

**65th Meeting of the NOAA Science Advisory Board
July 10-11, 2019
Meeting Minutes**

Location: Hyatt Regency Seattle
808 Howell Street
Seattle, Washington

Presentations for this meeting have been posted on the Science Advisory Board (SAB) website:
<http://www.sab.noaa.gov/SABMeetings.aspx>

SAB members in attendance:

Ms. P. Lynn Scarlett, Vice President for Policy and Government Relations, The Nature Conservancy (Chair); Dr. Michael J. Donahue, Vice President and Director, Water Resources and Environmental Services; 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. W. Christopher Lenhardt, Domain Scientist, RENCI University of North Carolina Chapel Hill; Dr. Steve Polasky, Professor, Department of Applied Economics, University of Minnesota; Dr. Denise Reed, Professor Gratis, Pontchartrain Institute for Environmental Sciences, University of New Orleans; Dr. Robert Rheault, Executive Director, East Coast Shellfish Growers Association; Dr. Martin Storksdieck, Director, Center for Research on Lifelong STEM Learning and Professor, College of Education and School of Public Policy, Oregon State University; and Mr. Robert S. Winokur, Consultant (ret. NOAA, Navy)

NOAA senior management and Line Office representatives in attendance:

Mr. Kevin Wheeler, Deputy Chief of Staff for Policy, Office of the Under Secretary; Mr. Craig McLean, Assistant Administrator for Oceanic and Atmospheric Research; Scott Lundgren, Emergency Response Division Chief, Office of Response and Restoration, National Ocean Service; Dr. Hendrik Tolman, Senior Advisor for Advanced Modeling Systems, National Weather Service; Dr. Eric Kihn, Ms. Michelle Mainelli, Director, Office of Dissemination, National Weather Service; Dr. Cisco Werner, Chief Science Advisor, NOAA Fisheries.

Staff for the Science Advisory Board in attendance:

Dr. Cynthia Decker, Executive Director and Designated Federal Officer; Ms. Elizabeth Akede; and Ms. Caren Madsen

In attendance via webinar:

Dr. Neil Jacobs, Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of the Under Secretary of Commerce for Oceans and Atmosphere.

July 10, 2019

Opening Statement of the Chair

Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

Lynn Scarlett welcomed the attendees to the meeting and highlighted the decision items for the Board on the day's agenda.

SAB Consent Calendar

Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

- April 2019 SAB Meeting Minutes
- June 2019 SAB Teleconference Meeting Minutes
- Working Group Status Reports
- EISWG New Members

Dr. Donahue made a motion to accept the items on the consent calendar; Dr. Storksdieck seconded the motion and it passed unanimously.

NOAA Update

Dr. Neil Jacobs, Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere

Summary

Dr. Jacobs provided a brief status update on the EPIC (Earth Prediction Innovation Center) program. NOAA has completed a draft internal white paper on EPIC and will host a workshop on the program in Boulder, CO, August 6-8. Dr. Jacobs reviewed the draft agenda for the workshop and sought comments on it from the SAB. The white paper will be distributed at the workshop in hopes of getting further input from external stakeholders which will be included in a request for proposal (RFP) to be released late summer/early fall to assist the agency in figuring out where EPIC will reside. The Global Forecast System (GFS) is now running in full on both Amazon Web Services (AWS) and Windows Azure cloud computing platforms. Google is running the core part of the model, but not the data simulation components.

Discussion

Chair Scarlett asked Dr. Jacobs to provide an overview of EPIC's key goals, as well as priorities, gaps, and needs the program will address. Dr. Jacobs said the Weather Research and Forecasting Innovation Act requires NOAA to make GFS a community model, which is not a trivial task given the complexity of the code and the systems required for job scheduling and other tasks. Currently the code can only be run on NOAA's machines, so it needs to be transitioned so that it can run externally. EPIC will be a virtual center for managing community model development for improvements to the global modeling system. Cloud vendors have helped port the code over at their own expense because they saw this as a good way to grow their customer base if they could make it user-friendly enough to attract to users. NOAA hopes to construct this so that it is system architecture agnostic.

Compute resources have been the biggest limitation to NOAA's weather prediction. It is very cost-effective to do surge development work in the cloud when running many experiments in a short amount of time. Not only does NOAA want to port all of the code over to the cloud so they can harness the intellect at the universities for crowdsourcing and model development, but it also makes sense internally for on-demand parallel surge development. NOAA is way behind the curve internationally when it comes to how much research compute they have available to their

scientists. Being able to spill over into the cloud and scale up to whatever size you need, then scale back again is a major benefit. NOAA is currently constrained by on-prem hard iron and have scientists waiting months to run their experiments. Visiting scientists that come from universities or other international centers that want to do development work on their systems have been waiting months or years to get security clearances to get access to NOAA's machines. A workaround involving an external sandbox followed by a detailed scrubbing of the code for secure ingest has been put in place. NOAA has been relying on industry to store many of their datasets and have found that due to their size, they can't be moved off the cloud vendors in a reasonable amount of time. These companies have begun co-locating a lot of their development work and their processing of NOAA data for their products and services, buying time on the same cloud vendors so their algorithms can be adjacent to NOAA data. By allowing cloud vendors to host NOAA data, they are driving business to them. In return, NOAA asks for discounted egress fees for internal use and also credits for cloud high-throughput computing (HPC). EPIC is fully funded in the FY20 budget and if there is a continuing resolution, NOAA has other ways to fund it through the Joint Technology Transfer Initiative (JTTI) and NESDIS STAR (Center for Satellite Applications and Research).

Craig McLean noted that Dr. Jacobs has brought an industry mindset to the NOAA community and is helping the agency get better bargains from HPC providers. To be able to extract some benefit back to NOAA is a positive step. He also commented on NOAA's difficult relationship to the Department of Commerce in terms of support their scientific objectives. NOAA's requests for budgetary attention to efforts that could save lives and property have not been well-received. The Department has made substantial investments in the Census Bureau's HPC capabilities, but not in NOAA's research or operational compute. This is a confounding and constant problem that NOAA has had to face since it was nestled into the Department of Commerce. Dr. Jacobs said that ~\$700 billion, or ~3.5% of the U.S. gross domestic product, directly fluctuates by weather annually (~\$1.5 trillion annually of indirect fluctuation due to weather) and \$250-500 billion or more in damages from severe storms are incurred each year in the U.S. NOAA's budget for helping to mitigate these costs is \$2-3 billion a year. If NOAA could improve forecast skill by 5-10%, and only 10% of that was actionable, the return on investment would still be a couple thousand percent. Even without taking loss of life into consideration, the financial picture for the agency does not make much sense.

Chair Scarlett asked about Congress' receptivity and understanding of this need and the challenges NOAA is trying to overcome. Dr. Jacobs said Congress has been generous in making sure NOAA's work is funded, but there is still a disconnect that the scientific community needs to be aware of. Congress is not equating a predictive ability on the front end to mitigating financial losses on the back end. For example, if NOAA could shrink zones of evacuation because of improvements to their track forecasts, it could save the U.S. government up to \$100 million a mile on evacuations.

Dr. Polasky asked if NOAA has attempted to quantify the value of this information. Dr. Jacobs said NOAA has had economists do this and they published the findings in the Bulletin of the American Meteorological Society (BAMS), but no one outside of the atmospheric science community reads it. While it is helpful to be able to cite these studies on the Hill, they really need to figure out how to better message to people outside of the field. Mr. McLean added that

NOAA has tried to link economics to the Cooperative Institutes (CIs) in order to establish the dollar amount invested in weather studies versus the value of the information derived. He hopes that this information will be valuable to the administration, which is very driven by return on investment (ROI). The congressional staffers that NOAA exchanges information with most frequently understand that there is a major challenge that is being inappropriately funded, but it is up to the elected members to demand different appropriations. The next step of this effort will be to get some ROI baselines and then blend that engagement with the social science community to have the physical and social scientists formulate a career cadre that will begin to tackle some of the challenges they have throughout the spectrum of weather, water, and climate.

Dr. Storksdieck said another component to this issue is that it is much easier politically to dedicate money to damage that has already occurred than it is to invest even small amounts of money in preventing unseen damages. The question isn't whether NOAA can come up with the right ROIs or messaging, but if they can help members of Congress sell the idea of appropriating funds to intangible avoided outcomes.

Dr. Reed asked how much of EPIC is a multi-agency effort. Since improved predictions saves expenditures for many federal agencies, it would be good to pivot the ROI conversation to be more governmental as opposed to the NOAA budget. Dr. Jacobs said they have been working very closely with the National Aeronautics and Space Administration (NASA), Department of Energy (DOE), Air Force, Navy, and the United States Geological Survey (USGS). While NOAA does not want to design EPIC and EPIC's budget to be dependent on other agencies, having their involvement definitely strengthens NOAA's position. All the agencies want a common modeling system so as to avoid doing parallel and redundant work. Chair Scarlett said NOAA should find a way to engage these other agencies in being more vocal about being beneficiaries of avoided damages through improved predictive capacity.

