RUTGERS, The State University of New Jersey & The University of Delaware

"Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS): Preparing for a Changing Mid-Atlantic"

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This project complies with the Project Design Criteria (PDC) of the Programmatic Environmental Assessment (PEA)

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PROJECT SUMMARY

Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS): Preparing for a Changing Mid-Atlantic

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Diverse Regional Needs on a Changing Planet: The **Mid-Atlantic Bight** (**MAB**) extends 1000 km alongshore, from Cape Cod, MA to Cape Hatteras, NC. It includes five major estuarine systems and a wide continental shelf cut by a deep cross-shelf valley and multiple shelf-break canyons. The region encompasses 10 states, the District of Columbia, 107 congressional districts and ~78M people (25% of US population). 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. 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. 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.

But ***warming of the climate system is unequivocal (IPCC, AR5, 2015).*** 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.

A Decade of Progress: The **Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS)** was established in 2004 as the U.S. IOOS Regional Association (RA) for the MAB. Since then MARACOOS, a 501(c)(3) Non-Profit Corporation, created the framework in which the Mid-Atlantic's coastal ocean user community identified its five highest priority regional themes: *(1) Maritime Safety, (2) Ecosystem Decision Support, (3) Water Quality, (4) Coastal Inundation,* and *(5) Offshore Energy*. To support these user themes, MARACOOS 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, our first 5 years focused on the development of our regional scale observing capabilities. Our second 5-year effort maintained the successful regional observation components and focused new development on the evaluation of an ensemble of prediction models for different applications. 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.

A Plan for the Future: Continuing to build on accomplishments and lessons learned, MARACOOS will again bring together over 30 investigators from over 15 institutions for our third 5-year maintenance and development cycle with a focus on products. We propose to: (a) enhance the RA management team to better support the requirements of certification; (b) maintain our existing observing infrastructure, with a surge capacity capable of responding to extreme events, while continuing to expand our ability to deliver data quality consistent with QARTOD; (c) expand our data management and curating activities to entrain even more external data providers into the common operating picture provided by our Data Explorer technologies; (d) focus on implementing the results of a metric-informed user-driven prioritization of data-assimilative prediction models for specific purposes; (e) integrate and grow the outreach, engagement and education team to enhance new product development, awareness, and use with targeted user communities; and (f) establish entrepreneurial innovation teams to grow future cross-cutting activities that broaden support for and enhance responsiveness to our 5 user themes. This will continue to foster the MARACOOS mission—to seek, integrate, share and apply new 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.

3) PROJECT DESCRIPTION

A) BACKGROUND

The Mid Atlantic Regional Association Coastal Ocean Observing System (MARACOOS), established in 2004, is the U.S. Integrated Ocean Observing System's (IOOS) Regional Association (RA) that covers the ocean and estuaries from Cape Cod, MA to Cape Hatteras, NC. Building on more than a decade of engagement, innovation and progress, the academic, industry, government and NGO partners that comprise MARACOOS will sustain and grow the operation, integration, and evaluation of this end-to-end regional-scale coastal ocean observing system for the Mid-Atlantic region.

MARACOOS has a successful history of managing, operating and integrating its 5 RA subsystems (Fig. 1). We grow 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 forecast 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 HF Radar Technical Steering Committee, Glider DAC, federal DMAC backbone, and national modeling plan development. Internationally, we participate in efforts that include the GEO Global HF Radar Network, WMO Glider Steering Committee, NPOMS Typhoon Workshops and UNESCO's Intergovernmental Oceanographic Commission. Our ocean observing infrastructure is used for

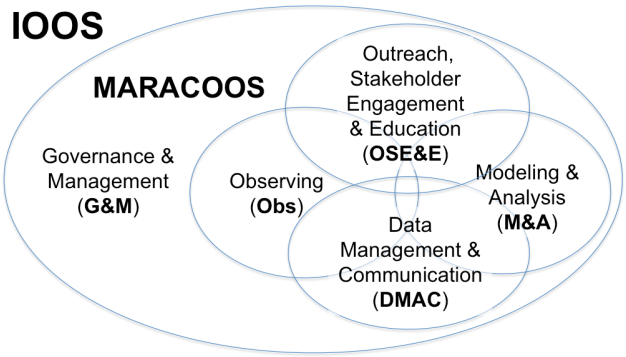

Figure 1: MARACOOS implementation of the 5 integrated subsystems (**acronyms defined in bold)** that comprise an IOOS Regional Association.

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.

Based on self-evaluation of our 5 subsystems and their impacts as documented in our 6 month progress reports, 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 following improvements/reprioritizations of our ongoing activities are proposed: (1) better resource our G&M subsystem to meet or exceed IOOS RA certification standards; (2) expand our OSE&E team by hiring a new innovation liaison to foster collaborative proposals that enhance industry participation and leverage and augment IOOS core support; (3) improve our 3 core regional-scale spatial ocean observation technologies, including their effectiveness for data assimilation; (4) expand our DMAC activities with an emphasis on accessing new data sources beyond IOOS and tailoring the MARACOOS integrated Data Explorer portal to better serve specific users; and (5) improve our primary multi-use regional data assimilative model by expanding coverage to the entire Northeast U.S. Large Marine Ecosystem (LME). We also propose to increase support for our 5 user-defined themes through a phased series of innovation projects in the areas of (a) ocean acidification, (b) biological monitoring/animal movements, (c) coastal inundation, (d) nearshore water quality and (e) offshore wind energy.

