

Meeting of the NOAA Science Advisory Board

November 30-December 1, 2022

Location: DoubleTree Silver Spring
8777 Georgia Avenue
Silver Spring, Maryland

Presentations for this meeting have been posted on the Science Advisory Board (SAB) website:
<https://sab.noaa.gov/past-meetings/past-meeting-documents>

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SAB Members in attendance:

Mr. John Kreider, President, Kreider Consulting LLC (Chair); Mr. Jon Allan, Senior Advisor, Senior Academic and Research Program Officer, School for Environment and Sustainability, University of Michigan; Mr. Jesse Ausubel, Director, Program for the Human Environment, The Rockefeller University; Dr. Ilene Carpenter, Earth Sciences Segment Manager, Hewlett Packard Enterprise; Dr. Chelle Gentemann, Program Scientist, Transform to Open Science, National Aeronautics and Space Administration; Mr. David Grimes, President and CEO, Grimes Consulting; Dr. Robert Grossman, Frederick H. Rawson Distinguished Service Professor in Medicine and Computer Science and Jim and Karen Frank Director, Center for Translational Data Science, University of Chicago; Mr. W. Christopher Lenhardt, Domain Scientist, Renaissance Computing Institute, University of North Carolina at Chapel Hill; Dr. Brooke Fisher Liu, Professor of Communication, The Graduate School, University of Maryland; Dr. Bonnie McCay, Distinguished Professor Emerita, Department of Human Ecology, School of Environmental & Biological Sciences, Rutgers University; Dr. Ruth Perry, Head of Regulatory Affairs, Shell Exploration and Production Company; Dr. Zhaoxia Pu, Professor, Department of Atmospheric Sciences, University of Utah; Dr. Denise Reed, Professor Gratis, Pontchartrain Institute for Environmental Sciences, University of New Orleans; Dr. Martin Storksdieck, Director, STEM Research Center and Professor, College of Education and School of Public Policy, Oregon State University; Dr. Steve Weisberg, Executive Director, Southern California Coastal Water Research Project; Dr. Anthony Wu, Executive Director, AeroMarine LLC; Dr. Donald Wuebbles, The Harry E. Preble Professor of Atmospheric Sciences, University of Illinois.

SAB Working Group Chairs in attendance:

Dr. Joellen Russell, University of Arizona and Climate Working Group Co-Chair; Dr. Jeff de La Beaujardiere, National Center for Atmospheric Research and Data Archiving and Access Requirements Working Group Chair; Dr. Jan Newton, Washington Ocean Acidification Center and Ecosystem Sciences & Management Working Group Co-Chair; Dr. Scott Glenn, Rutgers University and Environmental Information Services Working Group Co-Chair; Mr. Rick Wilson, Tsunami Science & Technology Advisory Panel Co-Chair; Dr. Rocky Lopes, NOAA Emergency Manager (Retired) and Tsunami Science & Technology Advisory Panel Co-Chair.

NOAA senior management and Line Office Representatives in attendance:

Dr. Rick Spinrad, Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator; Dr. Sarah Kapnick, NOAA Chief Scientist; Dr. Michael Morgan, NOAA Assistant Secretary of Commerce for Environmental Observation and Prediction; Ms. Janet Coit, National Marine Fisheries Service; Dr. Cisco Werner, Chief Science Advisor and Director of Scientific Programs, National Marine Fisheries Service; Mr. Ken Graham, Assistant Administrator, National Weather Service; Dr. Steve Thur, Assistant Administrator, Office of Oceanic and Atmospheric Research; Ms. Mary Erickson, Deputy Assistant Administrator, National Weather Service; Mr. Randy TeBeest, Deputy Assistant Administrator for Programs and Administration, Office of Marine and Aviation Operations; Ms. Margo Schulze-Haugen, Deputy Director, National Centers for Coastal Science, National Ocean Service; Dr. Mitch Goldberg, Chief Scientist, National Environmental Satellite, Data, and Information Service;

Staff for the Science Advisory Board in attendance:

Dr. Cynthia Decker, Executive Director and Designated Federal Officer; Ms. Courtney Edwards; Ms. Katherine Longmire; Mr. Andrew Peck; Ms. Viviane Silva.

Welcome and Roll Call

John Kreider, Kreider Consulting, LLC, and Chair, NOAA SAB

Chair Kreider welcomed attendees to the meeting and asked SAB members to introduce themselves. He announced this was Courtney Edwards' last meeting on SAB staff before moving to U.S. Integrated Ocean Observing System (IOOS) the following week. Katherine Longmire would step in as organizer for this meeting, and Rose Dyson would temporarily help with travel. Dr. Decker introduced Viviane Silva, the new Designated Federal Officer for the Ocean Research Advisory Panel, who was helping with the meeting. Also present was Andrew Peck, who had been on SAB staff for a year and a half.

SAB Consent Calendar

John Kreider, Kreider Consulting, LLC, and Chair, NOAA SAB

- August 2022 SAB Meeting Minutes
- Working Group Status Reports
- EISWG (New, Renewal, and Extensions)

Jon Allan made a motion to accept the consent calendar. The motion was seconded and passed unanimously.

NOAA Science Update

Sarah Kapnick, NOAA Chief Scientist

Dr. Kapnick opened her presentation by stating that NOAA has participated in several external engagements and partnerships since the last SAB meeting, including webinars with insurance companies, discussions with the World Bank, a Memorandum of Understanding (MOU) with the Electric Power Research Institute (EPRI), and several initiatives with the US Agency for International Development (USAID).

There are three NOAA research and development vision areas for 2020-2026: (1) reducing societal impacts from hazardous weather and other environmental phenomena, (2) sustainable use and stewardship of ocean and coastal resources, and (3) a robust and effective research development and transition enterprise.

NOAA began production of synthetic aperture radar (SAR)-based tropical cyclone products that were provided to the National Hurricane Center and Joint Typhoon Warning Center (JTWC) for improved

understanding of storm strength and morphology. National Environmental Satellite, Data, and Information Service (NESDIS) developed a new technique to combine 30-meter digital elevation maps with 375-meter visible infrared imaging radiometer suite (VIIRS) flood maps to produce a downscaled 30-meter flood depth product. It also developed all-weather high-resolution SAR flood products to ensure flood mapping even during cloudy conditions. NOAA coordinated with FEMA on RadarSAT 2 acquisitions. Unfortunately, the first SAR acquisitions occurred on October 2 after Hurricane Ian's landfall.

A 20-year drought caused by climate change had significantly impacted water availability in the Colorado River Basin, resulting in water shortages for 40 million people. To better manage water resources in the future, it was necessary to better understand the physical processes impacting the watershed and how much water ended up in the Colorado River. The Study of Precipitation, the Lower Atmosphere and Surface Hydrometeorology (SPLASH) campaign would measure temperature, precipitation, soil moisture, snowpack properties, and other variables using radars, instrumented towers, individual sensors, piloted instrumented aircraft, and un-crewed research aircraft.

With the use of the new Nearshore Wave Prediction System, the National Weather Service (NWS) can now provide height, period, and direction of the significant wave systems that made up significant wave height, helping to support better decision making by mariners.

The first Hybrid Spring Particle Lagrangian Integrated Trajectory (HYSPLIT) ensemble had the dispersion capability to predict and quantify volcanic ash plume uncertainty for serving both the public and private sectors, especially the aviation industry, and was scheduled for NWS implementation in December 2022.

NOAA Marine Fisheries Service (NMFS) research published in the Proceedings of the Royal Society demonstrated for the first time that environmental DNA (eDNA) offers a less expensive means of measuring populations of fish, such as Pacific hake, which supports the largest commercial fishery off the West Coast.

The Ropeless Roadmap is an important step in a series of actions NOAA is taking to protect and conserve North Atlantic right whales. It describes the current state of "ropeless" fishing and outlines a path for increasing adoption of this alternative technology in commercial fisheries (e.g. lobster) in the northwestern Atlantic Ocean. The future of this technology is based on ongoing gear development, evolving regulations, and continuing risk reduction of entanglement under the Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA).

As of May 2022, NOAA scientists are partnering with Viking Expeditions to expand their research in the Great Lakes. Teams of scientists aboard state-of-the-art Viking ships will work on a variety of studies that focused on changes in the weather, climate, ecosystems, and maritime heritage resources of the Great Lakes regions. Ships will also continuously collect observations on water quality, oxygen content, plankton composition, and more.

A new 3-D component enhancing the Surge and Tides Operational Forecast System (STOFS) with information about water conditions in the Atlantic Ocean would be operational by December 2022. STOFS was developed by National Ocean Service (NOS)/Office of Coast Survey (OCS) in collaboration with academic partners and the NWS. It is a global modeling system that provides forecast guidance for combined water levels caused by storm surge and tides.

NOAA NMFS was leading an effort funded by the NCCOS (NESDIS Cloud Archive Project) Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program to investigate harmful algal blooms (HABs) in Alaskan Arctic and subarctic waters. Resting benthic cysts of HAB species had lain dormant in cool Arctic waters, but as waters warmed due to climate change, conditions supported blooms and their associated toxins. The study observed the paralytic shellfish poisoning (PSP) toxin transfer to zooplankton, shellfish, finfish, marine mammals (walrus/bowhead whales), with risks to subsistence communities.

Discussion

Ken Graham praised STOFS as a true partnership across line offices. He stressed the need for a discussion around behavioral and social science, because there are some situations where lives would be lost if the public did not understand the inherent risks.

Jesse Ausubel asked (1) when NOAA would abandon stationarity as the underlying assumption of a lot of its management of marine life, (2) how NOAA was responding to a report by The Economist and The Nippon Foundation on marine chemical pollution, and (3) whether NOAA had made progress in obtaining funding for its Acoustics Roadmap. Cisco Werner agreed that NOAA should move beyond stationarity; the challenge is that NOAA needs to keep providing advice with current approaches while thinking about how to go forward. As for the Acoustics Roadmap, Dr. Werner said NOAA continues to meet with colleagues in the Navy and other organizations, but agreed that it could do more on this front. Dr. Kapnick said she had not seen the report Mr. Ausubel referred to, and would need to follow up.

Martin Storksdieck echoed Mr. Graham's concerns regarding the social and behavioral science, noting that part of NOAA's mission is to communicate with the public. He acknowledged that NOAA did have some cutting-edge new approaches to engaging communities, but sometimes they are underfunded. Dr. Kapnick said she worked closely with NOAA's chief economist, and they have been discussing some of these issues. She added that NOAA is also discussing these issues with other agencies in the Department of Commerce, like the Census Bureau and the National Institute of Standards and Technology (NIST), and she hopes to have more news on this front at subsequent SAB meetings.

John Kreider asked if there was a measurement of progress on success of communication with the public and if so, whether NOAA was monitoring it. Ken Graham agreed that this is important. He pointed out that social science is just as important with respect to decision makers as it was to the public; NOAA and FEMA are both very interested in this issue. Dr. Kapnick added that NOAA was discussing this issue with academic institutions as well. She welcomed advice from the SAB on this topic.

