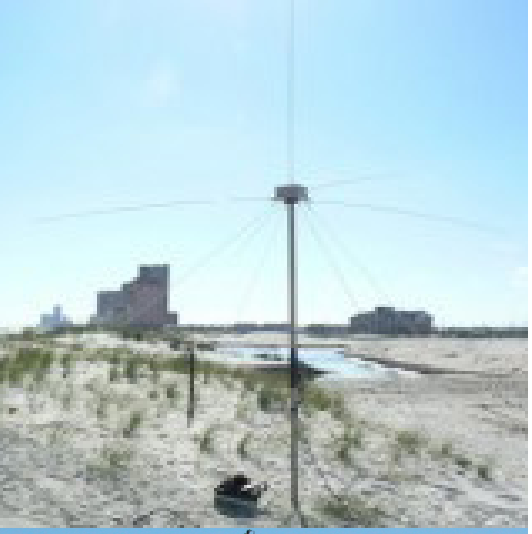

Recommendations to NOAA and the IOOC

by the U.S. Integrated Ocean Observing System Advisory Committee

Federal Advisory Committee to the National Oceanic and Atmospheric Administration and the Interagency Ocean Observation Committee

June 2021

The U.S. IOOS® Advisory Committee

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Executive **Summary**

The U.S. IOOS Enterprise is a mature integrated source of operational ocean observation data, products and services, and provides foundational intelligence to support climate science, coastal resilience, marine commerce, navigation safety, weather, water, climate and marine forecasting, energy siting and production, economic development, ecosystem-based marine, coastal, and Great Lakes resource management, and public safety.

The U.S. IOOS Advisory Committee is established under law by the Coordinated Ocean Observation and Research Act (COORA) of 2020 to advise NOAA and the Interagency Ocean Observation Committee (IOOC), two main components of the U.S IOOS Enterprise. During the drafting of this report, the committee was still operating under the authorization of the original Integrated Coastal Ocean Observation System (ICOOS) Act of 2009.

At the beginning of the current term (9/1/2018), the U.S. IOOS Advisory Committee identified three priority areas to focus their recommendations: (1) Vision and Strategy for the Future, (2) Creating and Sustaining Strategic Partnerships, and (3) Requirements Management and Infrastructure Investments for Success and Growth. The priority areas were based on a survey of IOOS Enterprise members and stakeholders that identified enterprise strengths, weaknesses, opportunities, and challenges. During the term, the committee decided to also focus more specifically on the work of the Integrated Ocean Observation Committee. This report synthesizes the committee's recommendations framed under these priorities, which are the result of three public meetings, briefings to the committee by NOAA leadership and staff and the IOOC, and independent analyses conducted by members of the committee.

The committee believes that these recommendations align with the Nation's priorities of economic recovery, climate, racial equity, and restoring America's global standing as a climate science leader. The work of the IOOS Enterprise in executing its mission naturally dovetails with these Administration priorities and provides valuable services to the nation.

High-level Recommendations

- **Ensure sustained observations to respond to changing ocean and climate conditions**
- **Capitalize on technological innovation to enable Smart Coastal Oceans and Great Lakes**
- **Maintain/Build on existing partnership models**
- **Use partnerships to accelerate innovation and inclusivity of underrepresented communities**
- **Leverage non-IOOS data initiatives**
- **Benchmark and ensure active management of requirements, including analysis, traceability, allocation, and guidance, to ensure effective annual and long-term budget formulation.**
- **Tie requirements management to Infrastructure Investments**
- **Enhance and expand IOOC coordination activities**

Background on U.S. IOOS

The U.S. IOOS Enterprise is a national integrated system of ocean, coastal, and Great Lakes observing systems, comprised of Federal and non-Federal components that includes in situ, remote, and other coastal and ocean observation and modeling capabilities, technologies, data management systems, communication systems, and product development systems. It is designed to address regional and national needs for ocean and coastal information, to gather specific data on key ocean, coastal, and Great Lakes variables, and to ensure timely and sustained dissemination and availability of these data to the public.

