70th Meeting of the NOAA Science Advisory Board
March 15 and 17, 2021

Location: Webinar

Advisory Board Members Present:
Mr. John Kreider, President, Kreider Consulting LLC (Chair); **Dr. Robert L. Grossman**, Frederick H. Rawson Professor and Jim and Karen Frank Director, Center for Data Intensive Science, University of Chicago; **Dr. Everette Joseph**, Director, National Center for Atmospheric Research (NCAR); **Mr. M. Christopher Lenhardt**, Domain Scientist, Renaissance Computing Institution; **Dr. Ruth Perry**, Marine Scientist and Regulatory Policy Specialist, Shell Exploration and Production Company; **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; and **Dr. Elizabeth Weatherhead**, Senior Scientist and Fellow, Jupiter Intelligence.

NOAA Representatives Present:
Mr. Benjamin Friedman, Deputy Under Secretary for Operations, Performing the Duties of Under Secretary of Commerce for Oceans and Atmosphere, NOAA Administrator; **Mr. Craig McLean**, Assistant Administrator for Oceanic and Atmospheric Research, Performing the Duties of NOAA Chief Scientist; **Dr. Karen Hyun**, Chief of Staff, NOAA; **Dr. Letise LaFeir**, Senior Advisor, NOAA; **Ms. Nicole LeBoeuf**, Acting Assistant Administrator, National Ocean Service, NOAA; **Dr. Steve Volz**, Acting Assistant Secretary for Environmental Observation & Prediction, NOAA; **Dr. Louis Uccellini**, Assistant Administrator for Weather Service and Director, National Weather Service; **Rear Admiral (RDML) Nancy Hann**, Deputy Director for Operations, NOAA Office of Marine and Aviation Operations (OMAO), and Deputy Director of the NOAA Commissioned Officer Corps; **Dr. Cisco Werner**, Director of Scientific Programs and Chief Science Advisor, National Marine Fisheries Service; **Ms. Mary Erickson**, Deputy Director, National Weather Service; **Dr. Gary Matlock**, Deputy Assistant Administrator for Science, Oceanic, and Atmospheric Research, NOAA; and **Dr. Mitch Goldberg**, Chief Program Scientist, Joint Polar-Orbiting Satellite System, National Environmental Satellite and Information Systems.

Working Group Co-Chairs:
Dr. Bradley R. Colman, Director of Science – Weather Science, The Climate Corporation and Co-Chair, Environmental Information Services Working Group (EISWG); **Dr. Jeff de la Beaujardiere**, Director, Information Systems Division, Computational and Information Systems Laboratory, National Center for Atmospheric Research (NCAR) and Co-Chair, Data Archiving and Access Requirements Working Group (DAARWG); **Dr. Kirstin Dow**, Carolina Trustees Professor, Lead Investigator, Carolinas Integrated Sciences and Assessments and Co-Chair, Climate Working Group; **Dr. Scott Glenn**, Professor, Department of Marine and Coastal Science, Rutgers University and Co-Chair, EISWG; **Dr. Molly McCammon**, Executive Director

of the Alaska Ocean Observing System (AOOS) and Co-Chair, Environmental Sciences and Management Working Group (ESMWG); **Dr. Jan Newton**, Senior Principal Oceanographer with the Applied Physics Laboratory of the University of Washington, and Co-Chair, ESMWG; **Dr. Joellen Russell,** Professor, Biogeochemical Dynamics, University of Arizona and Co-Chair, CWG; and **Dr. Lisa Wainger**, Professor of Environmental Economics at the University of Maryland Center for Environmental Science and Co-Chair, ESMWG.

Staff for the Science Advisory Board Present:
Dr. Cynthia J. Decker, Executive Director and Designated Federal Officer; **Ms. Tiffany Atkinson**, Program Analyst; and **Ms. Courtney Edwards**, Program Analyst.

March 15, 2021

Opening Statement of the Chair
John Kreider, Kreider Consulting LLC and Chair, NOAA SAB

Mr. Kreider thanked everyone for their attendance, updated the agenda, and took roll call.

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

The consent calendar consisted of the September and October minutes, the working group quad charts, and the Environmental Information Services Working Group (EISWG) co-chair and membership. Dr. Weatherhead moved to approve all items. Dr. Storksdieck seconded the motion. The four items were approved unanimously.

NOAA Update
Ben Friedman, Deputy Under Secretary for Operations and Acting Administrator, NOAA

Presentation
Mr. Friedman introduced himself and explained his current role in NOAA as the Acting Administrator. He emphasized the importance of the Science Advisory Board (SAB) to NOAA and that he had several discussions with the NOAA political team and senior NOAA leadership about the role of the SAB in the new administration. He then announced some changes brought on by the new administration. He noted that NOAA assistant administrators, as well as himself as the Deputy Undersecretary for Operations, will attend all SAB meetings. In addition, executive sessions will be reinstituted with the SAB members to discuss non-public topics, such as budget information and legislative initiatives. He also noted that public SAB meetings would include a NOAA update followed by a research update from the Chief Scientist of NOAA, as has been done in the past. Mr. Friedman said that once NOAA gets a new Administrator, the Administrator sets the direction of the SAB, so things could change.

Mr. Friedman then spoke about significant changes that had occurred at NOAA with the Biden Administration transition. He shared some of these developments, which included the appointment of a new Secretary of Commerce, Gina Raimondo who, since she took office, met with senior leadership at NOAA and hosted an all-hands town hall, visited the NOAA Rhode Island site, and met Rear Admiral Nancy Hann and other Office of Marine and Aviation Operations (OMAO) staff. He also identified the four political appointees who had already joined NOAA: Dr. Karen Hyun, Walker Smith, Dr. Letise LaFeir, and Emily McAuliffe.

Mr. Friedman addressed the administration's priorities and briefly presented four of them: climate change; racial equity, diversity, and inclusion; scientific integrity; and COVID response.

Climate Change: Mr. Friedman emphasized the importance of this issue to the Biden administration and that climate change would impact all of NOAA's endeavors. He emphasized the impacts climate change has on fish in migration, fish habitat, and endangered species. He touched on sea level rise, coastal inundation, as well as the increase in significant weather events, which were at a high of 22 in 2020, all with a billion-dollar or greater impact on the national economy, compared to an average of seven events per year over the last 40 years.

Mr. Friedman spoke about two executive orders that had been issued on climate change, the first of which involved review of all new regulations and policies over the last few years to ensure a focus on climate issues and environmental friendliness. The second established a National Task Force, to include NOAA. He also noted coordination at the Department level, White House level, and with sister agencies to focus on climate to formulate the fiscal year 2022 budget, which was expected to be climate-focused.

Racial Equity: Next, Mr. Friedman highlighted racial equity. He explained that this consisted of two parts: 1) diversity and inclusion (D&I) internally to NOAA, and 2) efforts to ensure that NOAA services are provided equitably around the country.

He shared internal efforts made by NOAA to increase diversity and inclusion because NOAA has not done well across many diversity categories. In light of the ongoing social unrest in 2020, Mr. Friedman explained that NOAA was quick to respond by hosting listening sessions at the leadership level, conducting an all-NOAA employee survey to obtain ideas for improvement, and setting up a working group of senior leaders to coordinate efforts for development of an action plan. This plan would contain short-term, mid-term, and long-term goals, of which he provided examples, including trainings on diversity and inclusion issues, increasing opportunities for minority leadership within NOAA, and expanding paid internship programs.

Mr. Friedman also spoke about Biden's second priority, the equitable distribution of NOAA services across the country. An executive order was signed that requires NOAA to establish a working group to evaluate programs and policies to identify possible inequitable distribution of services and recommend any needed changes.

Scientific Integrity: Mr. Friedman emphasized the Biden administration's dedication to scientific integrity. He referenced the incident at NOAA during Hurricane Dorian under the last administration, Two reports came out of this incident, one which focused on the allegations of scientific integrity misconduct by the National Academy of Public Administration (NAPA), as well as one provided by the Inspector General of Commerce. He reaffirmed NOAA's commitment to scientific integrity and to avoidance of political interference in order to provide accurate science to the country. He noted that NOAA had revised the NOAA scientific integrity policy as a result of these reports.

Mr. Friedman also mentioned that much of the interference regarding Hurricane Dorian stemmed from the Department of Commerce level or higher, so there has been priority to create its own scientific integrity policy. A new memorandum issued by the White House on scientific integrity requires every agency have a scientific integrity policy that will be reviewed at the White House level.

COVID: Lastly, Mr. Friedman highlighted the response to COVID by the agency. He cited the executive order which required mask wearing and social distancing in all federal facilities but noted NOAA was already doing that. While protection of the workforce is still a top concern, reintegration is being examined, as well as the possibility of changes arising from the COVID "work from home" era. Some of the benefits of this setup were a decreased economic and carbon footprint, as well as increased retention and productivity amongst employees.

Mr. Friedman concluded his presentation with some priorities for the SAB. He explained that while things could change once a confirmed Administrator was installed, he could say for the time being the SAB would still be responsible for developing a report on weather research priorities as this was congressionally mandated. He then turned to the six priorities the SAB had voted on prior and discussed internally with NOAA. The SAB had been approved to continue its focus on coastal resilience, social and behavioral science, and climate change. The remaining priorities of the SAB should be reconsidered and possibly move in a different direction. Mr. Friedman reiterated NOAA's eagerness to work with the SAB on its priorities in the coming years.

Science Update
Craig McLean, Acting Chief Scientist and Assistant Administrator for Oceanic and Atmospheric Research, NOAA

Presentation
Mr. McLean explained that generally the science update would be used to let the SAB know what was happening inside of NOAA since the last meeting but that this time he would provide a quick overview so that there was plenty of time for discussion.

Mr. McLean shared a 2020 document titled "The NOAA Research and Development Vision Areas," which he described as NOAA's strategy for science. He spoke about one of the three

vision areas titled "Reducing Societal Impacts from Hazardous Weather and Other Environmental Phenomena" and explained that the second half of this vision area was essentially focused on climate change.

Mr. McLean said NOAA saw the vision areas as basically sound - as representing societal impacts from severe weather hazards and climate change, sustainable use and stewardship of the ocean and coastal resources, and robust and effective development of transitions in the enterprise. NOAA believes it has been successful in these three areas.

Mr. McLean identified the science and technology focus areas that had been promoted by the previous Deputy Administrator, RDML Tim Gallaudet, which included 'omics, artificial intelligence, uncrewed systems, cloud, data, and citizen science. He accredited the success of these topics within NOAA to the Science Council, which brought the line organizations together and created collaborative strategies as opposed to multiple individual actors with their own agenda. Mr. McLean viewed this as a best practice for NOAA and one the agency planned to incorporate with the new administration and its new priorities. He also noted that these documents would be updated through the Science Council to ensure that they align with the new Administration's priorities.

Next, Mr. McLean cited to the executive orders Mr. Friedman referenced and further explained that NOAA has created a tracking mechanism that would ensure that requirements in these were addressed in a timely manner. Cynthia Decker, as NOAA's Scientific Integrity Officer, will play a key role going forward to maintain scientific integrity at NOAA and the Department of Commerce, and will ensure that the Department and all of its bureaus are fulfilling all obligations under the scientific integrity presidential memorandum.