Steve Thur said he had been Assistant Administrator at the Office of Oceanic and Atmospheric Research (OAR) for seven weeks and had been asking a series of questions, one of those being how best to invest NOAA's money to effect societal change. He added that his background was in economics, whereas most

of OAR's leadership consists of biogeochemical scientists. It is often unclear what type of information is most useful in bringing about change. Most of OAR's investment in social science is through the National Sea Grant College Program and Cooperative Institutes. It does not have a large, robust internal social science staff.

Denise Reed observed that there were many factors beyond NOAA's scope that influenced whether people would evacuate in an emergency. She noted that a lot of the items in Dr. Kapnick's presentation centered on a common theme of water levels, and asked whether there was an ambition at NOAA to pull it all together. Dr. Kapnick and Mr. Morgan assured her that there is.

Bonnie McCay commented that ropeless fishing and the North American right whale made for an excellent case study. Janet Coit of NOAA Fisheries agreed, adding that NOAA had advocated for additional funding, although decisions have not yet been made. A recent court ruling would likely result in large closures of traditional gear with vertical lines, so there is increased interest in ropeless fishing in several industries such as lobstering, but there is also a lot of skepticism.

David Grimes asked if there was a path between those doing nature-based studies and what NOAA was doing. Dr. Kapnick said NOAA's marine carbon dioxide removal Notice of Funding Opportunity (NOFO) had a link on Grants.gov to apply for funding. She also highlighted how NOAA's coastal-based projects related to nature-based solutions. She said she would consider organizing these efforts into a presentation. Margo Schulze-Haugen said she would be happy to put something together for the next science update.

NOAA Update

Sarah Kapnick, NOAA Chief Scientist

Dr. Kapnick started her presentation by noting that NOAA had a large presence at COP27, the 2022 United Nations Climate Change Conference, participating in bilaterals and other meetings and giving numerous talks on different subjects. The emphasis at COP27 centered not just on mitigation but also adaptation and resilience.

NOAA received \$345 million from the 2022 Disaster Relief Supplemental Appropriations Act, \$6.8 billion from the FY23 President's Budget, \$2.96 billion from the Bipartisan Infrastructure Law (BIL), and \$3.3 billion from the Inflation Reduction Act (IRA).

NOAA's priorities are: (1) establish that it is the primary source for climate products and services that could be applied to a diverse range of missions, just as it is for weather; (2) advance its complementary work on environmental stewardship and economic development with a particular focus on the New Blue Economy; and (3) exhibit equity in how it builds and provides services. Internally, NOAA will promote diversity, equity, inclusion, and accessibility. Externally, it will provide equitable access to its products and services.

NOAA-funded pilot projects to develop and address challenges were identified through eight climate and equity roundtables. Such projects included Building Knowledge to Support Equitable Climate Resilience in the Upper Mississippi River Basin and Expanding and Connecting Tribal-led Climate Change Capacity

to Serve Indigenous Community Needs in Alaska. \$21 million of the BIL funding was dedicated specifically for underserved communities. NOAA is also working to strengthen its engagement with youth. The first-ever NOAA Youth Leadership Program will launch in early 2023.

The New Blue Economy is a sustainable and equitable ocean and coastal economy that optimizes advances in science and technology to create value-added, data-driven economic opportunities, and solutions to pressing societal needs.

Since the last briefing, NOAA has advanced Climate-Ready Nation through existing activities and new funding under BIL and IRA. BIL has enhanced funding for coasts and wildfire and flood preparedness. IRA funding will further support coasts and address climate in fisheries, as well as drought in the West and extreme heat.

Challenges facing NOAA include offshore wind development, setting up the Office of Space Commerce, management of BIL and IRA funding, replacing old ships and aircraft, and building new satellite systems.

Discussion

Discussion for the NOAA Update was divided due to logistical issues.

Jon Allan asked (1) what were the key components driving the New Blue Economy and (2) whether NOAA was facilitating handoffs of its projections and measurements of volcanic and fire emissions to the National Institutes of Health (NIH) and other parts of government. Dr. Kapnick said one of the big pieces around the New Blue Economy is adaptation, and both the public and private sectors are working to expand that capability. Mr. Graham commented that NWS is looking for ways to couple its activities with other groups, and that the potential is greater than ever before. Dr. Kapnick added that NOAA is working with the Centers for Disease Control and Prevention (CDC) to address the impact of heat on human health. Mr. Graham stressed the importance of equitability of services. Dr. Thur noted that NOAA's Air Resources Lab has a model for multiple air transport particle sizes, including volcanoes, African dust, and smoke from wildfire.

Joellen Russell expressed concern at the lack of a global operational ocean forecasting system in the U.S. and any significant NOAA funding for biogeochemical floats. She noted that Arizona, where she lived, was exceptionally dry due to three years of La Niña. Dr. Kapnick assured her that one of her top priorities was determining how best to spend NOAA's funding on a long-term basis. She said a paper on La Niña by Michelle L'Heureux, et al., had been published in the last few weeks. Mr. Graham added that a modeling strategy is in the works.

Chair Kreider noted that the cost of capitalization of the fleet and aircraft had increased quite a bit and that he had not seen much consideration given to the use of autonomous systems. Dr. Kapnick assured him NOAA was being innovative in testing on that front, pointing to the use of Sairdrone for hurricanes and mapping. Mr. Graham stressed the benefits of using both crewed and autonomous systems. Chair Kreider said he would like to pursue this issue offline. Randy TeBeest, the Deputy Assistant Administrator (DAA) of the Office of Marine and Aviation Operations (OMAO), pointed to the successful test of the uncrewed airborne system (UAS) using P3 aircraft in Hurricane Ian, as well as the

work on the drifts with hydrographic surveys. Unmanned systems are really a force extender and multiplier. Additionally, the UXS operations center was currently evaluating nine projects that could move from a research to an operations capacity by 2024.

Chair Kreider asked if the drive at NOAA to be innovative and start new things was accompanied by an effort to stop things that aren't working. Dr. Kapnick replied that NOAA leaders shared HIS concern. Dr. Thur added that the agency struggles with this issue because it does not sunset many activities. He anticipated a need to reallocate existing resources rather than rely on new ones. Mr. Graham said NOAA was full of passionate people, and that passion often led it to attempting more than it was able to do. Recent strategy meetings in NWS have discussed narrowing the focus back to core mission functions.

Martin Storksdieck asked how NOAA's conversations with NASA were going. Dr. Kapnick said that was a complicated question she would save for Dr. Spinrad when he was present. For her part, she said she had a good relationship with the NASA chief scientist, and they often discussed things the two agencies could do together.

Data Archiving and Access Requirements Working Group (DAARWG) Report on the NESDIS Common Cloud Framework (NCCF)

Jeff de La Beaujardiere, NCAR, and Chair, DAARWG

Jeff de la Beaujardiere started by stating that DAARWG thanks Dr. Monica Youngman of the NESDIS National Centers for Environmental Information (NCEI) and members of her team for briefings and Q&A sessions. DAAARWG supports NCEI's plan to use commercial cloud resources rather than on-premises infrastructure for primary storage and access of archival data. The group believes this could yield lower operating costs and provide better proximity to scalable computing resources.

The report made the following recommendations:

1. DAARWG recommended that NOAA clarify which benefits it was seeking to maximize or optimize in the NCCF cloud archive project, whether it was ability to compute in place, decommissioning of on-prem hardware, efficient I/O, broader data access for external customers, proximity to NOAA data, staff costs, or other attributes. The goal should be stated along with quantitative metrics to assess whether they were eventually met.
2. DAARWG suggested that NOAA (1) consider more detailed planning regarding what data were migrated in what order, including contingencies for unexpected delays; (2) clarify the method(s) to be used for the actual bulk data transfer and data integrity verification; and (3) provide more detail on the incremental solutions in terms of functionality, whether to copy as-is or optimize data prior to initial migration.
3. DAARWG suggested NOAA include some provision for an exit strategy to be built into the contract with the initial cloud vendor. Concerns could include data egress costs; data transfer, copy, and verification methods; time and effort to perform a bulk transfer to get everything out; and whether to retain on-premises disaster recovery copy of data on tape just in case.
4. DAARWG suggested that the Spatio-Temporal Asset Catalog (STAC) be considered as an alternative to the Consolidated Metadata Repository (CMR), because STAC might have a broader

community of support and use. A related question was what would happen to the existing NOAA Data Catalog and NOAA OneStop projects.

5. To enhance data when transferred to the cloud, DAARWG recommended that NOAA consider data optimizations such as organizing datasets to provide a more holistic, multidimensional "cube" view of data rather than individual files; using cloud-optimized formats such as Zarr or COG (Cloud Optimized GEOTIFF); or storing as-is with structural metadata such as ncZarr or kerchunk.
6. The NESDIS Cloud Archive Project (NCAP) presentations included at least two concepts not normally found in the archive reference model: Virtual Archive Information Package (vAIP) and Knowledge Graph (K.G.). DAARWG recommended that NOAA clarify what vAIP and K.G. were and indicate their value to either NOAA or users of implementing them.
7. DAARWG urged NOAA to consider releasing code as open-source, and to contribute back to the community any enhancements it made to existing open-source projects. It would need to write and leverage a considerable amount of code to support the Cloud Archive Project.

Discussion

Chris Lenhardt asked how this fit in with NOAA's core data life cycle and curation aspects. Dr. de La Beaujardiere said DAARWG felt the current roles of data curation would continue. The fundamental question was the location of the machine that controlled the data. Joe Pica, the acting director of the NESDIS NCEI, said NCEI certainly considered Mr. Lenhardt's question, interpreting it as part of clarifying the goals of the project.

Chris Lenhardt made a motion to accept the DAARWG report with a modification adding a phrase clarifying how this fit with data curation and the overall NOAA data management strategy. Dr. Decker said the Board could either make that modification to the report or include it in a transmittal letter. Chair Kreider clarified that the Board could not revise the report without having to go through the whole process again. Mr. Lenhardt agreed to change his motion so that the curation language would be in a transmittal letter. The motion was seconded by Martin Storksdieck and passed unanimously.

SAB Ecosystem and Sciences Management Working Group (ESMWG) Report on the Rapidly Changing Marine Environment

Jan Newton, University of Washington, and Co-Chair, ESMWG

This report was developed at NOAA's request to provide advice regarding how its policies would need to evolve over the next decade to keep up with and anticipate possible future ocean states and its impact on ocean resources. It built upon an original NMFS study proposal, Rapidly Changing Marine Environment, from 2019. While NOAA was not able to address every ecological forecasting need in marine and Great Lakes ecosystems, the report evaluated a subset of modeling issues that were largely under the control of NOAA.

Cisco Werner presented the topic to the Working Group in May 2021. In July, the Working Group hosted a panel on marine ecological forecasting and prediction. It developed themes and a timeline for the report in January 2022. From February to November, the Working Group synthesized information and wrote the report. Three themes emerged in the report:

1. Scales relevant to biology: timescales and multi-stressor impacts
2. Promoting resilience by incorporating people in forecasting, risk assessment, and policy to respond to rapid change
3. Collaborative science, co-design, and co-production in a rapidly changing marine environment

Chapter 1 recommended (1) evaluating how models could more thoroughly integrate biological processes, paying particular attention to the cumulative impacts of multiple stressors at different time scales, specifically in the context of a rapidly changing ecosystem; (2) providing innovative ways to stimulate fundamental ecosystem understanding and associated model development; and (3) enabling models that were fit for purpose, but also that contained enough detail to be useful, highlighting the need for increased model skill assessment.