The observations collected, and the products developed by U.S. IOOS support climate science and coastal resilience, national defense, search and rescue operations, marine commerce, navigation safety, weather, water and climate marine forecasting, energy siting and production, economic development, ecosystem-based marine, coastal, and Great Lakes resource management, and public safety. U.S. IOOS is mandated to monitor and model changes in the oceans and Great Lakes, including with respect to water chemistry, harmful algal blooms, hypoxia, water levels, and other phenomena; and to improve the Nation's capability to measure, track, observe, understand, and predict events related directly and indirectly to weather and climate, natural climate variability, and interactions between the oceanic and atmospheric environments, including the Great Lakes.

U.S. IOOS also has a mandate to promote basic and applied research to develop, test, and deploy innovations and improvements in coastal and ocean observation technologies, including advanced observing technologies such as uncrewed maritime systems needed to address critical data gaps, modeling systems, other scientific and technological capabilities to improve the understanding of weather and climate, ocean-atmosphere dynamics, global climate change, and the physical, chemical, and biological dynamics of the ocean, coastal, and Great Lakes environments.

The components of the U.S. IOOS Enterprise are both federal and non-federal. The federal components include the Lead Federal Agency, NOAA, which has established an IOOS Program Office within the National Ocean Service; and the Interagency Ocean Observation Committee (IOOC), a subgroup of the Ocean Policy Committee's (OPC) Subcommittee on Ocean Science and Technology (SOST). The IOOC is comprised of 17 federal agencies that all contribute to our nation's ocean observing capabilities. The non-federal components of the system are the 11 federally-certified IOOS Regional Associations, which cover the complete geographic span of the U.S. EEZ and manage the regional coastal observing systems. The Regional Associations work with their local communities to provide specific products and services tailored to meet regional stakeholder needs.

Looking west from Key Biscayne, FL. Along this beach is an array of WERA antennae, part of the U.S. IOOS high frequency radar network. Credit: NOAA/IOOS/K. Culpepper

Vision & Strategy **for the Future**

Findings: While the IOOS Enterprise has a current (2018-2022) Strategic Plan, the Advisory Committee identified priority areas – aligned with national priorities - to help refine the IOOS Enterprise as it moves forward into the future and develops its next Strategic Plan. These include how IOOS develops and matures in response to changing ocean and climate conditions, and how to use technological innovation to refresh infrastructure and enhance IOOS. Below are recommendations on how to move forward in these areas, and are directly responsive to White House climate, economic recovery and global standing priorities.

Ensure sustained observations to respond to changing ocean and climate conditions

Long-term, sustained observations and the infrastructure necessary to collect them are invaluable in meeting stakeholder needs to respond to rapidly changing oceans and coasts at all time and geographic scales. They are critical in establishing baselines and enhancing climate and weather models. The data collected through the Regional Associations quantify coastal climate variability in addition to other changes and their impacts that occur in the nexus between land, the nearshore and the deeper ocean.

Detailed Recommendations:

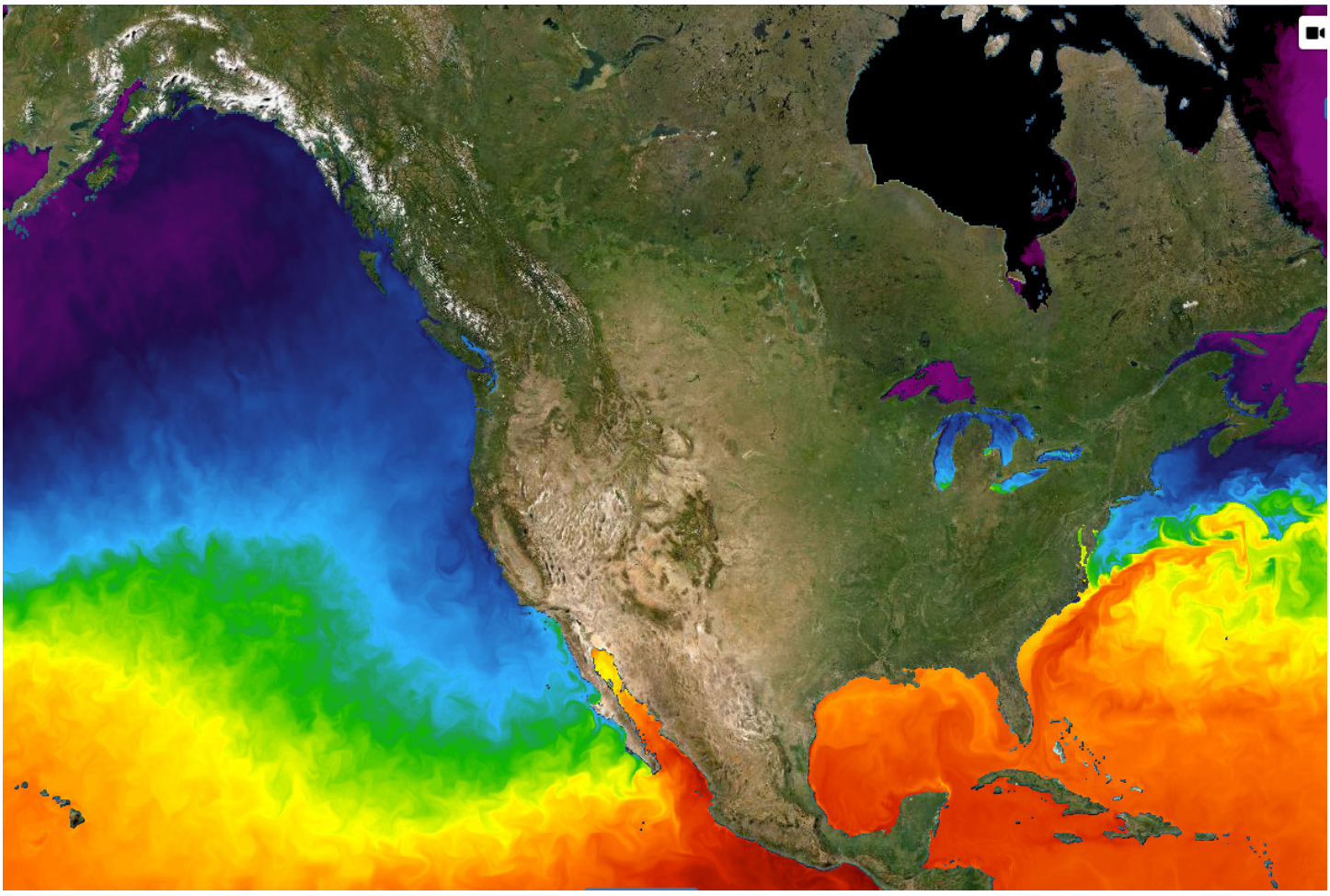
- **Maintain and increase IOOS observing infrastructure and measurements and ensure they capture the coastal climate signal and its impact through sustained observations and models.**
- **Advance linkages between regional near-shore and global ocean models and enhance integration with NOAA's Unified Forecast System.**
- **Continue to undertake economic valuation processes of observing systems to better quantify benefits and enhance messaging for sustained observations.**

Capitalize on technological innovation to enable Smart Coastal Oceans and Great Lakes

With marine technology rapidly evolving, the U.S. IOOS Enterprise needs a 5- to 10-year implementation plan to systematically replace aging infrastructure with newer, advanced, and often cheaper and better technologies. To complement the hardware, the plan should also include the transfer of older data tools to modern tools such as Cloud Storage, Machine Learning, and Artificial Intelligence to address the needs of the Regional Associations, extending from estuaries to the EEZ. This would reflect NOAA's overall technology initiatives in 'omics, autonomous systems, and artificial intelligence, and should be woven into the next IOOS Enterprise Strategic Plan.

Detailed Recommendations:

- **Ensure use of 11 federally certified regional data centers to implement advanced data tools and further data aggregation.**
- **Identify ways that NOAA can use technological innovations to address the needs of coastal and oceanographic communities and stakeholders, including for outreach and education purposes.**
- **Leverage diverse STEM expertise to enhance future workforce.**