Mr. McLean then assured the SAB that NOAA has done its best to complete work that was necessary throughout the COVID pandemic. He noted NOAA's efforts throughout COVID to maintain social distancing in all labs and only operate on a vital mission-essential lab presence to ensure a safe work environment. Mr. McLean then explained that it was important to continue monitoring and analyzing things such as atmospheric greenhouse gases on a daily basis. While NOAA was still able to complete much of their work during the pandemic, there was some work that couldn't be completed, citing a number of research cruises that had to be canceled.

Mr. McLean shared areas of interagency COVID-related engagement. He mentioned the National Environmental Satellite, Data, and Information Services' (NESDIS) collaboration with the National Biodefense Analysis and Countermeasures Center (NBACC) to explore how climatology influences transmission and availability of the disease. He also noted the successful COVID response among the labs in Boulder, Colorado examining ground-level ozone and how it changed with a reduction in communing traffic during the pandemic.

Mr. McLean pointed to a group of ocean community scientists who were examining underwater sound in a World Quiet Ocean Experiment which was centered around the cessation of all human

activity in the oceans for one day in order to measure the difference between naturally occurring noise and human-caused noise. He explained that, with COVID and the consequent break in commercial shipping and some drilling and survey work, discrete measurements were obtained throughout the season, made possible by the advancement of hydrophone deployment.

Mr. McLean then addressed each of the three vision area separately.

Reducing Societal Impacts from the Hazards of Weather and Other Phenomena: Mr. McLean spoke about the 2020 hurricane season, with 30 named storms and 13 hurricanes. He congratulated the Office of Marine and Aviation Operations (OMAO), which flew hurricane hunters into the storms and figured out ways to reduce the number of people needed on the aircraft through the use of telemetry to link with scientists on the ground. Thanks to data like this, the National Weather Service (NWS) forecasters were able to predict, within a mile, the geodetic position of the center of the eye of the hurricane three-and-a-half days before it occurred. He commended NESDIS for its use of satellite tools and those from the National Ocean Service for enhanced understanding of tidal surge. Mr. McLean shared the new satellite tools that brought increased accuracy in flood forecasting and mapping, which allows NOAA to adjust its water model more easily and FEMA to track escape and access routes in flood zones, as well as advise on evacuation areas.

Mr. McLean then moved to the 2020 wildfire season, which had enhanced activity, and explained that the improved satellites resulted in fire detection long before they might be detected on the ground and protected firefighters by detection of wind changes and better prediction of fire movement. He said that 2020 had 188 Incident Meteorologist missions. He mentioned the transition of smoke prediction research models to operation, which allowed the National Weather Service to run them routinely and mitigate the downstream effects of smoke.

Mr. McLean then spoke about harmful algal bloom forecast improvement through the transition of multiple three-dimensional models in the Great Lakes and noted that this was a collaboration by multiple parts of NOAA. These models not only forecasted algal blooms but also forecasted the organisms that cause the toxin that causes respiratory or eye irritation. He explained they were working on the application of biological sensing to determine cyst distribution of the toxin-generating organisms that bloom with the algae; when the cysts mature and burst, the air-borne toxin was introduced and caused irritation to humans. He noted that this work has been able to be completed unimpeded during the pandemic and that teams have been on the lakes to measure the presence of the toxin. These measurements inform the models and allow for model improvement.

Sustainable Use and Stewardship of the Ocean and Coastal Resources: Mr. McLean moved to the next vision area and explained the 2021 cruise track envisioned for the Okeanos Explorer, which included going to the Blake Plateau, the Gulf of Mexico loop current area, and then to the New England seamounts. The exploration would entail international collaboration through the Galway Statement, an agreement between Canada, the European Union, and the United States.

He noted that, through the Galway Statement, NOAA has been working with other nations to map the North Atlantic Ocean.

Also through the use of the Okeanos Explorer and the Deep Discoverer (a remotely operated vehicle), Mr. McLean said NOAA scientists published a scientific description of a new species without collection of a physical specimen for the first time, but instead by using underwater video footage. He explained that the capability of identification of a new species purely through high-resolution video was new for the underwater world. He attributed the discovery to two NOAA National Marine Fisheries Service (NMFS) scientists, Mike Ford and Allen Collins. He also spoke about the work that was underway with the Cook Inlet beluga whales in the monitoring of their physiology, genetic distribution, and gender distribution. He explained that this work has been a collaboration of NMFS with academic partners using tissue samples in order to have a better understanding of the species.

Mr. McLean spoke about the research development and transition enterprise including various technologies that had transitioned into operations, which included the next generation of satellites though NESDIS and an extra-tropical surge and tide operational forecast system through the National Ocean Service (NOS) and NWS, which enhanced the inventory of global tides and helps calculate the effects of storms. He referred to the new 22-meter Saildrone that was in development for NOAA to use as an autonomous ocean-mapping tool and mentioned that it circumnavigated Antarctica in 2020. Mr. McLean returned to satellites and spoke about the new generation that was being developed called GOE-XO which will replace the GOES series satellites.

Mr. McLean shared the work aimed at the creation of an operational component for uncrewed systems which was being done in partnership with the Roger Wicker Center in southern Mississippi and the Scripps Institute of Oceanography to increase surveillance of storms and many other aspects of climate, weather, and ocean science. He added that the work done on the Gulf was with the Navy and the Commercial Engagement Through Ocean Technology Act (CENOTE) Act. He provided further details about the Scripps collaboration, which is using autonomous vehicles to assess the potential fate of treating several hundred thousand barrels of toxic chemicals off the coast of southern California.

Mr. McLean listed a few of the recent implementations he was most excited about and noted that while he wished they could bring more research into operations, those projects that did transition were based on discussions regarding budget and priorities for the NWS. He noted that at the current level of funding, NWS cannot transition all research endeavors into operations.

Mr. McLean concluded his presentation and expressed his pride that NOAA had managed to stay in the high 90 percent of attainment of its mission in spite of COVID.

Discussion

Mr. Kreider asked how they viewed NOAA's working relationship with the Office of Science and Technology Policy (OSTP) moving forward in light of the new committees and focus groups OSTP had formed. Mr. Friedman and Dr. Karen Hyun explained that a former Administrator of NOAA, Jane Lubchenco, was now one of the deputies at OSTP, which should be beneficial for NOAA, and that Shelly Wilhelgi, the soon-to-be Deputy Chief of Staff, was also familiar with NOAA. They believed through these connections and the continued contact with OSTP, NOAA would have a strong presence at the White House level. Dr. Hyun added that the primary focus of OSTP now was to get the Director confirmed and then turn to the interagency leadership around scientific integrity and the creation of the Interagency Counsel of Meteorological Services (ICAMS). Dr. Hyun felt the work done across NOAA, the OSTP, and other White House councils would be well integrated and that hopefully NOAA would receive a larger budget because of the important work it could do on the administration's new priorities. Mr. McLean added that NOAA was happy to see the level of activity and attention to climate with Secretary Kerry and Administrator McCarthy coming on board in the current administration. He also noted that with the appointments to OSTP and with the detailees from NOAA who have been assigned to OSTP he was hopeful that NOAA will have a great deal of opportunities.

Dr. Everette Joseph asked about the Diversity, Equality, and Inclusion (DEI) at NOAA regarding DEI leadership reporting and whether it would sit with NOAA leadership or at the administrator level. Mr. Friedman responded that the Office of Civil Rights and Inclusion, which runs the diversity programs, had been expanded to handle diversity and inclusion issues. That office reports directly to the Deputy Under Secretary for Operations, so it was at a much higher level now, with the possibility in the future that it may report directly to the Administrator for NOAA.

Dr. Molly McCammon then asked about the relationship between the SAB and the new Ocean Research Advisory Panel (ORAP), which is now under NOAA with the National Ocean Partnership Program (NOPP). Mr. McLean explained that the exact relationship had not been worked out yet and execution of the law that created NOPP was still underway. He expressed a desire to have a future where the SAB worked in tandem with other science advisory bodies, including the ORAP, and potentially have individuals serve on more than one board.

Dr. Betsy Weatherhead asked about plans for new observations and observing systems. She also asked if NOAA planned to merge observations with modeling. Mr. McLean said many different options were under examination, and he cited some examples, including blending coastal and open ocean observations, and having modelers work closer with observers. Dr. Steven Volz added that whatever path they take, it would bring all the observation data together in a more cohesive manner to create even better models, improve artificial intelligence (AI), and create more data-driven science observations, utilization, and exploitation for the future.

Mr. Kreider then asked, in reference to an economists' workshop, about the conflict between environmentalists and economists on sustainable use of the oceans. He wondered if there was an opportunity for NOAA to take the lead to help resolve these issues and conflicts. Mr. McLean answered first with mention of some of the work done in NOAA that already bridged these gaps,

noting that the NMFS has managed to recover many species from overfishing status and the National Sea Grant Program does a fantastic job describing the economic impact of their work. He suggested that development of some co-designed programs between NOAA and the Department of Commerce could result in projects that are helpful to the Blue Economy while not harming the environment. Mr. McLean also mentioned the opportunities through the UN Decade of Ocean Science for Sustainable Development to work towards a circular economy rooted in sustainability. Ms. Nicole LeBoeuf added that NOAA's work with the Bureau of Economic Analysis (BEA in DOC) was a first step in evaluation of the importance of the industries along the coast to the overall economy. She felt the Blue Economy might be too big to fail but that having someone lead the Department of Commerce who also understands the ocean, as well as data and technological improvements, would help NOAA move forward in a sustainable way.

Dr. Martin Storksdieck asked, with respect to D&I, what representation should look like in NOAA at various levels of the organization. Mr. Friedman said he wanted NOAA to look like America but that there was not an exact target and that the importance of D&I was to have people in NOAA who could communicate to various communities around the country when information and emergency services were delivered. He also noted that NOAA has a long way to go in every category, including African American, Hispanic, and Native American, and pointed to some small improvements which he attributed to direct hire authorities. It was agreed there needed to be some foundational work done which started at a younger age to get people from underrepresented communities interested in scientific careers. Rear Admiral Nancy Hann added OMAO has recently contacted academic institutions that are both diverse and have programs focused on science and engineering.

Dr. Joseph inquired about NOAA's approach to post-docs and new hires who missed out on a year of mentorship and professional development due to COVID. Mr. McLean said there was a heightened mindfulness of what the experience was for them and noted that in some instances the labs had included more early career professionals in their conversations digitally than may have been included if physically located in the lab. These individuals were able to attend conferences that were held remotely that, in the past, didn't include early career professionals. Overall, there really was no way to compensate for the lost year beyond staying connected with them and involving them in projects where possible.

Dr. Ruth Perry asked next about plans or views on expansion of partnerships with private industry, as well as energy transition and climate resiliency groups. Mr. McLean spoke about the NOPP program again and explained he expected some of these partnerships when it came to infrastructure. He mentioned that NOAA did want to emphasize partnerships with industry, philanthropy, and NGOs and felt that, with the imminent threat posed by climate change, now was the time for these partnerships. He qualified that with a note that some of these partnerships were hindered due to risk-averse partners, so it would require analysis of how these opportunities could be made more fruitful for all parties. Dr. Volz reiterated that the sharing of data between internal networks and external industrial and commercial networks remained a high priority.

Mr. Kreider suggested two action items, one based on the topic of DEI for the SAB, and a second on barriers or impediments to partnerships between government and outside entities. Dr. Jan Newton made a final comment about the U.S. Integrated Ocean Observing System (IOOS), which was a successful partnership that could provide an example for future plans.