Chapter 2 recommended creating a better understanding of how humans responded to change by facilitating the collection of relevant human behavior data with emerging observational tools and establishing strategic and investigative priorities for integrative modeling investments based on effectiveness versus relative ease. Chapter 2 also recommended using traditional and emerging social science data collection methods to model human behavior and inform marine and coastal program design and create internal and external capacity and institutional pathways to develop, use, and apply social science methods as critical components of adaptive management.

Chapter 3 recommended expanding and integrating engagement tools and cultivating a one-NOAA culture and community around rights-holder and stakeholder engagement and co-production. This would increase NOAA's commitment as a science agency to elevating and training engagement personnel within the agency workforce, and to hiring people with a deep understanding of co-production.

What has worked in the past for ecosystem models might not for rapidly changing marine environments going into the future. ESMWG strongly advised that the time to act is now so that the nation can be better prepared. It urged attention to this topic and evaluating how linked modeling, observations, and data analysis could provide insights, resulting in optimized tools for tomorrow.

Discussion

Denise Reed noted several commonalities between this report and the coastal resilience report released earlier that year, stating that these were big issues on the minds of a lot of people. Dr. Newton agreed, saying that the coastal resilience report was excellent.

Chair Kreider asked if there was a sense of urgency associated with this report. If there was, he suggested the Board include that sense in its transmittal letter. Dr. Newton assured him that there was very much a sense of urgency.

Bonnie McCay felt there should be some mention of the importance of effective interaction between social scientists and other scientists involved in these projects. Dr. Newton said she thought Chapter 2 touched on this, but that she'd be happy to look into incorporating it more closely.

Chair Kreider suggested ESMWG provide three or four things worth highlighting for the transmittal letter. Dr. Newton said she would be happy to do that.

Jon Allan said he had been one of the SAB liaisons to the ESMWG and could attest to the richness of their discussions. Dr. Newton likewise praised Mr. Allan for his contributions. Mr. Allan added that co-creation and co-development did not just happen by accident; they required the help of skilled professionals to bring them about.

Denise Reed made a motion to approve the report. The motion was seconded by Bonnie McCay and passed unanimously.

Updates on SAB Work Plan

All SAB Members

Public-Private Partnerships (Jon Allan, Steve Weisberg, Betsy Weatherhead)

The Subcommittee is developing public-private partnerships recommendations around non-monetary models. It identified six types of non-monetary P3 applications available to NOAA. It heard from several speakers and had started developing thoughts that would form the basis of its report.

The Subcommittee had three initial recommendations:

1. Clarify future NOAA directions so investors understood where untapped opportunities existed
2. Nurture external research or technology development beyond the initial investment phase
3. Create partnerships to standardize new technologies

The National Academy of Sciences had codified the concept of "swim lanes." Consistent adherence to roles provides comfort for potential investors about niches being available or not. NOAA has done well with swim lanes, particularly in the weather enterprise. They allowed NOAA to focus on foundational services, such as observations, models, and warnings, and resulted in the private investment to build an array of specialized products that made use of NOAA data. However, there is room for improvement. Most of the shortcoming is in better defining the future, identifying what NOAA was planning to do, hearing what industry was considering, and providing confirmation NOAA was not planning to operate in that space.

The Subcommittee recommended NOAA expand its role identification beyond weather to climate services, ocean stewardship, coastal management, and so on. Role identification should not be adhered to rigidly because the technologies, capabilities, and needs of end users evolve. A more successful approach is to share future plans with the private sector. There are several avenues for such communication, including quarterly public meetings to discuss future plans, annual formal statements of plans, and briefings at professional society meetings.

The need for climate services is expanding rapidly on a global scale. NOAA currently provides some services through its climate toolbox, but it is unlikely it would be able to respond to all commercial or public needs. There are opportunities for NOAA to define the services it would provide, whether it would adapt to higher-resolution information, if it would provide detailed block-by-block heat maps for urban or agricultural fields (currently being contracted from academic and private sector sources), whether it

would provide climate information for areas outside the US, and what is the chance of an installation being flooded more frequently.

NOAA has several collaborative relationships to help with the early stages of technology development, including MOUs, CRADAs, and SBIRs. However, those investments do not typically transcend the "valley of death" for technology adoption. NOAA provides resources to get ideas started, but little support for identifying the gems among these investments and helping them shine. There are actions NOAA could take to provide greater follow-through for innovative technology collaboration.

The Committee suggested establishing a focal point to act as a champion for new collaborative technologies. That person would become an advocate for inclusion of their technology in NOAA programs, helping to create shared demonstration projects, hopefully using NOAA staff and facilities. The Subcommittee also urged holding periodic workshops where grantees presented their progress to high-level program staff and others, both internal and external, giving the developer and funders a feel for whether NOAA saw value in their technology, leading to conversations about next steps if the answer was yes. Lastly, the Subcommittee sought to create sharing opportunities where external investors could learn about early-stage technology development.

As an example of initial nurture investments, aviation weather observing systems were needed to support real-time safety of flight, emergency operations, commerce, and response to climate disasters. Private investment and development had resulted in several systems fielded internationally and used for government and commercial operations worldwide. Some private services use novel instruments, algorithms, and services, including augmentations with artificial intelligence, with minimal footprints, equipment installation, training, or servicing. Essentially, these functioned as an unattended control tower for airports with hundreds of based aircraft. The Subcommittee recommended removal of US government impediments and reduction of large-scale technical "Standards" to "mini-Standards" with functional performance specifications with flexibility for enhancements to expand commercial opportunities.

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impediments and reduction of large-scale technical "Standards" to "mini-Standards" with functional performance specifications with flexibility for enhancements to expand commercial opportunities.

Managers are more likely to adopt new technologies or processes after there was scientific consensus about their reliability. Part of that is developing standard operating procedures (SOPs) to consistently employ the approach. Another part is an accreditation program to ensure the SOPs were being employed correctly. Much of that standardization occurs outside of NOAA, either through federal agencies like EPA or NIST or through states. Industry typically relies on those standards for manufacturing and development of supplies. NOAA does a good job of coordinating its research with other federal agencies through such mechanisms as the National Oceanographic Partnership Program, but could do a better job with other entities, such as states, academia, industry, and certification bodies.

The Subcommittee called for creating avenues of communication with other entities that would help memorialize technologies. These could take the form of workshops to co-create standard operating procedures (SOPs). The focus should be on performance specifications and desired outcomes rather than just technical details. Pushing for SOPs too early could stifle development, but failing to standardize suppresses adoption. The key is distinguishing aspects that require standardization for the field to move forward. The Subcommittee favored developing a programmatic approach to handoffs. NOAA should be the trusted partner or the facilitator rather than the doer. It needs to develop partnerships with entities that would lead to standardization and adoption, such as states.

As an example, NOAA is making large investments in eDNA, tracking biota by measuring the genetic material they slough into the environment. The technology has matured to the point of scientific credibility, but there are many facets which have not yet been standardized. NOAA initiated a highly successful workshop to move the field forward, identifying the trigger points needed to achieve adoption by states. Eight federal agencies, six states, academia, and industry participated. Working groups were formed to determine how and what to standardize. Foundations have expressed interest in supporting studies that lead to standardization. The plan is to hold a follow-up workshop in two years to hear the outcomes.

The Subcommittee will conduct further interviews to verify and flesh out its ideas over the next two months, pending the SAB's feedback. It will transition from fact-finding to writing the report in February. It anticipates having a draft report for SAB consideration at the Spring meeting.

Jesse Ausubel asked how the report could be made more directly useful to NOAA. He suggested it could help NOAA think about priorities for sectors where it should pursue stronger partnerships. He also recommended that the report should be specific rather than generic. Dr. Weisberg agreed it was a good idea to put in more examples or even focal points in the report.

Denise Reed asked if the Subcommittee anticipated recommending specific approaches in particular sectors, or if the recommendations would be more towards the development of strategies. Mr. Allan said he would prefer to err on the side of being less specific about sectors and more specific about the underlying process. Chair Kreider added that the key for him was finding a way to enable more effective,

productive, and efficient science. He would like to see a commitment to this kind of partnership and the training that went with it both in the report and NOAA's response.

Chris Lenhardt asked whether the Subcommittee was looking for something different from what NOAA already did. He pointed out that there were already plans and strategic reports laying out what NOAA planned to do in the future and asked if those were not specific enough. Dr. Weatherhead replied that the existing reports are not always targeted in the most constructive way possible. When NOAA discusses what it is going to do, it does not always focus on the products it will produce or what it is not going to do. A targeted dialogue with very specific communities would allow for more clarity in this regard.

Steve Thur asked (1) did the concept of what fell on the half of the continuum that was a public good versus what fell on the private good side have any role in helping NOAA determine what its direction should be relative to the private sector; (2) where might the private sector not step in, indicating that the government should do something; and (3) if there were other agencies with successful nurturing efforts that NOAA could copy. Dr. Weatherhead said the Subcommittee had received no pushback from the private sector on NOAA's roles and responsibilities, that the private sector sought to supplement what NOAA did rather than keep it from getting involved in particular areas. She felt a two-way dialogue between NOAA and the private sector was most beneficial. Chair Kreider pointed out that the meeting was behind schedule, and suggested the Subcommittee finish addressing Dr. Thur's comments offline.

Mary Erickson noted that it took a lot of deliberate culture change in the organization at NOAA to make the partnerships cited in the Subcommittee's presentation possible.

Dr. Spinrad praised the Subcommittee for approaching the issue in a constructive manner. He identified one challenge as figuring out how to reward this kind of behavior. He recalled NOAA's award ceremony the prior day, where he was honored to give out 400 awards, but not one of them was associated with public-private partnerships. He encouraged the Subcommittee to focus on process while NOAA worked on changing the culture. He said he had no problem copying from other agencies if their examples worked. He asked if there were opportunities for developing legislative activity.

DEI@NOAA (Martin Storksdieck)

The Subcommittee identified the following objectives:

1. Understand the state of affairs around diversity, equity, inclusion, access, justice, belonging, and more (DEIAJB+) as it related to:
 - a. The scientific enterprise of NOAA
 - b. Staff diversity at NOAA (to what degree did NOAA staff represent the public?)
 - c. Recruitment, hiring, retention, and advancement of staff from underrepresented racial/ethnic groups and ability status
 - d. Potential implication for NOAA Mission fulfillment
2. Provide the SAB and NOAA leadership with guidance and advice
 - a. Review of key agency activities and staff needs around DEIAJB+
 - b. Reflection on the effectiveness of current NOAA activities around DEIAJB+

c. Recommendations for diversifying the scientific enterprise of NOAA

It conducted listening sessions with eight NOAA Employee Resource Groups (ERGs) (with two more planned), NOAA directors and leadership, and external speakers. It held biweekly meetings to plan, review, and digest what it had learned.