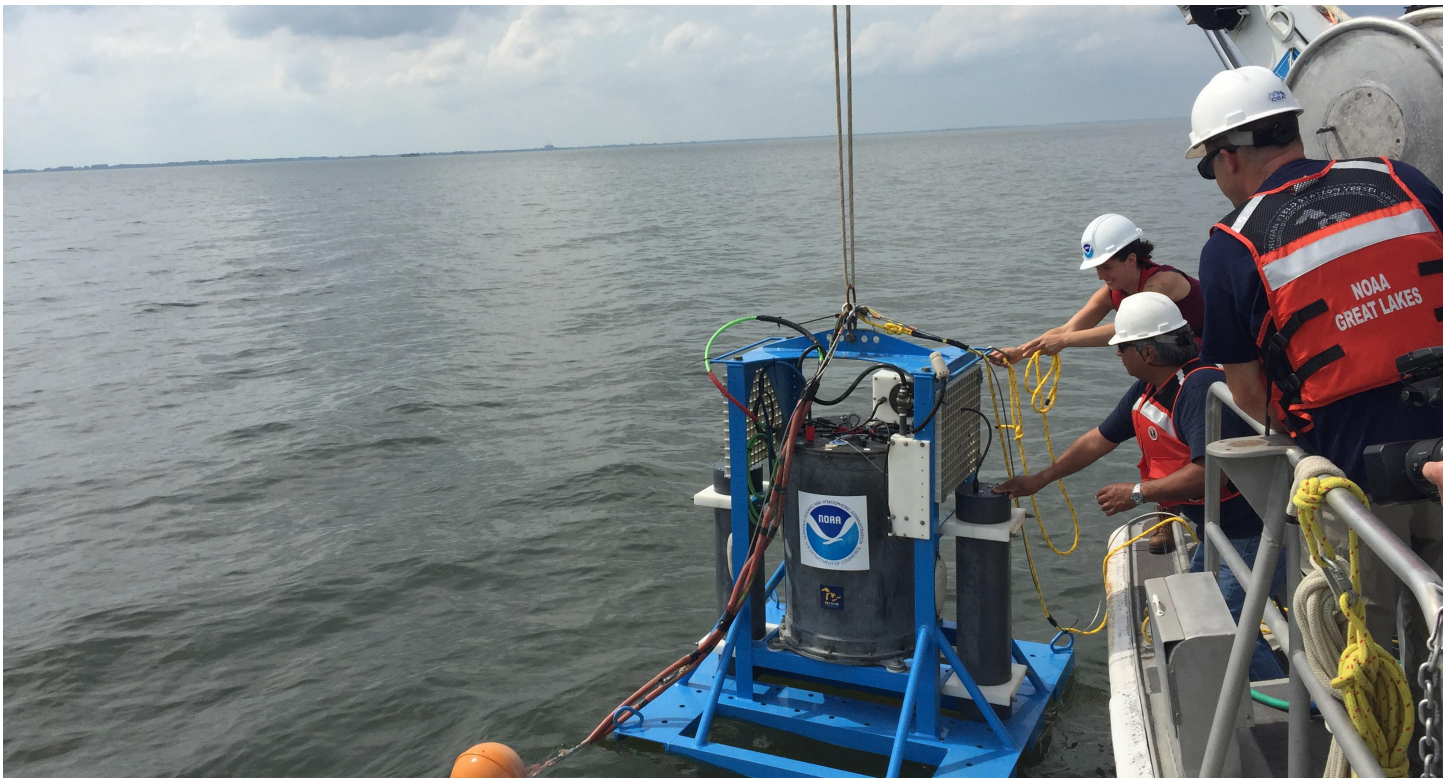


View of the Navy HYCOM model showing the water temperature layer, available thorough the IOOS Model Viewer. With the model viewer, users can examine numerous modeled variables together in a map-based environment, and generate time-series plots of the output. Real-time observations are also available for comparison purposes.

Creating & Sustaining **Strategic Partnerships**

Findings: IOOS is a distributed system that pulls together federal, state, tribal, academic and commercial partners in each of its 11 regions. The U.S. IOOS Advisory Committee assessed the range of critical partnerships for the IOOS enterprise. IOOS clearly benefits from the Regional Association structure that provides a deep bench of subject matter experts from many universities, companies, and native communities. These partners collect the data and translate the information for a variety of stakeholders. These stakeholders are also often formal partners with many paying dues to be members of the Regional Associations. This distributed partnership model is central to the IOOS enterprise and is critical to maintain. IOOS has also benefited from joint efforts with partner agencies with the opportunity to expand technology development that can then be integrated into the network.