NOAA Response to SAB Ecosystem Sciences and Management Working Group Report: Improving Fish Stock Assessments: A Report on Emerging Stock Assessment Technologies.
Cisco Werner, Chief Scientist, NOAA National Marine Fisheries Service

Presentation
Dr. Werner covered the SAB's recommendations and NOAA's response to the Ecosystem Sciences and Management Working Group (ESMWG) report on Improving Fish Stock Assessments: A Report on Emerging Stock Assessment Technologies.

He reviewed how this report came to the SAB, that it was through Topic 9 of the SAB work plan in 2018, which asked that they "evaluate fisheries' monitoring technologies to improve stock assessments." This topic was then broken down into three branches, which were that the ESMWG examine technologies to increase efficiency and accuracy of stock assessments, find ways to save both ship and personnel time in stock assessment surveys, and finally look at potential roles of new methods under development. Dr. Werner noted that seven recommendations emerged from this report, each with corresponding NOAA responses.

Recommendation 1: Technology should not be viewed primarily as a cost-saving approach but rather as a means to improve stock assessments.

Response: Dr. Werner said that NOAA agreed with this recommendation. They want to be sure NOAA uses technologies that fill data gaps, reduce uncertainty, and enable more stock assessments. Many technologies were in consideration, with a view to secure the technology and also set up the infrastructure and expertise within the organization to maintain these systems. The top priority remained identification of technologies that augment the current systems, rather than replace them.

Recommendation 2: NOAA should examine whether and how new technologies can be linked to current stock assessment models and supporting analyses, and to what degree any new techniques enhance stock assessments.

Response: Dr. Werner concurred with this recommendation. As new technologies and data streams arose, they would assess their fit with current methods. He gave some examples of technologies they liked, including the Fourier transform near-infrared spectroscopy method to count and age organisms faster and environmental DNA (eDNA). He noted that since they already use age as a factor in their assessments, this was a technology that could be incorporated relatively easy without much calibration, but that technologies like eDNA would require more

research to understand the capabilities for application. He also mentioned that NOAA invested in a new model for ingesting and analyzing data called the Fisheries Integrated Modeling System (FIMS), which would allow different data streams to be input to produce new assessment model concepts.

Recommendation 3: New technologies can be advanced by holding workshops with experts to develop ideas for how to apply these new technologies to stock assessment.

Response: NOAA strongly supports this recommendation. Dr. Werner discussed two examples of prior workshops held and their consequent benefits including a workshop in the early 2010s examining using optical data for fisheries assessments. Last year they were able to use optical data along with artificial intelligence and machine learning to conduct assessments during COVID.

Recommendation 4: Perform side-by-side comparisons between new technologies and ongoing assessments.

Response: Dr. Werner felt this was fairly evident but important to keep in mind. NOAA stays on top of the stock assessment time series and keeps them parallel where possible. He said that this side-by-side time series was a normal part of the assessment and related back to the blue economy and multi-use sectors of the coastal ocean and infrastructure changes. He noted that it was important to develop side-by-side time series to gain proper trust and confidence in the data so that they can transition from the current approach to the approach with new technology.

Recommendation 5: NOAA needs to invest in lab and field testing of the methods and consider Public-Private Partnerships.

Response: Dr. Werner viewed this recommendation as linked to Number 4 and noted it was still something NOAA concurred with. He mentioned that oftentimes, the people who develop the technologies are not the ones who use the technology to conduct the field work, and so they would be careful to maintain collaboration with those who develop the technologies, be it industry or academic partners.

Recommendation 6: NOAA should explore the potential for workforce development, cooperative institutes, postdoctoral programs and training classes.

Response: NOAA acknowledged this was an area it needed to focus on. Even among NOAA's six science and technology focus areas, each focus area had an emphasis on workforce proficiency. Dr. Werner identified increases in workforce proficiency internally, citing the new NOAA LANTERN Program (Leveraging Abilities, Needs, Talents, Energies, and Resource Network) and working with external cooperative education programs, like the Cooperative Science Centers, as two ways to address this recommendation.

Recommendation 7: NOAA should consider how AI, cloud computing, and other technologies can be employed to process large volumes of data.

Response: Dr. Werner reflected on some earlier discussions and reiterated that NOAA was building a wealth of data that the agency aims to make discoverable, interoperable, available, and shareable, and NOAA is working on a big data program to address this recommendation and its larger data goals. He noted that within NMFS itself, development of the Fisheries Information Management Modernization was underway, which brings together the data owners, the mangers, and the users to evaluate current and future high-volume data acquisition, processing, and management requirements. He added that this commitment to data collection and transparency was part of the U.N. Decade of Ocean Science for Sustainable Development.

Dr. Werner thanked the ESMWG for its work with NOAA to develop this list of recommendations. He emphasized that NOAA not only accepted the recommendations but that it would incorporate them as it improves its approaches to marine assessments.

Discussion

Mr. Kreider asked about platform procurement and if there was any discussion in NOAA around outreach to industry or the private sector to purchase outside data. Dr. Werner explained that NOAA recognized the work that needed to be done with the private sector regarding big data, and efforts are being undertaken to partner with IBM, Google, and Microsoft to make the data accessible. The International Oceanographic Data and Information Exchange (IODE), in which NOAA participates, contributes to efforts internationally to share data with others and have others share data as well.

Dr. Volz added a cautionary note that NOAA still struggles with the choice between buying existing data as opposed to building systems that produce it. He mentioned that for process studies or understanding, buying data is fine, but with providing operational services in perpetuity this might not be the best path. NOAA can't ensure the long term sustainability of that service, leaving the agency in a vulnerable situation. He added that NOAA does buy a great deal of data that is ancillary or additional for augmentation and enhancement. Mr. McLean, in response, said there had been sustained operational and functional relationships between NOAA and private industry, specifically, in nautical charting data, and he viewed partnerships like this as advisable. However, he was aware of NOAA's tendency to want to control all aspects of the data collected as a means to guarantee reliability. He added that there were areas where this is not practical and that mutually beneficial partnerships must be entered into.

Dr. Perry next asked what NOAA was doing to speed up the issues or these recommendations because the oceans are changing in terms of use, but stock assessments are behind with respect to these changes. She also asked where partnerships come into play with assessments, specifically in the offshore wind industry. Dr. Werner responded that NOAA's relationships with the offshore wind industry and the fishing industry continue to evolve. He noted that with partners,

coexistence was a necessity and the ability to use each other's technologies and data would accomplish larger tasks in more manageable ways.

Dr. Joellen Russell asked how NOAA handled system design itself, to assure all the technologies and new platforms worked as efficiently as possible by ensuring the basic design and plan, the foundation for these new data collectors is correct. She added that the Observing System Simulation Experiments (OSSE) recommendations that EISWG has developed could be a blueprint for the observing system design that NOAA needed to finalize. Dr. Werner agreed that the foundation needed to be as accurate as possible and that NOAA is building in OSSEs from the beginning.

Dr. Hyun mentioned that NOAA would be very open to discussions with partners, academic and industry, to determine how to bring all of their assets to bear and create a plan for the best configuration. These groups would work together to address some of these issues, particularly around offshore wind, survey impacts, and ocean conditions to try to develop some pilot project. Dr. Scott Glenn added that academic institutions already have ocean observing and modeling experience, along with large extension services set up, that could make them valuable partners as this conversation and planning moves forward.

Dr. Werner agreed with the statements provided and thanked everyone for their attention.

Data Archive and Access Requirements Working Group Report on Cloud and Data Implementation Plans
Jeff de la Beaujardiere, Director, Information Systems Division, Computational and Information Systems Laboratory, National Center for Atmospheric Research (NCAR) and DAARWG Co-chair

Presentation
Dr. de la Beaujardiere presented the Data Archive and Access Requirements Working Group's (DAARWG) recommendations on the NOAA data and cloud strategies. He introduced himself and the members of the working group and thanked NOAA for the ability to offer these recommendations. He gave some quick background and explained that the specific documents they looked at and made recommendations for were "The NOAA Data Strategy Implementation Plan" and "The NOAA Cloud Strategic Plan." He expressed his appreciation for NOAA's continued dedication to incorporation of these areas in their work. He added that DAARWG was pleased to see NOAA continuing to give data and cloud issues serious consideration.

The NOAA Data Strategy Implementation Plan: Dr. de la Beaujardiere stated that the group felt the goals and objectives were worthwhile and well supported by the actions, and he specifically appreciated the continued focus on open data sharing, the use of data standards, and the call for stakeholder engagement. They also saw the stated actions as achievable as long as resources were available. However, their plan did not include target due dates or responsible parties and that might hinder progress.

Action 1.1: To establish the NOAA Chief Data Officer (CDO) organizational structure.

Recommendation 1-2: Dr. de la Beaujardiere explained that this was not considered specific enough by DAARWG for determination of a responsible entity for owning and evolving the data strategy for NOAA and that it should be called out more specifically. He also said a budget should be established with an identifiable source of funding so as to avoid cuts in the future.

Action 1.2: Ensure the CDO is represented on the appropriate NOAA decision-making bodies.

Recommendation 3: The DAARWG felt that, with a plethora of NOAA councils and committees that had data connections, this might spread the CDO too thin, and so they recommended that more thought be given to which groups really needed CDO representation most.

Action 2.1: Establish a NOAA data governance body.

Recommendation 4-6: The DAARWG felt that having both a data governance body and an environmental data management committee (EDMC), which already exists, would be confusing and counterproductive. They recommended that the plan be clearer on the scope and relationship of the governance body to the EDMC or, as another option, to rename/recharter the EDMC to incorporate the new data governance body. They suggested that if both bodies were necessary, that instead they use NOAA's nomenclature of the Data Council and have EDMC report to that entity. And they felt the CDO should be the chair of this governance body.

Action 3.2 and 3.3: Publish and Promote a NOAA data plan and maintain a comprehensive NOAA data inventory.

Recommendation 7-8: The DAARWG acknowledged that a NOAA plan for public access to research results already existed through data.gov and that the plan should avoid duplication or rework of any policies or data systems that already exist but instead look at improvements to what already existed.

The NOAA Cloud Strategic Plan: Dr. de la Beaujardiere explained that the working group felt the goals and objectives set forth in this plan were good, and he appreciated that these actions did have specific target dates and responsible parties. The plan had many actions to be accomplished in FY '21 and almost as many in FY '22. With this many steps and such a prescriptive plan, it may not be as agile as hoped for. He also noted that the plan seemed to focus on costs and security rather than the benefits that could come from the cloud.

Recommendation 1-4: The DAARWG suggested better prioritization of some of the key actions and establishment of an exploratory environment as a high priority to experiment with the technology. This would allow NOAA to identify failures and successes, which would inform follow-on actions and create better agility. DAARWG also suggested that NOAA reduce or

consolidate the number of actions and determine how the plan could be adjusted during the execution for greater agility.

Recommendation 5: The plan mentioned cloud training for project managers, but the DAARWG believed that software engineers would also need training and that they should be permitted to spend work hours and project funding on training. They suggested that this action of the strategic plan provide a greater emphasis on training for diverse constituents.

