MARACOOS Strategic Operational Plan
2016-2021

INTRODUCTION

All human understanding is based, at some level, on observation. What we know about the land, air, sea, and even space is based on shared observations over time. The ability to see into the ocean and to measure its properties improved dramatically during the 20th century. Just as the science of meteorology has provided the means to quickly observe and predict the weather, the marine sciences are giving us the means to quickly detect and predict changes in the marine environment. Such prediction abilities are vital to the safety, health and well-being of all living organisms. Just as a sustained network of atmospheric measurements has produced rapid advances in meteorology, a sustained network of ocean observations will mean improved predicting abilities. In 2004, the U.S. Commission on Ocean Policy[1] and the National Ocean Leadership Council (NORLC)[2] identified the Integrated Ocean Observing System (IOOS) as a high priority and emphasized the importance of interagency cooperation for successful implementation. Five years later, the "Integrated Coastal Ocean Observation System Act of 2009" was signed into law. This legislation authorized the establishment of a national IOOS and recognized the National Oceanic and Atmospheric Administration (NOAA) as the lead federal agency.

IOOS is a coordinated national and international network of observations and data transmission, data management, and communications (DMAC), and data analyses and modeling that systematically and efficiently acquires and disseminates data and information on past, present and future states of the oceans and U.S. coastal and estuarine waters. IOOS provides an "eye on our oceans, coasts, and Great Lakes."[3] IOOS is a collection of federal, regional, and private-sector partnerships working to enhance the ability to collect, deliver, and use ocean information. IOOS spans the whole of the U.S. Exclusive Economic Zone (EEZ). Delivering the data and information needed to increase the understanding of our oceans and coasts, so decision makers can take action to improve public safety, enhance the economy and protect the environment.[4]

Acknowledging that national issues manifest themselves in unique ways at regional and local levels, Congress created the regional components of IOOS to augment existing federal efforts to gather information at the appropriate spatial and temporal scales to inform marine and coastal stakeholders and decision-makers.

The Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS), established in 2004, is one of the eleven Regional Associations (RAs) comprising the coastal network of U.S. IOOS. MARACOOS covers the ocean and estuaries from Cape Cod, MA to Cape Hatteras, NC. The RAs cover a broad range of ecosystems, driving the development of well-defined observing systems tailored to focus on regional and local priorities defined by regional managers, government agencies, academia, business and industry, non-governmental organizations, and members of the general public most connected to the wise use and management

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1 "An Ocean Blueprint for the 21st Century: Final Recommendations of the U.S. Commission on Ocean Policy" <http://www.oceancommission.gov/documents/welcome.html>

2 "Ten-Year Strategic Plan for the National Oceanographic Partnership Program (NOPP)" <https://www.coreoceandb.org/DisplayFile.aspx?qs=3A9B53A690BA1136E5A8F08DA262794EC39>

3 IOOS < https://ioos.noaa.gov>

4 "Providing Coastal Information in a Changing Climate." 2009. National Federation of Regional Associations for Coastal and Ocean Observing.

of marine and coastal ocean resources. Together, the RAs coordinate through the IOOS Association to establish linkages to ensure that the needs of the region are reflected in national policy and priority setting.

MARACOOS is a 501 (c)(3) Non-Profit Corporation currently involving participants from 25 universities, 21 state and federal government agencies, 18 private sector partners, and 12 non-governmental organizations. The current structure and operation of MARACOOS reflects the evolutionary history that was driven in part by initial incremental funding that continues to promote the practice of minimizing administrative overhead and maximizing leveraged investment. Building on more than a decade of engagement, innovation, and progress, MARACOOS is committed to sustaining and growing the operation, integration, and evaluation of this end-to-end regional-scale system for the Mid-Atlantic region.

Vision 2016-2021

Today, there is the dawn of a new era where sustained ocean observations are revolutionizing the way we understand and experience the coastal oceans and recognize the mutual dependence and need for stewardship. The challenge is to fulfill the potential inherent in a sustained *fully-developed* network of observational platforms that supply data and information needed for rapid detection and timely predictions of changes in our marine and coastal waters.

In addition to seeking the wisdom and advice of the MARACOOS Membership to develop this vision of the future, we have consulted with a host of representatives from academia, industry, and the general public and we have also factored in guidance provided by the IOOS Program Office. The input from all these sources has been invaluable in developing our long-range plan. We believe this document provides a legitimate framework upon which our program can operate in the next five years. We realize, however, that this plan is a "living" document, and as such, will need constant revision as new events affecting our marine and coastal resources occur, as our knowledge of important issues changes, and as our program's ability to address issues of our stakeholders continues to develop.

This Strategic Operational Plan demonstrates continued commitment to a process that builds and sustains an observing system and stakeholder engagement throughout the Mid-Atlantic region. In coordination and recognition of the overarching and societal goals of IOOS, the results of extensive stakeholder engagement and needs assessment, MARACOOS will continue to focus on five theme areas: **Maritime Safety; Ecological Decision Support; Water Quality; Coastal Inundation; and Offshore Energy.**

MARACOOS Mission: **To seek, integrate, share and apply knowledge and understanding of our coastal ocean—and will enable us to maintain our long-standing commitment to providing integrated ocean information for a changing world.** Central to accomplishment of this mission is the need to foster partnerships in which the academic, public, and private sectors pool their human and financial resources to help protect lives, health, and property, to promote a strong economy and jobs, and to support a healthy environment.

MARACOOS Vision: **To enhance the strength, sphere of influence, and effectiveness of MARACOOS through the building of *true working partnerships.*** These partnerships can take many forms, including collaborations with other regional entities, joint projects with industry, and additional co-sponsorship with other federal and state agencies. The marine/coastal challenges facing us are far too great for any single entity to resolve. IOOS/MARACOOS provides a constant foundation of support that can be leveraged by forming vested partnerships. The interaction among members of the partnership enhances the knowledge and wisdom of each, while resulting in a better response to real marine and coastal ocean problems and opportunities.

THE PLANNING ENVIRONMENT: THE MID-ATLANTIC REGION

The **Mid-Atlantic Bight** (**MAB**) extends 1000 km alongshore, from Cape Cod, MA to Cape Hatteras, NC; this span of coastal ocean encompasses an expansive continental shelf cut by a deep cross-shelf valley and multiple

shelf-break canyons, large estuaries, and significant populations. Important resources are located in both the shelf waters and the increasingly urbanized estuaries—Narragansett Bay, Long Island Sound, Hudson-Raritan River, Delaware Bay and Chesapeake Bay. Into these estuaries, the Connecticut, Hudson, Delaware, Susquehanna, Potomac, and James Rivers drain inputs from a significant portion of the eastern United States. Shelf waters generally flowing along the coast from the Gulf of Maine to the south at Cape Hatteras experience the cascading inputs from each of these rivers and estuaries. In addition to the spatial complexities associated with shelf geometry—the long, wide ribbon of water punctuated by headlands, bays, shoals, and canyons—temporal variability is introduced by strong and sometimes episodic forces that constantly push and prod the Mid-Atlantic Bight. The MAB is a dynamic boundary between the less variable waters to our north and south, with complex seasonal physical dynamics resulting in a highly variable 3-D thermal structure. These dynamics structure shellfish and migratory fish habitats that support both commercial and recreational fisheries, and directly impact our weather.

The Mid-Atlantic region encompasses 10 states, the District of Columbia, 107 congressional districts and the latest US Census data indicate that ~78M people (25% of US population) live within the MARACOOS footprint. The nation's highest coastal population density makes increasingly competing demands for marine and coastal resources. Ports in the region handle 25% of the total U.S. waterborne commerce, and include the nation's largest petroleum product hub and the world's largest Naval base. Developed watersheds and urban estuaries, impacted by a century of industrialization and growing coastal populations, degrade coastal water quality and diminish recreational economies. Inundation driven by tropical storms and northeasters are year-round threats to the large populations that live on the broad coastal plain. While the region's electrical power grid is the most congested in the nation, the high population density, reliable winds, and wide continental shelf combine to support the nation's nascent offshore wind energy development projects.

Additionally, ***warming of the climate system is unequivocal***[5]**.** Present and future generations will be challenged by its accelerating global impacts, including melting of land and sea ice, rising sea levels, ocean acidification (OA), and deoxygenation (hypoxia), and more frequent extreme weather. Improved knowledge of the trends and variability of our changing environment is required to address the challenges of energy, food, water and economic security and resiliency on regional, national and international scales. In the Mid-Atlantic, global sea level rise, along with coastal subsidence from the last glacial retreat, combine to produce a regional hot-spot for rising sea levels, creating a higher baseline for land falling hurricanes and devastating northeasters. Climatic warming and OA are altering MAB fish and shellfish habitats. The Mid-Atlantic's dense population further increases the region's economic sensitivity to climate change, where, for example, new rainfall patterns and more frequent extreme weather conditions are impacting homes, businesses, farms and reservoirs.

Clearly, MARACOOS is tasked with resolution of challenging and complex environmental issues and the societal stake in both inshore and offshore waters makes the availability of data and information supporting the delivery of valued and timely predictions critical.

MARACOOS

Background

The Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) is a 501 (c) (3) Non-Profit Corporation currently involving representatives from 25 universities, 23 state and federal government agencies, 18 private sector partners, and 12 non-governmental organizations. The current structure of MARACOOS reflects its evolutionary history that was driven in part by initial incremental funding. In 2004, funding from NOAA supported the first organizational meeting of the Mid-Atlantic Regional Association (MARA). In 2005, the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), based at

[5] *IPCC. ARS5* 2015**.** < http://www.ipcc.ch/report/ar5/wg1/>

the University of Delaware was formed and chartered under the provisions of the Not-For-Profit Corporation Statutes in the State of Delaware. MACOORA created the framework in which the Mid-Atlantic's coastal ocean user community identified its five highest priority regional themes:
(1) Maritime Safety, (2) Ecological Decision Support (3) Water Quality, (4) Coastal Inundation, and (5) Offshore Energy. MACOORA established the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS), based at Rutgers University, to provide the necessary ocean observing, data management, and predicting capacity to systematically address the prioritized regional themes. In 2011, these two entities merged into one organization, MARACOOS, governed by the initial provisions of the incorporation document, creating an academic-industry-government partnership that leverages the region's distributed centers of critical expertise to form an interactive, integrated regional network.