Dr. Grossman congratulated the team for getting GFS up and running in the cloud. It is not an easy task, but it is a big benefit to the community and to the agency. He asked if NOAA did not have their current fiscal constraints, what the balance between cloud and on-prem computing would ideally look like. Dr. Jacobs said NOAA is establishing a process to prioritize: what goes in the cloud; whether it goes on a commercial multi-tenant cloud, a single tenant commercial cloud, or on-prem hardware owned and operated by NOAA; and then when it should be executed. Mr. McLean added that another dynamic in terms of moving forward with cloud, is the rapid change going on within the computer industry that recognizes the importance of this type of computation. The compute designs that NOAA utilizes are highly inefficient for the type of work they need to do, but through working with industry they have moved things forward with a more appropriate compute design. NOAA does have to be careful, however, not to surrender the totality of their control over their own compute to the business model of a private sector interest. This is factored into the agency's thinking as well.

Dr. Joseph asked how the model would roll out within the community for the purposes of training researchers, which is part of EPIC's objective. Dr. Jacobs said training is a big part of EPIC's budget. The plan is to issue an RFP and have EPIC reside somewhere like CI or University Corporation for Atmospheric Research (UCAR) and host workshops training people to work on it who will then go back to their respective universities or companies and train others.

A large amount of training will be necessary in the beginning to get people comfortable with using the code. This should happen in conjunction with the vendors making the code more user-friendly, but the code needs to be as simplified as possible before NOAA begins external outreach and training in order to avoid scaring people off. Dr. Joseph followed up asking if NOAA envisioned a similar hybrid model in the community space or all cloud. Dr. Jacobs said it would be either/or. HPC cloud vendors have begun standing up cloud with high-speed interconnects and chip architecture that are almost identical to what NOAA would have on-prem. All of the code will be containerized and able to be run in either location. Dr. Tolman said it has to be a hybrid because NOAA needs the cloud to gain more capacity and they are working formally with the National Center for Atmospheric Research (NCAR) on the infrastructure. It makes the most sense for NOAA to port all of their codes to the heavy iron at NCAR. At least in the short term, they will need both.

Dr. Russell said they are excited to be one of the first universities to host SeaMet6. She stated that there is no new money in academia to invest in more computing. Going to the cloud is like having a co-pay every time you want to do something and this has been found in university settings to suppress research. NOAA needs to build a new computer and they are not going to catch up to the European models without that new capacity. NOAA needs resources to extend and improve the forecast. The enormous cost of disasters is increasing every year and it is an embarrassment that NOAA has not attracted the Air Force or Navy back to their models. Dr. Russell said that she understands that cloud computing is about saving money, but there is a fundamental mismatch between NOAA's objectives and their funding. Dr. Jacobs said NOAA can't do this without more money. There are two angles NOAA needs to take: (1) How does the agency get more investment from Congress for preventative measures; and (2) Going after industry investments. There is an incredible amount of financial loss in the U.S. due to weather and there is no reason that the weather industry and reinsurance companies that make billions of dollars on NOAA's efforts shouldn't be investing in what NOAA's doing to improve its models. These industries won't step up if NOAA offers to continue paying for everything.

Chair Scarlett asked for Dr. Jacobs' perspective on the 5G discussion and where he believes it stands on the Hill. Dr. Jacobs said the discussion has stalled out in Congress and will be an Executive Branch decision. The decision is not over having either 5G or weather satellites, but how to deploy 5G and what kind of protection limits are in place for certain bands of spectrum in order to protect the weather satellites. There is potentially a win-win. The telecom industry will still be wildly profitable in 5G with the more restrictive protection limits, but they will continue fighting for everything they can get. NOAA has studies to support what the potential impacts could be at the critical 23.8 GHz band, which show the satellite data may be corrupted to the point that it can't meet mission requirements. At the end of the day, the U.S. is going to have to reach a compromise but there are mitigation strategies. Much of this issue may be able to be solved by putting rules and regulations in place telling the telecom industry how to deploy 5G. Dr. Jacobs' argument is that if NOAA is going to take heat on potentially being locked in to future improvements on satellite capabilities, then they need access to the spectrum relocation fund for auctioning off this spectrum in order to fund additional deployment of various observing systems so that NOAA doesn't see a slowdown in the improvement of forecast skill.

Environmental Information Services Working Group (EISWG) Review and Recommendations to NOAA of “Report to Congress – Tornado Warning Improvement and Extension Program (TWIEP) Plan”

Brad Colman, Climate Corporation and EISWG Co-Chair
John Snow, University of Oklahoma and EISWG Co-Chair

Dr. Snow discussed the EISWG’s commitment under the Weather Act to review NOAA’s Reports to Congress. The Tornado Warning Improvement and Extension Program (TWIEP) is a program that is central to the Weather Act’s requirements. The EISWG has reviewed the TWIEP Report and prepared a series of recommendations on how the program and actions listed in the Report could be improved. General findings include:

- The Report is comprehensive and responsive to the requirements of the Weather Act.
- The Report provides a good assessment of the technological and social/behavioral challenges that are essential to address in parallel in order to increase both the skill of NOAA’s monitoring and forecasting, and the effectiveness of its warnings of tornadoes (and other destructive phenomena, such as microbursts, associated with severe thunderstorms).
- The Report describes the several NOAA efforts that are either underway or planned in order to address technological and social challenges.
- The EISWG was pleased to see the many mentions of working in partnership with the entire weather enterprise to achieve jointly the shared goals of saving lives, protecting property, and reducing the economic impact from tornadoes.

Recommendations related to technological objectives include:

- In its development of Warn on Forecast procedures, NOAA should include pattern recognition and artificial intelligence (AI) algorithms that take into account and adapt for the various known shortcomings in explicit computer model forecasts.
- NOAA should focus more strongly on reducing the false alarm rate (FAR) and other metrics of skill in current generation tornado warnings. As warning polygons are now updated as severe storms evolve, FAR measures will need to be assessed over space and time. The ways these metrics are computed should be transparent. NOAA should compute and release metrics by Forecast Office. Importantly, while the focus should be on reducing the FAR, such reductions cannot come at the expense of affecting negatively other tornado warning-based metrics, such as the probability of detection (POD).
- As a means for obtaining greater low-level radar coverage of non-supercell tornadic circulations and so significantly aiding in the warning of tornadoes, NOAA should consider:
 - reducing the lowest allowable elevation angle on all NEXRAD/WSR-88D radars to the minimum possible value, consistent with ground clutter and local environmental considerations
 - adding one or two tower sections to selected existing NEXRAD to reduce ground clutter, increase the radar horizon, and allow better overall coverage.
- To aid in the warning of short-lived tornadoes, NOAA should build on the experiences in south-central Oklahoma and across the multi-county Dallas-Fort Worth metropolitan area

and include networked X- or C-band as gap-filling radars to obtain greater low-level coverage of non-supercell circulations and strong winds.

- The NEXRAD processing software used to detect mesocyclone and tornado vortex signatures should be modernized/upgraded to reflect the best science now available.

Recommendations related to sociological objectives include:

- Given the limited number of federal social science positions within the agency, NOAA should utilize its set of joint and cooperative institutes to access social science expertise in the national university community.
- NOAA should have social science programs charged with investigating questions such as the following: Will people take action more than a few minutes in advance, even if given warnings an hour in advance? Where is the balance between lead time and good decision making? If actions are taken based upon lead times an hour or longer than at present, will this include fleeing and, if so, will road infrastructure and traffic management suffice? Will the public take action based upon probabilistic tornado warnings? How should the public best receive such warnings? Will the public be responsive to repeatedly updated warnings or confused by such frequent updates, waiting until the last minute?
- To reduce impacts in terms of minimizing loss of life and property, it will be necessary to implement stronger building codes. NOAA should develop and implement - in partnership with NIST, universities, and other organizations - a weather-ready home certification program as an extension of its StormReady community and Weather-Ready Nation program.

The EISWG noted that the resource plans seem generic and it is not clear that there are sufficient resources to accomplish everything that is set out in the TWIEP plan. This will make it difficult to assess whether NOAA is tracking favorably against the intended deliverables when reviewing subsequent reports.

Dr. Colman added that the EISWG thought the plan was ambitious overall. The Weather Act instructs NOAA to push tornado forecasts out to one hour and the EISWG did not see the resources or technology, given the complexity of storm-scale modeling, to really meet that goal.

Discussion

Mr. McLean said the EISWG has clearly identified the problem the agency faces. The Weather Act works as a frozen-in-time ambition of what NOAA needs to undertake, but NOAA cannot afford to implement the act with the funds they have available, even at the higher Congressional appropriation level. Chair Scarlett asked if NOAA has a mechanism for prioritizing what they do invest in, given that Congress is often very specific in what they appropriate funds for. Mr. McLean said they consult with the Weather Service and get direction from them on where the greatest needs are arising. Well-intentioned supplementals that only last for one year can be distracting because, regardless of how much money is directed towards an issue, it takes time to develop a product. Sustained funding is needed. NOAA also prioritizes based on what developments are high in readiness level. Ms. Mainelli added that the Weather Service has governance councils that prioritize mission requirements and send them into an R2O-O2R feedback loop. She also said that NOAA has to be careful what they implement using

supplemental funding because anywhere they increase effort has to be able to maintain operational support.