Recommendation 6-8: The DAARWG mentioned that the plan seems to treat the cloud simply as an infrastructure replacement but does not identify any new and potential benefits of the cloud for users of NOAA data, such as computing directly on high-volume data that's sorted in the cloud without having to move it. They also wondered if, aside from use of lessons learned from other agencies, if there was an opportunity to store cross-agency data in the same cloud location. The DAARWG recommended that NOAA discuss how it might leverage the more unique benefits of the cloud beyond infrastructure, if it would be possible or desirable to collaborate on data co-location with other agencies, and include language that constituted progress or success for NOAA in its cloud adoption.

Discussion

Mr. Kreider reminded everyone that whether to approve and forward this report to NOAA was an SAB decisional item. Dr. Weatherhead and Mr. Kreider both commended the report in its layout and attention to the main issues. Mr. Kreider asked NOAA attendees for initial thoughts.

Dr. Volz explained that these two areas were very dynamic right now, and there was progress seen in parallel with the issuance of the plans. He felt the DAARWG provided good, accurate feedback, though some actions were already underway. Mr. McLean also appreciated the feedback and indicated this report was a way the SAB could continue to affect change at NOAA.

Dr. Weatherhead then made a motion to move the report forward as it stands. Mr. Lenhardt seconded the motion. The motion was approved unanimously.

NOAA Response to the SAB Climate Working Group White Paper: Subseasonal-to-Seasonal-to-Decadal (S2S2D): A Pathway to Improved Prediction

Wayne Higgins, Director, Climate Program Office, Oceanic and Atmospheric Research, NOAA

Presentation

Mr. Kreider explained this was NOAA's response to a Climate Working Group (CWG) report previously completed and then passed the presentation to Dr. Wayne Higgins. Dr. Higgins noted this was NOAA's response to the report's recommendations, and he thanked the SAB and the CWG for their contributions to this paper. He provided some background, with a note that the SAB in 2019 published a paper called "Subseasonal-to-Seasonal-to-Decadal: A Pathway to Improved Predictions," in which SAB made nine recommendations with detailed approaches to inform NOAA's strategy for improving predictions at these time scales. He emphasized that the

paper should be read holistically and that, in spite of some great recommendations, legislative authorizations, appropriations, and mandates may supersede some of what he will outline.

Recommendation 1: Fund hybrid statistical dynamical models, to include contributions from machine learning, artificial intelligence, and deep learning, in order to bridge the gap between the needs of stakeholders and the current limitations of dynamical models and regional scales, especially for S2S2D predictions.

Response 1: Dr. Higgins stated that NOAA accepted this recommendation and acknowledges opportunities for additional investments in hybrid dynamical statistical approaches. NOAA is especially cognizant of support for techniques that allow the agency to implement these in close association with the ongoing dynamical model development. He added that there continues to be a heavy emphasis on underlying physical processes, especially tropical variability and working towards a seamless prediction of daily extremes out to S2S climate variability, with a view of acceleration to operations through testbeds.

Recommendation 2: Fund boundary layer chemical dynamical research to help weather forecasting and the related calculation and to use quantification of surface fluxes for air quality and climate needs.

Response 2: Dr. Higgins said that NOAA accepted this recommendation and noted that funds had been set aside and additional opportunities identified to fund research to advance understanding of chemistry and aerosols on land and ocean atmosphere interfaces. They also fund or hope to fund research on the related implications of microphysics, radiation, and air quality. He noted that there are a number of current and anticipated projects in this area focused on understanding atmospheric boundary layer processes, evaluating weather and climate models, and also improving model parameterizations, satellite retrievals, and then the routine components of the atmospheric and oceanic observing systems.

Recommendations 3 and 4: Work towards realization of an expansion of observation networks into the tropics, deep oceans, and polar oceans to obtain global oceanic biogeochemical observations through implementation of Deep Argo, BGC Argo, and enhancements in the Argo beyond the 2020 design. Restore ship time funding to support sustained observations and deployments.

Response 3 and 4: Dr. Higgins said NOAA accepted both of these recommendations as it recognized the potential to increase skill in observations, but they wanted to be sure they were the right observations, so this should be guided by theoretical considerations, including the use of OSSEs. He added that while the Global Ocean Observing System did have gaps in its systematic collection of biological observations, NOAA had opportunities and mandates to support active international efforts to address these gaps. He mentioned that to improve forecasting at decadal scales, it was important to integrate diverse and comprehensive ocean data into a useful, quality-controlled, and stewarded set of ocean observations. He said NOAA would redesign the

observing system in the tropical Pacific through the Tropical Pacific Observing System (TPOS) 2020 process, as well strategize expansion and implementation of ARGO capabilities to include BGC and Deep ARGO. Dr. Higgins concluded that NOAA would need to balance funding for ship time with enhanced use of emerging technologies, including unscrewed systems, artificial intelligence, and 'omics.

Recommendations 5 and 6: Fund global biogeochemically-sensored autonomous profiling float array [BGC Argo] and train personnel to deploy and calibrate such a network. Invest in terrestrial biogeochemical research and modeling, especially when collaborating with the United States Department of Agriculture (USDA). Collaboration between the Geophysical Fluid Dynamics Laboratory (GFDL) and the Climate Prediction Center (CPC) would accelerate improvement of terrestrial biogeochemical processes in S2S2D predictions.

Responses 5 and 6: Dr. Higgins said NOAA accepted these recommendations and agreed there were a number of opportunities for increased engagement, including with U.S. Navy, through the National Science and Technology Council's (NSTC) coordinating mechanisms such as the Subcommittee for Ocean Science and Technology (SOST), and through the Executive Office of the President's Office of Science and Technology Policy (OSTP) effort on Earth system predictability. He mentioned specific to Recommendation 6 that additional resources were needed to augment current endeavors, such as fire prediction modeling, assimilation of soil moisture and snow cover, and also improving analytical tools for causal attribution. Dr. Higgins also noted that improvements in representation of chemistry and aerosol emissions would also require additional resources.

Recommendations 7, 8, and 9: Train NOAA's workforce, academia, and commercial enterprises in the use of the Finite Volume Cubed (FV3) sphere or engine of the Unified Forecast System and invest in educational outreach and resources for this. Invest in social sciences and human infrastructure to engage sectors and communities in support of decision-making and communication of Earth system predictions. Expand capacity to assess the return on science investment using multiple metrics such as economic impacts, diversity, and number of people and locations served.

Responses 7, 8, and 9: Dr. Higgins stated that NOAA accepted these three recommendations as well and added that trainings were in development as recommended, as well as investment in educational outreach for model components. He spoke about two such training programs, the Climate and Global Change Post-Doctoral Program and the Bill Lapenta Internship Program. Dr. Higgins added that NOAA continues to enhance their social science research investments and incorporates practice-based social science where they can and will continue to do so. He closed with a reminder about NOAA's commitment to long-term studies on return on investment and reflections on this through the Office of the Chief Economist.

Dr. Higgins assured the SAB that NOAA is employing a broad approach to S2S2D prediction that continuously and holistically integrates all of the CWG recommendations. NOAA started

with improvement of the theoretical understanding of the sources and limitations of predictability in the climate system. The agency added intention to the augmentation of observing systems using the models and model-based studies to help guide and increase predictive skills. NOAA leveraged these observations to improve models in ways that increase fundamental understanding of prediction skill. Dr. Higgins then said that NOAA addressed model systematic errors through reformulation of various parameterizations with higher-resolution and improved component couplings.

Dr. Higgins then addressed a recent strategy at NOAA called the Precipitation Prediction Grand Challenge Strategy, which was approved by the Weather, Water, and Climate Board and is focused on the issue of addressing global model systematic errors. Dr. Higgins also stated that NOAA recognizes the importance of coupling all components simultaneously in order to balance the initial states and optimize the improvements in prediction. NOAA is also expanding its current S2S2D prediction system referred to as the Seamless System for Prediction and Earth System Research (SPEAR), and noted this already has incorporated the FV3 sphere dynamical core, the MOM6 ocean model, and other Earth system component developments.

Dr. Higgins talked about statistical post-processing of forecasts and projections as a critical point in the process in providing early warning and informing preparedness at these time scales. He then thanked the CWG and passed it back to Mr. Kreider for discussion.

Discussion

Dr. Weatherhead asked if any of these recommendations came as a surprise or if these were things already discussed internally and the report simply helped to prioritize them. Dr. Higgins responded that he did not find any of these to be a surprise but explained that was due to the ongoing and robust conversations they've had with the CWG in the past and he was happy to see this continue. He did appreciate the comments on coupled ensemble-based data assimilation systems as it was an area that needed additional work but would provide benefits across the timescales.

Mr. McLean stated that he also appreciated the CWG's perspective in this area and that NOAA is committed, but often the ability to accomplish certain goals like this is limited based on budget. Dr. Volz added that when the recommendations say 'do more of everything', it can be challenging with limited resources. These would require prioritization, and this can often include difficult decisions. He also agreed that it was important to have greater integration of integrated observations and models, which he noted was well received and well within the scope of what NOAA has been trying to do.

Dr. Russell emphasized NOAA was prepared to take these steps to advance their predictions and observations but were simply unable to due to a lack of funding and that this lack of funds affected not just this area but several other programs ready to be implemented. Mr. Friedman said that while they may not implement recommendations from the SAB right away, they appreciated hearing them because it enabled NOAA to raise these to a higher level with expert

support of its priorities and goals when seeking congressional approval and additional funds. Dr. Uccellini added that the research to operations process was often the most underfunded component.

There was additional conversation about the approval and funding process and the need to set priorities. Dr. Scott Glenn asked about possible ways to reduce barriers so that some of these research items could be implemented. Ms. Nicole LeBeouf responded that the new administration placed more value on NOAA and science than she'd seen before, and she saw the landscape set for potential success in better funding. It could be that personal relationships outside Department of Commerce get this point across, but NOAA was ready to make big strides in climate change and predictability. It had the science and experts needed, with further funding being the missing component. Some final comments were made in response to the financing and current political landscape.

FY21 Omnibus Appropriations Act: SAB Report on Weather Research Priorities
John Kreider, Kreider Consulting LLC and Chair, NOAA SAB

Presentation
Mr. Kreider first provided some background and actions that had been taken on the Priorities in Weather Research (PWR) study by the Weather Research scoping team and then finished with the recommended charge to the study team.

Mr. Kreider said this came about due to language in the FY21 Omnibus Appropriation Act that directed the SAB to publish a report no later than one year after the Act's enactment to provide policymakers with information necessary to prioritize investments in the various aspects of weather forecast modeling, data, supercomputing, among others, in an effort to help reduce the impact of weather, water, and climate events on the lives and livelihoods of Americans.

He shared the steps that had already been taken, beginning with the formation of a scoping team, which included Dr. Joseph and several other SAB members. The scoping team's responsibility was to recommend to the SAB a well-defined purpose, scope, and boundaries for the study team. He felt this initial scoping effort was critical because the current language was vague and broad, and the scoping team was unsuccessful in limiting the breadth of the study.

He added that the study team effort would be limited because members will be unpaid volunteers, and there are only nine months to complete the study. The scoping team concluded that if they can't change the breadth of the report and they can't change the due date of the report, then they will have to adjust the depth of detail and keep the report at a high level only.

After a few members of the scoping team met with Senate staffers to discuss intent and ask questions, they had several meetings to develop a draft charge, which the study team reviewed and finalized. It is this document that was brought to the SAB for review.