Mid-Atlantic's coastal ocean user community identified and has reaffirmed its five highest priority regional themes as: *(1) Maritime Safety, (2) Ecosystem Decision Support, (3) Water Quality, (4) Coastal Inundation,* and *(5) Offshore Energy*. To support these user themes, MARACOOS has formed a NOPP-style academic-industry-government-NGO partnership-based Regional Coastal Ocean Observing System (RCOOS) that leveraged the region's extensive expertise and capabilities. Operation of the integrated, regional scale observation, data management and prediction network is sustained in real-time and gap fills national capabilities. It includes an outreach, stakeholder engagement and education network that engages users, identifies opportunities, and educates citizens.

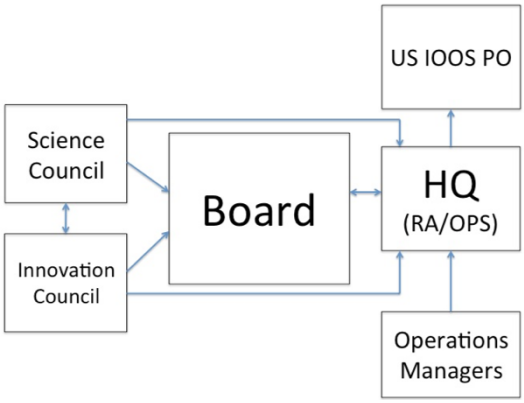
Working in 5-year segments, the first 5-year cycle established a sustainable regional-scale ocean observatory that filled gaps in the national infrastructure and supported our initial four user themes. The second 5-year effort (2011-2016) achieved operations and evaluated an ensemble of ocean and atmospheric prediction models to support our 5 user themes. Theme area successes include the first regional-scale network to be declared operational for USCG Search And Rescue (SAR), the successful use of MARACOOS data and models by the MA Fisheries Management Council to open new fisheries, DHS Impact Awards for aiding oil spill response, discovery of coastal processes that feedback on hurricane intensities and impact inundation, and the expansion of the observing network to enhance support for offshore wind development.

Governance

The structure and approaches of MARACOOS are designed to focus on engagement and understanding of the stakeholder community needs; resource prioritization, and allocation of operational capabilities commensurate with those needs. The result is a streamlined governance structure (Figure 1) that ensures responsible oversight and management while maximizing available resources to deliver state-of-the art products and services in the five priority theme areas.

A full-time Executive Director (G. Kuska), as Chief Operating Officer and spokesperson for the organization, will manage the day-to-day activities of MARACOOS, supported by a small staff complement to oversee technical operations, stakeholder engagement, and innovation-focused, applied partnerships. Further support for MARACOOS governance is realized through matching contributions from the University of Delaware and Rutgers University, as well as through the volunteer efforts of the member-elected Board of Directors and its supporting councils and working groups. In addition to the Executive Director, the MARACOOS Leadership Team will include several positions that emphasize the united nature of the regional association and observatory arms (Figure 1).

Figure 1: MARACOOS Organizational Diagram



The Chief Executive Officer and Chair of the Board (C. Thoroughgood) is responsible for managing Board functions, including the maximization of the program's intellectual and resource capital. The President and Vice Chair of the Board (S. Glenn) is responsible for general oversight of all aspects of the ocean observatory, including integration of regional observing programs/assets and compliance with milestone accomplishment. The Vice Chair of the Board and Chair of the Nominations Committee (E.Kelly) is responsible for Board member recruitment and private sector connectivity. The Chief Technology Officer and Technical Director (M. Crowley) oversees the day-to-day management of observatory operations, including data acquisition, management, as well as modeling and product development. For his role as MARACOOS Data Curator, M. Crowley brings extensive OOI experience as Program Manager for the Cyber-Infrastructure (CI) data management together with his IOOS experience to coordinate MARACOOS data lifecycle curation activities. The Director of Stakeholder Engagement ensures direct connectivity with the MAB stakeholder communities and leveraged engagement through partner organizations. A new position of Director of Innovation Partnerships will be phased in over the course of the grant period to oversee an innovation initiative being launched to enhance, develop, and maintain focused partnerships under the IOOS umbrella.

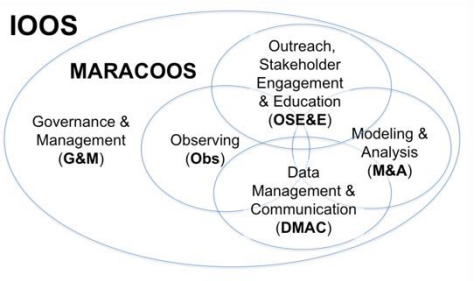
The Board composition represents a broad constituency, with members from industry, government, NGOs, and academia, and a broad geographic distribution throughout the MAB (http://maracoos.org/board). MARACOOS has over 60 dues-paying members, and several thousand direct-contact stakeholders, who have identified themselves with one or more of the five priority themes. A Stakeholder Engagement Initiative provides the formal basis for accessing and identifying regional needs and priorities via consultation with the broad range of regional stakeholders. This initiative comprises a variety of efforts, including: a) an annual member/stakeholder meeting; b) a series of theme-focused workshops; c) individual and group interactions across the region; and d) leveraged interactions through allied partners' organizations. Information is presented to the Board and the partnership for consideration, determination, and advice on enhancements, adjustments, and maintenance of the activities and resource prioritization within and across MARACOOS partners that ultimately guide product development. This approach is used for general as well as specific regional needs, and has directly informed the development of program goals and objectives in response to regional needs.

To further widen the reach and enhance the proactive nature of regional partnerships, MARACOOS has established an Innovation Council, with the purpose of developing and sustaining new focused partnerships under the MARACOOS umbrella. As a complement to the Innovation Council, the Science Council will advise on the scientific validity and data quality assurance. This approach allows MARACOOS to maintain its core strengths, while providing flexibility and a systematic pathway to engaging new partners with critical expertise and resources. This approach will also position MARACOOS to pursue, attain, and maintain IOOS regional certification as per 15 CFR Part 997.

Management

MARACOOS has a successful history of managing, operating, and integrating its 5 RA subsystems (Figure 2).

Figure 2: MARACOOS implementation of the 5 integrated subsystems that comprise an IOOS Regional Association.



We increase participation and set priorities through user/stakeholder engagement activities ranging from large annual meetings to sponsored topical workshops to individual contacts through our dedicated stakeholder liaison and allied outreach entities (i.e. Sea Grant). We develop, demonstrate, and deliver new observing technologies prioritized for sustained real-time data that are regional in scale, gap filling for the national backbone, and quality controlled, based on national standards. Furthermore, we engage external data providers from industry and local, state, federal and international programs to facilitate their integration into a common operating picture for our coastal environment. We have developed and operate a standards-based data management system that enables discovery and real-time access to data and information by users, data-assimilative modelers, and lifecycle data curators. We operate an expanding suite of data assimilative prediction models that are consistent with the developing national modeling framework.

Our stakeholder engagement activities, augmented by collaborations with a diverse set of vested MARACOOS members, ensure the end-to-end delivery of MARACOOS products. Our education activities, further enabled through NSF, focus on a) bringing real time data and information into the classrooms as well as to the marine resource users, b) contributing to the science pipeline and c) engaging a new workforce. Our infrastructure and professional expertise contribute to and are leveraged by numerous state and federal agencies beyond IOOS, including *NOAA* (NOS-COOPS, PORTS, OCM, NERRS, NCCOS, OCS, and the NOS Roadmap; NWS-NCEP, NDBC, WFOs/AWIPS; NMFS-NEFSC; OAR-OAP, NSGCP-SGD, CPO-CINAR; NESDIS-National Broadband Plan; and several agency-wide programs and efforts), *DHS* (USCG, S&T COE), *DOE* (NREL), *DOS* (UNESCO-IOC), *EPA*, *NSF* (OOI, OPP), *NASA*, *Oceanographer of the Navy* (Fleet Weather Center), *USACE*, and *USGS*.

Our implementation teams contribute to national IOOS infrastructure through participation in the HFR Technical Steering Committee, Glider DAC, federal DMAC backbone, and national modeling plan development. Internationally, we participate in efforts that include the GEO Global HFR Network, WMO Glider Steering Committee, NPOMS Typhoon Workshops and UNESCO's Intergovernmental Oceanographic Commission. Our ocean observing infrastructure is used for decision-making in 5 major user-defined theme areas of Safety at Sea, Ecological Decision Support, Water Quality, Coastal Inundation, and Offshore Energy. The RA is supported by scholarly productivity published in science journals, including 3 MTS and 1 CSR special editions. Activities conform to the Programmatic Environmental Assessment best practices.

MARACOOS evaluates each program component area annually based on a number of criteria. The evaluation process provides information needed to assess the effectiveness, efficiency, and impact of each component within the system, and informs a decision-making process that determines additional investment, sustainment, or retirement of individual observing assets, services, or component groups. A number of factors are considered

in the evaluation of each component area; these include: IOOS Program Office guidance; demonstrated level of need or use; uniqueness of service; potential for positive, significant impact; reasonable use of financial and human resources; ability to integrate into existing regional and national networks; level of customer utility and number of identified users; balance of partner contributions; level at which partners rely on the component area of operations; cost of operations and maintenance; and performance record. An evaluation of component areas using these criteria allows MARACOOS to select which projects to continue or discontinue.

Accountability and Liability

The distributed nature of MARACOOS results in there being two principal organizational and fiscal sponsors of MARACOOS: (1) The University of Delaware, Newark, DE and (2) Rutgers University, New Brunswick, NJ.

MARACOOS has a signed Administrative Services Agreement with the University of Delaware (UD) (http://maracoos.org/certification/doc/Administrative%20Services%20Agreement.pdf); under this agreement UD provides all services necessary or desirable for the operation of MARACOOS business and activities. As such, all employees of MARACOOS are employees of the UD, and their actions while under employ of the university are seen as activities taken by the university, with associated liability and self-insurance protections provided to employees as allowed for in University personnel policies. All actions taken by MARACOOS employees are assessed and reviewed annually through established employee evaluation requirements — ensuring supervisors of record are engaged in the ongoing activities of staff, and afforded the authority to hold staff accountable for actions, while also promoting and rewarding success. With respect to liability protection and through the Administrative Services Agreement, UD's General Counsel's Office is responsible to handling damages or injury caused by UD's agents, officers, and employees in the course of their employment to the extent that UD's liability has been determined by a court or otherwise agreed to by UD, and the university shall pay for damages and injury to the extent permitted by law.

Rutgers University is currently the recipient of the IOOS Program Cooperative Agreement and as such serves as the primary fiscal oversight body. There are no MARACOOS employees located at Rutgers University. MARACOOS Observatory operations are coordinated through the Center for Ocean Observing Leadership in the School of Environmental and Biological Sciences. As a research center housed within Rutgers University, liability and self-insurance protections are provided by Rutgers University.