Dr. Reed said one thing she noted in the initial report was how NOAA as an agency thinks about social science and how well integrated it is with their work. She asked if there have been advances in how the forecasted impacts of weather events should be presented so that it is more useful to those on the ground. Dr. Snow said NOAA received feedback, particularly in events where there is loss of life or dramatic property loss. Service Assessment Reports written after events describe how forecasts were received. They are not done by social scientists but are comprised of anecdotal information. NOAA has a small, nascent effort to look at these questions, but it is financially constrained and is not well set up to assess whether the agency is improving the effectiveness of their warnings.

Dr. Tolman said that the reorganization of the National Weather Service (NWS) a few years ago was a major change, particularly in that they are not just thinking about making a forecast but doing decision support. It will take time to get there, but they are moving in that direction. Social science interaction is a significant part of the hurricane cone of uncertainty, new Storm Surge products, and a large part of FACETs (Forecasting a Continuum of Environmental Threats). NWS recognizes that they need more social science involvement and they are preparing a Federal Funding Opportunity for things like JTTI, which will specifically include social science. Dr. Reed said this is good, but they are still talking about social science as a separate thing when it has to be integrated as one. Dr. Tolman said there will be a workshop in September where they hope to address this.

Dr. Colman said that much more needs to be known in terms of lead time and how people respond, how to better communicate, and how to deal with changes in polygon sizes. The report mentions one minute updates and lead times of an hour, but it is not known how the public will respond to that. There is much more to do to optimize the science being done in this area.

Dr. Kihn said NOAA hosted a workshop on numerical weather prediction and weather management, and one of the issues that was raised concerned the provenance of forecasts and the surety of how predictions were made when AI is used. Dr. Snow said the EISWG proceeded from the perspective of seeing AI as another tool to advise the human forecaster. Relying on forecasts made exclusively by AI is a long way off. Using AI to analyze mesoscale outputs may just be a way of warning the forecaster that the model is not very good.

Dr. Joseph said that, from the research community perspective, the emphasis on messaging is less important than how research is designed and integrated in order to arrive at an actionable product. This has been part of the problem in leveraging for additional resources. Atmospheric scientists have been trying to message their need to Congress within the context of the science they do, but it doesn't resonate with politicians. True integration with social sciences changes the dialog among researchers and then allows them to better communicate the value of the science to the broader community.

Mr. Winokur made a motion to approve the review and recommendation report; Dr. Storksdieck seconded. The motion passed unanimously.

Environmental Information Services Working Group (EISWG) Annual Report to Congress

John Snow, University of Oklahoma and EISWG Co-Chair

Brad Colman, Climate Corporation and EISWG Co-Chair

Dr. Snow provided a brief presentation on the EISWG's second annual report to Congress, as required by the Weather Act. EISWG has realized that the reactive review process they initially proposed was going to be too slow because of the complexity of many reports. These will require extended periods for development and internal review within NOAA and the Executive Branch. Therefore, in addition to reviewing the required reports as they become available from the NOAA Line Offices, the EISWG will develop analysis, reports, and recommendations on some of the key topics contained within the Weather Act that Congress clearly wants addressed. The 2019 EISWG Report to Congress was reviewed and approved by the full EISWG and presented to the SAB at the June 2019 EISWG meeting. The report acts as a cover letter for two studies done this year: the TWIEP and the Observing Systems Simulation Experiences (OSSE) reports. The OSSE and TWIEP reports offered several recommendations to NOAA and were forwarded to the SAB for approval. Xubin Zeng's group that led the work on the OSSE report has continued their leadership and prepared a manuscript based on their work, which they submitted to BAMS for publication. Next, the EISWG will be looking at seasonal-sub seasonal weather in collaboration with the Climate Working Group.

Dr. Colman added that the NOAA liaisons have been very helpful as the EISWG maneuvers the multiple topics contained in the Weather Act.

Mr. Winokur made a motion to approve the EISWG Report to Congress; the motion was seconded by Dr. Storksdieck. It was approved unanimously.

Topic 9: New Technologies for Fisheries Stock Assessments Preliminary Report

Mike Castellini, University of Alaska/Fairbanks and ESMWG Co-Chair

Rob Johnston, Clark University and ESMWG Co-Chair

Dr. Castellini provided an update on SAB Work Plan Topic 9, to evaluate fisheries monitoring technologies to improve stock assessments, considering how to optimally balance electronic monitoring, eDNA, and other technologies. The working group also operates within the context of the 2018 Stock Assessment Improvement Plan, designed to provide the best information possible and meet the demands for increased quality and quantity of stock assessments.

In May, the Ecosystem Sciences and Management Working Group (ESMWG) met in-person with NOAA experts that are testing out Next Generation Stock Assessment methods. In late summer 2019, ESMWG will release the first draft of their report, which they will finalize during their fall 2019 meeting and submit to the SAB by the end of the year. It has become evident to the ESMWG that none of the new technologies are yet at a "plug and play" stage of development. There are no immediate cost savings and all will require dedicated research to compare with standard operating procedures. Currently, these technologies should be considered

as means to continually improve stock assessments going forward. The report groups emerging technologies into three readiness scenarios and gives example case studies for each. These are: (1) Technologies that are currently being field verified for near term use (e.g., modern otolith assessment methods for fish age and life history); (2) Technologies at field testing stages in the medium term (e.g., remote observing systems); and (3) Technologies in longer term development in laboratory and field (e.g., eDNA, molecular methods, omics). Dr. Castellini discussed each of these scenarios and the representative case studies. New methods in fish otolith chemistry for determining age using infrared technology is very close to full deployment. It is more than 800% faster than traditional methods, but requires a highly trained workforce. Medium stage technologies are in the calibration and testing stage, such as fleets of Saildrones operating around a mothership to assess ocean conditions and population distributions. Many trials are under way and are revealing that their best use is offshore and in remote areas. Longer term scenarios include conceptual models or laboratory and university collaborations, such as exogenous DNA (eDNA), omics, and molecular tools. Having the machinery to analyze eDNA on remote systems for species identification, presence, distribution and life history is still ten years out or more.

Discussion

Dr. Werner provided some updates on the current state of stock assessment technologies. National Marine Fisheries Service (NMFS) has funded a three-year otolith initiative that is moving forward, but will require significant effort with more challenging species, such as highly migratory species. These will require not just counting rings but looking at the protein structure within otoliths. This is a promising method, but not yet ready for use. The Saildrone project for the hake survey between Vancouver Island and the U.S-Mexico border has proven they are up to the task. The next step will be calibrating them this year to see how they perform compared to ships. NMFS is beginning to consider how to use machine learning or AI methods to unravel acoustic signals that are not calibrated from a nearby ship. There is so much acoustic data being collected that being able to incorporate it and extract signals from it will be one of their next big challenges. The hake survey is also collecting water samples and doing eDNA analysis and beginning to calibrate those methods. This is the first year that NMFS is putting together a possible time series of eDNA signals, which they will hopefully be able to use to help out in stock assessments. This advancement will not replace current methods, but rather be another tool to help characterize the ecosystem better and its associated energetics.

Dr. Grossman asked if there is a general marine microbial environment component to NMFS' surveys. Dr. Werner discussed the long-running California Cooperative Oceanic Fisheries Investigations (CalCOFI) program, which looks at data that has been collected over 60 years to try to characterize what the water column's microbial component is or has been. CalCOFI has gone from doing retrospective marine microbial surveys to doing them actively within the same survey. Mr. McLean said NOAA had historically been involved in the marine microbial effort, but funding for it has diminished and the number of people working on this topic has dwindled. There is more interest now inside of NOAA for omics work and it could gain traction; NOAA welcomes any additional input from the SAB on this. It has been too long neglected and deserves further investment. Dr. Grossman noted the critical role of the microbiome in human health and development. Dr. Werner said they are trying to include a microbial component in the hake

survey, but several minor hurdles have delayed the effort. Dr. Castellini said they are using the technologies coming out of the medical world because NOAA could not afford to develop them. Mr. Lenhardt asked if the ESMWG was thinking about these technologies as data platforms or data systems, and about other ways to leverage the data beyond stock assessments. Dr. Castellini described the NSF-funded R/V Sikuliaq, which was designed from scratch to ingest huge amounts of data measuring many variables, including physical oceanography conditions, fish/bird counts, microbial assessments, etc. The computing power onboard the ship itself is immense and there are many more possibilities once HPC capabilities are brought to bear on the data. Dr. Werner said minimizing the latency of the data is hugely important, as there can be a two-year lag between collecting data and completing the stock assessment. Mr. Lenhardt said that now is the time to address this as the systems are being designed. Dr. Castellini said that in order to be useable, the new systems needs to be designed to be in concert with standard methods. Dr. Kihn added that NOAA is working on an unmanned systems strategic plan and strategic implementation plan, which includes a strong data and information component. The amount of data UxS can generate is great for the researcher, but if the agency is going to reap its benefits, they need an integrated policy.

Dr. Russell said that the community has already picked this up and Ocean Carbon and Biochemistry (OCB) is going to be hosting a workshop called Data Hack which focuses on bringing ship data and autonomous vessel data into alignment. The community is fully engaged in making this happen, but they should coordinate with NOAA better.