Mr. Kreider then explained that the team developed three pillars for weather research investments and that they kept these pillars broad to account not just for physical platforms or technology but also to cover people and process. The three pillars are observations and data assimilation, forecasting (including the United Forecast System, UFS, and coupled Earth system models) and information delivery. He explained that arrows connecting the pillars in both directions represented the weather information pipeline from left to right and feedback of requirements and evaluation from right to left. These three pillars are underpinned by four foundational elements - the weather enterprise, to include public and private partnerships; workforce development to include education and training; high-performance computing, such as cloud and cyber infrastructure; and science, to include physical, social, and behavioral topics.

The study team organization was developed, which consists of a SAB steering team of one to three members, an executive study team with six to nine members, and three task teams, one corresponding to each of the three pillars. The steering team will have direct connection with NOAA leadership, and NOAA will provide a support team to help out where needed. By structuring it this way, any conflict of interest were avoided and the structure provided an independent perspective.

Mr. Kreider then shared the proposed timeline for accomplishment of this task that would lead to the final submission of a report to Congress in December. Before general discussion, Mr. Kreider asked Dr. Brad Colman and Dr. Scott Glenn, who will be the co-chairs for the study team, if they wanted to add anything; they both reiterated the tight schedule and the need for collaboration between SAB and NOAA to accomplish this.

Discussion

Mr. Friedman said he appreciated the thought that went into the planning and that the structure and timing laid out looked good. He reiterated NOAA's commitment to help where it can to get this accomplished. Dr. Uccellini added that he liked the pillars in conjunction with the foundational underpinnings, and he especially liked the focus on post-processing.

Dr. Volz cautioned that as the teams go through the parallel processing for each pillar that they continuously connect to the underpinning foundational, crosscut themes throughout to ensure they properly incorporate them into the study. Dr. Colman agreed and indicated the intent was to have continuous discussions between the groups throughout the process to integrate those themes. Mr. McLean added his appreciation for the approach being used in this report for keeping it at a high level so that it wouldn't end up being too prescriptive for NOAA.

Dr. Denise Reed then asked how the team interpreted the language about providing the relevant information necessary to prioritize investments. Everything that they have developed was based on that statement, and what did they imagine the end product will look like. Mr. Kreider answered that Senate staff are looking for SAB's opinion on prioritizations, and the end product would present higher-level ideas rather than getting too detailed and giving the Senate reason to focus too narrowly without an understanding of the larger, high priority issues.

Ms. Molly McCammon next asked how they envisioned the role of the non-Weather Service line offices in the development of the report priorities and incorporating other voices in weather information. Mr. Kreider emphasized that this would be a OneNOAA effort and that NOAA leadership was sensitive to the effects of this report and that weather priorities could affect the other subject areas. Dr. Glenn added that the foundational cross-cuts would be where a lot of the overlap and opportunity for including other parts of NOAA would exist. Dr. Colman said this process would start with information-gathering, which included an across-line-office strategy.

Dr. Reed moved to accept the charge to the team as presented. Dr. Storksdieck seconded it. The charge was approved unanimously.

Public Comment Period

Dr. Decker opened the meeting for public comment. There were no public comments.

Adjourn

At 5:10 p.m., this first day of the Science Advisory Board was adjourned.

March 17, 2021

Opening Statement of the Chair
John Kreider, Kreider Consulting LLC and Chair, NOAA SAB

Mr. Kreider thanked everyone for their participation in Monday's meeting and determined that a quorum of members was present.

Climate Working Group White Paper on Advancing Earth Systems Prediction
Joellen Russell, Professor, Biogeochemical Dynamics, University of Arizona

Presentation
Dr. Russell introduced the paper. She explained that the work took just over a year and came about thanks to a group of scientists who volunteered to help NOAA and the nation in advancing Earth system predictions. They collaborated with members of the Environmental Information Services Working Group (EISWG). This work resulted in recommendations from the Climate Working Group (CWG) to NOAA on ways to expand the breadth of NOAA's Earth system modeling and extend the infrastructure and user support for the United Forecast System (UFS) to full Earth system coupling.

The paper has 22 recommendations targeted towards improving sources of predictability for the development of a seamless forecast system across all time scales. They encompass many different areas, including observations, land and atmospheric chemistry, ocean and coastal shelf, ice and inundation, operational oceanography and ocean forecasting, decision-maker needs, enhancing coordination, and model technology. Dr. Russell emphasized that improving Earth system predictions under massive climate change would need to be an all-NOAA, multidisciplinary, cross-line office integration effort that would require many priorities to be addressed simultaneously.

Land Observations:

In order to enhance NOAA's observational network to improve or assist in prediction, Dr. Russell said NOAA should incorporate additional sources of predictability and increase predictive skill to address the merits of targeted observations and process studies. The recommendation also included advancing the initialization of prediction through assessment of ongoing observation systems, preventing degradation of observational networks, and expanding and improving observational networks where Earth system prediction requires additional measurements.

Recommendation 1:
For land observations, the recommendation was for NOAA to lead coordination through multi-agency collaboration on observations of surface, deep soil, groundwater, atmospheric boundary

layer and free troposphere clouds, and precipitation profiles, which are mostly available, but not coordinated in space and time.

Recommendation 2:
The second recommendation was that NOAA develop and improve gridded snow mass data sets, to include investment in quality check of the Citizen Science measurements, in the U.S and globally, for improved model initialization of weather and Seasonal to Subseasonal prediction, especially for stream and river flows and floods over snow-covered regions..

Atmospheric Chemistry Observations:

Recommendation 3:
The CWG recommended more chemistry observations to identify major changes in the boundary layer and in the height of our troposphere and its evolution through the seasonal cycle. The goal would be to enhance land observations, with a focus on land impacts on atmospheric boundary layer structure and biogenetic dust and biomass burning aerosols and their interaction with clouds and precipitation. This work could be accomplished by NOAA initiating its own effort or through joint efforts and realignment of some of the chemistry measurement capabilities to enhance weather prediction, deposition process understanding, and climate change science.

Recommendation 4:
Dr. Russell continued with a recommendation to enhance and refocus NOAA infrastructure, including people, heavy-lift aircraft, chemical, aerosol, and radiation measurements, to help inform weather forecasts, emission quantification, societal action, climate change quantification, mitigation and adaptation, and reduce impacts of wildland fires. The CWG felt that including chemistry in atmospheric models will bring a change in Earth system prediction and understanding of how the boundary layer is evolving under climate change.

Ocean & Coastal Observations:

Recommendation 5:
Dr. Russell said the first recommendation here was to target major gaps in the ocean-observing system including shelf seas, deep and polar oceans, and the living ocean. This could be done through the expanded use of new and improved drifters, buoys, and autonomous instruments to facilitate a cost-effective expansion of the observing network below the ocean surface. This need arose from studies that have proven the ocean's value to enhanced predictability and prediction. She suggested taking an operational approach with this knowledge and understanding.

Recommendation 6:
The next recommendation shared by Dr. Russell was to ensure capability through robust observing system design projects and to implement the experiments to design networks of integrated observations and platforms, including satellites, ships, floats, gliders, and moorings for

both physical and biogeochemical parameters. These chemical parameters are needed in ocean observations to improve predictability, in addition to supporting fisheries.

Recommendation 7:
Dr. Russell continued with the next recommendation, to assess the utility of a nationwide shallow-water network of autonomous platforms, like gliders and floats, for physical and biogeochemical measurements for the shelf and coastal oceans and under ice, which are not currently available but would help to advance prediction for weather, inundation, flooding, algal bloom, fisheries, and so on.

Recommendation 8:
The final recommendation in this section was to build out the Argo network, to include deep Argo and floats with biogeochemical sensors and plan to enhance the fleet of global ocean-observing ships. Each year there are fewer ship days, with ships going out of service and not being replaced at the same rate, essentially diminishing NOAA's ability to observe and make predictions and implement new technologies.

Ice and Inundation:

Dr. Russell pointed out that ice and snow have a major impact on the amount of solar heating on Earth, and extreme weather and ocean turbulence are connected to strong temperature gradients near snow and ice. She added that meltwater from land and sea ice and river runoff were known to alter ocean stability and sea surface temperature through ocean mixing and circulation, and meltwater was a concern for coastal inundation due to sea level rise. Other factors that impact coastal inundation, such as storm surge, may compound the threat of inundation from meltwater and runoff.

Recommendation 9:
The first recommendation for this area was to create a strategic plan to implement global predictions, projections, and scenarios coupling the dynamical sea ice and ice-derived runoff components with the atmosphere, ocean, and land in global models. Sea ice and ice sheet components must have high-quality initializations for ice sheet and sea ice mass and coverage through advanced data assimilation means. Dr. Russell felt this was important to understand the global impact of the change in the amount of freshwater in the ocean versus on land.

Recommendation 10:
The next recommendation was to work towards using an ensemble of predictions from a global model for stakeholder products. Regional modeling for calculating inundation should be nested within boundary conditions from global model simulations with coupled sea ice and ice sheets for consistency in treating variability and meltwater and its influences on ocean stability and circulations. Dr. Russell emphasized that ice is missing from our predictive efforts and it has profound implications for coastal-dwelling citizens and weather.

Operational Oceanography and Forecasting:

Dr. Russell reviewed the next set of recommendations, which focused on the fact that the U.S. needs a NOAA-led ocean forecasting system that produces regional and global products to support ocean and weather predictions, the Blue Economy, with fishery and ecosystem prediction applications. Europe is much further along in its advancements in this area. She noted that NOAA is clearly positioned to take the lead on this effort because they are the only agency with a mission that includes the blue ocean.

The CWG added that applying Earth system prediction to operational oceanography will improve ocean and weather forecasts. They'd like NOAA to assimilate ocean data, including biogeochemistry, and perform ocean re-analyses, especially those including carbon, that support their predictive capability of changing initial conditions under climate, and also support verification of international carbon and other pollution emissions.

Recommendation 11:
The first recommendation under this section was to implement an open-source operational ocean forecast system using MOM6, NOAA's current ocean model, on an accelerated timeline and not wait until 2025. This system should also include Earth system prediction benchmarks that quantify ocean pH, carbon, nutrients with the intent of enabling consistent regional downscaling of ocean transport and ecosystems.

Recommendation 12:
The next recommendation was that the NOAA ocean forecast system, based on MOM6, include development and implementation of ocean data assimilation, ocean re-analysis, and a framework for coupled ocean-atmosphere assimilation and re-analysis. This does not currently exist in operations.

Recommendation 13:
The last recommendation for this category was that NOAA's current capability in regional ocean forecasting benchmarks and skills test should be applied to evaluate MOM6 global and regional simulations to accelerate the transition to robust climate-relevant timescale boundary conditions.

Decision-Maker Needs:

Dr. Russell explained that decision-maker needs to address longer timescale climate decisions were distinct from immediate hazard mitigation, response to warnings, and other weather response decisions as longer-term decisions increase in importance as climate change manifests. She also noted that there are sector-specific needs to understand what to adapt to and when. Rates of change, deep uncertainty, and abrupt changes are key elements of this decision space. These issues are also essential to understanding the limits of current hazard mitigation strategies.

Recommendation 14:

The first recommendation for this category was to enhance product specifications to include the distinctive dimensions of decision requirements for infrastructure and investment decision-making which can be influenced by progressive and abrupt changes in climate processes and timescales and how Earth system predictions can meet these needs across sectors.

Recommendation 15:
The second recommendation for this category was to develop plans to foster the continued refinement of model information and derived products at multiple timescales and spatial scales. In order to better characterize decision spaces, the Earth system prediction model outputs should be made available in combination with other decision-relevant information.