The focus of the Subcommittee's report is on policy, analysis, questions, and recommendations, with findings from NOAA ERG engagements, a critical review of DEIA efforts so far, and recommendations for NOAA. Topics include DEIAJB+ efforts and culture within NOAA; coordination of DEIAJB+ efforts and support for ERGs and other groups; recruitment, hiring, retention, and advancement of NOAA's non-dominant groups; how NOAA measured, monitored, and shared intel about DEIAJB+ issues, and the link between NOAA operation and mission fulfillment. The report pertains to NOAA's scientific enterprise.

The topic was introduced and refined by the SAB and the Subcommittee was formed in 2021. In the latter half of 2022, the Subcommittee met with ERGs, NOAA leaders, and external stakeholders. It will draft, review, and revise the report from December 2022 to March 2023, and deliver the report to SAB at the Spring meeting.

Listening sessions with ERGs were highly appreciated. NOAA leadership was listening and using tools like SAB to solicit input. ERGs were already playing an important role in supporting non-dominant communities at NOAA, providing a safe place and a sense of belonging, bringing awareness of the group to the entirety of NOAA, advocating for the respective group within NOAA, and supporting NOAA as a group of dedicated staff, both science and non-science. The link between internal NOAA operations and mission fulfillment around DEIAJB+ was clearly identified by most stakeholders, along with the need for trust, representation, and community voice.

Talent management is changing. New ideas for supporting a more diverse workforce at NOAA exist, but implementation still lags behind. The culture of NOAA and the federal government is not yet supportive of more aggressive H.R. strategies. NOAA leadership had created a DEI Strategic Plan, but financial support from Congress is missing. The plan does not identify baseline issues or define numeric outcomes or the desired state of affairs. It is oriented around process, not outcome.

ERGs would benefit from more NOAA leadership support and respective staff-level management; additional resources such as funding, time, and internal and external development; the ability to coordinate between groups; and opportunities to be utilized as an external engagement tool for diversifying the scientific enterprise of NOAA.

Chair Kreider noted that this was an emotional topic with tentacles into most if not all aspects of the agency. He felt it was important that SAB remain focused on DEI as it impacted quality and effectiveness of science, and urged the Subcommittee to set boundaries as to what it would and would not address. Dr. Storksdieck assured him that the Subcommittee couched all its fact-finding around the idea of what it all meant for the scientific enterprise at NOAA.

Dr. Spinrad asked if the Subcommittee intended to meet with external stakeholders. Dr. Storksdieck said it wanted to keep the scope limited. Dr. Spinrad pointed out that the slide had mentioned external stakeholders. Mr. Lenhardt said most of the conversations had been with ERGs. Dr. Storksdieck added that the Subcommittee's interest in external stakeholders was in how NOAA staff and leadership perceived the work in, at, and through NOAA affecting them. Dr. Spinrad commented that there were traditional external stakeholders and there were newer external stakeholders such as tribes and faith-based communities. He urged the Subcommittee to think of that new class of stakeholders, and pleaded with them to consider leading indicators as well as lagging ones. Dr. Storksdieck and Mr. Lenhardt responded that it was not clear at this point what the indicators were.

Denise Reed recalled a discussion at a past SAB meeting on cooperative institutes (CIs) and whether CI evaluations should include DEI issues. She asked if anything had come from the SAB's discussion of the lack of diversity among NOAA presenters. Chair Kreider said the next item on the agenda was an SAB letter on that topic. Dr. Reed suggested that issue was better suited to the Subcommittee's report than a letter. Dr. Storksdieck acknowledged that the Subcommittee had not gone in that direction. Mr. Lenhardt said he recalled a few examples that came up and offered to go back through his notes.

Open Discussion

John Kreider, Kreider Consulting, LLC, and Chair, NOAA SAB

SAB Letter on Diversity of NOAA Presenters

Chair Kreider initiated this by reminding the members of the letter that was drafted after the last meeting. The first question was whether the letter was ready to be sent. Chair Kreider said one member had suggested to him that the point had been made and sending the letter might not be necessary. Denise Reed asked what exactly a letter entailed, noting if these points were in a report, a response would be required. Chair Kreider said he had received feedback from people in NOAA saying a letter would be helpful to reinforce what they were trying to do. Dr. Decker said that by putting its request for a more diverse set of presenters in a letter, the Board was putting it in writing, where it could not be ignored.

The CI matter (asking NOAA to incorporate criteria on DEI in CI reviews) was a more substantive issue that perhaps could be addressed by the DEI Subcommittee. Martin Storksdieck said he would prefer it be in a letter, because for the DEI Subcommittee to pick up a specific component of work done in NOAA would require it to add more time and a completely different perspective. Jon Allan felt there was real value in the SAB putting in writing what was on its mind regardless of whether NOAA responded. Chair Kreider said putting the SAB's position in writing had a broader impact on the community. Bonnie McCay questioned whether the letter should be framed in something broader than CIs. Chair Kreider commented that a letter should be focused on one or two things, whereas a report could have multiple points. Jon Allan pointed out that the evaluation of CIs is in SAB's remit, so CIs should have some reflection of DEI issues. Bonnie McCay argued that two different letters would be appropriate because the CIs and NOAA presenters are separate issues.

Brooke Fisher Liu noted that the SAB has already put out the letter for review and that not sending it would be a bad signal. Chair Kreider asked if anyone objected to sending the letter. No one did, so the SAB proceeded under the assumption that it would send only one letter. Chair Kreider said it could come

back to the question of whether to send more than one. Betsy Weatherhead favored a single letter, because she thought of the Cooperative Institutes as an integral part of NOAA science. Jon Allan countered that SAB was not the sole agent in CI review, and that any letter would be sent to NOAA, not the CIs. Bonnie McCay said she had been under the impression that it would go directly to the CIs, but it was now clear that it would not.

Dr. Decker noted that the CI reviews were the subject of NOAA policy documents, and that having the CIs adopt a formal diversity metric was not a casual matter. It would need to be included in the policy and procedural handbook. Dr. Terence Lynch said a new handbook was coming out soon, so this might be a timely recommendation.

Chris Lenhardt observed that the SAB itself was not particularly diverse, and suggested that the Board might note that as another dimension to be worked on. Ilene Carpenter thought that was an excellent idea. Mary Erickson asked if that was within the SAB's control. Mr. Lenhardt said the letter would ask NOAA to continue efforts to make sure the group was diverse. Chair Kreider asked members if they were comfortable including language on the diversity of the SAB. Ms. Erickson asked if it would delay the letter going out. Dr. Decker said she thought minor modifications could be made, reviewed by the SAB, and sent out quickly.

Chair Kreider commented that the letter included language about DEI research, and there was some question as to what that meant. Brooke Fisher Liu said that the idea was to ensure that the science on DEI advanced at the same time the array of presenters became more diverse. Martin Storksdieck said he felt it was SAB's role to make scientists aware of what was out there and translate it into practice. Dr. Liu agreed that was a good point, and that perhaps it was best to start at the baseline and talk about applying existing research. Mary Erickson suggested that the SAB was really interested in ensuring that key metrics be tracked or goals be set. Martin Storksdieck thought that was implied and did not need to be spelled out.

Chair Kreider summarized the SAB's discussion to that point: it wanted to send the letter, keeping it a single letter, while adding thoughts about continuing efforts to diversify the SAB and applying existing research at the CI level. In the interest of time, he asked that anyone interested in working on this further meet with him right after the Board recessed for the day. Jon Allan made a motion to approve the letter with the changes articulated to be reviewed soon. The motion was seconded by Martin Storksdieck and passed unanimously.

Other Topics

Chris Lenhardt suggested bringing someone in to give a brief seminar on team science. Martin Storksdieck seconded the idea, adding that the National Academies had issued a report on this subject. Chair Kreider felt this was incredibly important, noting he had had some experience with this at Oceanoeering. Joellen Russell pointed out that there was an extraordinary level of expertise at NOAA in team science. Bonnie McCay felt it would be valuable to discuss team science, as well as concepts like co-production. Jon Allan asked if there was anyone at NOAA who could take a year to encapsulate what it had learned from team science in a report. Dr. Spinrad said he thought there were many people at NOAA who could do that, but that he felt the issue deserved an approach with more visibility. Chair

Kreider asked if NOAA would find this topic valuable. Dr. Spinrad felt it would be useful to look at where it was working well and where it could be applied elsewhere in NOAA.

Martin Storksdieck noted that National Science Foundation (NSF) was very concerned with misinformation and asked if that could be a component of NOAA conversations.

Chair Kreider suggested forming a smaller group to frame up the topic of team science. Chris Lenhardt pointed out that his suggestion had been just to have someone come in and introduce the subject. Chair Kreider agreed that might be a good first step, and then the Board could decide where to go from there.

Tony Wu recalled Dr. Spinrad asking how NOAA could collaborate with other agencies, and mentioned an Environmental Protection Agency Inspector General's (IG) report on harmful algal blooms and the lack of a national plan from EPA. Dr. Spinrad expressed surprise at the IG'S report, because there was an active interagency working group on harmful algal blooms, and he would want to look at what that group had done before commenting further.

Ilene Carpenter remarked that the Board had discussed finding more agile means of communication with NOAA than report and response and asked whether anything had come from that. Chair Kreider said that no subsequent actions had been taken. Martin Storksdieck pointed to the letter the SAB had just decided to send as a faster way to communicate. Jon Allan felt there were times when the call-and-response model was appropriate but there were other times that called for a more conversational approach. Chair Kreider thought that the Net Zero Emissions fleet, which the Board would discuss the following day, might provide an example of a more agile approach. Dr. Spinrad noted that NOAA had an annual budget cycle, and that it might be useful to discuss activating the SAB in an advisory role for that process. Chair Kreider said the Board would appreciate the opportunity to provide that kind of input.

Jon Allan expressed concern over the long-term viability of science agencies amid the palpable undercutting of the belief in science by the broader nature of society, and hoped that at some point the SAB could discuss what it might be able to do about it. Dr. Spinrad suggested inviting Arati Prabakhar, the new Office of Science and Technology Policy (OSTP) director, to talk about that at a future SAB meeting. Martin Storksdieck proposed inviting someone from NSF as well given that agency's emphasis on combating misinformation. Chair Kreider raised the possibility of getting someone from industry who was involved in science, perhaps as part of a panel discussion. Dr. Storksdieck said it also might be worth contacting the National Academies.

Updates from SAB Working Groups

Working Group Co-Chairs

Climate Working Group (CWG) (Joellen Russell, Kirstin Dow)

CWG's 17 members formed a diverse group in terms of both gender and ethnicity. Don Wuebbles and Chelle Gentemann are the Group's two liaisons. Rong Fu was nearing the end of a one-year extension. Joellen Russell, Kirstin Dow, and Ravi Ravishankara were all on their second terms. The Group was working on three white paper topics, all of which were still in the discussion phase: emerging hazards and

vulnerabilities, climate and air quality prediction, and civilian operational ocean forecasting. It hoped to have at least two of them complete for the spring CWG meeting. The Group continues to support EISWG and other working groups as appropriate. It continues to provide input on strategies like the Climate and Fisheries Initiative as requested.