Program Planning and Integration

Strategic planning involving constituencies both external and internal to MARACOOS has been a long-standing and integral component to the development of MARACOOS. The first level of external guidance for strategic planning comes from the IOOS Program Office. With national priorities in hand, MARACOOS engages many levels of federal, state, and local/regional governments, business and industry sectors, non-governmental organizations, community groups, academic partners, and coastal residents of the MARACOOS region to identify high priority issues relevant to Mid-Atlantic region. Input is gathered at community and in-person meetings, workshops, training sessions, focus groups, through web-based feedback services and through review of strategic plans, prioritization documents, and needs assessments compiled by partner organizations at local, regional, and federal levels. Engagement is on-going throughout the region and MARACOOS is committed, as is evident through its formal Stakeholder Liaison Program, to growing and maintaining a strong, diverse, and engaged user base that provides regular inputs on needs and priorities. Through stakeholder engagement, MARACOOS also gathers critical assessment on the effectiveness of the reginal system in satisfying its diverse user needs. In addition to Mid-Atlantic stakeholder engagement, MARACOOS also has international liaisons with stakeholder groups in Brazil, Korea, Spain, South Africa, Portugal, and Indonesia.

In addition to ongoing and regular contributions to needs assessments, gap identification, and priority identification, stakeholders may choose to participate more directly in MARACOOS priority setting through the

governance framework of the non-profit MARACOOS Corporation. It is through membership in MARACOOS that the Board of Directors are nominated and elected. MARACOOS members populate electing cohorts, including sub-regional, business and industry, non-governmental organizations, state and local government, and academic representatives, and are elected to 3-year terms on the MARACOOS Board of Directors at the annual MARACOOS business meeting.

Preparation of the Program Plan 2016-2021

MARACOOS, through its Board of Directors and rich stakeholder engagement process, sets a 5-year planning horizon for the program, and is reviewed annually to ensure that the organization is focused on relevant, appropriate, and timely activities while still maintaining its focus on overarching goals and objectives tied to the national observing enterprise. The goals, objectives, and recommended actions represent a collection of expressed needs, gathered over years and geographies, carefully matched with the capabilities of MARACOOS Principal Investigators, Staff, and Board of Directors to create a cost-effective, operational observing system.

Continuing to build on the accomplishments and lessons learned and based on self-evaluation of our 5 subsystems and their impacts, national level guidance (via the FFO itself and the national guidance documents quoted within), and continued stakeholder input for prioritized expansion of our activities, the goal of this third 5-year (2016-2021) planning cycle is to focus on the generation, refinement, and maintenance of new integrated products to address expanding user needs. To that end, the following improvements/reprioritizations of our ongoing activities will be implemented:

(1) Enhancement of the RA management team to better support the requirements of IOOS certification;
(2) Maintenance of the existing observing infrastructure, with a surge capacity capable of responding to extreme events, while continuing to expand the ability to deliver data quality consistent with QARTOD;
(3) Expansion of the data management and curating activities to entrain even more external data providers into the common operating picture provided by the Data Explorer technologies;
(4) Implementation of the results of a metric-informed, user-driven prioritization of data-assimilative prediction models for special purposes, expanding coverage to the entire Northeast U.S. Large Marine Ecosystem (LME);
(5) to enhance new product development, awareness, and use with targeted user communities; and
(6) Establishment of entrepreneurial innovation teams to grow future cross-cutting activities that broaden support for and enhance responsiveness to MARACOOS stakeholders.
    a. MARACOOS proposes a phased series of innovation projects; annual focus points are prioritized as follows:
        i. ocean acidification (YR 1), responding to large east coast gap in national OA monitoring and addressing documented needs of the shell fishing industry;
        ii. biological monitoring/animal movements (YR2), responding directly to the IOOS Program Office FFO's emphasis on ecosystems, as well as addressing significant Mid-Atlantic region user needs and augmenting NOAA fisheries observations;
        iii. coastal inundation (YR3), leveraging the well-supported NYHOPS implementation of NY Harbor and the development of new community response models in Hampton Roads, both of which can be expanded regionally;
        iv. nearshore water quality (YR4), leveraging state and county support for monitoring hypoxia (e.g. NJ coast) and *Vibrio* bacteria (e.g. Long Island Sound, Chesapeake Bay); and
        v. offshore wind energy (YR5), integrating the projected state growth for offshore sine energy development.

This Strategic Operational Plan represents the continued commitment to a process that builds and sustains an

observing system throughout the Mid-Atlantic region. The Mid-Atlantic is a densely populated region with diverse base of commercial and recreational ocean users. MARACOOS therefore must support multiple user-driven themes with responsive products developed from an integrated ocean observing and prediction system. This need led to the implementation of an integrated matrix approach, whereby a capability developed to support a critical user need in one theme can then be repurposed to serve numerous user needs in multiple themes. This matrix approach codifies the power of integration, has enabled a wide range of stakeholders to enjoy the benefit of collaboration and data sharing and is increasingly being adopted by ocean observing communities internationally.

The following section highlights the MARACOOS high priority theme areas, with their integrated stakeholder engagement, outreach, education and DMAC components to guide the annual work plans over the next five years and to secure Certification of MARACOOS during this same time period. The goals and recommended actions in each section represent a collection of expressed needs, gathered over years and sub-regional geographies, carefully matched with capabilities of the MARACOOS Principal Investigators, Staff, and Board of Directors to create a cost-effective, operational ocean observing system for the Mid-Atlantic. The comprehensive list of priorities includes the following:

MARACOOS Priority Focus Areas

(1) Ensuring MARITIME SAFETY AND RESILIENCY
(2) Providing ECOLOGICAL DECISION SUPPORT by supporting commercial and recreational FISHERMEN
(3) Helping maintain WATER QUALITY
(4) Protecting against COASTAL INUNDATION
(5) Supporting OFFSHORE WIND ENERGY

MARACOOS PRIORITY FOCUS AREAS

1. *ENSURING MARITIME SAFETY AND RESILIENCY*

Background

The general goals associated with this focus area include:

(1) Supporting emergency rescuers by defining smaller search areas and assisting people more quickly with a greater chance of preserving life and property;
(2) Monitoring vessels by supporting DHS protection for life and property; and
(3) Providing safe navigation by supporting NOAA PORTS products for ship pilots.

The U.S. Coast Guard (USCG), for its Search And Rescue (SAR) mission, responds to over 28,000 incidents with over 5,000 lives saved each year. The Search And Rescue Optimal Planning System (SAROPS) is the protocol used to respond to these incidents. The effectiveness of SAROPS to define search areas depends critically on the observed real-time and prediction surface current data that are delivered through their Environmental Data Server (EDS). The USCG SAR operators are trained in SAROPS and educated in modern ocean observation and regional current conditions. Similarly, the U.S. Lifesaving Association (USLA), for rip current safety mission, estimates that nearshore rip currents are responsible for over 100 deaths per year—the primary cause of drowning along U.S. coasts. Over 80% of the more than 12,000 annual lifeguard rescues are related to rip currents. The National Weather Service Weather Forecast Offices (NWS WFOs) provide daily rip current guidance to lifeguards through a rip current warning system. The accuracy of the NWS rip current forecasts depends critically on the observed nearshore waves and currents that go into their statistical models. The primary data need in this regard is the alongshore drift direction and nearshore waves.

Maritime safety was the highest MARACOOS priority area during its initial years. MARACOOS and

recreational fishers jointly developed the broad support necessary to partner with NOAA's National Data Buoy Center (NDBC) to deploy a weather buoy that provides ocean/atmosphere environmental data at the seaward end of the Hudson Canyon, improving fishing safety. Advances in port and harbor maritime safety continue through the execution of a preliminary data sharing agreement between Stevens and NOAA CO-OPS. Developed at the request of NY USCG Harbor Ops committee, under the agreement, Stevens will deliver full water column current observations from 3 locations in NY Harbor to CO-OPS at the required NOS standards for integration into the PORTS system and use by harbor pilots. The agreement leverages instrumentation funded by the NJDOT OMR for integration into the NYHOPS - MARACOOS observing system and serves as a prototype agreement for other harbors in the region.

The USCG Office of Search and Rescue and MARACOOS have jointly demonstrated that surface current maps improve the effectiveness of SAROPS. In a simulated search case, using a USCG surface drifter released south of Long Island, the USCG used surface currents from an operational HYCOM model and the MARACOOS HFR respectively with their SAROPS. The HFR surface current-derived search area was centered on the drifter and was three-times smaller than that derived from the HYCOM simulation. Thus in spring 2009, HFR surface current data were installed on the USCG EDS for use as an operational component of SAROPS, an important first step toward a national capability. The USCG estimates that 50 additional lives will be saved each year after the national implementation of the HFR surface current network. The indirect benefit is that USCG assets, which are typically redirected to SAR missions, will spend more time on their law enforcement and homeland security missions.

Since HFR and the Short Term Prediction System went operational with the USCG for search and rescue in the Mid-Atlantic in 2009, MARACOOS has consistently exceeded the USCG 80-80 metric for data availability in SAROPS. In 2014, MARACOOS provided data to the USCG as it carried out 247 SAR cases with 96 lives saved and 319 lives assisted. Encouraged by the USCG and others, HFR demonstration projects are transitioning new products into NOAA PORTS systems for NY Harbor, Chesapeake Bay and San Francisco Bay to support safer port operations.

Goals and Objectives: The Next Five Years

Goals and Objectives

Overarching Goal: To increase availability and use of high quality data products for search and rescue personnel, maritime transportation operators, and recreational boaters.