Dr. Donahue asked if the ESMWG had a general time frame for each of the readiness scenarios. He also asked if in the final report they will be trying to quantify potential savings from incorporating these emerging technologies. Dr. Castellini said he did not believe the ESMWG was going to attempt to figure out the value associated with these technologies, but they will bring it up in their discussions. Some of these technologies are effectively being used now others could still be ten years out.

Dr. Rheault asked if NOAA has quantified the value of their stock assessment work. Dr. Werner said this has been done and he would get the figures to Dr. Rheault after the meeting. The hope is that investments in new technologies will eventually result in more efficient assessments.

Mr. Lundgren said NOAA's Office of Response and Restoration recently hosted a colloquium on defining the Gulf of Mexico microbiome, bringing together many of the partners who worked on the Deepwater Horizon response. He also noted that they are working with industry to develop an autonomous gulper and water chemistry system to provide both sampling and detection in the water in a spill situation. There may be a convergence of that system with eDNA or other elements down the road.

Dr. Reed asked if the goal of these new technologies is to generate the same information using new methods or to develop totally different ways of doing a stock assessment. Dr. Werner said it is a little of both. In the case of improving the otolith work, it is a matter of getting age and growth data much faster than traditional methods, which have been a real impediment to stock assessments. UxS will be able to cover more areas, be in places the ships can't access, and help characterize more broadly the distribution of the ecosystem and species. The omic and molecular

approach are similar; NMFS has moved from single species approaches to ecosystem-based fishery management because they now have much more information. Dr. Castellini said that NOAA people he's spoken with have expressed interest in what these tools set out to find, but they really hope that the improved refinement will allow them to see fish with higher density data, which will lead them to ask new questions that will lead to a better understanding of the processes and develop better management practices.

Dr. Storksdieck said that what Dr. Castellini has described is a different way of thinking about the data they have and what they will be using it for, rather than optimizing existing technology by deploying more tools. He asked if new tools were needed because the current stock assessments are not performing well. Dr. Castellini said that you cannot understand how the systems work the way they work without knowing what is there and finding out what is there is what this effort is about. Dr. Werner said it is an incremental step towards being transformative. The benefits from UxS will include freeing up ships to do other things and allowing a more process-oriented to fisheries management. NMFS wants to head towards an ecosystem-based management approach. With things changing as fast as they are in the ocean, they need to think differently in terms of how they understand how the system is adjusting to jolts. Dr. Storksdieck said the bigger question is if NMFS is doing this work in order to extract more fish from the ocean or if it is for the benefit of keeping healthy ecosystems under higher risk of global change uncertainties. It would be useful to have these discussions in parallel so there are no surprises from the unintended consequences of optimized technologies.

Mr. McLean said that the U.S. can achieve anything it is motivated to do and NOAA needs to figure out how to make the argument to motivate Congress and the public to declare war on these challenges. NOAA is committed to working towards modeling the biological component of the ocean and coupling it with the atmosphere and ocean models into a single model for the ecosystem, from which users could extract fisheries forecasts. Finding the right resolutions for this effort is something the agency is looking at now. Bringing the biological component into modeling will require 33 times more compute than is currently available to NOAA researchers. Dr. Castellini added that it is critical to emphasize workforce development and training in order to meet these challenges.

Dr. Joseph brought up a discussion the National Academies have been having on federal agencies becoming more myopic and what may be causing it. In the past, interagency partnerships on big experiments were fairly common and several agencies bringing assets to the table yielded great results. This may be a result of greater compliance and accountability limiting program managers from thinking bigger and taking more risks. This is a topic that's continuing at the Academies and is something the SAB should think about as well. Mr. McLean said the pressure on program managers is exceptional and it is incumbent upon the agency leadership to give program managers the license to branch out.

NOAA has a need to turn towards a scientific campaign in subjects that allow multiple agencies and nations to work together to pursue these things. The UN Decade of Ocean Science is designed for just this type of opportunity and NOAA is starting to come back around to these types of collaborations. Dr. Russell suggested NOAA be more focused. Prediction science is exploding and the ocean plays well in this field due to its 45 days of predictability as opposed to

the seven days for the atmosphere. What is keeping forecasters from fully utilizing the predictive power is not knowing well enough what is there in order to start the run. Leveraging the ocean data requires a massive compute increase.

Chair Scarlett said none of this will bear its greatest potential for improving stock assessments unless some of the problem sets and management questions are defined now rather than later, because they actually affect which systems NOAA invests in and what data they are gathering.

Plans for the FY 2020-2021 SAB Work Plan

Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

Chair Scarlett reviewed the topics contained in the SAB's current Work Plan and gave the working groups an opportunity to provide a brief status update on each. The SAB has the option to carry over any of these elements in the 2020-2021 Work Plan. The SAB will need to have a collaborative discussion among themselves, the working groups, and with NOAA on what topics are the most relevant.

Mr. McLean and Dr. Werner offered some initial thoughts and comments from the NOAA Research Council perspective. Mr. McLean would like the SAB's input on how NOAA can get past suppression of innovation and how to find a more structured pathway to allow greater innovation. Other areas of interest included how to be more effective in marketing NOAA's science, how to convince the public of the importance of their work, what future techniques and methodologies might be used to monitor greenhouse gases in the atmosphere more efficiently, how to move forward with HPC vendors without getting caught in a position where the agency is paying more and getting less, ongoing input on the draft five-year research plan, the need to better understand stratospheric chemistry and what impacts the introduction of substances might have, and guidance on introducing ecosystem forecasts into NOAA's coupled earth modeling. He also encouraged the SAB to stay vigilant on ensuring that NOAA builds a system that integrates social science into its science program. Dr. Werner said that the National Ocean Service is interested in several topics in the SAB Work Plan, but that they did not see themselves in the topics as currently written. Also as written, the topic of UxS is very focused on extreme weather and water but there are areas that could be broadened to include the work of NOS. eDNA also has many more applications beyond stock assessments. Other comments he received included the desire for a brief description of the plans for each of the standing working groups and a suggestion for rewriting Topics 1 and 2 with the intention of weaving emerging technologies into the topic of social sciences, which Dr. Werner will forward to the Board.

Discussion

Mr. Winokur said that the SAB has responded to NOAA's draft R&D plan but maybe they could look at creating a score card once it is implemented. Innovation takes at least two things: people and money. Those agencies that have been successful at innovation have both, in addition to a long-term commitment. There are models that NOAA could look at and consider emulating, but without people and money it is hard to do. The Coast Guard and others have set up offices in Silicon Valley to work with venture capital firms to see how true modern innovation is done.

Chair Scarlett suggested recasting the discussion as “how does one develop structured pathways to innovation in a resource-constrained context.” There are several people with expertise on this subject.

Mr. Lenhardt said innovative approaches to government procurement processes would be worth exploring. He asked if there is more potential to leverage the work of other agencies.

Dr. Rheault said there is a rich literature on pathways to innovation. He will request SAB approval at the following day’s session to include language on this in his aquaculture report. The SAB should make recommendations on how NOAA can integrate this literature and establish approaches in a low-cost manner to encourage innovation in their projects.

Dr. Storksdieck said it is important to step back and look at the rules NOAA operates under and how that differs from private industry. The SAB needs to understand what NOAA means by innovation and what impediments to innovation are simply due to the nature of being a federal agency. He also said a distinction needs to be made between making sure everyone knows about the work NOAA produces and being able to make a broader political argument for why some of the foundational things NOAA does are important. The SAB should be careful about which conversation they want to have.

Dr. Kihn said the discussion seems focused more on the need for NOAA to be more agile, rather than innovative. There is a tremendous amount of data NOAA could be harvesting from other agencies and industry if the agency was more agile. The SAB could be helpful in advising on this.

Dr. Joseph suggested conducting a gap analysis on how NOAA partners with other agencies in achieving shared objectives, exploring how NOAA could partner in a much larger way.

Dr. Tolman said that if NOAA wants a more rapid transition to operations they should assess public-private partnerships. Much of the slowness in transitioning to operations within NWS is not risk-averseness on the agency’s part, but doubts from the private partners. NWS has not had the discussion with end users on what an acceptable risk is and how much benefit there could be from real innovation. A discussion about being more agile should start on the end users’ side. Ms. Mainelli said it is external partners but also the funnel of research-to-operations.

In regards to Dr. Werner’s comments, Mr. Winokur said NOS attends SAB’s meetings and had an opportunity to have a voice in any of the conversations about shaping the Work Plan. The SAB does not necessarily need to have an element in their Work Plan to address all of the Line Offices.

Dr. Reed said the SAB needs to help NOAA keep the issue of coastal adaptation front and center and she suggested asking NOS what they would like the SAB to do on this topic. Mr. Lundgren said many of NOS’ subject areas are topics the SAB should take up, such as coastal inundation and storm surge. The other issue is the debate on what the right scale of science investment from NOS has been between Congress and NOAA itself.