The U.S. IOOS Advisory Committee investigated relationships across federal agencies, as well as with non-federal partners, and provided recommendations to strengthen and enhance those relationships. These include outreach activities (by IOOS AC members) to provide informational briefings about the Enterprise and explore ways to tighten collaborative efforts. In addition to strengthening existing partnerships, the committee investigated where the IOOS Enterprise can forge strategic alignments with new and unfamiliar communities; and will provide those recommendations to the appropriate entities within the Enterprise. This partnership model is a unique observing system strength and should be encouraged, promoted, and further strengthened.



Researchers deploy an Environmental Sample Processor into Lake Erie as part of an early warning system for harmful algal bloom in the region. This project, a collaboration between IOOS Regional Association GLOS; NOAA's Great Lakes Environmental Research Lab and Center for Coastal Environmental Health & Biomolecular Research; LimnoTech; and the Cleveland Water Alliance. Credit: NOAA/GLERL

Maintain/Build on existing partnership models

It is critical to maintain and build on existing partnerships in and outside of the NOAA and the federal government. Partnerships can innovate the nation's approach to the National Climate Assessment and in achieving national leadership on a global scale. However, aging infrastructure provides an ongoing struggle for IOOS as backbone observing infrastructure ages out. Exploration of different partnership models to leverage infrastructure from other federal, tribal, state, private, and academic partners is critical. Partnerships span from within NOAA, as well as with other agencies (DoD, NASA, NSF, USGS, EPA) and build around themes of interest with a range of proprietary agreements and targeted IOOS investments. Additionally, enhancing academic, tribal and private sector partnerships is critical for providing infrastructure and expertise which is core to the evolving IOOS enterprise.

Use partnerships to accelerate innovation and inclusivity

A number of private and academic entities are available to partner with IOOS and can help advance IOOS and NOAA priorities at an unprecedented scale to meet national priorities and provide reliability of ocean predictions to communities. IOOS provides a distributed system well suited to benefit from external partners. Frameworks such as those from the National Ocean Partnership Program (NOPP), Ocean Technology Transition (OTT) program and interagency agreements should be fostered by IOOS. Creating a program similar to the Department of Defense's Advance Research Projects Agency (DARPA) for the ocean might provide additional opportunities. Targeted partnerships might also provide an effective means for expanding integration with underserved black, Indigenous, and people of color (BIPOC) communities providing a conduit for traditional and Indigenous knowledge.

Leverage non-IOOS data initiatives

IOOS can partner to leverage use of and development with non-IOOS (big) data initiatives spanning operational (e.g. storm intensity forecasting) to innovation (e.g. eco-forecasting) initiatives. Partnerships with entities within NOAA, other agencies (e.g. DoD, NASA) and universities should enhance interactions and integrations with other data initiatives of interest to IOOS functions. These partnerships may complement or supplement themes of interest with a range of agreements and targeted IOOS investments.

Detailed Recommendations:

- **Analyze NOAA initiatives with established partnership models to ensure alignment with IOOS effort.**
- **Expand engagement with private industries and other entities to rapidly establish partnerships to augment aging ocean observing infrastructure.**
- **Pursue leveraged support from other agencies and private sources through the National Ocean Partnership Program.**
- **Collaborate with NOAA Big Data Project, and other relevant entities, regarding IOOS contributions to ecological forecasting and regional ocean forecasting efforts.**
- **Expand the participation at all levels of BIPOC and underserved and underrepresented communities, including co-production of knowledge and incorporation of local and traditional Indigenous knowledge.**

Requirements Management & Infrastructure Investments for **Success and Growth**

Findings: The national-regional construct of the IOOS Enterprise makes requirements management particularly difficult, since a comprehensive process would involve managing national-level requirements across the 17 federal agencies in the IOOC, including the IOOS Office within NOAA, as well as regional-level requirements across the 11 IOOS Regional Associations. This was the vision of the original ICOOS Act of 2009, but has yet to be fully realized and implemented.