Objectives:

1. Ensure 80/80 coverage of HFR
2. Enhance data quality through:
    a. Integration of the bistatic vector measurements into regional products
    b. Increasing the Lagrangian trajectory modeling skill of the radar network
    c. Development and application of additional QA/QC procedures, including QARTOD
    d. Commencing real-time automated QA/QC of the radial and total surface current measurements
3. Maintain data product availability via HFR, DAC, STPS, NDBC; and enhance OceansMap to expand functionality and access
4. Develop and execute engagement, education plans for tutorials with USCG and maritime pilots and identify changing needs to enhance data use
5. Monitor data product use through automated reporting of user surveys

2. ***PROVIDING ECOLOGICAL DECISION SUPPORT BY SUPPORTING COMMERCIAL AND***

RECREATIONAL FISHERMEN

Background

The general goals associated with this focus area include:

(1) Minimizing bycatch and catch full quotas by creating predictive habitat models to inform fishermen about areas of high bycatch;
(2) Developing customized web and mobile applications, integrating historical catch information with real-time data and predictions to improve performance and reduce fuel use; and
(3) Supporting ecosystem-based fisheries management through
    a. incorporating of MARACOOS maps of observed and modeled oceanographic variables into stock assessments,
    b. tracking anoxic zones for resource managers,
    c. helping fishermen avoid anoxic zones, and
    d. reducing scope of fishery closures

Among the many issues requiring improved Ecological Decision Support, MARACOOS has focused its attention on fisheries and will continue to do so over the next five years. Direct, indirect, and induced economic impacts of commercial and recreational fisheries in the MAB are substantial with commercial fish landing values averaging close to $1.0 billion/year, and annual recreational fishing estimated at $7.4 billion/year. MARACOOS has worked with the fisheries community to incorporate environmental observation and prediction fields to support more informed management of this valuable resource.

MARACOOS has worked with sectors of the fishing community to identify effective ways to use environmental observations and predictions. These products enable offshore recreational fishers to fish more safely and commercial fishers to fish with reduced take of bycatch, less disruption of the environment, and more fuel-efficient operations. In the early 1990s, daily real-time satellite Sea Surface Temperature (SST) maps were made available to the MAB recreational and commercial fishing communities. More recently, MARACOOS, with input from different sectors of the fishing community, has defined and built more useful satellite SST products and web-based interfaces. Leveraging IOOS supported regional ocean observing assets in the MAB with research support from the Fisheries and The Environment (FATE) program, NOAA NEFSC and MARACOOS researchers were able to construct statistical models that linked fish abundance with observed pelagic habitat variables. Through direct interaction with the management community, these models are now being applied as a habitat-based approach to reduce butterfish bycatch in the squid fishery throughout the MAB.

The result of the MARACOOS Mid-Atlantic Bight habitat modeling effort was a “term of reference” (ToR) in the 59th NEFSC stock assessment review. As written in the final report of this review, “this ToR was met.” The review panel stated that the MARACOOS analysis was “rigorous and highly innovative.” Following the panel’s advice, the MARACOOS method has been included in the SARC 60 assessments of bluefish and scup in 2015. Further, 2014 was the first year of a small, directed fishery for butterfish, with a landings limit of 3,200 mt. This limit represents revenues of approximately $4.7 million (at 2013 average prices). Under the proposed 2015 specifications, the average landings limit for 2015-2017 would be 21,408 mt, or potentially $31.7 million additional ex-vessel revenues (at 2013 prices), with a significantly higher overall economic benefit through post-landing multiplier effects.

Animal telemetry and tracking is a rapidly growing field that can provide information on the distribution of animals and, in combination with observing technologies, oceanographic conditions the animals inhabit. Telemetry data standards are emerging in the regional community (ATN, OTN, MATOS, ACT) and there is broad interest in annotating animal locations with oceanographic data provided by IOOS.

Goals and Objectives: The Next Five Years

Overarching Goal: To increase availability and use of high quality data products for fisheries managers, fishermen, and living marine resource managers

Objectives:

1. Target engagement with fishermen and managers to identify areas and species for enhanced new data products and training and tutorials
2. Establish and support MATOS Integrated Animal Telemetry Users Council
    a. Host a workshop focused on telemetry data annotation to encourage the integration of oceanographic and telemetry data in the MARACOOS region.
    b. Based on workshop input, acquire fisheries acoustic tags and glider based receivers and passive acoustic systems for sensing and reporting fish and marine mammal occurrence.
    c. Deploy acoustic and satellite tags (YRs 3-5) with our telemetry partners, incorporate the passive acoustic (DMON2) sensors in MARACOOS glider surveys, and deploy two additional active and passive acoustic gliders for fish and marine mammal surveys (1 long-term, near-shore lithium mission in the fall, and one offshore alkaline mission in the winter).
3. Enhance data quality through:
    a. Refinement of Doppio domain for the data-assimilative ocean model
    b. Regular 3-day predictions for Cape Hatteras to Halifax initialized via ROMS 4DVAR DA
    c. Quantifying prediction uncertainty using intra-model ensembles
    d. Deploying 3 gliders during the stratified season each year
    e. Developing and applying QA/QC procedures, including QARTOD
4. Deploy and maintain enhanced OceansMap to expand functionality and access

3. *HELPING MAINTAIN WATER QUALITY*

Background

The general goals associated with this focus area include:

(1) Monitoring water quality via satellite imagery, surface current radar, robotic glider fleets, drifters, buoys, air-quality sensing, and computer modeling
(2) Tracking sewage, pollution, and oil spills, providing predictions to support beach and coastal managers and enabling rapid response
(3) Determining beach closings through the use of gliders and buoys monitoring toxic algal blooms, anoxic zones, and water temperatures

The Mid-Atlantic Bight has a wide range of water quality issues spanning low dissolved oxygen harmful algal blooms, and low pH water that vary in importance across the region. Given the connection of these issues to the large population of the Mid-Atlantic region, most water quality issues are located in estuaries and along the coast. This situation localizes the need and application of water quality product development. MARACOOS will continue to facilitate the connection between the regional IOOS and the work of local stakeholders to fill local needs with specific focus on the major bays within the MARACOOS footprint.

MARACOOS long-term support of water quality product delivery is expressed through a series of technical interactions with the water quality community across federal, regional, state, county and local agencies and governments. Since 2006, MARACOOS, in partnership with NOAA and others, have hosted water-quality workshops to encourage the development of effective water quality products on all scales. At the federal level, the effectiveness of IOOS and National Water Quality Monitoring Network (NWQMN) interaction has been demonstrated through the initiation of the Delaware Bay Pilot Project. At the state level, the NJDEP and USEPA are funding dedicated glider deployments that leverage IOOS investments in the region. At the county level, the same MARACOOS HFR network that serves the USCG is used to monitor river plumes to warn of

possible water quality impacts on recreational beaches. Leveraged data products such as these have been developed in response to specific needs of water quality professionals with local interests.

These interactions demonstrate the benefit of leveraging the regional assets for improved monitoring of the inner shelf and estuaries to support local water quality applications. MARACOOS has helped identify priority observations that could improve water quality in the MAB, through its collaboration with the NWQMN via collaborations with USGS. The collaboration has enabled product development such as the U. Delaware MARACOOS satellite based chlorophyll product that was used in late August this year to detect a large phytoplankton bloom off coastal New Jersey. A grant from USEPA, Region 2, in cooperation with NHDEP Marine Monitoring, supported a glider deployment that provided critical subsurface data. The USEPA and NJDEP used MARACOOS modeling support from Stevens to build a 4-D representation of the bloom that identified potential water quality impacts throughout the water column. In another example, at the request of NJDEP, MARACOOS used surface current observations, combined with regional ocean model predictions, to successfully back-track the source of medical wasted discovered off an Atlantic County beach. In 2011, MARACOOS supported NY and NJ authorities as they managed their response to an 8-million-gallon raw sewage spill in the Hudson River. A year later, MARACOOS HFR observations and NYHOPS predictions supported water quality issues in the harbor and along the coast, ranging from sewage and trash spills to debris plumes following Hurricane Sandy. MARACOOS, through the Chesapeake Bay Interpretive Buoy System (CBIBS), supports water quality monitoring (oxygen) along the full 250 km length of the Chesapeake Bay. These are but a few examples of the quality of products and services that come from strong partnerships with the growing water quality user community throughout the MAB. There is now growing interest in water quality as related to ocean acidification on the shelf and *Vibrio* in the estuaries impacting the shell fishing industry, the Mid-Atlantic regions largest commercial fishery. These two new issues will be addressed in the 2016-2021 period.

Goals and Objectives: The Next Five Years

Overarching Goal: To increase availability and use of high quality data products for federal and state shellfish authorities, and beach/recreational managers.

Objectives:

1. Convene local workshops to identify and prioritize water quality needs.
    a. Water Quality Working Group hosted meetings in each of the major bays (Chesapeake, Delaware, Hudson, Long Island, and Narragansett) to develop local strategies to best leverage MARACOOS assets to fill existing data gaps (YRs 1-2).
    b. Implement priority strategies identified in workshops (YRs 3-5).
2. Partner with NOAA Pacific Marine Environmental Laboratory (PMEL) collaborators in the development and deployment of the first moored Ocean Acidification (OA) buoy in the MAB shelf waters.
    a. Measure carbonate chemistry and other physical, biological, and water quality parameters.
3. Plan user need identification and product training by:
    a. Supporting intergovernmental pilot for Long Island Sound Water Quality database for *Vibrio* forecast
    b. Convening partners to develop a Mid-Atlantic Ocean Acidification Network
    c. Adapting Choptank Habitat Pilot project for implementation in other regional watersheds.
4. Enhance data quality through:
    a. Leveraging yearly glider deployments to measure water quality parameters
    b. Development and application of additional QA/QC procedures, including QAPP and QARTOD
    c. Commence real-time automated QA/QC of the radial and total surface current measurements
5. Deploy and maintain enhanced OceansMap to expand functionality and access

4. *PROTECTING AGAINST COASTAL INUNDATION*

Background

The general goals associated with this focus area include:

(1) Predicting storm surge and hurricane intensity by providing this information to emergency managers responsible for protecting lives, health, and property;
(2) Developing accurate predictions of inundation and delivering atmospheric models and real-time validation of surface data via the MARACOOS Asset Map and website;
(3) Monitoring water levels and transmitting real water gauge date via the MARACOOS Asset Map and website.

Following the 2005 IOOS/MARACOOS inundation workshop, the Chesapeake Inundation Prediction System (CIPS), in response to the needs of emergency managers, constructed a real-time prediction system with storm-surge visualizations down to street-level spatial resolution. CIPS formed a government, academic, and private-sector partnership to produce the predictions and deliver the information to the emergency managers to enhance their ability to respond to surges or sea-level rise. This partnership successfully used an ensemble approach that improved the accuracy of both atmospheric and water-level predictions. One of the primary goals of CIPS was to take the lessons learned from the local Chesapeake case to expand inundation predicting throughout the entire Mid-Atlantic Region. The inherently small spatial scales of inundation and the need to deal directly with the user community dictate that it will continue to be a fundamentally local process. However, significant improvements in accuracy and efficiency will accrue to these local efforts by addressing the issue from a regional perspective.