Data Archiving and Access Requirements Working Group (DAARWG) (Jeff de La Beaujardiere)

DAARWG finally brought in five new members, but a couple members who were up for renewal decided not to return. Dr. de La Beaujardiere said he himself would need to step back due to health reasons. A new chair would need to be identified from among the current members. DAARWG finished its report; Dr. de La Beaujardiere presented it to SAB earlier that day and the SAB approved it. DAARWG hopes to keep interacting with the cloud archive project, which it considers very important. The group maintains extensive contact with NESDIS, but it hopes to build stronger ties with other Line Offices like OAR and NMFS. Chair Kreider promised to meet with Chris Lenhardt and Ilene Carpenter to brainstorm possible new DAARWG members and a new chair.

Environmental Information Systems Working Group (EISWG) (Brad Colman, Scott Glenn)

Since 2017, EISWG had been focused on the Weather Act reports, but that process was coming to an end. Since the Group is transitioning to more self-guided topics, it needs to build a broader team. It is finishing a radar gap study. The new focus areas are radio occultation, space weather, heat and its impact on human health, and drought and floods. The Group used the American Meteorological Society (AMS) Washington forum to devise best practices for considering diversity through the entire recruitment process and for explaining what the expectations were. It put together a solicitation, distributed it through some listservs. The new recruits were evenly split between men and women, but one of the prospective female members was discouraged from serving by her employer, so there were now six males and four females. The cohort includes one Hispanic, one person of African origin, two of Asian origin, and one from the Middle East. Two are from the Gulf Coast region. The new membership filled expertise gaps in terms of GIS, satellite, energy, policy, social science, data science, numerical modeling, data assimilation, reanalysis, and hydrology and land use applications.

Ecosystem Sciences and Management Working Group (ESMWG) (Jan Newton, Molly McCammon, Lisa Wainger)

Four members will end their three-year terms soon: Erik Chapman, Kenny Rose, Bob Twilley, and Jan Newton. Lisa Wainger stepped down as co-chair. ESMWG's recent efforts largely centered on the Rapidly Changing Marine Ecosystems report, which the SAB approved earlier. The Group had held two virtual meetings, one in September and one in November. The co-chairs met with Cisco Werner, NMFS liaison, to discuss future directions. There was a sense that the lack of in-person meetings had limited the group's capacity for the fruitful discussions it relied on. The group looked forward to planning an in-person meeting in the next calendar year. It is still deciding what topic to address next.

Tsunami Science & Technology Advisory Panel (TSTAP) (Rocky Lopes, Rick Wilson)

TSTAP continues to have subject matter expert briefings. It is preparing an SAB update report, which it plans to issue on an annual basis as required by terms of reference. It expects to have the report ready by the SAB's April meeting. Because the group was establishing precedent, it was trying to create a workable model that it could continue to follow. It is learning how to couch certain findings in ways that can be actionable by colleagues in the states and territories as well as NOAA and the National Weather Service.

It had planned to hold an in-person meeting, but funding was not made available. It hopes to meet in person in 2023. The Group anticipated receipt of NOAA's response to its quadrennial report, which it had submitted in January 2021, in time for the spring SAB meeting. The report consisted of eight diverse members and liaisons to the National Weather Service and U.S. Geological Survey.

Public Comment

Dr. Decker announced that SAB did not receive any requests for public comment prior to the meeting. She asked if there was anyone in the room or online who would like to make a comment. One request was received from the online participants.

David Wartofsky introduced himself as the owner of Potomac Airfield, a small airport near Washington, D.C. He said he had years of experience with rulemakings, technical regulatory standards, and creating and implementing interagency policies. He defined innovations, good or bad, as anything beyond current standards. Government agencies have always had difficulty embracing change, especially from the outside. Mr. Wartofsky cited the Federal Communications Commission (FCC) as an example to look at. FCC was continually overrun by technological change and developed a process to adopt those changes. This process allowed innovations to be proposed, tried, used, refined, and accepted that could lead to new standards and regulations. He suggested NOAA look at this model.

Remarks by Dr. Spinrad

Dr. Spinrad responded to a question raised during the NOAA update about NOAA's relationship with NASA. He said the two agencies have a long history of working together, particularly on an array of 16 satellites, where NASA takes the lead on contractual work and NOAA handles operations. There is a Joint Center for Satellite Data Assimilation (JCSDA) supported by both agencies. He has talked with NASA Administrator Bill Nelson about trying to identify the roles and responsibilities of both agencies regarding climate, possibly codifying them in a MOU; it remains a work in progress. Recently, OSTP announced that it wanted to start a fast-track committee on climate services. Dr. Spinrad asked Jane Lubchenco, who had a lead role on the committee, whether it would identify the roles and responsibilities for the agencies. She assured him it would.

Dr. Spinrad also shared with the Board that he had the opportunity to meet with French President Emmanuel Macron and U.S. Vice President Kamala Harris at NASA headquarters that morning, along with the head of the Centre national d'études spatiales (CNES), the French space agency. The meeting included a briefing on the effort associated with space for a climate observatory. Another session consisted of a panel of four or five industry leaders in the development of remote-sensing platforms and sensors. President Macron spoke of the role space played in developing the most important products with respect to climate change and biodiversity.

NOAA had never introduced the SAB to its role in space commerce. By presidential decree and the National Space Directive, NOAA has a responsibility for space situational awareness and commercial space traffic management. This is a highly complex scientific and technological field, and Dr. Spinrad

thought the SAB should be aware of it as part of NOAA's portfolio. Both the previous and current administrations realized the field was growing and NOAA needed to address these issues. The Office of Space Commerce now reports to the Assistant Secretary for Environmental Observations and Prediction (ASEOP). A request for a major budget increase is working its way through the system. During his visit, President Macron had called for a joint French-U.S. agreement around this burgeoning industry, and Dr. Spinrad anticipated this issue would get a lot of visibility in the US government. He thought it may be worth arranging for a briefing from the science and technology side of the Office of Space Commerce at the next SAB meeting.

Mitch Goldberg added that the French CNES had started an activity called the Space Climate Observatory (SCO), which seeks to take all the information gathered by satellites and turn it into actionable information to mitigate impacts of climate change. NOAA is the lead U.S. agency for SCO, which currently has four projects. At the meeting at NASA headquarters, Dr. Goldberg gave a presentation on flood mapping - how a constellation of satellites could be used to observe where the floods were and act. President Macron had asked a question about predictive capability, and Dr. Goldberg had replied that it was in NOAA's five-year strategic plan to expand forecasting at the street level with flood inundation maps.

NOAA Response to SAB Priorities for Weather Research Report (PWR)

John Kreider, Kreider Consulting, LLC, Panel Moderator

Brad Colman, PWR Report Co-Lead, and EISWG Co-Chair, Panel Moderator

Scott Glenn, PWR Report Co-Lead, and EISWG Co-Chair, Panel Moderator

Michael Morgan, NOAA Assistant Secretary of Commerce for Environmental Observations and Prediction

Ken Graham, Assistant Administrator, NWS

Steve Smith, Director, Office of Science and Technology Integration, NWS

Dorothy Koch, Director, Weather Program Office, OAR

Introductions

John Kreider, Brad Colman, Scott Glenn

The team opened by stating that the Priorities for Weather Research Report (PWR) was a community effort. The community was motivated by the urgency with which it saw the need for transitioning of the NWS to a new level where high-impact weather response is not just a periodic situation requiring a temporary surge capacity but an everyday need. It was also motivated by an opportunity for the community to contribute through the PWR activity and by NOAA's noble goal of saving lives and property and promoting equity and resiliency. Because of those motivations, the community stuck with the SAB and EISWG through this intense process.

NOAA leaders were willing to work with EISWG through the scoping document, which helped get PWR on the right path. NOAA staff gave EISWG in-depth briefings to make sure PWR did the best it could. EISWG appreciated NOAA's response to the PWR report, but thought this response was really the beginning of a dialogue, not the end.

Michael Morgan

Dr. Morgan started by stating that the charge of the study team was to evaluate and provide information necessary to prioritize potential government investments in a requirements-based framework to advance the U.S.'s weather research and forecasting capabilities over the next decade. The PWR report could not have been timelier, being delivered a few weeks before Dr. Morgan was formally nominated for his current position as the as ASEOP. In this position, he is responsible for providing agency-wide direction regarding weather, water, climate, and ocean observations, including in-situ instruments and satellites, and the process of converting observations to predictions for environmental threats. As he prepared for his confirmation hearings in the spring of 2022, he sought out authoritative, thoughtful guidance on priorities identified by the weather community on issues related to his prospective portfolio. He found that many of the PWR report's recommendations resonated with his own sense of priorities and were in accord with conversations he had had with others in the weather-water-climate community over the last several years. One of the three focus areas he has adopted - advancing the nation's earth system predicting capability - fell squarely at the heart of many of the report's recommendations.

The PWR recommendations can enhance the already exceptional, dedicated job that NOAA has been doing in advancing predictive skill and observing systems. In some areas, resource limitations have stifled NOAA's ability to make progress in important areas of its research and operational portfolio, while in others, IT security barriers may be viewed perhaps as impediments in data dissemination and collaborative research partnerships. Further, he recognizes that there are many other priority areas that require additional emphasis like workforce development, data simulation, information delivery, and forecasting applications, to name a few.

The respect and attention with which the PWR report will be received by Congress ensures that many of the recommendations made will be transformed into actions and may possibly help garner additional funding for NOAA's activities with respect to weather research and operations. The guidance provided by the report will have important implications on workforce development, advancing modeling capabilities, maximizing the utility of current and future observing systems, and enhancing computational resources and collaborations, as well as engagements with the external community. The report's recommendations will help advance the weather enterprise's ability to protect and save lives and property, and ensure the efficient conduct of commerce because of timely, more accurate, and well disseminated forecasts leading to better decision-making.

Ken Graham

Mr. Graham appreciated the public-private partnership associated with the PWR report. He was excited with the research and how it related to operations. He praised the report's focus on saving lives, protecting property, enhancing the nation's economy, and recognizing environmental justice. He particularly appreciated the report mentioning the urgent need to accelerate investments. Investments are not just dollars but also setting priorities. Mr. Graham was struck by how many of the report's recommendations related to a briefing he gave EISWG on the vision of NWS.

Steve Smith, Dorothy Koch

Dr. Smith and Dr. Koch led the team that provided the NOAA response. In responding to the PWR report, NOAA tasked subject matter experts through the line offices, focusing on critical actions.

Responses were consolidated through the writing team into a first-pass, one-NOAA narrative. The team worked many weeks to achieve consensus on the language, keeping the narrative succinct and at a high level. Strategy documents were referenced. Specific initiatives were highlighted to address critical actions, so there could be some cognitive dissonance where the report responded to those actions rather than the recommendations. The response went through full approval clearance.

NOAA concurs loudly and comprehensively with the PWR report. The report touches on many things NOAA does in its mission, and there is a sense among NOAA leadership that it was the right report at the right time. It was well aligned with existing strategies, while not simply parroting back the words of NOAA leaders. It underlined the agency's critical foundational needs, including workforce development, high-performance computing, and robust dissemination of infrastructure.