Potential Work Plan Topics from SAB Working Groups

EISWG

Dr. Colman said that, from their discussions with NOAA liaisons, the EISWG felt the most timely and significant topic for the Work Plan would be assessing NOAA's progress towards meeting the seasonal-to-sub seasonal requirements set out in the Weather Act. NOAA presented to the EISWG a plan and outline of the report they are working on that was initially due to be completed in October 2018 but is not expected to be completed until early 2020. From this presentation, the EISWG thought there were some critical questions they could explore, such as stakeholder requirements. The EISWG proposed working with NOAA liaisons and several subject matter experts to aid them in the effort. They would pay particular attention to how NOAA's seasonal-to-sub seasonal forecasts are used by public planning and preparedness agencies, as well as how NOAA is planning continued improvement, including improved products. The EISWG's proposed timeline depends upon whether they receive a report to leverage NOAA's findings; if not, they would expect their own report to take 9-12 months and would likely be an attachment in next year's EISWG Report to Congress. Seasonal-to-sub seasonal forecasting is clearly a topic important to Congress and the Climate Working Group (CWG) intends to look at it from the R&D perspective. These efforts in parallel should complement each other.

Discussion

Mr. McLean said he felt the EISWG's input on how NOAA is doing with respect to the Weather Act's seasonal-to-sub seasonal requirements would be very useful.

Climate Working Group

Dr. Russell proposed a similar focus but different approach. The CWG proposed developing a white paper that will provide research-based priorities in seasonal-to-sub seasonal-to-decadal (S2S2D) forecasting to understand and predict changes in the Earth's environment, with recommendations from the two-year, five-year, and long-term perspectives. The report will focus on hybrid dynamic-statistical models, boundary layer processes, expanded ocean observations, and the use of biogeochemical profiles. The CWG will also look to support the EISWG where they can on their massive workload and provide comments directly to the SAB on NOAA's climate-related programs.

Discussion

Dr. Tolman said that NWS, through their MOA with NCAR, has some nice working prototypes up and running that incorporate MOM6, FV3, sea ice, Wave Watch and some chemistry. NOAA needs more feedback on coupled modeling in general, particularly on how to fully integrate these and avoid creating a weather stovepipe.

Dr. Werner said the four focus areas cited within S2S2D are important but very broad. Dr. Russell said these are the areas that the group thought they had the deepest expertise on and were most timely, though they recognize there is much more to do.

Dr. Storksdieck asked how models anticipate how people, communities, and cultures will respond to certain incentives that come from improved understanding of the climate models' output. Dr. Russell said they don't know how people will respond and so they envelope potential scenarios and run them all. There is no direct feedback with these models, so they make some assumptions about what they might do. The models don't often predict well major technological or societal changes. Dr. Storksdieck suggested considering at a later time what a human model would look like and how it would interact with climate models.

ESMWG

Dr. Johnston discussed three topic proposals for the ESMWG to work on in 2020-2021: (1) the socio-economic dimensions of integrated ecosystems assessments (IEAs); (2) Practical methods for adaptive risk management and decision making under uncertainty; and (3) aquaculture and ecosystems in the 21st Century. The ESMWG is able to start on one or two of these topics as of their next meeting. The goal for each one would be a 10-15 page report and each would take about a year to complete.

Discussion

Dr. Donahue suggested integrating some of the ideas in the first item into the other two. Dr. Johnston said that was something they would consider, as some of the overarching social science issues would be present in topics two and three.

Dr. Reed said that she did not believe IEAs were worth addressing unless they are a NOAA priority. As written, the title of topic two could apply to all aspects of NOAA. Examining practical approaches, then providing ecosystem management examples would be a good idea. There is a lot of thinking going on in the area of decision making under deep uncertainty and some focus on this could be really helpful in fertilizing thinking within the agency. Dr. Reed continues to believe that coastal adaptation is one of the great national challenges of our time and NOAA should be the agency in the forefront of that effort. This needs to be addressed somewhere in the Work Plan.

Dr. Polasky said there is some confusion about what people mean when they talk about IEAs. If topic one is trying to address how we're manipulating systems and how that impacts the things we care about, than it is a huge priority. Dr. Johnston said these topics are adaptable to whatever the SAB is most interested in.

Dr. Rheault said it would be very informative to have the SAB address the current state of aquaculture to inform decision makers in Congress who may have misconceptions about the field. He also suggested thinking about how they communicate the value of what NOAA does to the general public.

A synthesis of this discussion will be circulated to the SAB members who will have an opportunity to add new thoughts to the document, which will provide a basis for the board to become more focused on what is next in developing work plans.

Dr. Reed asked about new members that will be joining the SAB and how their expertise might factor into the Work Plan topics. Dr. Decker said they are working through the process of bringing on new members for the SAB and the working groups. NOAA anticipates releasing a Federal Register notice in the fall for new members and is open to suggestions on what expertise is needed for the SAB.

Public Comment

There was no public comment.

July 11, 2019

Welcome

Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

Lynn Scarlett welcomed everyone to the second day of the meeting.

Additional Discussions on the SAB Review Report on the Draft Strategic Aquaculture Science Plan

Lynn Scarlett, The Nature Conservancy and Chair, NOAA SAB

Robert Rheault, East Coast Shellfish Growers Association and SAB Member

The SAB held a teleconference discussion on the SAB Review Report on the draft Strategic Aquaculture Science Plan and agreed to the recommendations proposed in the plan. As they were preparing to do a final review before submittal to NOAA two things surfaced: Dr. Rheault recognized that a paragraph pertaining to innovation should be included as it was discussed in the teleconference, and that two paragraphs concerning permitting included language that may appear to be policy statements that would not be appropriate for the SAB. Dr. Rheault was in agreement that some editing would make the report consistent with the purpose of the Board.

Dr. Rheault discussed the proposed language pulled from a review of innovation literature recommendations, such as encouraging multidisciplinary participation, encouraging racial and gender diversity, sponsoring maker spaces/business accelerators/pre-permitted aquaculture development zones, mini grants to encourage new approaches, and encouraging researchers with no prior experience to collaborate on aquaculture projects. Chair Scarlett approved including this language in the document.

Chair Scarlett discussed the permitting language and the sentences that were felt to go beyond observation to making what might be considered policy statements. The intention was to edit a few sentences but not remove the entire recommendation because it had been approved by the SAB.

Dr. Reed suggested changing “especially for novel projects that are a challenge to get permits” to “NOAA should consider the potential for developing demonstration projects and test bed facilities, especially for novel projects where potential impacts or negative interactions” without linking it to permits and regulations. Dr. Rheault said NOAA’s dual role of protecting and permitting the resources puts them in a unique position, but he felt the precautionary principle is limiting permitting activity and NOAA has a unique potential role to evaluate some of these protected resources interactions in test bed or demonstration facilities where a commercial operation would not. Dr. Reed said there are much larger issues present concerning permitting for novel projects and would rather not open that discussion for aquaculture unless the SAB feels aquaculture is unique in this regard. If the SAB wants to take on the subject, they could do so in a separate document on how NOAA applies the precautionary principle in its regulatory mission.

Mr. McLean said that either way the language comes out, NOAA will take it in a manner that would be useful to the agency. He did not wish for the Board to get unnecessarily distracted by the issue. Kevin Wheeler added that NOAA has been looking at their aquaculture permitting authorities under the existing statute as well as ongoing litigation. What they are doing is consistent with Dr. Rheault’s proposal and the SAB does not need to weigh in on the problems of the permitting aspects.

Dr. Rheault agreed with Dr. Reed’s recommended language change: “NOAA should consider the potential for developing demonstration projects and test bed facilities, especially for novel projects that have questions about potential impacts or negative interactions.” Robert Grossman moved to accept the change, Dr. Storksdieck seconded. The motion was unanimously approved.

Dr. Reed requested to review all of the edits to the section for a full Board discussion. Dr. Rheault discussed the existing language and the proposed changes and SAB members made further suggestions to the wording of the report.

Dr. Reed made a motion to approve the edits to the report; Dr. Polasky seconded. The motion was approved unanimously.

Topic 3 Update: Enhance Strategic Investment and Use of Unmanned and Autonomous Systems

Bob Winokur, Consultant and SAB Member
John McDonough, Office of Marine and Aviation Operations (OMAO)

Mr. Winokur said that Topic 3 has been partially overcome by other events and activities at NOAA, particularly the direct interest by Tim Gallaudet and the inclusion of at least \$4 million for UxS in the FY20 budget. Recently, Charly Alexander from OMAO has been detailed to work directly with RDML Gallaudet on putting together an investment strategy and implementation plan for UxS. This is an evolving activity and group will present a more complete briefing at the SAB’s fall meeting. They will also be reviewing the OMAO Standing Review Board’s ship implementation plan.

John McDonough said the overall strategy remains the same, conceiving a strategy for moving forward that consists of three pillars: (1) increasing cross-Line Office coordination and collaboration on mission-relevant research, monitoring, and other efforts that involve UxS; (2)

establishing UxS operation capability within OMAO; and (3) increasing coordination and collaboration with external partners who share similar or complementary mission requirements. In addition to the investments made by individual programs and activities involving UxS, OMAO received \$2 million in FY18 specific to unmanned surface vehicles, to continue to improve areas across NOAA where there was significant progress already being made. Additional funds were made available in FY19 to continue those activities. The FY20 budget request includes \$4 million to initiate the development of a NOAA UxS operation program in OMAO, recognizing how these platforms are increasing and allowing NOAA to acquire information in new and difficult to sample locations, often for longer periods of time. Ultimately, this will allow NOAA to dedicate staff to ensure a standardized approach for coordinating operations, research assessment, and acquisition, as well as integration of UxS. Progress has been made on unmanned aerial systems, in terms of governance and guidance. The Unmanned Marine System (UMS) Symposium revealed other NOAA efforts on UMS that are becoming more systematic in nature, such as the simultaneous acquisition of data relevant to atmospheric and oceanographic observations, fisheries stock assessments, and hydrographic mapping. A proceedings document should be available online soon. NOAA can build upon all of these foundations as they move toward a more formal use of UxS. The CENOTE Act is a key driver of many of these activities and captures much of the efforts already underway at NOAA. The act supports efforts to develop sustained operational capabilities and acknowledges the role of OMAO, OAR, and the cross-Line Office Unmanned Systems Executive Oversight Board in executing its requirements. It also authorizes the collocation of a dedicated UxS facility to take advantage of collaborative opportunities with external partners. This will be central to the NOAA strategy as they move forward.

