistent with The Weather Act. Although reconciling potential overlap between USGCRP and ICAMS in the climate services and S2S forecasting areas is still in progress, NOAA will need to continue coordinating with both groups to increase international engagements.

## **2. Current S2S Products and Services**

2.1. Recommendation 9: NOAA should maintain a true S2S Product “Internet clearinghouse.” The Weather Act (2017) directs NOAA to “develop an Internet clearinghouse” to provide S2S forecasts and associated information on their impacts, at both national and regional levels. We recommend the current S2S forecast products and information available on the CPC webpage be expanded and titled/described as a “clearinghouse” to fully meet this direction and include all national and regional S2S forecasts and impact-based products.

NOAA Response: NOAA partially concurs with this recommendation with some modifications. Full execution of this recommendation will require resources. Impact evaluation will require dedicated social science resources. The NWS Climate Prediction Center (CPC) will require resources to start serving additional products. Before CPC is asked to increase its scope in these areas, a resource assessment needs to be developed and resources identified before the service is expanded. Development of this clearinghouse will be geared in part toward streamlining products that enhance decision-making while identifying and reducing duplication of effort. The clearinghouse will clearly define operational products and distinguish those from the many research-grade tools and experimental products from across NOAA.

2.2. Recommendation 10: NOAA should provide additional product verification and use metrics to enhance user awareness of forecast skill usefulness. The Forecast verification pages on the CPC website provide Heidke Skill scores and associated data archives for S2S temperature and precipitation forecasts. We recommend the verification pages be expanded and upgraded to:

10.1. Ensure all verification tools and information are accessible to the public.

NOAA Response: NOAA concurs with this recommendation. NWS National Centers for Environmental Prediction (NCEP) centers are transitioning to use a community Model

Evaluation Tool (METplus) for verification of all forecasts ranging from hurricane, short-range weather, medium-range weather and S2S time scales. All verification methods should be described clearly so that results can be reproduced. Although skill metrics explanations can bring more questions than answers, details can be made available separately (as additional reports, attachments, in appendices) from primary product distribution.

10.2. Provide summarized verification information on all S2S products, including hurricane seasonal outlooks.

NOAA Response: NOAA concurs with this recommendation for operational products.

10.3. Include long-term changes and trends in verification scores that indicate changes in skill of specific products, types, regions, etc. over time.

NOAA Response: NOAA concurs with this recommendation. NOAA notes that information beyond summarized verification metrics (Recommendation 10.2) will require resources and cannot be implemented until the needed resources are provided.

10.4. Make updated product use and download metrics publicly available (e.g., aggregate “web hits” as provided in the NOAA S2S Report).

NOAA Response: NOAA concurs with this recommendation.

10.5. Develop and publicize comparative skill metrics with S2S products from other sources such as almanacs and commercial weather organizations (e.g., news media) that develop seasonal predictions based on “analog” past years with global weather patterns and trends that resemble current year.

NOAA Response: NOAA concurs with this recommendation with some modifications. Comparative skill assessments depend on products sharing the same attributes (domain, forecast variable, target period, gridded v. station, etc.) and being readily available for comparison. This type of comparison is most relevant to models, including the CFSv2 and the Global Ensemble Forecast System (GEFS). Other S2S service outlets do not publicize their forecast methodologies and forecast outputs in a standard format that could be used for direct comparison with NOAA S2S forecast products. The Recommendation also is vague regarding which, or how many, organizations the comparative skill assessment should be conducted.

Skill score comparisons may not be true for all variables/products. Erosion, inundation frequency, extremes heat/precipitation/surge, water resources, marsh and habitat loss (and others) are examples of applications where the usefulness of a prediction may depend on more than skill scores.

2.3. Recommendation 11: NOAA should maintain an updated, online version of the “Potential Future Products List” that is provided in Appendix B of the official NOAA S2S report. This will enable stakeholders to better plan for the use of these products as they become available.

NOAA Response: NOAA concurs with this recommendation with some modifications. Not all “POTENTIAL Future Products” will come to fruition and thus risk alienating stakeholders planning for their use. Perhaps one section of “Products in Development” which have a high chance of being operational, and one section of “Potential Products” that could be open to comments from stakeholders. It may be useful to distinguish between “experimental products” (e.g., North American Multi-Model Ensemble probabilistic seasonal forecasts) for which there already is publicly available forecast guidance and “potential future products” for which none currently exists. This should also include clarification on which products will require resources to develop and implement. We need to consider the highest priority needs of stakeholders when the “Potential Future Products List” is generated.