Recommendation 16:
The next recommendation was to develop a framework incorporating research and development needs informed by the end-user decision spaces. Dr. Russell said the framework should include systematic and regularized opportunities for collaborative exploration based on decision-centric benchmarks of data and product performance of new components of the Earth system prediction.

Recommendation 17:
The last recommendation for this category was that in conjunction with planning for the implementation of the Service Delivery Network at NOAA, there should be an evaluation of the appropriate level of specialist support to maximize benefits of advanced Earth system predictions. By coordination of these activities, NOAA could integrate feedback from decision-makers and users' applications into continuing Earth system prediction improvements.

Enhancing Coordination:

Dr. Russell said that Earth system prediction required interdisciplinary, cross-workforce, cross-line office collaboration and coordination to be successful, and they were concerned that the historical substructures within NOAA have made change difficult to implement, so they set forth the following recommendation.

Recommendation 18: The CWG recommended that every NOAA Strategic Implementation Plan related to Earth system prediction should include a line addressing the goals, objectives, responsible parties, and metrics of assessment relevant to the collaboration and coordination between responsible line offices within NOAA, NOAA and other federal agencies, NOAA and state agencies, NOAA and other academic and industry partners, and NOAA and stakeholders.

Model Technology:

Dr. Russell said technology will be what allows NOAA to best address the needs of the people and public for Earth system prediction information. She noted that NOAA needs to enable Earth System prediction extension beyond the 10-day forecast with better skill and similar increased

confidence, including forecasts of different Earth system areas. NOAA's accelerating adoption/ adaptation of technologies need to be informed to optimize model forecast performance while implementing a "do no harm" approach. Lastly, the CWG felt that research to operations transitions would benefit from benchmarking improvements prior to operational use by allowing competition for model performance demonstration from academic and industry teams within a pseudo-operational environment using cloud environments and advanced observations.

Cloud Computing:

Recommendation 19:
For Cloud Computing, the CWG recommended that NOAA establish agreements with cloud service providers and members of the Earth system value chain to realize benefits of cloud technology for advancing Earth system prediction. This would plug FV3 into the full Earth system model framework.

Artificial Intelligence / Machine Learning:

Recommendation 20:
For Artificial Intelligence / Machine Learning, the CWG recommended that NOAA must establish accurate and high-quality historical training data sets and indicators for trust in applying artificial intelligence and machine learning technologies to advance Earth system predictions.

Advanced Remote Sensing Technology:

Recommendation 21:
For Advanced Remote Sensing Technology, the first CWG recommendation was that NOAA accelerate the acquisition and assimilation of commercial sources of data and delivery systems along with the development of Earth Science Decadal recommended observing systems.

Recommendation 22:
The second recommendation under that area was that NOAA benchmark performance quality, productivity, and cost using proven methodologies to quantify improvements to close gaps, identify root causes for deficiencies, and inform actionable improvement opportunities.

At the end of this presentation, Dr. Russell offered to answer any questions the SAB might have about the report.

Discussion
Mr. Kreider congratulated the CWG for creating such a comprehensive report on Advancing Earth System Prediction. He also noted that while he was impressed with such a comprehensive report, he was concerned that NOAA would be overwhelmed by 22 recommendations without prioritization. He suggested the CWG identify three of the most leveraging priorities that would

provide better guidance to NOAA on where they could start with advancing Earth system predictions.

Dr. Russell replied that while the CWG's concern was that limiting the recommendations too much might de-emphasize some and would potentially slow progress as a whole since this was an all-NOAA, multidisciplinary, cross-line office integration effort. The CWG is deeply knowledgeable about NOAA's capabilities and their potential progress, and that's why they created such a comprehensive report. She added that the CWG was one of the few Federal Advisory Committee Act groups that serve in climate, and they didn't feel that limiting the recommendations would strengthen the paper or its usefulness to NOAA or the nation.

Dr. Glenn spoke next and said he appreciated that, in spite of how comprehensive the report was, he could easily see where he would fit into the report and have an impact, and there were likely a lot of other people who would also see their roles, and so he felt it was successful as a high-level organizer for preparing NOAA to tackle this issue. Dr. Kirstin Dow responded that the CWG had considered an organizational systems view so that one recommendation didn't get held back because another element somewhere else hadn't been considered a priority.

Dr. Reed asked if the report at any point suggested NOAA stop doing something they were currently doing and instead pivot to another priority. She also asked if the prediction system that the CWG was suggesting would provide boundary conditions in a consistent and useful framework for those working on the ground with more localized predictions. Dr. Russell said the goal would be to bring all the regional models together and integrate them into a nested framework that was consistent across NOAA and allow all the observations and benchmarks to improve overall predictions so that information gained through regional modeling improved global model development and vice versa.

Dr. Bob Grossman then asked what percent of additional resources would be required if NOAA were to implement all these recommendations. Dr. Russell responded that eventually all the items on this list would be addressed in the long-term by NOAA, but it needs to happen much faster to prevent loss of life and property. She estimated that NOAA would need an additional $5 billion over the next five years. Dr. Russell was of the opinion that NOAA has the dedicated personnel needed to accomplish these goals, and so it's really about how quickly they can be completed, and with additional funds, she thought they could be accomplished much sooner.

Dr. Weatherhead suggested that by looking at what is happening internationally, NOAA could better focus on what the U.S. and NOAA could be responsible for and potentially prioritize the recommendations in that way. Dr. Russell was persistent that the CWG did not wish to prioritize the recommendations. She noted that the U.S. accounts for more than half of the floats, gliders, and other measurement tools out in the world, and while the international contributions and collaborations are important, the U.S. needs to take a leadership role, and implementing these recommendations are how that will be accomplished.

Dr. Uccellini gave some history about the ocean model developed starting in 2005 called the Hybrid Coordinate Ocean Model (HYCOM), noting that it was developed following SAB recommendations at that time, which now serves as boundary conditions for some National Ocean Service models and all of the hurricane models. He emphasized that the recommendations regarding operational oceanography and forecasting weren't really starting from ground zero. He also mentioned that for supporting decision-makers, the Weather Service has developed a way of influencing federal, state, and local decision-makers through Impact-Based Decision Support Services (IDSS). Generally he thought the climate community should pay attention to IDSS for some of these items and not attempt to build from the ground up. Dr. Russell acknowledged the great work that had already been done and clarified that the recommendations would take those systems and improve them so they could be expanded to Earth system predictions.

Mr. McLean said he could see where the recommendations would lead NOAA. He understood why priorities were not given, but by having these laid out the way they were, this report covered everything with respect to showing Congress what the SAB sees as incredibly important elements. He appreciated that the SAB would be giving NOAA the opportunity to prioritize the recommendations themselves. Dr. Russell responded that the CWG wanted to get this in front of the new administration as soon as possible to show that an across-line-office, all-hands NOAA effort was what's required to make real progress for the health and well-being of the country. Dr. Dow added that the CWG approach acknowledged the slow movements in adaptation around the world and they didn't want this country to move at a similarly slow pace. With the report, they hoped to instill a sense of urgency around a coordinated approach.

Ms. Nicole LeBeouf commented that she has often been faced with two competing temporal scales with the need to act quickly for our resources and with the length of time that it takes for people to change their behaviors. She thought Dr. Dow was spot on with her comment. Ms. LeBeouf also noted that she appreciated the lack of prioritization on this list and also believed all of it was necessary to bring light externally to what was needed for a fuller Earth operations approach at NOAA, but perhaps some advice could be given on which recommendations could more greatly leverage other recommendations. Dr. Russell reiterated that they tried to do something along those lines but couldn't extract anything because they felt everything was equally important. Further, hey didn't want to give Congress the opportunity to pick a couple of "low-hanging fruit" without understanding how all of these work together.

Mr. Kreider brought the discussion to a close and limited comments to SAB members only as they decided how to proceed. Dr. Storksdieck suggested they transmit the report as is to NOAA with a letter suggesting it can be NOAA's internal decision to decide how to prioritize the 22 recommendations. Dr. Joseph agreed with that suggestion and moved to accept the report and transmit as is. Dr. Weatherhead seconded the motion. With acknowledgment that the report would be transmitted with a letter explaining that NOAA should prioritize internally as well as acknowledging the comprehensiveness of the report, the motion was approved unanimously.

Ecosystem Sciences Management Working Group Report on Decision-Making Under Deep Uncertainty (DMDU)
Lisa Wainger, Research Professor, University of Maryland Center for Environmental Science, ESMWG Co-Chair

Presentation
Dr. Wainger gave an overview of the report. The project was initiated by the Ecosystem Sciences and Management Working Group (ESMWG) itself, not requested by NOAA, and, therefore, the working group kept the report fairly simple. The report attempts to answer the two questions of what is decision-making under deep uncertainty and how might NOAA use it. She said the group eventually defined deep uncertainty as what occurs when 1) the likelihood of future events and outcomes cannot be characterized well with existing data and models, 2) the uncertainty can't be reduced by gathering additional information and 3) stakeholders disagree on the consequences of actions.

She then explained that there was a range of techniques that could be used under DMDU which were difficult to generalize, but the common goal between the different techniques was to identify decisions that would succeed under a wide range of outcomes even if they may not be very likely. Dr. Wainger added that it was not about making your best guess but about making a guess that covers not just the most likely outcome but also works in the case of an unlikely outcome. The techniques vary from qualitative to very complex models.

She explained that a common element of DMDU techniques entails engagement with stakeholders from beginning to end in order to get multiple feedback sources about what models and data are needed so that everyone has confidence in the analysis and are engaged in the scenarios to run. She added that one of the advantages to DMDU is the structured approach to scenario development that incorporates uncorrelated drivers of change and then presents scenarios that capture all the drivers and ultimately produces optimal actions one can take for any event.

Dr. Wainger also stated that these can be utilized in a more piecemeal fashion by stress-testing a recommended action but that generally the goal of DMDU was to understand and attempt to minimize any regret if resulting actions are wrong. Regret is measured by what the stakeholders see as important. She said DMDU incorporates an element of dynamic planning, meaning it has an adaptive characteristic that looks towards how to optimize decisions through time.

She addressed the differences between DMDU and a well-done risk assessment with a lot of sensitivity analyses and explained the differences are subtle but that DMDU might not be the right choice for simple or well-constrained systems. Dr. Wainger explained that as uncertainty increases and the stakes increase, DMDU becomes more advisable to use to know the cost of being wrong is as the cost of investments increases, and as the sensitivity of one's decisions to

uncertainty evolves. She also noted that with probabilistic risk assessment one wants a best-guess solution and is bound to an assumption that one knew how probable a future event was, while DMDU allows one to imagine outcomes without needing to evaluate the probability distributions, instead testing how well the solution performed under various conditions.

Dr. Wainger then moved to the potential benefits of DMDU for NOAA. One benefit is that DMDU helps avoid unintended or unanticipated consequences by seeking low-regret solutions. She gave a second potential benefit as possibly decreasing risk mitigation costs because the tool allows one to use risk triggers to determine timing and sizing of actions. These can be planned around the pace at which an element changes so at any point there is a path to follow, and as the situation becomes more dire, the path becomes more urgent and serious.