A NOAA UxS Strategy Paper and a NOAA UxS Implementation Plan are both targeted for completion by September 30. The team is close to completing a short draft UxS Strategy Paper that will describe the need, opportunities, and vision for the use of UxS within NOAA and will contain the agency's goals and objectives. This paper will form the core of an action-oriented implementation plan that will provide more detailed milestones and the resources required to meet those milestones over at least a 36-month period. By establishing a NOAA UxS Program consistent with CENOTE, NOAA will consolidate core functions to ensure an efficient organizational structure to advance UxS across the agency, advance research and innovation at NOAA by using UxS, accelerate UxS Research-to-Operations, strengthen and expand UxS partnerships inside and outside of NOAA, promote a NOAA workforce that is proficient in all aspects of UxS, and transform the agency by exponentially increasing its capability and efficiency through the use of UxS in virtually every NOAA mission area.

Mr. Winokur added that, what started out as an SAB recommendation that NOAA develop a strategic plan for agency-wide use and coordination of UxS has now taken on a life of its own and transcends what the Board had recommended. Going forward, the SAB will be kept up to date on the topic's progress, but this will no longer be a direct product from the SAB. It will be a NOAA product that the SAB will have the opportunity to review in draft form.

Discussion

Chair Scarlett commended Mr. Winokur for his work on this Work Plan item and said it was gratifying to see a topic of interest for the SAB translating into a whole program of actions.

Dr. Storksdieck said UxS is not just a big deal for NOAA, but beyond NOAA as well. He asked if the report will address the consequences of this new transformative technology and what it will mean for the existing techniques that it will likely replace. Mr. Winokur said his opinion is that UxS will not be significantly transformative, but rather will be complementary to existing NOAA operations. The Navy is utilizing UxS in much more transformative ways than what NOAA is considering. The coordinated operations center will be critical to NOAA's effort, as well as the ability to coordinate the R&D for applications.

Dr. Grossman said, at the broader level, the use of autonomous/semi-autonomous/unmanned systems is pretty transformative, particularly for data-intensive disciplines. He asked if the use of this technology within NOAA over the next few years is going to be due to limitations in budget, ideas, or organization. Mr. McLean said it will be significantly budget-limited. The plus-up for the UxS program in the budget zeroes out the unmanned aerial systems program. He cautioned the members that they are a Science Advisory Board, not an Operations Advisory Board; when operations subsumes science, there is a danger that the innovation and research will disappear. He asked the SAB to remain diligent in their role of oversight and advising, to ensure NOAA does not lose focus on the science side, however, NOAA will never get to the operational aspect of this if they don't create a program inside of OMAO where capacity can be acquired and allocated. Dr. Tolman said NOAA has been looking at why several projects have stalled when they had research that did not go into operations. One of the big issues they have found is that many of the research projects did not have end goal considerations when they started. It is extremely important that there be an operations program for UxS, as well as a business model for actually getting this into operations.

Dr. Werner asked about the relation of this plan to the 2015 Road Map. He also commented that, given budget limitations, the centralization of core functions is this going to limit the amount of innovation that would happen if it were less centralized. Dr. McDonough said he appreciates the research being done on these platforms to determine how they can best be used by NOAA, but centralization will enhance the process for making appropriate decisions. Some will be better served by centralization while others may not. The 2015 Road Map was specific to unmanned aerial systems. There is a parallel between that road map and what they intend for the Implementation Plan, though the Implementation Plan will be much more detailed in terms of achievable milestones.

Dr. McDonough commented on oversupporting operations in deference to science, which is always a concern. Many of the programs experimenting with these types of technologies eventually start spending more and more money on operating the systems as opposed to development of sensors and the use of data and information to determine how they're meeting their mission requirements. NOAA needs to ensure there is an operational evaluation done concurrent with the scientific experimentation of the platforms to be sure they are not overspending on operations.

Mr. Winokur said that UxS has been transformational to the oceanographic community. Over the last year, many of the start-up companies that have been producing the platforms have been bought up by large corporations and there has been a lot of consolidation.

Data Science and Public-Private Partnerships Session

Robert Grossman and Christopher Lenhardt introduced the session and mediated.

Cloud-based Partnerships for a Climate-stable Future

Lucas Joppa, Microsoft, AI for Earth Program

Lucas Joppa presented on Microsoft's core operational, policy, and technology deployment in the environmental space. The presentation included an overview of Microsoft and some of the specific ways that Microsoft is deploying their broader data science and artificial intelligence offerings in NOAA-relevant areas. Microsoft is defined by what they call an "intelligent cloud strategy," a growing fleet of data centers around the world building a network that is the world's first planetary computer, computing at a scale never before seen and putting privacy and security foremost, all supported by 35 years of investment and research in the field of artificial intelligence. Budgetary constraints are one of the primary reasons organizations move to the cloud, which allows them to scale up when they need to and scale back down when they can. One of the key differences between the Microsoft of today and that of 30 years ago is their complete embrace of open source and the open source community.

Research computing has the benefits of using the fundamentals of AI, but often strays into the world of HPC or true supercomputing. This has been a roadblock for many large-scale research organizations in moving to the cloud. Microsoft has been investing heavily in this area and has built a relationship with Cray so that users can access Cray infrastructure with all of the ecosystem that Azure provides. Microsoft has been asking themselves and their partners about what the company's role in improving a data-based understanding of the Earth might be. NOAA, NASA, other federal agencies, as well as private companies and universities are collecting incredible amounts of raw data, far more than the people deploying data collection systems will ever be capable of processing. The goal is to turn that environmental and natural resource data into knowledge so that users can enter a question into a search engine and get a response. This won't apply only to questions where the answers already exists, but will allow for new answers to be brought through as well. This ambition has led to the development of Microsoft's AI for Earth program. The program aims to fundamentally change the way human society monitors, models, and manages earth's natural systems. The 5-year, \$50 billion program was announced in early 2018 and was the first dedicated program at Microsoft to deploy all of their cross-company AI resources into one vertical model and has become the template for other "AI for Good" initiatives. The three pillars of the program are: (1) increase access to cloud and AI technologies through grants; (2) provide education on cloud and AI and increase collaboration through our community; and (3) fuel innovation through Microsoft research and strategic partnerships. The program has over 400 grantees in 66 countries, all taking a "machine learning first-based" approach to tackling problems in climate, water, agriculture, and biodiversity challenges. AI for Earth is a dedicated program focusing on these four key areas of environmental science, but everything Microsoft does is aligned with the way their technology stack is structured. Mr. Joppa ran some open dataset demos, showing how easy it is to use and to scale.

Discussion

Mr. Lenhardt commented that data is only as good as its annotations and structure. The challenge is that this is usually done by humans. The tradeoff is in leveraging AI to identify and extract information versus how much value-add a human has to do in order to make the AI successful. Mr. Joppa said that this trade-off is particularly interesting in areas like remote sensing where it is difficult for people to do large-scale annotation tasks. Machine learning models do not always transfer well geographically. Microsoft has tackled this issue in two ways: by getting more training data from more places and by building the applications with a human-in-the-loop perspective where users note inaccuracies and the algorithm is refined.

Dr. Kihn asked if Microsoft has done much in the area of data provenance, so that downstream users know what they are working with. Many decision makers want to know where data come from, how authoritative it is, and what standards were followed to acquire it. Mr. Joppa said that when the data is coming from external organizations, they often rely upon the metadata provided. Microsoft wants to be able take the output of a model and trace back what data went into it so users can quickly pull out biases or make corrections. The issue of data provenance is becoming more important, but also more mature as organizations build it into the JSON (JavaScript Object Notation) structure of any data or machine learning API.

Mr. Wheeler asked if there is an opportunity for AI or machine learning to rewrite or transform NOAA's code into a more modern programming language so it would be easier to share and recruit people to manipulate it. Mr. Joppa said code translation is an active area of research. The tech sector is very good at language translation but they don't have the ability to translate Fortran into Python yet. They are getting closer, particularly in some of the application development languages where they have made it as easy as possible to write cross-platform applications. Mr. Joppa offered to get Mr. Wheeler in touch with some people that are working on this issue within Microsoft.

Dr. Grossman asked how AI for Earth is dealing with some of the fragility of machine learning and AI infrastructure. Researchers are very interested in being able to replicate their work and it can be quite hard to do this after some time has passed. Mr. Joppa acknowledged that this is a big problem and there is a significant shift towards ensuring longevity through versioning. Whether or not researchers will be able to run versions in a way that is as performant as it was previously is a question that the move towards containerization is designed to address. With all of the innovation in AI comes not just confusion about the best applications to use, but also some redundancy.