2.4. Recommendation 12: NOAA should collect, publicize, and maintain an online catalog of “best practices” regarding the use of S2S products in public planning and preparedness. This will enable regional planners and decision-makers to share and gain knowledge regarding product use as well as support collaboration with NOAA regional organizations and other federal/regional/local partners.

NOAA Response: NOAA concurs with this recommendation. This will require the availability of dedicated social science resources. There should be two-way dialogue between NOAA and regional planners/decision-makers (Recommendations 15 and 16) that may inform S2S products and therefore help to shape best practices. This catalog also would be supplemented with active outreach, including training, virtual workshops and seminars, etc., especially to underserved communities.

### **3. Current Plans for Improving S2S Products and Services**

3.1. Recommendation 13: NOAA should develop and maintain (more) specific plans, goals, and priorities under both overarching goals (improving forecast skill and enhancing stakeholder value) that can be mapped to budget requests, EPIC project initiatives, collaboration efforts with “core partners,” etc. Goals that are specific, measurable, achievable, relevant, and time-based (SMART) would help increase community support and potentially drive successful budgetary increases.

NOAA Response: NOAA concurs with this recommendation. NOAA needs to coordinate the upstream program efforts, map these against gaps, and use those results to prioritize investments.



3.2. Recommendation 14: NOAA should maintain holistic roadmaps for the two overarching goals (increased forecast skill and enhanced stakeholder value) that include SMART goals and priorities along with desired end states. Frequently updated, publicly available roadmaps with critical path elements would provide additional transparency into status, progress and evolving requirements that would help garner public support and engagement around NOAA's S2S programs and initiatives.

NOAA Response: NOAA concurs with this recommendation. The coordination of upstream program efforts should improve forecast skill. NOAA also needs greater outreach and coordination to better understand and incorporate a wider variety of potential users and their needs over this time scale.

3.3. Recommendation 15: NOAA should develop a framework, using social/behavioral sciences and direct coordination with stakeholders, to establish value metrics and assessment processes for key categories of S2S product stakeholders. This could include well-coordinated communication and coordination with stakeholders by NOAA's various regional offices (e.g., NWS Regional Headquarters, Regional Climate Centers, Regional Integrated Science and Assessment activities). These coordinated efforts should consider multiple sectors of the weather/climate/earth science enterprise, to include the many local/state/regional public and private weather organizations that provide S2S forecasts and decision-making support (including news media). Consultation with other entities within the Department of Commerce, such as the Office of Native American Affairs and the Minority Business Development Agency, may also prove valuable in developing this framework.

NOAA Response: NOAA concurs with this recommendation. NOAA is funding social, behavioral, and economic science projects at OAR/WPO. It is imperative to properly convey probabilistic outlooks and likelihood of extremes. Ongoing stakeholder engagement activities related to S2S outlook products of coastal flooding, conducted by NOS (CO-OPS in particular) should be mentioned in the report. Other stakeholder engagement and outreach on coastal regions have been led by the NOS Office for Coastal Management (OCM), National Estuarine Research Reserves (NERR) and Sea Grant offices, State Climate offices as well as State Geological Surveys.

3.4. Recommendation 16: NOAA should increase interagency collaboration around social and behavioral sciences, to include how S2S products and services can be more effective toward influencing public behavior and responsiveness, to include planning and preparedness by all levels of government. Given the growing impact of extreme conditions on public safety and security, collaboration with organizations within the Intelligence and Homeland Security communities such as the National Geospatial Agency (NGA) and Federal Emergency Management Agency (FEMA) is strongly recommended.

NOAA Response: NOAA concurs with this recommendation and will leverage ICAMS and other coordination opportunities to increase societal benefit through social,

behavioral, and economic science (SBES) infusion into NOAA's S2S suite of products and services. SBES integration is critical to the development of successful and repeatable service co-production processes, wherein users and service providers iterate throughout the stages of development, deployment, and communication.