Panels

Actions - Immediate First Steps

The panelists were tasked with addressing expected impacts of actions that NOAA had or will as a result of the PWR report, as well as any specific challenges.

Mike Farrar of the National Weather Service said one challenge was trying to coordinate all the various recommendations. NOAA is looking for ways to better integrate its earth system modeling. NOAA has been working on this for years through the Unified Forecast System (UFS) project, and is continuing to align its requirements and programs into a coherent path forward. Another challenge is the NOAAHPC environment. While the agency has gotten quite a bit of funding in the supplemental appropriations for new research computing, it has lacked a third tier beyond operations for testing and evaluation/verification and validation. The biggest challenge is staffing, with NWS engaged in a worldwide competition for experts, such as in data assimilation. NWS has been collaborating and discussing ways to grow the workforce in this specific area with its counterparts at the European Centre for Medium-Range Weather Forecasts (ECMWF) and the UK Met Office.

Frank Indiviglio of the Office of the Chief Information Officer (OCIO) said the need for HPC is growing across NOAA. OCIO is taking steps to increase capacity where it can. Mr. Indiviglio saw the opportunity for a lot of advancement. Not only is there a need to build capacity, but a lot of engineering work is required, too. Capacity is no longer something that can simply be bought. OCIO must rewrite software to really take advantage of what is out there. It is making the necessary investments and will continue to make them. An array of software tools can be used to ease the transition. Other challenges include base funding, workforce development, and incorporating new technology and AI.

Ariel Stein of the Air Resources Laboratory pointed to the recent incorporation of composition as part of the mainstream of the lab's portfolio. Chemical composition is now at the center of NOAA's portfolio, which is an important path forward for the enterprise. A big challenge is the sustainability and maintenance of observations needed to keep the composition piece ongoing for the long-term.

Mitch Goldberg of NESDIS expressed confidence that the HPC issue would be resolved, and that there would be plenty of HPC to go around in five years. The problem is researchers want the HPC now.

Another problem is getting experts in data assimilation. It is not possible to simply manufacture more data assimilation scientists. There have been discussions at NWS on creating a training center or boot camp that could recruit those with an aptitude for computer science and math and train them to become data assimilation scientists.

Ed Clark of the National Water Center (NWC) reported that the PWR report had given the NWC the impetus to reinforce some of the things it had already been doing, including its commitment to providing flood inundation mapping for over 3.4 million square miles over the next five years, effectively putting lifesaving, property-saving information in the hands of decision-makers for every single community across the country. The big challenge is bandwidth. Dr. Clark feared that his team is being pushed beyond the breaking point.

Jenn Mahoney of OAR said the PWR report had fostered great progress in collaboration. OAR, NWS, and NESDIS have developed a comprehensive plan on fire weather research, and delivery. She highlighted the IT challenges. OAR wants to be able to communicate and share with the community and provide a collaborative environment, particularly with the fire community outside of NOAA, and that requires IT collaborations. Getting the right federal workforce in place that could take on challenges in the long term is also critical.

Chair Kreider opened the floor for questions from the SAB members.

Zhaoxia Pu asked if there were any plans to address the shortage of data assimilation scientists. Dr. Goldberg reiterated that there had been discussions about creating a boot camp or training center, adding that he was open to any suggestions the SAB might have. Dr. Pu proposed making an SAB recommendation to AMS regarding education on data assimilation as well as model development. Dr. Farrar noted there were certain barriers, particularly on data science for machine learning and artificial intelligence. To compete with industry, government must invest in experts in those fields and be willing to pay industry rates. Much of the funding comes from short-term grants, which makes long-term retention difficult. Chair Kreider asked if these positions needed to be filled by postdoctoral scientists, or if they could be done by an undergraduate or technician. Dr. Farrar said a very good master's-level person might be able to do data assimilation, but it was a field that required high-level math and science, and there were not a lot of people willing to do it. Martin Storksdieck asked about the scale of the problem. Dr. Farrar estimated there are dozens to hundreds of qualified individuals. Ms. Mahoney said there is work being done to put forward a consortium on data assimilation using some of the opportunities with BIL and IRA funding. Ilene Carpenter suggested recruiting from other scientific disciplines. Dr. Farrar said the key is stable, long-term commitment. Bob Grossman proposed framing the question in terms of how NOAA could make a long-term commitment to a short-term program. Jon Allan raised the possibility of having on-loan programs. Another idea he had was along the lines of the National Health Service Corps, where someone's medical degree was financed in exchange for agreeing to spend some time serving an underserved community.

Chair Kreider proposed that the two biggest issues for the panel were HPC and computing infrastructure and the shortage of data assimilation scientists. Dr. Smith concurred with the Chair's assessment.

Actions - Long-Term

These panelists were tasked with addressing NOAA actions that are planned or being taken in the longer term that are associated with the three pillars in the PWR report and/or foundational cross-cutting elements

Robin Webb of the Physical Sciences Laboratory (PSL) said the biggest challenge is to overcome the problem of systematic errors and model biases. NOAA is moving forward in incremental activities like the Precipitation Prediction Grand Challenge (PPGC) to improve rainfall prediction. Something foundational on which NOAA can move forward is to develop a coupled reanalysis and reforecast system that takes on the challenges of how to describe the state of the earth system in four dimensions. Such a system needs to be tailored for more than just the typical NOAA applications; it should involve working with communities such as the Army Corps of Engineers to determine what they need to assess and determine their risks.

David DeWitt of NWS reported that the PPGC directly addressed the fifth theme of the PWR report, the need to improve predictions of hydrologic extremes. He stated that significant progress requires significant investment on multiple fronts: stakeholder engagement; understanding, improving, and reducing systematic errors; process studies; high-performance computing; and understanding the impact of improved precipitation forecasts and how society uses them.

Dave Michaud of NWS' Office of Central Processing (OCP) said his office is looking at the next phase of its operational supercomputing. A lot of thought has been put into how the contract is formulated; for the first time, price performance guarantees were not built in, and OCP has the opportunity to take advantage of the latest and greatest technology without being locked in five years in advance. On the equity front, OCP is looking at adaptive neuro-machine translation, having some success working with startup companies, determining how to allow automation to come into its forecast process to enable a broader reach to the community in more than a dozen languages at an affordable cost. OCP's third focus area is trying to overhaul its visualization systems and how forecasters interact with the data coming off the supercomputers. It has initiated a contract as part of a multiyear process to refactor all its Advanced Weather Interactive Processing (AWIPS) software to be cloud-ready. OCP is taking steps to look at its entire infrastructure in terms of how its observational platforms connect.

V. Ramaswamy of the Geophysical Fluid Dynamics Laboratory (GFDL) endorsed earlier comments about HPC, the budget situation, and the long-term commitment required. He spoke of the weather-climate nexus and stressed the importance of focusing on the hydrologic cycle, particularly at the extremes. The relationship between the water and energy cycles is going to be very important over the next three to five years. In addition to the aforementioned problems about data assimilation, NOAA is starting to look at the biology and chemistry systems (Earth System assimilation), as well as the matter of data management storage distribution. The external community, both industry and academia, is increasingly involved in the science, developmental models, operational applications, and data distribution.

Molly Baringer of OAR mentioned the Hurricane Forecast Improvement Project as a program that demonstrates how NOAA is working well across line offices. The project involved OAR, National

Weather Service, OMAO, and NESDIS, and features a five-year strategic plan. NOAA has been standing up a lot of test beds, including the Bill Lapenta Laboratory at the National Hurricane Center. She praised the PWR report for its emphasis on interdisciplinary collaboration, bringing together forecasters, researchers, and social scientists. Dr. Baringer also liked the report's emphasis on research continuity and innovation, as well as air-sea interaction and subseasonal to seasonal (S2S) research. OAR is looking to develop new technologies and use test beds to include those technologies in front of forecasters so they can see the data and improve their forecasts, as well as make the sustained global ocean observing system more weather-ready.

Tony LaVoi, NOAA's Chief Data Officer, said he was glad to see in the PWR report a strong alignment to many elements currently within NOAA's data strategy. OCIO is in the process of developing and releasing NOAA's first-ever enterprise data management handbook that will be comprehensive across the entire full data life cycle from requirements through to preservation. Several activities are underway to increase the openness and interoperability of NOAA's data, including comprehensive data dissemination recommendations, analysis-ready data standards, formats to support cloud-based computing, and new ways of incorporating and sharing data. It is critically important that NOAA begin to implement full life cycle data management thinking into all aspects of its mission, including planning and budgeting.

Chair Kreider commented that he was hearing a lot of general long-term goals but not much in terms of specific steps to achieve those goals or milestones to measure progress. Dr. Smith mentioned the plans are in place for the AWIPS infrastructure, and that the plans for HPC are also in motion. NWS is launching a series of high-level projects, which will undoubtedly generate a series of roadmaps. NOAA's test beds and proving grounds serve to validate the concepts that NOAA believes will result in the benefits. Dr. Webb added that PSL was also focusing on the tractable things it could take on and move forward in the next five years. One of those will be a winter precipitation prediction improvement project. Mr. Michaud noted that another challenge from an implementation perspective was uncertainty around the budget. Also, the technology that we have today is not the technology that NOAA is going to have by 2030. So, these things take time to put in place and move into operations. Dr. Smith cited probabilistic forecasting and Impact-Based Decision Support Services (IDSS) as a long-term strategy that NOAA is finally addressing with help from the Infrastructure Investment and Jobs Act (IIJA; aka BIL) funds.

Brad Colman stated that resources and priorities go hand in hand - the PRW team didn't want to prioritize in the report, but NOAA does need to prioritize. He pointed out that there were several recommendations in the PWR report where NOAA concurred but lacked sufficient resources. One of the challenges in producing the report was having NOAA come in with specific performance metrics. A big question is what NOAA had gotten out of the supplemental resources it had received. Dr. Smith said every one of the supplemental spend plans requires the formulation of metrics, but that NOAA often has to develop them on a very short deadline. NOAA never seems to get the time to develop robust metrics. There are many aspects to the way NOAA tracks progress that are antiquated and outdated. Dr. DeWitt pointed out that transformational change requires commensurate resources, and that it is very difficult to reallocate federal funds. NOAA can certainly develop milestones and metrics, but it is difficult to achieve them without the necessary resources. He thought that the SAB and the PWR community can help NOAA advocate for those resources. Dr Colman emphasized that NOAA and the community talk a lot about priorities, but

don't talk very much about what will be sunsetted or gotten rid of. And those are equally hard choices. But they do fit into that equation about resource availability.

Zhaoxia Pu asked if the NOAA labs and centers had any plans for long-term collaboration to make some real achievement and whether there were any specific plans in terms of earth system modeling. Dr. Ramaswamy said there was already a move toward a global storm-resolving model in OAR, and that an ocean model is being developed for climate forecasting needs. A dynamic vegetation land model is being tested.

Community Involvement

This panel was about collaborations and partnerships and what can be done by the broader enterprise for NOAA. The members of this panel were asked what they were doing to engage non-NOAA partners to enable a good solution, what SAB could do to support NOAA's implementation of PWR recommendations, and how they would promote and ensure open science and data.