The U.S. IOOS Advisory Committee reviewed the requirements management processes of the Enterprise, beginning with NOAA's process for managing observing requirements across the agency, as well as the U.S. IOOS Office approach for managing regional requirements. NOAA currently manages all observing system requirements through the NOAA Observing System Council (NOSC), with the National Environmental Satellite, Data, and Information Service (NESDIS) Technology, Planning, and Integration for Observation (TPIO) Office providing a catalogue of observing system components, their connections to NOAA mission areas, and a value tree. However, it appears the TPIO database of agency observing requirements has not been updated or re-evaluated since 2012. The Advisory Committee believes this database is not appropriate for the U.S. IOOS Office to use in order to manage observing system requirements on an annual basis. In order to allow IOOS to leverage the TPIO database, TPIO would need to update their non-satellite ocean observing requirements gathering approach. Additionally, that system is not currently organized to ingest and manage the numerous regional requirements identified by IOOS Regional Associations through their regular stakeholder outreach and engagement activities. Furthermore, the TPIO database cannot be used to generate a regional unfunded requirements list, which makes it difficult for the U.S. IOOS Office to adequately manage growth and changing needs across the nation.

It is noteworthy that the IOOS office issues an Annual Guidance Memorandum with identified priorities for implementation of each year's budget. While this guidance memorandum is based on a requirements management framework, there are, nonetheless, opportunities to improve the requirements process across the IOOS enterprise, addressing the need for both regional and national needs and consistency while also identifying funding gaps, shortfalls and trends.

Benchmark and ensure active management of requirements, including analysis, traceability, allocation, and guidance, to ensure effective annual and long-term budget formulation.

The committee notes that IOOS requirements are based on a number of foundational documents and identification of a set of core variables. However, the committee cautions IOOS against managing requirements solely using a parameter-driven framework . Doing so could prevent the IOOS Regional Associations from engaging fully in an annual, stakeholder-driven requirements management process. However, the committee notes that a more high-level structure in terms of requirements management, including clearly delineated objectives for growth outlined in the semi-decadal U.S. IOOS Enterprise Strategic Plan would benefit the U.S. IOOS Office.

The committee notes that in addition to IOOS, observing elements are located across various Line Offices at NOAA; however, the committee also notes it is not clear how NOAA divides its ocean observing mission and programs across several Line Offices or within a single Line Office. We recommend that NOAA leadership assess whether this organization is efficient or if improvements to the organizational structure would benefit the IOOS Enterprise and other parts of NOAA.

Both NOAA and the IOOC should be ready to quickly and easily answer the following:

1. Who conducts ocean observing (in NOAA and across the federal government)?
2. What activities do those entities conduct?
3. What is their funding level?
4. What are their unfunded requirements and gaps?
5. How can activities and budgets be realigned to more rapidly respond to national and community needs?

Detailed Recommendations:

- **The U.S. IOOS Office should adopt a requirements management system that begins with higher-level objectives (e.g. "IOOS observations will lead to a XX% improvement in hurricane intensity forecasts over the next X years")**
- **NOAA Leadership should develop a coherent description of the many ocean observing programs within its Line Offices, including associated budgets in a cross-Line Office roll-up**
- **U.S. IOOS Office should develop an annual investment strategy based on a traceable requirements management process**
- **NOAA Leadership should position IOOS as the oceanographic operational integrator at NOAA**

NOAA AOML and CARICOOS partners retrieve underwater gliders at the end of the 2020 hurricane season. Gliders like these are helping gather critical ocean data during the season to improve hurricane forecasting. The effort is a significant partnership between many partners including NOAA, IOOS, and the U.S. Navy. Credit: NOAA

Tie requirements management to infrastructure investments

The IOOS Enterprise, including NOAA, has an aging ocean observing system, exclusive of satellite systems. It is important to define requirements in order to ensure the maintenance, operations, sustainability, and modernization of the overall system. It is imperative that the requirements management process begin in IOOS and at NOAA. In order to successfully develop an infrastructure sustainability or refresh plan, IOOS needs to understand its position in the context of the greater federal ocean observing assets. That context includes identifying where it is possible to leverage resources, observing infrastructure, and expertise across the federal government in order to identify where new investments are needed and ensure the biggest return on those investments.

From the level of the IOOS Program up to the level of the IOOC, infrastructure refresh and refurbishment needs are largely predictable. The committee would like to see NOAA be more proactive to plan for, and address, aging infrastructure issues in IOOS and other ocean observing programs as appropriate. The committee recognizes that managing and sustaining the IOOS infrastructure is challenging since the "system" is a network of regional and national components (essentially a system of systems) and sources of funding are not solely from the federal government. Nonetheless, it is essential to have a coordinated investment plan for critical observing system infrastructure.