#### **4. Requirements for Improving S2S Products and Services**

4.1. Recommendation 17: Using the SAB Priorities for Weather Research (PWR) Report as an initial reference, NOAA should develop a process for the establishment and periodic review, validation, and prioritization of longer-term S2S research and development requirements priorities. This would help the SAB and its working groups (e.g., EISWG and CWG) provide valuable assistance around the development/enhancement of requirements prioritization based on their breadth of expertise and experience.

NOAA Response: NOAA partially concurs with this recommendation. NOAA notes that this will require resources and a governance process. The Hurricane Forecast Improvement Program (HFIP) model could be applied here, where operations have an active role in requirement setting and evaluation of research results to ensure that they are fit for purpose. A coordinated and periodic review of priorities in S2S research and development will support and sustain a strong research to operation transition at NWS that leads to increased forecast skill. The coordinated view of upstream S2S research, and priorities determined by gaps, should be shared with SAB and such groups as needed.

4.2. Recommendation 18: In addition to the extensive research needs described in the NOAA S2S Report, NOAA should support additional basic research across the Earth System research enterprise into the limits and variability of Earth System predictability.

NOAA Response: NOAA concurs with the spirit of this recommendation. NOAA can increase support for foundational and applied research at early readiness levels, although NOAA should principally resource only efforts that use NOAA's models (i.e., UFS, GFDL Suite) and model output, and resources should be made available to improve the access to NOAA's models and data.

OAR plays a leading role in research at early readiness levels, and sets research priorities in conjunction with NOAA operations and service delivery providers. For example, OAR, NWS, and NCEI collaborate on climate attribution efforts that assess not only the predictability of observed S2S variability, but also how much of the observed anomalies are attributable to climate change. In addition, NOAA may leverage basic research supported through interagency partnerships such as the National Oceanographic Partnership Program (NOPP) for advancing S2S prediction.

4.3. Recommendation 19: NOAA WPO and CPO should foster a stronger synergistic relationship and clarify their respective roles to the research community as well as interagency partners. Confirm the validity and accuracy of the diagram above and then use it to guide and publicize cross-office R&D and R2O transition efforts regarding S2S capabilities.

NOAA Response: NOAA concurs with this recommendation. This communication is critical and hopefully will lead to more focused research within the S2S time scales.

4.4. Recommendation 20: NOAA should increase collaboration with Integrated Ocean Observing System (IOOS) leadership and the myriad IOOS and Global Ocean Observing System (GOOS) organizational activities to help address ocean observing and monitoring gaps as they relate to S2S requirements.

NOAA Response: NOAA concurs with this recommendation. Joint collaborations between NWS/NCEP and IOOS/GOOS are needed to help address huge ocean observing and monitoring gaps for improved ocean states for S2S predictions. Joint efforts/projects on the efficacy of ocean observing systems are needed for improved S2S forecasts. The ocean observing community could use assistance from NWS and OAR in understanding modeling systems which may be able to benefit from ocean observations. To help address ocean observing and monitoring gaps that are needed for improving S2S forecast skill, NOAA needs to enhance the development of coupled data assimilation schemes and production of coupled reanalysis.

4.5. Recommendation 21: NOAA should continue to develop and prioritize funding for S2S pilot projects that involve Earth System prediction and the application of associated products to decision-making involving specific use cases (e.g., underserved populations).

NOAA Response: NOAA concurs with this recommendation. NOAA will specifically connect SFS development with the S2S pilot projects, for better coordination, including constantly verifying and making available both experimental and operational streams of information and data. In addition, NOAA plans to work on pilot projects for client products in other line offices. In particular, Integrated Ecosystem Assessments (IEA) and Fish Stock Assessments will use S2S forecasts through CEFI. This also seems to be the nexus for fisheries and marine ecosystem management in terms of forecasting and decision support tools. NOAA plans to include language regarding coordination with CEFI and IEA programs on the uptake of S2S products into decision support, as well as details about the specific process for feedback from users and decision-makers on the skill of such information. It takes several years to evaluate the skill of a prediction over various climate process time scales, assess the usefulness of prediction/outlook products, evaluate the level of outlook required, quantify ancillary impacts of uncertainty ranges in key variables (sea level anomaly, precipitation, tropical cyclone development), train managers and decision-makers on how to interpret outlook guidance, broaden usage, modify product based on user feedback, identify other use cases for similar

types of products, and more. Focusing longer-term on select S2S projects may provide valuable guidance that can be applied to other areas of the country.