Ajay Mehta of the NWS Office of Observations (OBS) reported that his office is trying to better coordinate and collaborate at the federal level to avoid duplicating work. It is developing a new plan for similar observations, which is mandated. The plan is expected to be released in the next two years, which will be coordinated between the U.S. Global Change Research Program (USGCRP), the US Group on Earth Observations (USGEO), and the interagency Council on Advancing Meteorological Services (ICAMS). The plan will capture observational priorities with a specific focus on commercial engagement.

Michelle Mainelli of the NWS Office of Dissemination said her office continues to conduct partner engagement meetings, webinars, and roundtables. With the SAB support in 2021 and 2022, it had received additional funding the past two years. Ms. Mainelli saw challenges as opportunities indicating where NOAA needs to go. She stressed the importance of maintaining community support and engagement.

Allie Allen of NWS Analyze, Forecast, and Support Office (AFSO) highlighted a transformation in how the different sectors and partners are working together, moving from a transactional relationship to a collaborative one. Competition between sectors is starting to be replaced by jointly defined visions and actions to achieve outcomes.

Brian Gross of the NWS Environmental Modeling Center (EMC) said his office is committed to implementing community-based modeling systems that have undergone open development. The code is sitting in GitHub repositories for anyone to download and/or contribute to and, most importantly, for anybody to contribute to so that innovations can be evaluated in a research context and then eventually in an operational environment. While this is a transformational change, much of the impetus to get there is transactional. People want to get money to help, which is a challenge if NOAA is the only funding source. Federal Information Security Management Act (FISMA) High systems is operational, so the numerical guidance can get out on a regular basis all the time. Another challenge is incorporating and operationally hardening community-based systems. There is also the need to figure out how to leverage worldwide intellectual capital into NOAA's operational system. The Joint Effort for Data assimilation Integration (JEDI) Academy is going well, but it is not nearly enough to support the data assimilation workforce

needs. The last challenge is figuring out how to engage the private sector in the modeling piece while having what they learn transferred back into NWS operations.

Dorothy Koch of the OAR Weather Program Office (WPO) said the Earth Prediction Innovation Center (EPIC) has started to put some emphasis on the vision NOAA had been developing with the Unified Forecast System (UFS). EPIC is trying to address several of the challenges NOAA faces, including putting the modeling systems out for the community to work with in a welcoming environment and providing resources for the community. The compute resources for the community is a huge challenge. A Cooperative Research and Development Agreement (CRADA) that NOAA recently announced with Microsoft is a great example of a first step towards working together with the private sector. The WPO strategic plan addresses 25 of the PWR report's 33 recommendations. Dr. Koch mentioned WPO's innovations competition and its Innovation for Next Generation Scientists (WINGS) Fellowship that EPIC is hosting.

DaNa Carlis of the Global Systems Laboratory (GSL) made a distinction between his lab's operational high-performance computing and Research & Development (R&D) high-performance computing. Currently the ratio is about one-to-one, which is not a sustainable means of achieving innovation in any organization. The Joint Center for Satellite Data Assimilation (JCSDA), the Developmental Testbed Center (DTC) in EPIC are important outside organizations GSL works closely with on the research side. The relationship among various stakeholders is transactional at times, so there is a need for support.

Denise Reed, SAB member, was struck by the fact that a panel on community involvement did not consist of a single person from outside NOAA. She added that she heard a lot of people stress the importance of the social and behavioral component, but knew of few concrete examples of what is being done. Dr. Smith pointed that NOAA is beginning to develop prototype agent-based models that are being applied to flood inundation and hurricane evacuations, hopefully to wildfires. He added that NOAA is looking at applying GIS-based technologies to identify community vulnerabilities and adapting its messaging accordingly. Dr. Carlis noted that GSL is investing in a social and behavioral science branch to conduct R&D. Dr. Koch said WPO is starting to budget for almost all its projects involving high performance computing (HPC), and almost all its research projects budgeted for social sciences. Ms. Allen cited the NWS Hazard Simplification project and the storm surge graphic, as well as probabilistic forecast communication. Dr. Gross added that NOAA has recently formed a modeling team within the Earth System Integration Board (formerly Weather, Water, Climate Board) and is looking for a community modeling board that could represent the interests of those outside NOAA.

Chair Kreider asked how the unsustainable one-to-one operational to research HPC ratio would be resolved. Dr. Gross said part of the solution was the supplemental funding, which contain a lot of research supercomputing support. Dr. Carlis felt that conversations between SAB and OCIO would be helpful. Mr. Michaud suggested defining the right ratio and then mapping out how to get there. He added that NOAA had looked at combining the operational and R&D contracts and concluded there was not much benefit from a cost savings perspective or any synergies. Dr. Koch said the move to the cloud gives NOAA more flexibility.

Closing Remarks

Dr. Glenn reported that EISWG has been using many of the best practices it saw in PWR to evolve its own work. Those best practices include the co-designing of plans right from the very start in collaboration with NOAA leadership, the collaborative approach to all the work, and people being motivated by the noble goals of NOAA. EISWG would like to meet with Dr. Smith and Dr. Koch to discuss best practices - lessons learned - and bring that back to the SAB

Mr. Graham hailed the PWR report as a transformative document, one that dovetailed well with his vision for NWS. He acknowledged a need to narrow the priorities because if he tries to do everything, he won't be able to do anything well. The end goal is saving lives, protecting property, and enhancing the economy. Without an appropriate risk perception, people are still going to die, so perhaps NOAA needs to reconsider some of its metrics.

Chair Kreider reiterated his main takeaways from the first panel - the need for more HPC and the lack of data assimilation scientists, which it is a deep problem. After hearing the second panel, he said he would encourage NOAA to prioritize and sunset things with the mission focus in mind, understanding that plans, milestones, and metrics are critical to ensure sustained funding, measure progress, and change course as required. Panel 3 illustrated the importance of mapping out a plan to increase the ratio of research HPC to operational HPC, looking for more innovative community involvement, and the high value of community engagement in co-development.

Chair Kreider asked members to comment on the panel format, whether it was better or worse than the traditional presentation and Q&A. Denise Reed felt that the large size of the panels made them unwieldy and smaller panels would have allowed for greater depth of discussion, but that it was infinitely better than a PowerPoint presentation. Ilene Carpenter wished that more time had been allotted for each panel. Bonnie McCay thought the panels were a great format for exchange of ideas and conversations. Ken Graham suggested devoting more time for panel discussions.

Dr. Colman acknowledged that the panels merely scratched the surface. The plan now is to reconvene the PWR core team, go through the NOAA response, provide feedback, and continue the conversation. When NOAA works with the community, the country benefits.

Dr. Glenn said there is significant community interest in the PWR report. The team had given talks to Congress and at the American Meteorological Society (AMS) meetings as well as panel discussions, and the community wants to be involved. The PRW team's job is now to develop and share best practices, after which it will go back to Congress. The SAB will play a critical role in determining next steps and keeping the PWR process alive.

Chair Kreider thanked the panel and participants and announced that the revised diversity letter was available online.

SAB Report on Open Science and Open Data

Bob Grossman, University of Chicago, and SAB Member

NOAA has well-defined Cloud and Data strategies that clearly identify goals, objectives, and mechanisms to support open data and has made substantial progress implementing those strategies. The subcommittee created nine surveys, which were filled out by NOAA scientists and leaders, and held seven virtual meetings with those who responded. Through the process, they collected input from approximately 18 NOAA scientists, leaders, and outside experts. The report provides four recommendations and highlights some issues, challenges, and opportunities that arose from this process.

In general, software developed by NOAA and NOAA-supported products should be open-source with a permissive license that encourages engagement and reuse. Research by NOAA and NOAA-supported products should be accessible and reproducible.

The subcommittee discussed its scope and formulated surveys in February and March 2022. From March through July, it conducted surveys, presenting its scoping document to the SAB in April. The first draft of the report was completed between August and October, and the second draft was done in November.

The report made the following recommendations:

1. NOAA should follow the principles of FAIR (findable, accessible, interoperable, reusable) open data, and whenever possible, these principles should be prioritized over other mission requirements.
 - a. Since FAIR can be open to interpretation, all NOAA data should be required to have persistent identifiers (PIDs), metadata, open-access APIs, and a standard open license (e.g. cc-0 or cc-by).
 - b. Issuing PIDs for NOAA datasets should be made the highest priority and bottlenecks removed.
 - c. NOAA should consider how use restrictions on purchased commercial data may impact reproducibility and scientific impact. NOAA should strive to minimize the use of non-open data whenever practical, as well as negotiate contracts that transition it to open data after an appropriate period.
2. Encourage and support the use of open-source software as a key component of open science.
 - a. NOAA should develop agency-wide guidance recommending the use of permissive open-source software licenses for most projects, unless there are compelling reasons otherwise.
 - b. Any new projects should agree at the project start to use a widely accepted permissive open-source software license, and terms requiring this should be included in NOAA contracts and partnership agreements.
 - c. NOAA-developed open-source software would require maintenance over time. NOAA should develop agency-wide guidance on how this would be supported if the project that developed the software ended, while other NOAA projects relying on the software continued.
3. NOAA should engage with the open science community around open, reproducible research and support workforce training on how to do open, collaborative, and reproducible science in support of the NOAA mission.
 - a. When NOAA scientists publish scientific papers, the software and configurations used for figures, tables, and core results should be made available at time of publication.

- b. NOAA should invest in workforce development in broad support of open-source software, make research results reproducible at the time of publication, and more open science.
 - c. NOAA should sponsor or leverage an annual conference or other annual event, such as a session at a larger scientific conference, with an accompanying report to consistently engage with the external scientific community on open data, reproducible research, and more generally open science.
4. Consider providing consistent guidance across the agency for best practices, checklists, and dashboards to track adherence to open science principles, policies, and mandates across the enterprise, while still supporting NOAA's distributed culture of data and science.

Discussion

Chris Lenhardt emphasized that open science is a key component of many things the SAB was interested in, including diversity and equity. Dr. Grossman noted that Mr. Lenhardt was one of the active members of the subcommittee.

Dr. Spinrad mentioned that NOAA is both an operational and a regulatory agency. He asked if the subcommittee had any advice or best practices on balancing between open science and regulatory responsibility. Dr. Grossman stressed the importance of distinguishing between open data and open science and separating data that was broadly used for research from data used for decision support. Other than that, the subcommittee did not spend much time discussing this issue, but it could revisit it.

Jon Allan asked if there was a lack of clarity between which data went in the regulatory bucket and which went in the non-regulatory. Dr. Spinrad said he did not believe that was the case. Cisco Werner agreed that in most cases the separation was straightforward, but there were some gray areas, like electronic monitoring which could be used for law enforcement. Dr. Grossman added there was a whole subfield emerging of open science open data for regulatory science.