The IOOS Regional Associations stand out to the committee as a success story in terms of managing requirements to steer infrastructure investments. Currently, the IOOS Association is completing a five-year "Fill the Gaps" campaign that identified stakeholder-prioritized observing system gaps for high-frequency radars, profiling underwater gliders, and other coastal observing assets throughout the entire U.S. EEZ-- and delivered an incremental plan to fill those gaps on an annual basis with modest base budget increases. Those gaps were the Regional Associations' "unfunded requirements list" in terms of coastal infrastructure, and having that list in hand paved the way for the success of their campaign.

Finally, developing a requirements-based recapitalization plan for the infrastructure of today should be a priority. The committee notes the importance of also being forward looking to the infrastructure and technology needs of the future and to prioritize the modernization of the ocean observing system. In order to look ahead successfully, partnerships with the private sector, academia, and with regional stakeholders are critical for understanding projected future needs, as well as early technology development that may be useful for future operations.

Detailed Recommendations:

- **IOOS Office should create an unfunded requirements list based on a gap analysis**
- **IOOS Enterprise should develop an Observing System Recapitalization Plan to include maintenance, operations, sustainability, and modernization of the observing system**
- **NOAA should set up PAC budget lines for IOOS, for infrastructure refreshes and equipment servicing as part of a larger plan to fully fund present and future known and emerging infrastructure needs**
- **IOOS should, where possible without a federal budget cross-cut, assess requirements in the context of the total federal investments**
- **The IOOC should conduct the federal budget cross-cut mandated in both the ICOOS Act of 2009 and the Coordinated Ocean Observation and Research Act (COORA) of 2020, and ensure their membership has the expertise, resources, and influence in their agencies to accomplish this task.**

Additional Recommendations **specific to the IOOC**

Findings: The U.S. IOOS Advisory Committee supports the Interagency Ocean Observation Committee (IOOC) as a leader in interagency ocean observation activities. The IOOC has done well examining immediate agency commitments and missions. The IOOC co-chairs are a valuable resource with its committee members that play a pivotal role executing ocean observing initiatives.

Enhance and expand IOOC coordination activities

The IOOC should develop consensus strategies laying the groundwork for future ocean observation priorities. IOOC members and staff can also help the IOOS AC connect programmatic initiatives to executive requirements, legislative directives, and community recommendations. The IOOC co-chairs should leverage agency leadership to bring greater attention to their particular agency-based goals. The committee encourages the IOOC to work closely with other Interagency Working Groups (IWGs) in other thematic areas including Ocean Partnerships, Facilities and Infrastructure, Ocean and Coastal Mapping, Ocean Acidification, and others.

Detailed Recommendations:

- **Consider new task teams to address critical U.S. government-wide priorities such as communications and messaging, ocean climate modeling, and environmental justice (underserved users).**
- **Generate a list of the IOOC's top ten accomplishments of the past decade, in order to provide context to the impacts of that committee on the federal ocean observing enterprise.**
- **Align outcomes of OceanObs'19 and Ocean Studies Board workshops focused on sustaining ocean observations with emerging priorities, programs, and concepts linked to the UN Decade for Ocean Science and Sustainable Development goals.**
- **Manage a crosswalk of the status of all essential ocean, biology, climate, and other relevant variables; and suggest best practices or standards to best integrate the data from a local-to-global scale.**

Grassy dunes lead to the ocean at Isle of Palms Beach near Charleston, SC. Credit: Kate Culpepper

Conclusion

The IOOS Enterprise is delivering substantial benefits to NOAA and the nation through its core programs and regional associations. The Federal Advisory Committee believes strongly that the recommendations provided in this report build on the foundation and framework of the IOOS program and office and are intended to continue to strengthen the IOOS Enterprise by addressing critical gaps and requirements, sustaining infrastructure, and sustaining and building critical new partnerships. The Advisory Committee hopes NOAA, the IOOC and the IOOS Office will give careful and strong consideration to implementing the recommendations provided in the report.

Sea lions bask at LaJolla Cove in California. Sea lions, along with other marine life, are swiftly taking a place at the ocean observing table as biological observations, like those gathered through the Animal Telemetry Network and the Marine Biodiversity Observation Network, play a key role in understanding our ocean, coasts, and Great Lakes. Credit: K. Culpepper