Ms. Mainelli asked if AI for Earth has a relationship with Esri's GeoServer so that users can view GeoServer on the cloud. Mr. Joppa said that Microsoft is in close conversation with Esri on deploying some GeoServers at scale for data hosting. Ms. Mainelli asked what kind of work AI for Earth has done with organizations that need to do code conversions in a public cloud in order to create efficiencies and take advantage of the tools. Mr. Joppa said they meet their customers' business model needs by offering both platforms that allow users to do this themselves and side-by-side assistance. If you build for the cloud, it can be exceptionally efficient and performant, but if you did not build for the cloud and are trying to lift and shift it can be problematic,

especially when running at large scale. Even if it does not make sense to do the refactoring necessary to translate existing code, you can still run it and benefit from having a much closer integration with new things you may be developing. Ms. Mainelli said that NWS currently has in their private cloud their development environment, their quality assurance, and their production together and they are looking at moving the development environment and doing a demonstration on the public side. She asked if there are sufficient boundaries and constraints that could be placed on the public side. Mr. Joppa said that Microsoft has put a lot of work into privacy on the public cloud. Clients can lock their programs down to being as clean, crisp and clear as they want it for both external inspection and to control the level of access.

Mr. Lenhardt said AI and the cloud are both subject to the hype cycle and are often not as far along as people have been led to believe. He asked where earth science AI applications are on the spectrum of being operational. Mr. Joppa said there is a lot of rhetoric but there are also many organizations doing full-scale, robust deployments in this space. As an example, he discussed the Wild Me project which has discovered 10 times the number of whale sharks in the last few years than had been previously discovered throughout all of human history. The program is almost entirely automated and detects patterns on animals to identify species and individual animals.

Data Access and AI-based Analysis of Environmental Data

Robert Grossman, University of Chicago and SAB Member

Christopher Lenhardt, RENCi and SAB Member

Dr. Grossman provided the update on the task group's recent work. The topic areas of their 7-10 page report on AI, data science, and their applications to the NOAA mission will include: (1) Selected applications of AI and data science to the NOAA mission; (2) Enabling technology, including the required data management and cloud computing infrastructure; (3) Issues around preparing NOAA data resources to be AI and data science "friendly;" and (4) How might AI and data science accelerate NOAA's economic impact and contribute to an increase in US competitiveness? Since the last in-person SAB meeting, NOAA hosted a three-day workshop on AI that was very well done and the materials are available on NOAA's website. The workshop focused on AI and machine learning applications to satellite earth observations and numerical weather prediction. Rather than high-level presentations on the potential of AI, it consisted of 40 technical talks focusing on NOAA-specific applications by the scientists that use them. This is a big step in the maturity curve of this topic. The work group will be reaching out to the organizers of the workshop and requesting a report which will comprise a big part of what goes into the work group's input to their report. Next steps for the group include discussions with DAARWG on four questions they were tasked with addressing:

- (1) How are we going to make analysis-ready datasets?
- (2) How to re-tool how people work in this area?
- (3) What are the right questions to ask, pathways, etc.?
- (4) What is the best approach to sharing training data?

NOAA has a unique opportunity to prepare transfer of learning datasets that can be used by NOAA scientists and the broader research community. The task group hopes to hear about some

of these efforts from the DAARWG. They will also be requesting information from the NOAA AI Working Group to get their perspectives and perhaps invite them to present at a future SAB meeting. The task group also seeks to learn more from NOAA about the agency's plans to make data accessible to the broader research community. The task group has learned that one of the biggest barriers to discovery is charging for data. There is a very rich trade-off space in terms of how data is made available in the cloud and how it is made available to the research community. Cloud computing is commoditized now and it is no longer a question of whether to use the cloud or HPC, but rather what the appropriate hybrid model between on-prem computing and cloud computing is and how much flexibility is needed to do that. This is another issue the group is looking at in regards to NOAA's plans.

The 2019 Update of the National Artificial Intelligence Research and Development Strategic Plan is particularly important for federal agencies and is available online. It is a consensus report from a committee of experts assembled by the National Science and Technology Council and contains seven strategies for addressing AI R&D and application in the federal realm. Dr. Grossman queried seven different federal agencies that are about the size of NOAA to find out where they are in this transformation. They all seemed to fall into three phases: (1) The agency puts some relevant data in large scale private, public or hybrid cloud computing infrastructure; (2) The agency is beginning to build an internal and external user community that leverages available AI and data science frameworks and computational environments to improve current approaches and devise new ones; and (3) The agency is developing specialized expertise that develops application- and agency-specific frameworks that go beyond the current state of the art. NOAA is making progress with Phase 1 with the Big Data Program and the AI Workshop shows the community developing to support Phase 2.

Mr. Lenhardt emphasized a few points, including the importance of recognizing AI as an adjunct that needs to have a human in the loop, particularly in terms of doing the necessary value-added work for the data going in but also in terms of interpreting results. The task group also hopes that the DAARWG will identify software as being among the data objects that should be thought about in terms of archiving. Ethical and legal considerations need further discussion, as well as considerations of leveraging social science and social science methods which can benefit from big data. He asked if the SAB had additional concerns that they would like to see worked into the report going forward.

Discussion

Dr. Werner said this is an area where he would particularly welcome guidance. People feel overwhelmed when faced with ingesting the data needed and then being able to process it. Any advice on how they might overcome this would be helpful. Mr. Lenhardt said the problem in integrating large and complex datasets is munging the data to make ready to use. This is a significant challenge for researchers and is a good thing for the task group to keep in mind.

Dr. Snow suggested that the task group should consider their audience as they prepare their report. Many of the existing reports on this topic are inaccessible to those not working in this field, which includes many of the decision makers. Staff at NOAA's data repositories probably have plans of their own in this area and it would be important to at least summarize some of

those plans and what NOAA is actually moving on. Some of these data repositories are very difficult for the broader community to get data from.

Dr. Kihn said the workshop was successful, but NOS and Fisheries partners were absent. NOAA intends to bring them in next time. He recommended Sid Mukhabara's summary report of the workshop, which captured many of the things they asked for, including what NOAA should be doing for workforce development and industry transition. The report was still in draft at the time of this meeting. In order to take advantage of AI, data infrastructure is needed and the cloud is not a data access and archive infrastructure. NOAA needs more input on making data discoverable, accessible, and understandable, as well as their role in providing training data for external stakeholders.

Dr. Tolman asked that the report begin with a definition of what is meant by artificial intelligence. Because AI is not well-defined, there are many groups within NOAA looking at it and the agency needs to ensure that there is communication between these groups. It is important that the SAB provide the link back to RDML Gallaudet in order to avoid having different groups doing the exact same thing. Dr. Grossman agreed and clarified that their title of AI and Data Science was intended to provide flexibility to explore the topic broadly. Mr. Lenhardt noted that they do have an action item to follow up with RDML Gallaudet and will also have further conversations with Ed Kearns.

Martin Storksdieck asked that they make it clear to the reader in the beginning what the focus of the report will be so they don't ignore it if it is important to them. He also asked about workforce development and the degree to which they were hoping to see the report go beyond NOAA to support other agencies in workforce development. NSF has made major investments in developing the idea of a transdisciplinary scholar that is simultaneously an expert in their field and also in AI/machine learning. Mr. Lenhardt said they have tried to narrow down the topic description, but the point is well taken. Transdisciplinary team science is also a part of this issue.

Dr. Grossman asked the SAB who they thought the intended audience should be. Dr. Kihn said the ground level is very active, but the SAB's input on potential benefits at the strategic level would be helpful, particularly what coordination will help this effort and not impair it. Dr. Joseph agreed that the target should be the strategic level and advice should be pointed to the Executive level. Congress is a stakeholder and sensitivity to how NOAA leadership may use this advice at that level is warranted. Dr. Tolman said operational outcomes need to be addressed and should drive who the intended audience is. Dr. Reed said they should be cognizant of where the boundary between a science advisory board and an operations advisory board is when considering the audience. Dr. Tolman responded that all operations in NOAA are science-based at their core and each depends on the other, so they should not create an artificial barrier between them. He noted that Mr. McLean has repeatedly stated that OAR and NWS are getting much better aligned, and OAR has cautioned against shifting research work to be close to operations at the expense of the fundamental research that is needed on a longer time scale.

Dr. Werner said decreasing the latency in making the data available to use operationally is an area of keen interest to NMFS.

Learnings from Staging Petabytes of Data for Analysis in Amazon Web Services

Joe Flasher, Amazon Web Services

Joe Flasher presented on Amazon Web Services (AWS) and how they find ways that their infrastructure can help customers get what they want. This includes both customers that want access to NOAA data and NOAA itself, who wants to make their data accessible. The Open Datasets program works with many groups in the public sector to make data publicly available in the cloud in a smart way and to customers that wish to access the data in an efficient manner. Sharing data in the cloud lets data users spend more time on data analysis rather than data acquisition. Through the Big Data Project, AWS has made several NOAA datasets available for free. The cloud model is pay-as-you-go pricing so customers only pay for the resources they use. Mr. Flasher discussed the example of the NEXRAD dataset on AWS, which when NOAA made it available in AWS saw a 230% increase in data usage and a 50% server decrease on NOAA's side. This is a demand that was not being met. Data notifications are filterable and instead of having to search and find new data, customers can have it pushed to them when new data is available. This allows user to set up automated pipelines, which can help with latency issues.