Coastal and estuarine inundation modelers will be able to improve their predictions by exploiting MARACOOS ensembles for their offshore boundary conditions. These local models are inherently more accurate because they assimilate real-time MARACOOS observations to improve estimates of upper-ocean heat content and the thickness of the wind-driven layer. In addition, coastal and estuarine inundation modelers can reduce their prediction uncertainties by exploiting the full ensemble of MARACOOS atmospheric forcing products. All these resources will be readily available for delivery from the MARACOOS servers via OPeNDAP. CIPS showed that the delivery of these products to the emergency manager in a form that can be used is at least as important as accuracy of the predictions. For this reason, MARACOOS will be able to facilitate local inundation efforts not only through delivery of regional modeling products, but also through transferring the lessons learned through the CIPS experience of working with local emergency managers to inundation efforts throughout the region. In addition, MARACOOS demonstrated the improving accuracy of surface wind fields through the continuing collaboration of WeatherFlow and the regional NWS Weather Forecast Offices. WeatherFlow continues to collaborate with the NWS Forecast Offices within the MARACOOS domain to build an increased understanding of surface wind fields. The ultimate goal of this effort is to build high resolution and accurate gridded wind fields for meteorological applications. This product will have broad application with the overall IOOS community.

Global sea level rise along with coastal land subsidence from the last glaciation combine to produce some of the fastest rising regional sea levels worldwide. Norfolk is currently ranked tenth in the world in assets exposed to increased flooding due to sea level rise, with city officials estimating over $1billion required to repair infrastructure and keep water out of homes and businesses. Long-term sea level rise also creates a rising baseline for inundation and flooding that require accurate inundation predictions—for rainfall, as in Hurricane Irene (ranked eighth with >$15B in damage), and for storm surge, as in Hurricane Sandy (ranked second with >$60B in damage). Demonstrating regional collaboration, NYHOPS, with RU-WRF-predicted atmospheric forcing, produced the most accurate storm surge predictions for Sandy. Based on these and other successes, the

NYHOPS ensemble operations have leveraged MARACOOS to garner City of New York support (well beyond typical regional funding levels) to make even more accurate storm surge predictions in the future.

The recent Hurricanes Sandy and Irene not only demonstrated immense destructive power to coastal regions in the Mid-Atlantic Bight and Northeast, but also revealed the crucial need for improved storm surge prediction and information delivery to save lives and property in future storms. Emphasis will be given to activities designed to improve hurricane intensity and storm surge models.

Goals and Objectives: The Next Five Years

Overarching Goal: To increase availability and use of high quality data products for federal, state, local, and private entities for infrastructure protection and flood control, and federal and private weather entities.

Objectives:

1. Use local scale models, including the unstructured FVCOM (Finite-Volume Community Ocean Model) and the New York Harbor Prediction System (NYHOPS) model to predict storm surges along the open coast of the Mid-Atlantic Bight and major estuaries.
    a. Conduct high-resolution inundation simulations at high-risk areas such as New York/New Jersey Harbor, Barnegat Bay, NJ, Norfolk, VA, and the Eastern Shore of Maryland.
        i. Product ensemble prediction of storm surges and coastal inundations.
        ii. Use visualization software to develop static and animated images depicting inundation at the street level.
2. Develop engagement plan for identification of user needs and product use training and tutorials.
3. Enhance data quality through:
    a. Adding realism in model physics (surface wave effects and atmospheric pressure influence)
    b. Development and application of additional QA/QC procedures, including QARTOD
4. Deploy and maintain enhanced OceansMap to expand functionality and access

5. *SUPPORTING OFFSHORE WIND ENERGY*

Background

The general goals associated with this focus area include:

(1) Siting and maintaining offshore facilities factoring in wind, wave, and current information from regional observations and models;
(2) Supporting onshore energy utility decisions, working with state regulators using MARACOOS sea breeze estimates to support day-ahead energy market predictions, ultimately saving money for utility rate payers.

Academic and industry weather forecasters in the MAB have over a decade of experience collaborating with the land-based energy industry. These collaborations have provided forecasts of summertime sea-breezes used to estimate day-ahead power consumption for improved generation efficiency, and year-round forecasts of severe weather to reduce down time from electrical grid damage. Forecasts are typically delivered through a website with an on-call meteorologist during events. The collocation of large coastal populations with Class 4 winds offshore make the MAB the most viable U.S. location for offshore wind energy to succeed. Nearly all Mid-Atlantic States already have plans in place for offshore wind resource development, with some exceeding the national target of 20% renewables by 2030. MARACOOS has responded by hosting participants from the offshore wind industry at their annual meetings as well as a dedicated stakeholder meeting to assess their ocean observing needs. MARACOOS PIs have been requested to serve on state implementation panels throughout the

region. Through these needs assessments and service opportunities, MARACOOS has learned that developers and regulators need improved understanding of the wind resource derived from high-resolution sea-breeze resolving predictions, delivered as maps, and used as input to state GIS systems for wind farm site planning. Additionally, local estimates of the wind resource and environmental conditions must be delivered as time series for historical analyses, financing, permitting, construction and operations. Better data are also needed to assess the risk of waves, currents, salt spray, and biofouling on the offshore wind farm system. Companies are assessing the cost of operation and maintenance and require wave height information to determine the number of days per month they can be working onsite and how much scour to expect around power cables and structures. Once wind farms are operating, they will need detailed and accurate wind, boundary layer, wave and current observations, and, most importantly, accurate weather predictions to compete on the day-ahead market. The benefit to society are the improved estimates of the wind resource and environmental data for wind farm siting, improved construction/operation, and improved power generation predictions.

Leveraging IOOS capabilities and expertise allows individual states to make cost effective investments in new observing system components to support the developing offshore energy industry. For example, the NJ Board of Public Utilities (NJ BPU) recommends state support for the RU-WRF weather forecasts and a nested high-resolution HFR network covering the inner shelf of southern NJ. The state funded enhancement of MARACOOS will provide a more detailed analysis of the wind resource for marine use planning, and will develop a state-of-the-art predicting capability for the day-ahead energy market that ultimately will reduce utility costs for the NJ rate-payer.

In 2015, a 5-turbine windfarm project off Block Island was initiated. Development is being pursued offshore of several MAB states, with future estimates running as high as 3000 turbines in Mid-Atlantic offshore windfarms. NJ Board of Public Utilities continues to support MARACOOS product enhancements in NJ, including the RU-WRF atmospheric prediction to generate detailed wind resource statistics, while contributing to the MARACOOS ensemble, and four HFR sites to enhance MARACOOS nearshore current products in the vicinity of the planned NJ windfarms.

WeatherFlow will act as a private sector partner with specialized expertise in coastal and marine weather observations and modeling. They will assume the lead on creating, updating, and disseminating an ensemble of multiple meteorological models over the MARACOOS domain, handling the integration of model members and the calculation of model ensemble output. They will also run statistical performance verifications on the ensemble members, using WeatherFlow and selected other observational data to compare predicted versus observed values as a way to assess model performance. WeatherFlow will run the analysis processes and provide the resulting statistics to MARACOOS for display on its system.

Goals and Objectives: The Next Five Years

Overarching Goal: To increase availability and use of high quality data products for federal and state renewable energy entities, private energy companies, and private wind energy developers.

Objectives:

1. Develop engagement plan for identification of user needs and product use training and tutorials.
2. Enhance data quality through:
    a. Leveraging regional atmospheric prediction models to form the MARACOOS ensemble
    b. Providing validation statistics on ensemble components based on federal, state, and industry network
    c. Development and application of QA/QC procedures, including QARTOD
3. Deploy and maintain enhanced OceansMap to expand functionality and access

MAINTENANCE AND ENHANCEMENTS OF EXISTING MARACOOS SUBSYSTEMS

Background

The proposed 5-year plan maintains and enhances existing subsystems, and broadens their integration through cross-cutting innovation projects. Sustaining the fulfillment of existing needs comprises the majority of MARACOOS funding and is spread across all MARACOOS subsystems. For the Governance and Management (G&M) Subsystem, continuing support will be used for coordination/facilitation of interactions with the U.S. IOOS Program Office, IOOS Association, government agencies, Board of Directors, and the membership community. The Outreach, Stakeholder Engagement and Education (OSE&E) Subsystem supports the Stakeholder Liaison Service to ensure consistent contact with the user community. For the Observing (Obs) Subsystem, funding will maintain the year-round operation of the (a) extensive HFR network, (b) satellite imagery downlink stations, (c) underwater glider flights (seasonal at present) that all yield quality controlled datasets; and (d) data-assimilative prediction models and ensembles. For the Data Management and Communication (DMAC) Subsystem, funding will be used to maintain and expand the data management system to properly support MARACOOS data-acquisition and data-assimilation model activities at the core of our user-driven, product-centered environment. For the Modeling and Analysis (M&A) Subsystem emphasis will be given to ESPreSSO model that has been found to be more skillful than seven other real-time models covering the MAB.

We propose annual enhancements to augment capabilities that improve user responsiveness and promote new product development. Specific targeted growth activities include: 1) addition of professionals dedicated to increased engagement of diverse MARACOOS stakeholder communities; 2) expansion of satellite capability and archiving activities including 4km GOES-East sea surface temperature; 3) support for the HFRs contributing to NOAA PORTS consistent with that for the HFRs supporting USCG SAROPS; 4) provision of rapid response capability to storms via glider deployments to enhance coastal inundation efforts; 5) expansion of infrastructure to meet growing needs for data management and application of QARTOD to model data streams; and 6) increased data assimilation into models for fisheries habitat assessment via leveraging NSF OOI and other data sources.

The following sections describe the essential MARACOOS subsystems that underpin and support all MARACOOS projects, activities, and accomplishments. These subsystems are:

(1) Governance and Management (G&M)
(2) Outreach, Stakeholder Engagement, and Education (O,SE&E)
(3) Observing (Obs)
(4) Data Management and Communications (DMAC)
(5) Modeling and Analysis (M&A)

1. Governance and Management Subsystem

The governance and management structure of MARACOOS is designed to foster an entrepreneurial ecosystem, driven by stakeholder engagement and needs identification, vested partnerships, resource priority allocation, and competitive opportunism to operationally deliver valued information and products. The result is a lean governance and management structure that ensures responsible oversight, while leveraging and maximizing available resources to accomplish stated MARACOOS goals and objectives in a timely fashion. It should be noted that MARACOOS continues to enjoy the substantial benefits of in-kind support from the University of Delaware and Rutgers University.