Dr. Wainger then discussed recommendations for DMDU usage developed in the study. It could be used as part of the Marine Strategy Evaluation or Management Strategy Evaluation used by Fisheries, where some risk-based planning is already being used. DMDU could be used to take a more systematic approach and improve the decisions being made. Also, DMDU is most commonly used to inform coastal planning; he mentioned a handbook produced by the New Zealand government for guiding local governments in coastal planning that suggests DMDU techniques throughout. Dr. Wainger referenced the prior Earth system prediction discussion and noted that it can be intimidating to make high-cost, low-confidence decisions but that DMDU was specifically designed for that situation.

The second recommendation was that DMDU could be used to design monitoring programs since it creates various models. The models allow you to figure out which uncertainty is most useful to reduce in terms of changing a decision, not just making the model better. The ESMWG recommended that NOAA develop guidelines and data to enable systematic scenario development.

Dr. Wainger next discussed steps NOAA could take to initiate a broader discussion about how DMDU could be used. If the agency wanted to move forward, it would need to identify where there are other promising areas of DMDU application. NOAA would then need to identify research needed to develop guidance on application of DMDU within the agency's work. Finally, Dr. Wainger introduced the other members who worked on the report and thanked them for their input. She closed with the thought that DMDU had its place in risk analyses where diminishment of regret was a high priority.

<u>Discussion</u>

Dr. Storksdieck praised the report and also noted some additional benefits of DMDU, which include the stability of decisions, the trust in them, and the broader buy-in from stakeholders. Since it allows negotiation on what people agree on, it is more community-conscious than a standard technology or technocrat-oriented decision process. The formality of the process also allows people who take part in it to understand what they're doing. He strongly recommended that NOAA look more deeply into where it can be applied. Dr. Uccellini also commented on the

quality of the report and believed the concept could be of use by the Weather Service. He acknowledged that this was a more rigorous foundation than the current Impact-Based Decision Support Service (IDSS) NWS currently uses and could be of benefit to improving that. He emphasized that he looked forward to learning more about DMDU.

Dr. Reed informed the group that the State of Louisiana had used DMDU for its coastal master plan approach for ten years and it had been well accepted by stakeholders. They understood the uncertainty better than the baseless decisions that were sometimes made when there clearly wasn't enough evidence. She also requested that some of the experts speak to the SAB on the water and weather field examples where DMDU was utilized that were noted in the report.

Dr. Werner reiterated some of the previous points, specifically about involving stakeholders from the beginning of the fisheries management strategy evaluation process, adding that he thinks it's very important for the trust aspect of decision making. He added that NOAA was probably attempting some of this a bit naively, but he appreciated the systematic way the ESMWG outlined the process. He saw it could provide help to managers as they make decisions by providing possible outcomes, even if they are uncertain.

Dr. Friedman added that NOAA does a lot of large projects with risk management and he felt that one of the biggest issues with this was that there were often a lot of unknown variables and the best judgement doesn't always suffice. The adaptable framework DMDU provides could be more helpful in developing these approaches. Dr. Wainger responded that they believed the best way to incorporate this process into NOAA was through development of some data pieces, or scenarios, and creation of a systematic approach model that can then be adopted by several groups for a smoother transition.

After a few additional comments that reiterated much of what had previously been said, Mr. Kreider asked if there was a motion to approve this action item. Dr. Reed moved to approve the report. Dr. Grossman seconded the motion, and with no further discussion or opposition, the motion was passed unanimously. Mr. Kreider added that it would be transmitted with a letter that emphasized SAB's support and the number of applications it made available to NOAA.

Environmental Information Services Working Group Update on Focus Area Topics
Brad Colman, Director of Science, Weather Science, The Climate Corporation
Scott Glenn, Director of Accounting Operations Division, NOAA

Dr. Glenn and Dr. Colman explained that this was a quick update on the focus area definition process the Environmental Information Services Working Group (EISWG) has been working on the past year. They wanted to update what topics EISWG decided on, their process, and get input on next steps. He added that the group's motivation in defining the focus areas was to create sub-groups more easily within the EISWG in an attempt to get more done each year. This would allow the working group to move from being more reactionary to being more proactive and to provide the best support to the SAB.

Dr. Glenn briefly described the process they went through. The EISWG took a virtual collaborative approach where ideas could be shared, comments could be made, topics could be voted on, and then grouped into five overarching categories. Many of these topics directly map onto the study areas that the SAB is interested in. In parallel, they developed criteria to rank and prioritize the categories. Those topics that were prioritized at the top were more general items that a larger group of people could see themselves contributing to, for example next generation warning systems and emerging technologies. Towards the middle of the prioritization list were some areas that cross-cut across other topics, like workforce, social sciences, and support for rural indigenous populations. While Dr. Glenn said these items were important, they likely fell in the middle of the rankings due to fewer experts available to take the lead. For each topic, the EISWG created one-pagers that included objectives, the value, the scope, the boundaries for each of the topics, and the steps the working group could take to contribute a report or recommendations.

Dr. Glenn then shared observations they made through the process, and while they felt it was an important process, they acknowledged it did leave some items at a lower priority simply because they had fewer topical experts. Some of the top priority topics were quite broad, but when the one-pagers were written, the scope of the topics was narrowed down. Dr. Glenn added that all the work done for these topic areas had come from the EISWG wanting to be more proactive and productive, which resulted in monthly meetings. Dr. Colman added that they would like to get to a point where the planning process didn't take a full year, and so that is part of the feedback they hope to gain from the meeting.

Dr. Glenn finished the presentation by sharing what they hope to gain from the discussion. Examples were provided. He again emphasized that the cross-cut elements that were ranked as mid-level priorities, including workforce and social sciences, would be included throughout the other products developed by the EISWG. Dr. Colman added that the most valuable piece to come out of this was the establishment of sub-panels so the subject matter experts could focus on their topics and allow more to be done overall.

Discussion

Mr. Kreider stated that he believed spending time on the process was an important part of getting work done and while it took time, it resulted in people unifying and being more engaged in discussion and debate, which in turn resulted in better outcomes. He added that it was aimed at a balance between the time for process and then getting to work. Mr. McLean suggested that NOAA improve the timing for when the EISWG is consulted on the NOAA reports to Congress as they were developing, early enough to get EISWG's reaction before NOAA moved forward and then EISWG's response became rushed.

Dr. Colman responded to Mr. McLean that, unfortunately, there really wasn't much NOAA could do, because the EISWG was not made up of Special Government Employees and therefore they could not access pre-release material, and oftentimes that meant waiting up to two years for

the reports to make it through Department of Commerce before coming to EISWG. Mr. McLean suggested they look into it and see if there was a way on the agency side to adjust the pathway a bit to allow a Congressionally-authorized body to review pre-release materials. Dr. Colman finished off by noting that NOAA has always been very responsive to the EISWG's requests when having informal conversations.

Dr. Volz suggested that when it comes to the cross-cuts that were of a lower priority, but still of interest to everyone in the EISWG, those components could be included in report responses and with thoughts on how that subject area could affect, as an example, the workforce. This would allow the cross-cut elements to be included while not being the main focus of a report. He also noted that the EISWG ranking seemed to have a disconnect between emerging technologies and technologies that had been in development for a decade and were finally just coming online, for example satellites. A technology may not by definition be brand new, but it could finally reach a point of usefulness and need to be included in the discussions on how these technologies could be used. He noted that the emerging technologies and the investment in major technologies are connected in the minds of those working on the investment side as those programs get defined. Dr. Glenn followed up that the emerging technologies one-pager had a focus on satellites and the EISWG agrees that satellites are included in emerging technologies.

Mr. Kreider asked next what EISWG's free bandwidth was, given the priorities in weather research (PWR) report and other responsibilities. Dr. Colman explained that they have very little extra bandwidth now that they would be helping with the PWR report from the Omnibus Appropriations bill. Now all the time they spent on picking the EISWG focus area topics was overshadowed by this bigger priority. He did mention, though, that there was a lot of overlap between the report and the focus area topics, and they could address some of them as they pushed forward on the PWR report. Dr. Glenn added that the EISWG will be deciding how to move forward on the PWR report now that the scoping document has been approved.

Dr. Uccellini commented about the idea of using cross-cut elements throughout the EISWG's activities and how that could also be a valuable process by cross-cutting across different SAB products, specifically noting the ESMWG's Decision Making Under Deep Uncertainty report and its linkages to social and behavioral science.

Update on the SAB Work Plan Priority Topics
Ben Friedman, Deputy Under Secretary for Operations and Acting Administrator, NOAA

Mr. Friedman explained that with the administration change, there had been a change in the priorities and focuses for NOAA, and so, when looking at the list of SAB priorities, there were a few areas they wanted to continue ahead with but others they may want to modify or refocus. He noted that they would like the SAB to continue to focus on coastal resilience, Earth system prediction and predictability, and prediction of Earth Systems at seasonal/subseasonal timescales. Mr. Friedman continued by adding that while integrating social and behavioral sciences into every NOAA mission area is important, it might be better to modify that effort to specifically

start thinking where the social and behavioral sciences can be incorporated into Earth science or how it can be more useful. He also noted that the application of emerging science and technology topic that could also benefit from being modified. Mr. Friedman suggested the SAB should not pursue at this time the assessment of NOAA's capability to understand regional sources of environmental impacts.

Dr. Karen Hyun, the current top political appointee at NOAA, spoke next and added that she felt they were in a good place with this administration to push forward on the work they were doing, especially the pieces centered around climate change. She added that the work they've already done on Coastal Resilience will help push forward that conversation on policy, inter-agency work, and develop credibility with the White House and the Hill in regards to getting the budgets needed, which went back to Mr. Freidman's earlier point on aligning NOAA's priorities with those of the administration. She noted that they were suggesting minor changes to the SAB priority topics to better align with how NOAA leadership sees themselves positioning NOAA in this administration.

Dr. Joseph commented and said he appreciated the fact that amid this transition they were still allowing the SAB to move forward, noting standstills in the past with administration changes. Mr. Friedman responded and by assuring the SAB that there was no desire at NOAA to shift focus since they feel the SAB had developed priorities that would further NOAA's mission even with a few adjustments. There were a few additional comments made by Dr. Storksdieck and Dr. Werner, followed by discussion on how some of the topics could be changed to better fit the administration's priorities.

Dr. Reed and Mr. Friedman also discussed that the goal of this conversation was to finalize what it was NOAA wanted in order to get everyone moving forward without further delay. Mr. Friedman again reiterated that he wants the SAB to move forward with these priorities, and he continues to believe the results would be extremely useful to NOAA.

Mr. Kreider summarized the five current priorities, and it was agreed that the SAB could proceed based on the feedback from NOAA.

NOAA Response to the SAB Data Archive and Access Requirements Working Group Report Report: Preparing for a Cloudy Future
Tony LaVoi, Acting Chief Data Officer, NOAA

Presentation
Mr. LaVoi explained that the Preparing for a Cloudy Future report was submitted to NOAA in 2019 and that this response was supported by members of the NOAA Environmental Data Management Committee and the Science and Technology Strategy Teams. He noted that the purpose of the presentation was to provide examples of progress and directions that they were headed based upon the Cloudy Futures report. He also noted that he would provide alignment between the recommendations and NOAA's Science and Technology strategies.

Mr. LaVoi spoke about how NOAA had evolved in terms of its adoption of cloud and cloud technologies and broke down that advancement into four categories: planning, execution, innovation, and training support.