Jon Allan asked what the recommendations ultimately intended to achieve. Dr. Grossman replied that the recommendations were small steps that would have a big impact and were called out multiple times in the surveys as pressure points. Instead of big requests that could be highly transformational, the subcommittee focused on things that could be achieved in the near term. This does not preclude pursuing more ambitious changes later. Chris Lenhardt added that the recommendations also supported the development of a supportive culture. Dr. Grossman noted Recommendations 1 and 2 were more operational in nature, while 3 and 4 were more cultural.

Chair Kreider suggested an item in the transmittal letter that this report represents a first step, but that it would be beneficial to SAB and NOAA to have an ongoing dialogue.

Mitch Goldberg noted that reproducible software helps with changes in the workforce. Dr. Grossman said that was an incredibly important point.

Jon Allan moved for approval of the report. The motion was seconded by Martin Storksdieck and passed unanimously.

Net Zero Emission (NZE) Fleet for NOAA

John Kreider, Kreider Consulting, LLC, and Chair, NOAA SAB
Jesse Ausubel, The Rockefeller University, and SAB Member

NOAA asked the SAB to consider conducting a study on creating an NZE NOAA fleet by 2050. SAB discussed this request at its August meeting. Chair Kreider and Mr. Ausubel discussed and consulted with a few others, and had drafted a proposed response with recommendations that was posted on the NOAA website.

The SAB believed that achieving an NZE NOAA fleet by 2050 is a worthwhile topic to pursue, but that it should be led by NOAA, not the SAB. The study should not be a science or research study, but should instead focus on operations, engineering, and a strategic plan. SAB believes critical aspects of the study would include stressing that success of implementation requires NOAA and OMAO ownership, that actions taken before 2030 are critical to achieving an NZE fleet by 2050. In addition, the role of a concept of operations (CONOPS) and the use of associated technology such as autonomous underwater vehicles (AUVs) have a large potential impact which needed to be factored into NOAA's overall strategy and timeline for implementing associated technology. SAB recommended dividing a program into phases to achieve the 2050 NZE goal. The SAB is willing to help NOAA by developing a recommended outline for initial study by the end of the year, assembling a team to review progress and make recommendations, and assisting with the NOAA study as it progressed to enable quick feedback and course changes.

Jon Allan said he does not want to miss the pragmatic problem of recapitalization, but he also does not want to miss the opportunity to rethink the entirety of what a net zero fleet could get NOAA in the 30-to-50-year time horizon. Chair Kreider pointed out that NOAA had asked SAB to take the existing NOAA fleet plan as a given rather than start from scratch.

Dr. Spinrad told the SAB he does not want it to concentrate around organizational and budgetary issues of the endeavor but rather the opportunities and risks. What NOAA wants is a sanity check, SAB's honest opinion of whether it was looking in the right places and the science and technology-based realities. He suggested a dialogue between SAB and NOAA's fleet council, perhaps as soon as the spring meeting. He does not want SAB to be too constrained by the realities of current acquisition cycles but to concentrate on what it thought is possible and why. Jon Allan liked the idea of a dialogue with the Fleet Council and hopes enough time would be allotted for it.

Chair Kreider asked the SAB if it was okay to forward the document, or if anyone wanted to make changes to it. Denise Reed questioned whether it was necessary to forward the document, noting that NOAA's request had been informal. If everyone agreed SAB should develop ideas for the initial study by the end of the year, it should proceed along those lines. Chair Kreider said he was fine with that approach if there was general agreement with it. No one voiced an objection.

Plans for Next Meeting

John Kreider, Kreider Consulting, LLC, and Chair, NOAA SAB

The next SAB meeting will be on April 26 and 27, 2023, in the Washington, D.C. area.

Review of Actions

Cynthia Decker, SAB Executive Director, and Designated Federal Officer

Dr. Decker reviewed actions from the meeting, including:

- Approval of the DAARWG Report on the NESDIS Common Cloud Framework and transmitting it to NOAA, recognizing that NCCF was part of NOAA's overall archiving and curation efforts.
- Approval of the ESMWG Report on the Rapidly Changing Marine Environment and transmitting it to NOAA. The report would convey a summary of three to four key points, including that the rapidly changing marine environment was reaching a crisis and actions should be taken now.
- Sending NOAA the drafted letter requesting more diversity in presenters from NOAA and a desire for the cooperative institute reviews to include metrics for DEIA. SAB members would provide suggestions for finalizing the language. A second draft of the letter was already posted on the website.
- Agreeing to identify and invite an expert on team science to speak at a future meeting.
- Having NOAA present to the SAB at a future meeting how the SAB could engage on the annual budget process.
- Having NOAA consider inviting the director of OSTP and/or other high-level federal science policy experts to speak to the SAB.
- Having NOAA arrange for the Office of Space Commerce to speak to the SAB at its spring meeting.
- Approval of the Open Science Open Data Report and transmitting it to NOAA. The transmittal letter would talk about creating an ongoing discussion with NOAA on this topic.
- Having NOAA bring the fleet council into a discussion with the SAB regarding the net zero emission fleet.

Adjourn

Dr. Spinrad presented Dr. Cynthia Decker with the Silver Sherman Award for her superior service to NOAA, the Department of Commerce, and the nation.

The meeting adjourned at 12:09 p.m.

Acronyms/Glossary

<i>AFS</i>	NWS Analyze, Forecast, and Support
<i>AMS</i>	American Meteorological Society
<i>API</i>	Application Programming Interface
<i>AUV</i>	Autonomous Underwater Vehicle
<i>AWIPS</i>	Advanced Weather Interactive Processing System
<i>BIL</i>	Bipartisan Infrastructure Law
<i>CI</i>	Cooperative Institutes
<i>CDC</i>	Centers for Disease Control and Prevention
<i>CEO</i>	Chief executive officer
<i>CMR</i>	NASA Consolidated Metadata Repository
<i>CNES</i>	Centre National d'Etudes Spatiales (French space agency)
<i>COG</i>	Cloud Optimized GeoTIFF
<i>CONOPS</i>	CONcept of OPerationS
<i>COP27</i>	2022 United Nations Climate Change Conference
<i>CRADA</i>	Cooperative Research and Development Agreements
<i>CWG</i>	Climate Working Group
<i>DAA</i>	Deputy Assistant Administrator
<i>DAARWG</i>	Data Archive and Access Requirements Working Group
<i>DEI</i>	Diversity, equity, & inclusion
<i>DTC</i>	Developmental Testbed Center
<i>ECO HAB</i>	Ecology and Oceanography of Harmful Algal Blooms
<i>EISWG</i>	Environmental Information Systems Working Group
<i>EMC</i>	Environmental Modeling Center
<i>EPA</i>	Environmental Protection Agency
<i>EPIC</i>	Earth Prediction Innovation Center
<i>EPRI</i>	Electric Power Research Institute
<i>ERG</i>	Employee Resource Group
<i>ESA</i>	Endangered Species Act
<i>ESMWG</i>	Ecosystem and Sciences Management Working Group
<i>FAIR</i>	findable, accessible, interoperable, and reusable (pertaining to data)
<i>FCC</i>	Federal Communications Commission
<i>FEMA</i>	Federal Emergency Management Agency
<i>FISMA</i>	Federal Information Security Management Act
<i>GFDL</i>	Geophysical Fluid Dynamics Laboratory
<i>GIS</i>	Geographic information system
<i>GSL</i>	Global Systems Laboratory
<i>HAB</i>	Harmful Algal Bloom
<i>HPC</i>	High Performance Computing
<i>HYSPLIT</i>	Hybrid Single-Particle Lagrangian Integrated Trajectory model
<i>ICAMS</i>	Interagency Council for Advancing Meteorological Services
<i>IG</i>	Inspector General
<i>IJA</i>	Infrastructure Investment and Jobs Act
<i>IOOS</i>	U.S. Integrated Ocean Observing System (IOOS)

<i>IRA</i>	Inflation Reduction Act
<i>JCSDA</i>	Joint Center for Satellite Data Assimilation (NOAA-NASA-DoD)
<i>JEDI</i>	Joint Effort for Data Assimilation
<i>JTWC</i>	Joint Typhoon Warning Center
<i>K.G.</i>	Knowledge Graph
<i>MMPA</i>	Marine Mammal Protection Act
<i>MOU</i>	Memorandum of Understanding
<i>NASA</i>	National Aeronautics and Space Administration
<i>NCAP</i>	NESDIS Cloud Archive Project
<i>NCAR</i>	National Center for Atmospheric Research
<i>NCCF</i>	NESDIS Common Cloud Framework
<i>NCCOS</i>	National Centers for Coastal Ocean Science http://coastalscience.noaa.gov/welcome.html
<i>NCEI</i>	National Centers for Environmental Information
<i>NESDIS</i>	National Environmental Satellite, Data, and Information Service
<i>NIH</i>	National Institutes of Health
<i>NIST</i>	National Institute of Standards and Technology
<i>NMFS</i>	National Marine Fisheries Service
<i>NOAA</i>	National Oceanic and Atmospheric Administration
<i>NOFO</i>	Notice of Funding Opportunity
<i>NOS</i>	National Ocean Service
<i>NSF</i>	National Science Foundation
<i>NWS</i>	National Weather Service
<i>NZE</i>	Net Zero Emissions
<i>OAR</i>	(Office of) Oceanic and Atmospheric Research
<i>OBS</i>	Office of Observations
<i>OCIO</i>	Office of the Chief Information Officer
<i>OCP</i>	Office of Central Processing
<i>OCS</i>	Office of Coast Survey (NOS)
<i>OMAO</i>	Office of Marine and Aviation Operations
<i>OSTP</i>	Office of Science and Technology Policy
<i>P3</i>	Type of maritime patrol aircraft
<i>PID</i>	Persistent identifier
<i>PPGC</i>	Precipitation Prediction Grand Challenge
<i>PSL</i>	Physical Sciences Laboratory
<i>PSP</i>	paralytic shellfish poisoning
<i>PWR</i>	Priorities for Weather Research
<i>S2S</i>	Subseasonal to Seasonal
<i>SAB</i>	Science Advisory Board
<i>SAR</i>	Synthetic aperture radar
<i>SBIR</i>	Small Business Innovation Research
<i>SCO</i>	Space Climate Observatory
<i>SOP</i>	Standard Operating Procedures
<i>SPLASH</i>	Study of Precipitation, the Lower Atmosphere and Surface Hydrometeorology
<i>STAC</i>	Spatio-Temporal Asset Catalog

<i>STEM</i>	Science, Technology, Engineering, Mathematics
<i>STOFS</i>	Surge and Tides Operational Forecast System
<i>TSTAP</i>	Tsunami Science & Technology Advisory Panel
<i>UAS</i>	Unmanned Aircraft System
<i>UFS</i>	Unified Forecast System
<i>USAID</i>	U.S. Agency for International Development
<i>USGCRP</i>	U.S. Global Change Research Program
<i>USGEO</i>	US Group on Earth Observations
<i>UXS</i>	Unmanned Systems
<i>vAIP</i>	Virtual Archive Information Package
<i>VIIRS</i>	Visible Infrared Imaging Radiometer Suite
<i>WG</i>	Working Group
<i>WINGS</i>	Weather Program Office (WPO) Innovation for Next Generation Scientists
<i>WPO</i>	Weather Program Office