Looking out over the next five years, there are both opportunities and challenges that have resulted in MARACOOS enhancing and realigning its governance and management structure. The opportunity lies with the

prospect to become a Certified Regional Association, enhancing the value proposition of MARACOOS through the verification of quality control of data served through the MARACOOS data portal that is further enhanced by federal indemnification. The challenges result from the increasing societal demands of the Mid-Atlantic's dense population on marine and coastal resources that are exacerbated by the impacts of changing climate. For this reason, MARACOOS has enhanced the management team to better address these conditions and will launch a proactive approach to seek additional financial resources to meet the growing stakeholder needs. Enhancements of particular note include a full-time (as compared to three-quarter time) Executive Director of MARACOOS and a consulting position, Director of Innovative Partnerships.

The MARACOOS governance structure reflects the key role of Members, who elect the Board of Directors. The Board makeup deliberately represents a broad constituency, with members from industry, government, academia, and NGO's and a broad geographic distribution throughout the MAB. The Board has the benefit of advice and counsel of two advisory bodies—the Science Council and the Innovation Council. As a 501(c)(3) Non-profit Corporation, the MARACOOS Bylaws provide the overarching guidance for operation of this membership organization.

This new governance and management structure has been previously described under the MARACOOS Management section (see page 6).

2. Outreach, Stakeholder Engagement, and Education Subsystem

Strong partnerships in the Mid-Atlantic are a critical component for a robust MARACOOS response to stakeholder needs, applying intellectual capital and expertise to problems and opportunities that matter to marine and coastal resource users. The integration of outreach, engagement, and education improves the ability of MARACOOS to reach further into communities with tailored products and communications to solve multi-dimensional problems.

A stakeholder engagement strategy initiated during the past 5-year period established a structure and approach for implementing the research to applications continuum, emphasizing the input from the user community into design and development of information products. Strong relationships built on trust with the fishing community have yielded better fisheries management and significant benefits for the fishing economy. MARACOOS engagement will expand outreach and connections with the fisheries sector; attend to high-priority water quality and inundation issues; and enhance interactions with the marine safety and offshore energy sectors.

Until resources allow for growth of the Stakeholder Liaison Service to match the region's needs, MARACOOS will increase leveraging opportunities with allied partners, specifically with Sea Grant and Agriculture Cooperative Extension, multiplying impact that cannot be achieved through current funding. Regular communications via electronic means (newsletter, website, social media), workshops, conferences, one-on-one meetings, and the MARACOOS Annual Meeting will continue to support the outreach, engagement and education efforts. The following are examples of the MARACOOS' role in integrating outreach, engagement, and education:

- Ocean Acidification (OA). OA has been identified as a concern to stakeholders. Working with stakeholders, MARACOOS will develop a collaborative OA Monitoring and Data Serving Network. Key partners will include NOAA's OA Program, Sea Grant, MARCO, NERRS, fishing and shellfish industry members, and other federal, state and academic partners. MARACOOS plans to convene a regional OA Network and serve as the regional DMAC and data-serving hub.
- Mid-Atlantic Animal Tracking Observing System (MATOS) Integrated Animal Telemetry: In support of a MARACOOS-led Chesapeake pilot project to demonstrate a user- friendly, common platform, readily accessible to all telemetry professionals, MARACOOS will convene an Innovation Council Working

Group to support regular interactions, an outreach campaign, liaison activities and compatibility with allied efforts, DMAC and product development, and feedback, updates, and connections to existing data and models in MARACOOS network.

- Long Island Sound Water Quality Pilot: MARACOOS will support the efforts of state, federal, academic and shellfish industry partners to develop an accessible database of real-time or near real-time water quality measurements to aid prediction incidence of *Vibrio* spp., with potential application in other parts of the region. As part of this effort, MARACOOS will conduct a regional workshop for managers, industry and scientists in Winter 2016.

- Inundation and Sea Level Rise. MARACOOS will work with key Virginia partners to foster cooperation across the Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project and to identify information needs and integrate relevant data streams for application into user-defined decision tools.

- Innovation Council. MARACOOS will launch an enhanced focus on public-private partnerships through the creation of a new Innovation Council to provide an adaptive framework for focused opportunity response. Through a series of theme-specific working groups, the Council will discuss, analyze and help implement strategies to accomplish high priority stakeholder defined projects, collaborating on project definition and the acquisition of funding. An innovation liaison will coordinate the working group efforts to identify regional needs and priorities, drawing in existing and new partners, especially from the industry/private sector, to provide a path for technology testing and development of stakeholder-identified, value-added products. This effort strengthens existing and creates new strategic partnerships with private sector firms, and grows the capabilities and reach of MARACOOS/IOOS partners—all with an eye on developing an ocean enterprise that advances technology, develops a stronger economy, and facilities society's ability to manage and benefit from its ocean and coastal resources.
  - *Enhancements*: Under the auspices of the Innovation Council, a series of Innovation Workshops will be carried out to advance specific regional partnerships in the areas of:
    (1) ocean acidification;
    (2) integrated animal telemetry;
    (3) water quality,
    (4) inundation and sea level rise;
    (5) offshore energy

  These workshops will draw in additional partners, with an emphasis on the private sector, to develop user-identified solutions and identify strategies for sustained funding.

- Product User Experience Design. With guidance from a new Innovation Council, MARACOOS will continue to enhance OceansMap capabilities with new products for key stakeholders, engaging User Experience (UX) designers to utilize moderated focus groups, surveys, contextual inquiry techniques, and usability testing to provide guidance to the product development and OceansMap teams. MARACOOS will design and/or test one product each year.

- Data Tutorials. Contextual information is lacking on how to properly access, analyze and interpret MARACOOS data sets/products on its OceansMap. MARACOOS will develop a series of online learning modules to train users, particularly undergraduate/graduate students and stakeholder data users, in accessing, visualizing and using specific datasets. Examples include: a) comparing Glider and Argos profiles to analyze data quality, b) accessing HFR or STPS data to create a trajectory map, and c) visualizing glider data to analyze subsurface water quality properties. Modules will include example code for users to adapt along with additional resources that faculty can use to integrate assets into their curricula or to help train interns.

- Short Course Development for Continuing Education. MARACOOS will develop three types of courses: 1) 1-day face-to-face course for recreational fishermen, highlighting MARACOOS data assets; 2) hybrid

course (one day on campus and online resources) for Emergency Management Officials in partnership with the Jacques Cousteau NERRS Coastal Training Program; and 3) on-line courses for the U.S Coast Guard highlighting HFR resources.

3. Observing Subsystem

MARACOOS operates three gap filling ocean observing technologies: satellites receiving stations, HFR, and Gliders. DMAC integrates these datasets with additional external datasets and data assimilative models. In the period 2015-2021, MARACOOS proposes to evolve the Obs Subsystem as follows:

Satellites. MARACOOS will continue to acquire satellite SST and ocean color imagery with the RU & UD ground stations. These stations back each other up, and gap fill from NASA databases. With this dual station approach, we maintain the real-time de-clouded SST and chlorophyll products delivered via OPeNDAP, THREDDS, ERDDAP, Google Earth, and standard web pages to meet the needs of our broadest and most diverse user base. Ocean color data are quality controlled with the latest NASA processing software and coefficients. De-clouded SST data are quality controlled by comparing to climatologies and NDBC surface buoys. Spatial fisheries products using seascapes, SST and ocean color are being developed through leveraged projects that also support joint efforts with the National Telemetry and U.S. Marine Biodiversity Observation Networks. The new MARACOOS coldest-clear pixel SST product was developed to capture coastal upwelling and storm mixing impacts on coastal atmospheric predictions for offshore wind energy and storm surge predictions.

- *Enhancements*: UD recently acquired a geostationary dish capable of receiving GOES- East (4km) SST, providing 4 SST scans per hour that will be de-clouded and delivered to the MARACOOS online servers. Regional weekly climatologies and anomalies based on our historic data sets will be generated so that real-time data users know what conditions represent an unusual event. We will increase access to satellite data for animal telemetry and fisheries users by developing a query tool that accepts ungridded longitude, latitude and time requests. This tool will return requested satellite data values for user generated times and positions and will support the growing animal tracking, fisheries, and biodiversity efforts. In addition, the MARACOOS team will rebuild the backend of the 20 year archive of online satellite imagery at Rutgers so that it is more easily and directly available for historical SST research by GCOOS, CARICOOS, SECOORA, MARACOOS, NERACOOS and GLOS.

High Frequency Radar (HFR). The HFR work plan has two elements: (1) operations and maintenance, and (2) improvements and expansions. The MARACOOS HFR Network – established in 2007 - has been an operational data source to the USCG since 2009. The continued operation and maintenance of the network, one of the highest MARACOOS priorities, is essential for delivering quality-controlled data to the MARACOOS modeling group, National HFR Network, USCG SAROPS, NWS AWIPS and NOAA PORTS. Sustained data acquisition requires that we maintain efficient regional coordination of technical support, track resiliency statistics so as to prioritize gap-filling needs, implement gap-filling measures as resources allow, and incorporate new sites into the regional network. Our objective is to continue to exceed the USCG availability metric of 80% coverage, 80% of the time. To increase the use of the HFR products in USCG SAR responses relative to the global NCEP HYCOM and Navy NCOM models, we will work with the USCG Office of Search and Rescue to develop an education plan to present to the National Search and Rescue School and sector SAR controllers.

The second element of the HFR work plan focuses on system improvements to support new product developments. We propose to (1) integrate the bistatic vector measurements into the regional product as a stepping stone to national products, (2) increase the Lagrangian trajectory modeling skill of the radar network, and (3) commence real time automated QARTOD-level quality control of the radial and total

surface current measurements.

- *Enhancements*: HFR data is now available through NOAA PORTS for the Lower Chesapeake and New York Harbor. We propose to help expand this service by providing similar products to PORTS in Delaware Bay, Eastern Long Island Sound and Block Island Sound. We also propose to release surface drifters in the field of the HFR coverage on a quarterly basis to help improve the surface current measurement by the radar network consistent with USCG Office of Search and Rescue expressed need for regular validation data

Gliders. Regional glider missions support the core MARACOOS science themes through direct observations and assimilation into our ocean model. These subsurface glider observations improve 3-D ecological predictions and support regional fisheries habitat modeling, stock assessments, and animal tracking - in ways that both respond to needs of users/stakeholders (e.g., NOAA Fisheries/the fishing industry; Animal Tracking Network-ATN) and enhance national efforts (U.S. IOOS Underwater Glider Network Plan, the National Telemetry Network, U.S. Marine BON). As such, the timing and trajectories of the glider missions are designed with input from the end-user communities and data-assimilation ocean modelers. We propose the annual deployment of three gliders; each measuring a suite of ocean variables. The glider trio will simultaneously sample cross-shelf triangles (optimized for data assimilation) in May/June and in late August/September – times that mark the (a) establishment and break-down of the Cold Pool and coincides with the (b) cross-shelf migration of many MAB fisheries. These glider missions will be completed in accordance to the QA/QC operating procedures (adapted from QARTOD standards) and will be publicly available on the MARACOOS website. These glider data available in real-time via DAC/GTS will allow open availability and assimilation into MARACOOS research-operational ocean models. The glider fleet will be managed by a team from the five Glider Technology Centers (Rutgers, UDel, UMaryland, UMass, VIMS). Depending on mission objectives and platform availability, funds will be directed to the different Centers for operations as well as glider data/information product development.