For planning, Mr. LaVoi referred to the NOAA Cloud and Data Strategies and the other four Science and Technology (S&T) strategies that all leverage these two. For execution, he spoke about creating a NOAA Enterprise Cloud Committee that was focused on operations and was comprised of individuals from all the line offices. They also had three major contracting vehicles that were actively being worked on, the cloud utility contract, Big Data Program, and a high-performance computing contract, with the ultimate goal to leverage shared services and data throughout the line offices rather than each office having its own closed system. Mr. LaVoi also noted that all NOAA line offices were at some level of cloud adoption.

In innovation, Mr. LaVoi spoke about the National Environmental Satellite, Data, and Information Service's (NESDIS) common cloud framework as well as the Google artificial intelligence test that was underway. And he mentioned that overall they had a strong commitment to training and support so NOAA personnel were ready to use the technologies as they came online.

Mr. LaVoi then shared the four recommendations that came from the DAAWRG report. The first one was to prepare analysis-ready data sets. The second one was training researchers to work in the cloud. The third was to prepare training data for machine learning. And the fourth was to have agile cloud development. He explained that, in response to the report, they were ensuring that all of the SAB recommendations made their way into the operational plans focused on data, the cloud, and artificial intelligence (AI).

Mr. LaVoi then gave a few examples of how they were proceeding based on the report. He explained that while NOAA had been participating in an interagency group, it has not yet set an overall federal community standard for moving towards AI-ready data. However, while waiting for the standard, NOAA had been working with the Earth Sciences Information Partnership (ESIP) and were actively working towards the potential development of an AI-ready "sandbox" (community-accessible space) where NOAA and other ESIP participants could work collaboratively to continue to build out their understanding of what a potential AI-ready data standard might look like.

He also spoke about the desire to have 80 percent of the standard set by the end of 2021, and then long-term they would like to have an international or national standard body to adopt that AI-ready standard. He also noted that NOAA had created an internal high-performance computing testbed for its internal projects, and they had put forth a project proposal for with a continuation of the AI-ready data efforts.

Mr. LaVoi then spoke about the Big Data Program (BDP), which was a cooperative research and development agreement from 2015. The relationship turned out to be successful and led to signing contracts with Amazon, Google, and Microsoft just over a year ago, and it was now an operational NOAA program. NOAA has established some stability by putting in place a long term, 10-year contract and forming a strong contractual relationship. This specifically addressed the Cloudy Future report by making eight petabytes of data available through the three cloud service providers, which already contain 145 individual NOAA data sets. He noted that this was a direct result of SAB recommendations. He cautioned, though, that there has been limited success doing data transformations to move current and past NOAA data to the cloud since resources are limited. NOAA recognizes this is a critical future activity that would increase the usability of data. He noted that NOAA is continuing to move as much data to the cloud as possible.

Mr. LaVoi moved on and addressed specifically the Google AI and Machine Learning (ML) agreement, which addresses Recommendations 1 and 3 of the Cloudy Future report and the importance of developing testbeds. He gave some background about this agreement and noted that this was the first official Other Transaction Authority (OTA) agreement NOAA has entered into; it is a contractual agreement between a government agency and a commercial entity in which both parties agreed to jointly contribute effort, resources, and funding to create a work product.

Through this OTA, NOAA's first goal was to test whether this was a good relationship type. From a technology standpoint, NOAA has three specific goals for the OTA. The first is to increase NOAA skillsets and exposure for NOAA scientists and information technology staff to the Google AI/ML subject matter experts to continue to build the expertise within NOAA; this ties into workforce development. The second was to jointly develop code, to which NOAA would have unlimited access. And lastly, Mr. LaVoi added that NOAA would address some of the challenges they experienced with big data, "nowcasting" and numerical weather prediction.

Mr. LaVoi addressed Recommendation 2, increasing cloud proficiency in the workforce, directly and assured that all of the S&T strategies NOAA is developing has a strong emphasis on workforce development, as do the Information Resource Managements (IRM). As NOAA works to educate the current workforce on the new technologies coming, the agency has also had the opportunity to diversify the workforce and its partnerships.

He highlighted three additional items that also speak to the Cloudy Future recommendations, among them the NOAA Center for Artificial Intelligence, a partnership with the NOAA office of Education exploring internship and training opportunities, and NOAA's leveraging of joint expertise in collaborative investments through cooperative institutes.

Mr. LaVoi then spoke about the Graphics Processing Unit (GPU) Hackathon held in December in partnership with NVDIA and through NOAA's High-Performance Computing Program. There were over 100 participants. A couple of the teams used the National Centers for

Environmental Prediction (NCEP) FV3 GPS modeling system and the code they could obtain through the GitHub and were able to expand that during the Hackathon. He added that they were planning the next Hackathon event since the NOAA Citizen Science Strategy identified Hackathons and similar events as a best practice in continuing to address infrastructure issues and science challenges.

Mr. LaVoi concluded his presentation and opened the floor to discussion.

Discussion

Dr. De la Beaujardiere offered to get the National Center for Atmospheric Research (NCAR) together with NOAA to chat about collaborating on conversion of cloud-optimized R format and what might constitute AI/ML. Mr. LaVoi thought that would be a good idea, especially since many of the key staff of the NOAA Center for Artificial Intelligence were also located in Boulder, CO.

Dr. Grossman noted that the data that NOAA does have on the cloud is a good opportunity for both the community experience with this type of data and the broader community. He asked how NOAA was imagining evolving search and discovery for outside communities who won't know where everything is located. Mr. LaVoi explained that, at the moment, efforts were focused on setting up NOAA internally through the NOAA Data Catalog and NOAA OneStop. The agency is also looking at implementing a pilot NOAA Data Lake where they could implement some of the cloud catalog techniques within the Amazon Web Services (AWS) environment. But NOAA does not currently have a coordinated effort between the cloud service providers (CSP) for external search and discovery for data; at the moment NOAA is simply utilizing standard outreach when a new data set is added, and as the data grows, NOAA will have to look at a multi-cloud search-and-discovery platform for external usage.

Dr. Volz added, in regards to the CSPs, that the main goal would be for NOAA scientists to process their data in the cloud so people could use what is available there available for data-driven science and application development. With the limited amount of data available at the moment, most people quickly download the data they needed access to, but the goal is to push forward and get to the point of processing in the cloud environment. He also mentioned the AI workshops taking place weekly are well attended and already being utilized by industry and community experts to determine how AI can be used in environmental applications. Getting all the data into one format and one place where everyone can access it is a slower process.

After a final comment by Mr. LaVoi on the CSPs and the continued goal to get data uploaded so that third-party consumers could access and process it in the cloud, Mr. Kreider ended the discussion and moved to the next presentation.

Updates from the SAB Working Groups

John Kreider, Kreider Consulting LLC and Chair, NOAA SAB

Mr. Kreider informed everyone that the third meeting of the working group co-chairs occurred on February 23. One of the topics they discussed was the extent of working knowledge SAB members have on what the working groups were actually doing. There is difficulty in continued conversation after the SAB meetings end due to the virtual format. Because of this, he explained the co-chairs decided to dedicate 15 to 20 minutes at every SAB meeting to go through the important items they were working on.

DAARWG: Dr. De la Beaujardiere, as co-chair of DAARWG, gave a quick overview. He spoke about the trouble with membership as the group hovered at the very bottom level of the desired number of members, so they have started the process of looking for new members. He then moved on to share activities since the last meeting, including approving him as a new co-chair and working on feedback for the cloud and data implementation plans. Lastly, he spoke about items they would like to continue working on, like building relationships with NESDIS, NCEI, and the new AI center. He also noted that DAARWG was interested in data access, data governance, hosting science data in the cloud, and ensuring that data is properly archived and stewarded for the long term. He added that they would also like to identify additional topics beyond those for involvement and also the group would like to branch out from NESDIS and work with other line offices, as well, who may have more unique data types.

Mr. Christopher Lenhart added quickly that the group is looking for candidates with capabilities that align with some of the priorities that had been set. He also said that as far as future goals, AI/ML archival algorithms could be a future topic to consider.

CWG: Dr. Kirstin Dow, as co-chair of the CWG, mentioned that its recent major accomplishment to share was that they have brought in new members, Ali Omar and Kwabena Asante. They asked for a one-year extension for Rong Fu since they needed her topical system expertise. Dr. Dow also mentioned that Paul Fleming would be rotating off and that the group had 11 members total. As far as what they had done since the last meeting, she mentioned the joint working session with EISWG on the NOAA service delivery and decision support effort. They plan to continue this collaboration and review the seasonal and sub-seasonal forecast report from NOAA along with EISWG. They're leaving some room to respond to the Climate and Fisheries Initiative Implementation Approach and the Coastal Inundation and Climate Time Scales white paper, if asked. In the immediate future, they are finalizing content for their next meeting in April.

EISWG: Dr. Colman, as co-chair for the EISWG, mentioned that the big activity for them was the PWR report and their annual report to Congress, which they were looking to restructure and reformat in an effort to optimize the information in it. They were working on a couple of studies, including reviewing a radar gap study report released by NOAA in response to the Weather Act. Then they would also like to take the fast approach they took with the EPIC report and apply it to a Weather Service dissemination issue since more and more dependency has developed by both private and public services for the data flow from NOAA Weather Service. They have had

several meetings with Weather Service leadership to help them make some emergency fixes, but a long-term solution is still pending and could include throttling the data flow to some of the heavier users. Dr. Colman anticipated the EISWG bringing the issue to the SAB sooner than might otherwise be accomplished through the current timeline since the issue is urgent.

ESMWG: Didn't present because they provided multiple presentations in the course of the meeting.

Next Meeting Discussion
John Kreider, Kreider Consulting LLC and Chair, NOAA SAB

Mr. Kreider discussed the next meeting and explained that it would be in the July/August timeframe and would be virtual, with hopes of having an in-person meeting in the fall. There was a request by Dr. Reed to have some time in the next meeting to discuss some potentially emerging issues in some sort of depth; the past few meetings had been so full of report presentations. It was agreed that in order to accommodate that, the SAB will look into making the next meeting three shorter sessions as opposed to two longer ones.

Review of Actions
Dr. Cynthia J Decker, Executive Director and Designated Federal Officer

Dr. Decker reviewed all the actions:

- Consent calendar approved.
- SAB Accepted the DAARWG report on the NOAA Data and Cloud Strategic Plans and will transmit to NOAA.
- SAB accepted the proposed charge to the priorities for the weather research study team; the SAB and EISWG will move forward with that.
- SAB accepted the Climate Working Group report on advancing Earth system predictability and will transmit it to NOAA.
    - The transmittal letter will include some of the key points raised at the meeting, including prioritization, urgency, and the comprehensive nature of the report.
- SAB accepted the ESMWG report on decision-making under deep uncertainty and it will be transmit to NOAA.
- SAB priority topics will be adjusted. While three will be maintained, there will be some changes to two of them, and one will be dropped.
- The next meeting will be virtual, but they will work on developing shorter sessions and leave room for open-ended discussion.
- Schedule a call with a few of the members who want to pursue DEI actions.
- Identify people to chair the study topics and start moving forward on them.
- The SAB will consider whether and how to work with NOAA on recommended actions for leveraging partnerships with academia and the private sector.

Mr. Kreider reminded the SAB members that they had an executive session following this meeting, but they opted to take a break before it began.

Adjourn

At 4:20 p.m., this meeting of the Science Advisory Board was adjourned.