Anything that leaves the cloud incurs an egress fee that someone needs to pay. If the data is available in a requester pays bucket, the requester pays. If it is not set up this way, the person who owns the bucket pays. The person who pays for the egress of the data, even in a requester pays bucket, can be the bucket owner and this can be set up in a way that allows users to egress the data on your expense but with a cap.

Mr. Flasher discussed the NASA Cumulus project, which is a good example of using containerization as a way of dealing with different legacy codes, and the Pangeo project as an example of a community effort. Pangeo is predicated on the fact that it can get the cloud to optimize data formats. If publicly available data is not in a cloud-optimized format it may not work for a particular pipeline. He encouraged the SAB, when they think about how to make data available, to try to find the sweet spot between not doing anything and doing too much. Spending a lot of time processing data and putting a lot of effort into how to make the data available does not necessarily mean it will be better. You generally want to find the formats that work for the most people and cause the least amount of pain if someone needs to transform it into something else. While it will be different for each dataset, once you find the sweet spot you allow other people to work on top of it for their own purposes and build value into it down the line.

Discussion

Dr. Kihn asked about the workflow engine for the NASA Cumulus project and who/what controls the workflow. Mr. Flasher said that it uses AWS step functions (a task orchestration system) to manage the workflow. Hybrid models get harder the more native functionality you want to use. If you're looking to take advantage of the most recent features, which is generally how you'll see the best performance, that is going to be unevenly distributed across different cloud providers.

Mr. Lenhardt asked Mr. Flasher to expand on the netCDF example and if this is an issue of just having the right libraries up in the cloud to make it work or that it actually needs to be

transformed. Mr. Flasher said cloud-optimized is a narrative description, not a technical one. The problem with CDF is that it does not allow users to draw a bounding box to select just the desired data from a file. Users have to grab too much data they do not want to get the bytes they do want. This means more egress fees and higher transfer times.

Dr. Tolman said NOAA's data will still be sitting on a piece of real server in a real location that will require bandwidth. Coupled ecosystem models will face the problem datasets that may all be on the cloud but hosted in different physical locations, which will involve costs and lags when moving data over networks. If this is to be considered as a structural NOAA approach, they will have to choose one place where everything exists or else they will never be able to harness the power of doing everything in the cloud. Mr. Flasher said this is correct and is another piece of the hybrid approach. All of this works better when you're working within the same region where the data is located. All of NASA's earth science data, USGS's Landsat archive, and other customers are putting all of their data in AWS, making it a good target for hosting data but there will be users that will want to utilize it from other locations, on-prem, or with other cloud providers. Technically it doesn't mean your code needs to change, but if you can get super-fast access to one dataset and you're slow waiting to get it off an FTP server from another, that may fundamentally change your cost or how long it takes something to run. Dr. Tolman asked if they choose AWS and to locate everything in one region, could NOAA become a captive customer. Mr. Flasher said a captive customer is one that is bound to contracts. NOAA would not be locked into anything and AWS provides ways to quickly move data out if that's what they choose to do.

Ms. Mainelli asked if the AWS systems for the Cumulus project was built as NASA-centric. Mr. Flasher said his sense is that they were building it to meet their specific mission needs, however, they are keeping it very high level so that it will be generically usable. One of the developers, Development Seed, has a history of developing Cumulus for fundamentally different kinds of work and it was built to be easily adaptable.

Dr. Storksdieck said the advantages are obvious, but asked what the barriers, whether rational or irrational, are to getting this done. Mr. Lenhardt said there are some tradeoffs in terms of government providing public access to data and a risk of privatization of a public good. Presumably these issues could be dealt with through contract negotiations. Mr. Flasher said AWS is just an infrastructure provider, they do not claim any ownership of the content they host. NOAA already pays for servers and hard drives and pipes, they would just be paying somebody different for infrastructure. Mr. Lenhardt said it may be more of an issue stemming from the Big Data Project experience where they were using cloud providers to allow better access to difficult to access data and there was a concern that providers could get a return by commercializing services. Mr. Joppa said that limitations at the highest level center on the pace technological innovation and social/cultural/work norms. The gap between what people feel comfortable using and what they could be doing is growing larger and they need to find a way to shrink this gap. That is a tradeoff we are continually asking people to make - as you move more towards cloud-based remote scalable infrastructure, you're also moving more towards increasingly complex techniques that you may know less about.

Ms. Mainelli said NOAA needs to be careful to balance providing 24/7 information with providing many options to customers. Mr. Flasher described one of the Big Data Project

experiments using GOES data which had different storage tiers, one of which does not allow immediate access to data but is a fraction of the cost to store data. They experimented with putting all of the GOES data into this tier after 60 days to see what it looked like from a cost model and an access model. For some datasets, users can wait 10 minutes to two days, which can be very cost-efficient. Mr. Joppa agreed, and said that the nice thing is that you can experiment with what you need. Customers often don't know what they want when they ask how much this will cost, but can always modify their cloud settings to fit their needs.

Laura Dobbs, Microsoft, said that the work NESDIS is doing with HPC is a great example of using the cloud to experiment with different providers to ensure that it is cloud-agnostic. She suggested that the SAB get in touch with GAMA-1 Technologies to hear more about this effort.

Dr. Kihn said that NESDIS has been focusing on this for a long time and is very excited to move to the cloud. The two challenges they think about are: predictability, since their budget always works in surges, and the throttling that cloud provides. NESDIS has a natural throttle on their archives so when there is a big event they are inundated with customers. Opening this up on the cloud will mean more access but will come with a big bill. People currently accept that NESDIS can only provide so much capacity during events, but they may not be so accepting when they know it's on the cloud and is just a matter of cost. Mr. Joppa said there will still be a need to build on-prem data centers for long-term uses and then there will be benefits to connecting that to a broader public cloud. He also commented that he didn't think data requesters were going to be okay with being throttled by core instrument limitations for much longer. The cloud may be part of this, but some rethinking about budget allocations is also needed.

Dr. Tolman said the cloud will have massive benefits for their work. In moving to the cloud, the biggest issue is benefit versus risk. Tests have shown that these things are working and he recognizes that the agency needs to move in this direction, but it is unknown where they will hit a wall. Mr. Joppa said a roadblock is not knowing that you could be doing something differently. Mr. Flasher said there are more barriers users will run into, but NOAA is not the first customer to attempt this. Many similar agencies in the U.S. and around the world are undertaking this move and part of his job is connecting different customers so they can learn from each other.

Mr. Joppa concluded saying that scientific research to operational deployment is really where the cloud sits. Microsoft and AWS are all about allowing people to do the research they need to do in the environments that they need to do it in and then making it easier to take that research output and deploy it to something that can truly operate at a global scale.

Plans for Next Meeting

Cynthia Decker, SAB Designated Federal Official

Dr. Decker said the next meeting has not been scheduled yet, but it will likely be in November or December. A substantial part of the meeting will probably be focused on the Work Plan, but other items will come up. SAB staff will start putting together a draft agenda soon. Mr. Winokur suggested continuing the model of having external speakers present. He suggested inviting one or two speakers to address innovation, particularly from agencies with small budgets. Dr. Decker asked that members submit recommendations for speakers. Dr. Donahue suggested having a set schedule prior to the next meeting for finalizing the Work Plan, as it will be FY20 by the time of

the meeting. Mr. Lenhardt suggested considering finding the right level of communication to continue the dialogue between the SAB and the working groups. Dr. Storksdieck said he felt the time allotted for discussion was very good at this meeting and was a model for a productive and informative meeting.

Discussion

Review of Actions

Cynthia J. Decker, Executive Director, SAB and Designated Federal Official

Dr. Decker reviewed the actions from the meeting, including:

- Approval of the consent calendar.
- The Science Advisory Board (SAB) Office will provide the agenda for the upcoming NOAA Earth Prediction Innovation Center (EPIC) workshop to the SAB members.
- The SAB office will take the work plan discussion and provide the SAB Chair with a summary of the discussion. She will group the items into topic clusters; this will be then distributed to the SAB for comment.
- The SAB approved the EISWG Tornado Warning Improvement and Extension Program Plan (TWIEP) review report. The SAB Office will facilitate the report being transmitted to NOAA.
- NOAA will respond to the recommendations in the EISWG TWIEP Review Report within a year of its delivery to the agency.
- The SAB approved the EISWG report to Congress. The SAB Office will facilitate the report being transmitted from to NOAA.
- NOAA will transmit the EISWG Report to Congress to the appropriate Congressional committees per the requirements of the Weather Research and Forecasting Improvement Act of 2017.
- The SAB approved the modifications to *the NOAA Science Advisory Board Report: A Review of NOAA's Aquaculture Science Portfolio*. The SAB Office will circulate the new draft back to the SAB for review before transmitting to NOAA.

Adjourn

The meeting was adjourned at 12:43 p.m.