- *Enhancements*: Over the past five years, four new storm gliders were procured and deployed in hurricanes through leveraged support from NOAA CINAR. To continue to provide data to improve storm intensity predictions, support the needs of the NWS, and enhance NWS's Hurricane Forecast Improvement Program (HFIP), Rutgers and UMaryland propose to deploy their two storm gliders each year in the MAB in rapid response to hurricanes. These storm glider data will provide crucial ocean surface boundary condition information for weather/storm prediction models, enhance coastal inundation efforts, and provide data for assimilation into an operational fisheries habitat modeling system.

The proposed above enhancements are part of the longer term build out plan found at (http://maracoos.org/about_maracoos); the long term observing system gaps are summarized in Figure 3.

Figure 3: MARACOOS Platforms Now & Future

	TYPE	TOTAL NEED	Existing #	O&M PRIORITY (low, med, high)	GAP #	Gap filling Priority
Offshore Moorings	Deep Water	2	0	Low	2	Low
	Slope Water	2	0	Low	2	Low
	Shelf Water	3	0	Low	3	Low
Estuary Moorings	Block Island Sound east to Nantucket Sound	5	0	Medium	5	Medium
	Long Island Sound	5	0	Medium	5	Medium

	New York/New Jersey Harbor	5	0	Medium	5	Medium
	Delaware Bay	5	0	Medium	5	Medium
	Chesapeake Bay	5	10	High	0	Low
Meteorological Stations	Continental Shelf (moorings)	10	0	Medium	10	Medium
	Coastal	10	1	Medium	9	Medium
Pier Stations	Meteorological/Oceanographic Stations	20	0	Low	20	Low
Platforms of Opps	Shelf Water	3	0	Low	3	Medium
	Coastal Water	2	0	Low	2	Medium
Gliders	Continuous Transects Nearshore	15	2	High	13	High
	Continuous Transects Shelf Wide	15	2	High	13	High
	Continuous Shelf/Slope Edge	10	1	Medium	9	Medium
	Specialty Gliders	5	2	Low	3	Low
	Storm Gliders	5	2	High	3	High
Ferry Boxes	Block Island Sound east to Nantucket Sound	5	0	Low	5	Medium
	Long Island Sound	5	0	Low	5	Medium
	New York/New Jersey Harbor	5	0	Low	5	Medium
	Delaware Bay	5	0	Low	5	Medium
	Chesapeake Bay	5	0	Low	5	Medium
REMUS and other AUVs	Block Island Sound east to Nantucket Sound	3	0	Low	3	Low
	Long Island Sound	3	0	Low	3	Low
	New York/New Jersey Harbor	3	0	Low	3	Low
	Delaware Bay	3	0	Low	3	Low
	Chesapeake Bay	3	0	Low	3	Low
Ships of Opps Transects	Block Island Sound east to Nantucket Sound	1	0	Low	1	Medium
	Long Island Sound	1	0	Low	1	Medium
	New York/New Jersey Harbor	1	1	Low	0	Medium
	Delaware Bay	1	0	Low	1	Medium
	Chesapeake Bay	1	0	Low	1	Medium
Drifters	Seasonally Stratified (May-October)	32	9	Medium	23	High
	Seasonally Unstratified (November-April)	18	0	Medium	18	High
Space Based	X-band Polar Satellite Ground Station	2	1	High	1	High
	L-band Polar Satellite Ground Station	1	1	High	0	Low
	L-band Geostationary Satellite Ground Station	1	1	Medium	0	Low
Airborne	Aircraft with Multispectral Imager	1	0	Low	1	Low
HFR stations	SAROPS: Low Frequency (5	30	17	High	13	Medium

	MHz)					
	PORTS: High Frequency (25 MHz)	20	9	High	11	High
	Beach Waves: Medium Frequency (13 MHz)	15	7	Medium	8	High
	Sounds/Bays: High Frequency (25 MHz)	15	8	Low	7	Medium

4. Data Management and Communications Subsystem

The MARACOOS DMAC team manages and operates a robust services-oriented system that includes tools to auto-aggregate, quality-control, and monitor a variety of observational and numerical model assets. The team is responsible for (1) managing direct and remotely sensed observations and model data; (2) building data-model connections for assimilation and
comparison; (3) implementing and managing standards-based data access services such as TDS, OPeNDAP, ncWMS, SciWMS, and ncSOS; (4) providing data in approved common data formats such as NetCDF; (5) providing infrastructure for hosting data and services; and (6) delivering data to operational users.

Distributed data systems with different storage and distribution methods are difficult to monitor and enforce consistent processes and standards. For this reason, MARACOOS has moved towards a centralized data aggregation approach - a regional DAC - for model and remotely sensed observation data and is moving towards a centralized approach (with at a secure offsite server farm) for direct observation data. Our centralization efforts include management of data generated by MARACOOS partners such as CBIBS, Rutgers, and Stevens as well as data collected via outside efforts such as HRECOS, Maryland DNR, and NERRS. Where applicable, MARACOOS data will continue to be delivered to national DACs and NCEI for long term archiving. This approach helps us to better manage data quality, distribution, and services.

The DMAC subsystem facilitates discovery, access, and understanding of regional and relevant national observation and model data. All MARACOOS services are registered with NDGC and listed in the IOOS catalog, enabling user-discovery. Data can be accessed via DAP, WMS, and SOS, and visualized in the MARACOOS OceansMap. We are updating the OceansMap with a modular and scalable infrastructure - enabling expanded functionality. The MARACOOS Data Sharing Plan is described on page 4.d-45 of the appendix.

The MARACOOS DMAC system uses a combination of the Environmental Data Server (EDS) and THREDDS to manage model data and results. The DMAC supports the modeling and analysis subsystem by providing stakeholder access to model data, visualizations, and the capability for model-model and model-observation comparisons. We will be using these data to identify ocean and ecosystem anomalies in support of the NOAA Ecological Forecasting and Storm Surge Roadmaps. Our DMAC team leads the COMT cyber-infrastructure project and will continue collaborating with regional modeling efforts, as appropriate.

The MARACOOS DMAC team - a successful operator of a regional DAC - has been managing both distributed and centralized data; which has been made available via the mechanisms outlined in the IOOS/DMAC Guidance. MARACOOS has implemented QA processes for CBIBS and leads the national DMAC implementation of QARTOD. The latter adds to our other national efforts, such as archiving with NCEI, development of the certification plan and implementation of the certification requirements. The DMAC team is tracking the expansion of ESRI GIS implementation within NOAA and currently evaluating implementation of ESRI technology. As the OOI CI primary developer, the DMAC team is well positioned to ensure the possible future coordination of IOOS and OOI data and services. Should we be required to meet the expanded Federal Information Security Management Act (FISMA) standards, the DMAC team can implement (FISMA)-compliant servers.

- *Enhancements*: To meet growing data demands, the DMAC team will expand hardware/infrastructure;

enabling us to harvest and serve new or existing data sources to support new MARACOOS goals. MARACOOS is implementing QAQC for observational data (as required by certification). We propose to help implement QARTOD for the model data streams. This will allow MARACOOS to serve QAQC'd model data to the public.

5. Modeling and Analysis Subsystem

In 2009, MARACOOS implemented a real-time ROMS modeling system (ESPreSSO), using 4-D variational (4DVAR) data assimilation (DA) of CODAR currents and satellite data. Each day for the past 6 years, the system computed a 3-day ocean prediction for the MAB. In 2012, the DA was augmented with CTD data from gliders, NMFS ECOMON surveys, and GTS profiles to enhance skill for bottom temperature, which is a key determinant of fish and shellfish habitat in the MAB. Based on a comparison of surface current and subsurface T/S, ESPreSSO (Wilkin and Hunter, 2013) was found to be more skillful than seven other real-time models covering the MAB. ESPreSSO model also output has been used in studies of sediment dynamics and ecosystems (e.g. Dalyander et al. 2013, Hu et al. 2012; Mattern et al. 2013; Miles et al. 2015; Xu et al. 2013).

MARACOOS personnel propose to expand the present ESPreSSO MAB domain to include the Gulf of Maine, Georges Bank, and Scotian Shelf. This extended ESPreSSO will encompass the entire NEFSC marine ecosystem and enable the assimilation of NERACOOS, MARACOOS and GOOS data into an inter-regional analysis/prediction. The proposed extended ESPreSSO has been prototyped through (a) several NASA projects to develop satellite altimetry applications of, and (b) an NSF project using OOI Pioneer Array data for model validation. ESPreSSO convergence rates will be improved, representing error covariances and analyzing the impacts of different observation schemes in Observing System Simulation Experiments (OSSE). We propose to continue our ESPreSSO quantitative Eulerian and Lagrangian skill assessments using data from OOI Pioneer Array and an extensive Gulf of Maine drifter data set (Manning et al. 2009).

Recognizing the goals of NOAA's draft Storm Surge Roadmap, we propose to include real-time assimilation of coastal corrected satellite altimeter data to provide Total Water Level above Datum shelf-wide boundary conditions for regional inundation prediction models. This model enhancement also addresses the focus areas in Section 2.1.2 of NOAA's Ecosystem Forecasting Roadmap, with the MARACOOS modeling team aiding NOS on R2A transitions (e.g. recent integration of the Gulf of Maine HAB forecast into the ROMS open source code). Co-PI Wilkin co-chairs the IOOS/IOOC Modeling Strategy Task Team and will ensure that MARACOOS modeling developments are at the forefront of implementing that strategy.

While sustaining and validating ESPreSSO will be our priority, we also will initiate a significant effort to quantify prediction uncertainty. For example, in 4DVAR, the analysis posterior error covariance reveals uncertainty in the initial conditions (IC). We propose to generate prediction uncertainty envelopes from an ensemble of runs in which ICs are sampled from a statistical distribution. We also propose to add realism to ESPreSSO physics by implementing surface wave effects on turbulence and atmospheric pressure effects on sea level. The latter will improve ESPreSSO inundation predicting capabilities by allowing the retention of remotely- forced storm surge that is captured in coastal satellite altimetry. Deliverables will include: (1) regular 3-day predictions for Cape Hatteras to Halifax, (2) analysis and prediction skill metrics, and (3) quantified prediction uncertainties.

- *Enhancements*: The Gulf Stream (GS) Warm Core Rings (WCRs) impact MAB circulation and water mass variability throughout the year. We propose to (1) archive our digitization of Jenifer Clark's 1975-2015 Gulf Stream (GS) charts, with special focus on GS pathways and WCRs; (2) validate multiple models (e.g., NCEP, ROMS, MARACOOS, NERACOOS) for these features; and (3) analyze these GS-related features for variability on seasonal to climatic time scales. We will conduct OSSEs that improve MARACOOS glider deployment strategies to optimize ESPreSSO estimates of the MAB Cold Pool ecosystem habitat. This effort responds to a key research area identified in the IOOS Modeling Task Team IOOC progress reports, namely: IOOS coastal modeling should support observing system design and

operation, and identify needs/gaps.

The observing, data management, and modeling subsystems are leveraged to maximize their utility across all regional priority themes. Figure 4 illustrates the matrix approach to leveraging these subsystems.

Figure 4: Technology Leveraging Matrix

Regional Observation & Modeling Capabilities

Regional Priority Themes	**Weather Mesonet**	**HF Radar Network**	**Satellite Imagery**	**Glider Surveys**	**Dynamical Ocean Predictions**
Theme 1. Maritime Safety	Operational Input to USCG SAROPS	Operational input to USCG SAROPS	SST for survivability planning	Assimilation dataset for prediction models	Surface currents for SAROPS
Theme 2. Ecological Decision Support	Weather prediction ensemble validation	Circulation and divergence maps for habitat	SST & Color for habitat	Subsurface T & S for habitat	3-D fields of T, S, circulation for habitat
Theme 3. Water Quality	Winds for transport, river plumes, & upwelling	Surface currents for floatables, bacteria, spill response	Ocean color for river plumes	Nearshore dissolved oxygen surveys	Surface currents for floatables, bacteria, spill response
Theme 4. Coastal Inundation	Weather prediction ensemble validation	Current prediction model validation	SSTs assimilation into prediction models	Assimilation dataset for prediction models	Nested prediction ensembles
Theme 5. Offshore Energy	Historical analysis & wind model validation	Historical current analysis & wind model validation	Historical analysis surface fronts & plumes for siting	Historical analysis of subsurface fronts & plumes	Coupled ocean-atmosphere models for resource estimates

Funding the System

MARACOOS is in receipt of financial support from public and private sector entities and membership dues that

are applied to serve the prioritized needs of diverse stakeholders in the Mid-Atlantic region. With the commitment to sustain and grow the operation, integration, and evaluation of this end-to-end Mid-Atlantic regional observing system, MARACOOS leadership has chosen to minimize administrative overhead and maximize leveraged investment. U.S. IOOS has provided the steady, consistent base of financial support. MARACOOS regularly engages with the U.S. IOOS Program Office to determine the maximum amount of IOOS Program federal funds—awarded as the result of a competitive review process—available to support the continuation and further development of MARACOOS operations. Since the inception of MARACOOS, the U.S. IOOS has been joined by two principal organizational and substantial fiscal sponsors: (1) the University of Delaware, Newark, DE and (2) Rutgers University, New Brunswick, NJ. Specifically, these institutions have covered salaries of the principal investigators and numerous senior investigators, along with providing in-kind match of administrative services, fiscal oversight, and the return of university overhead to support MARACOOS program activities.

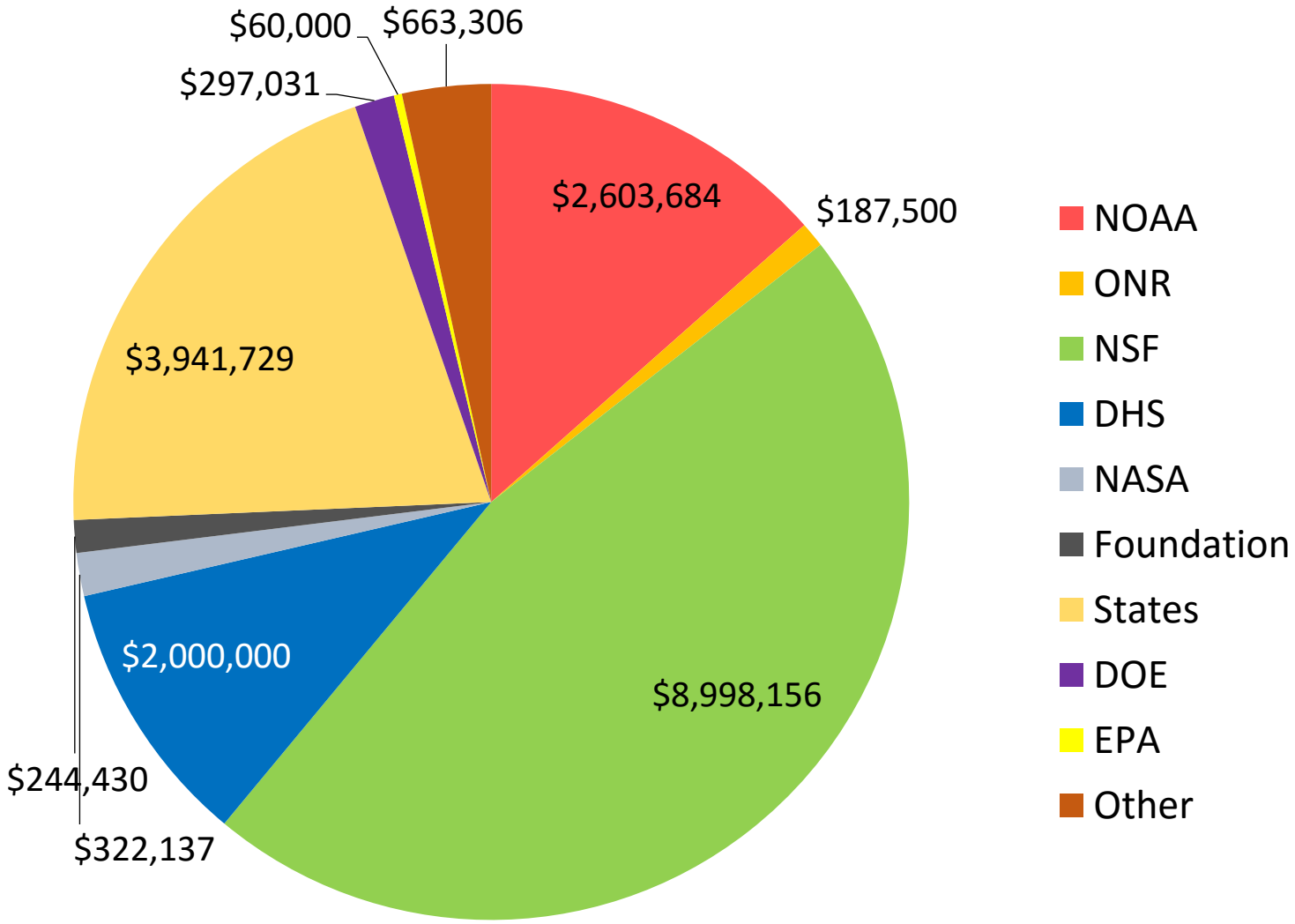
Budget allocation criteria prioritize activities in each of the 5 subsystems, followed by the allocation of funds to each activity, and finally assignment of responsible institutions and personnel. The annual budget template includes Base and Enhanced. Base support reflects the cost of maintaining all the existing functions of the RA and RCOOS. Enhanced activities are prioritized based on the evaluation criteria found in the Project Evaluation Policy (http://maracoos.org/certification/doc/MARACOOSProjectEvlauationPolicy.docx) If cuts are required beyond the base level, maintaining the activities associated with the Governance and Management Subsystem is our first priority, the time series of observations is second, and all other base-level functions are third. Budget cuts below the base will be applied with 0 shares from G&M, 1 share from Obs, and 2 shares each from DMAC, OSE&E, and M&A Subsystems. Partners are informed/aware of the decision criteria and the ultimate decisions on annual funding, based on the known criteria, which are discussed with the Board and distributed through established transparent means, including electronic/web distribution and bi-monthly conference call meetings for the Board and for the partners.

While the MARACOOS Board and leadership plan the organization's activities with the expectation of continued federal funding through U.S. IOOS and match support from the University of Delaware and Rutgers University, uncertainties in future federal funding are unlikely to result in funding levels sufficient to support the needed growth and development of MARACOOS, as laid out in the MARACOOS 10-year Build Out Plan. For that reason, it is imperative for MARACOOS to develop and maintain a diverse portfolio of investing partners; such support will be critical in fulfilling the mission of MARACOOS.

From the outset, MARACOOS has worked to maximize and optimally leverage all available human capital, ocean observing assets and expertise, and financial resources, and has demonstrated its ability to serve as an entrepreneurial ecosystem.

To date, total funding provided by private and public partners has exceeded that provided by U.S. IOOS; however, U.S. IOOS funds remain a critical foundation of support to attract vested partnerships. The current sources of support are found in Figure 5. For a full list of funding sources please see the MARACOOS Funding Sources document: http://maracoos.org/certification/doc/Appendix_A_MARACOOSFunding.pdf

Figure 5: FY16 MARACOOS Funding $19,317,97; Leveraging NOAA Dollars 6:1



In an effort to diversify its funding base during this 5-year period, MARACOOS has launched a new, proactive Innovation Initiative to expand, develop, and maintain focused partnerships, including a focus on private sector partnerships. The Innovation Initiative involves the formation of an Innovation Council, with the purpose of developing and sustaining new relationships under the MARACOOS umbrella, and the creation of a new position of Director of Innovative Partnerships to facilitate and operationalize the outcomes of these efforts.

MARACOOS will continue to seek out and obtain funding from partners in the public and private sectors and will also integrate, as appropriate, income-generating services into the existing suite of data, data products and information provided by the program. MARACOOS will also take advantage of its non-profit corporate status in attracting philanthropic gifts to support MARACOOS operations. Furthermore, since U.S. IOOS funding is anticipated to remain the primary base support, as well as being critical to developing committed and invested partnerships, MARACOOS will work with its partners in the Mid-Atlantic and across the nation to sustain and grow support for the U.S. IOOS program within the federal budget process.