B) GOALS AND OBJECTIVES

The MARACOOS Build-out Plan articulates the long-term vision to provide better data and information for better decisions (http://maracoos.org/documents). We continue to implement that plan in 5-year increments. The first 5-year cycle established a sustainable regional-scale ocean observatory that filled gaps in the national infrastructure and supported our initial 4 user themes. The second 5-year cycle (2011 – 2016) achieved sustained operations and evaluated an ensemble of ocean and atmospheric forecast models to support our 5 user themes. The goal of this proposal (2016 – 2021), our third 5-year planning cycle, is to focus on the generation, refinement and maintenance of new integrated products to address expanding user needs.

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 the funding request and is spread across all MARACOOS subsystems. For the RA's G&M, 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 OSE&E subsystem maintenance funding will support the Stakeholder Liaison Service to ensure consistent contact with the user community. For the observatory, funding will maintain the year-round operation of the (a) extensive HF Radar network, (b) satellite imagery downlink stations, (c) underwater glider flights (seasonal at present) that all yield quality controlled datasets; and (d) data-assimilative forecast models and ensembles. For DMAC, 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.

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 HF Radars contributing to NOAA PORTS consistent with that for the HF Radars 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; 6) increased data assimilation into models for fisheries habitat assessment via leveraging NSF OOI and other data sources; and 7) addition of a new innovation liaison to foster enhanced partnerships and growth beyond direct IOOS funding.

We propose annual focal points for new innovation projects, currently prioritized as 1) ocean acidification (OA), 2) biological monitoring/animal movements, 3) coastal inundation, 4) water quality, and 5) offshore wind energy. OA is our Year 1 growth priority, responding to the large east coast gap in national OA monitoring programs and addressing documented needs from the shell-fishing industry. The Year 2 priority of biological monitoring, including fish, reptile and mammal tracking responds directly to this FFO's emphasis on ecosystems and significant Mid-Atlantic region user needs and fosters collaborative growth that will augment NOAA fisheries observations. The Year 3 priority for inundation leverages the well-supported NYHOPS implementation in NY Harbor and the development of new community response models in Hampton Roads; both of which can be expanded regionally. The Year 4 priority for water quality leverages state and county support for monitoring hypoxia (e.g. NJ coast) and *Vibrio* bacteria (e.g. Chesapeake Bay, Long Island Sound). The Year-5 priority of offshore wind energy regionally integrates the projected state growth for offshore wind energy development.

Meeting the stated goals and objectives is a key to our success. MARACOOS has established a culture in which collaborators actively participate in the achievement of stated goals and objectives. Weekly conference calls alternate between discussion of programmatic issues and operations - to track progress, define problems, and seek collaborative solutions using the breadth of MARACOOS experience. Integration of the many moving parts of MARACOOS is accomplished through direct contact and liaison, working groups, cross-functional teams, and its matrix structure. Feedback is sought through multiple interactive mechanisms, and the status of MARACOOS is reported to its membership each year at an annual meeting.

C) CONNECTION TO USERS/STAKEHOLDERS AND BENEFITS

The Mid-Atlantic is a densely populated region with a 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 our 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. Some examples of the past and future benefits are highlighted below:

Theme 1: Maritime Safety. HF Radar (HFR) and the Short Term Prediction System went operational with the U.S. Coast Guard for search and rescue in the Mid-Atlantic in May 2009. MARACOOS consistently exceeds the USCG 80-80 metric for data availability in SAROPS. In 2014 in the Mid-Atlantic (>3 NM to 200NM), 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 to support safer port operations.

Theme 2: Ecological Decision Support. The result of our MAB 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 our analysis was 'rigorous and highly innovative.' Following the panel's advice, our 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.

Theme 3: Water Quality. MARACOOS, through the Chesapeake Bay Interpretive Buoy System (CBIBS), supports water quality monitoring (e.g., oxygen) along the full 250 km length of the Chesapeake. MARACOOS HFR observations and NYHOPS predictions support water quality issues in the harbor and along the coast, ranging from sewage and trash spills to debris plumes following Hurricane Sandy. In late July 2011, MARACOOS supported NY and NJ authorities as they managed their response to an 8-million-gallon raw sewage spill in the Hudson River. Additional water quality efforts arise with ocean acidification on the shelf and *Vibrio* in the estuaries impacting the shellfishing industry, our region's largest commercial fishery.

Theme 4: Coastal Inundation. 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 10th in the world in assets exposed to increased flooding due to sea level rise, with city officials estimating over $1B 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 (#8 with >$15B in damage), and for storm surge, as in Hurricane Sandy (#2 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..

Theme 5: Offshore Energy. Offshore windfarm development continues in the MAB, with 2015 marking projects off Block Island for a 5-turbine windfarm. Development is being pursued offshore several MAB states, with future estimates running as high as 3000 turbines. NJ Board of Public Utilities continues to support MARACOOS product enhancements in NJ, including the RU-WRF atmospheric forecasts to generate detailed wind resource statistics, while contributing to the MARACOOS ensemble, and 4 HF Radar sites to enhance MARACOOS nearshore current products in the vicinity of the planned NJ windfarms. Weatherflow is our regional integrator for this effort and similar state-funded activities through the MARACOOS weather ensemble.

D. WORKPLAN Part 1: Maintenance and Enhancements of Existing Regional Subsystems

1. Governance and Management (G&M) Subsystem.

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 (Fig 2) that ensures responsible oversight and management while maximizing available resources to deliver state-of-the art products and services in the 5 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 (Fig. 2). 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 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 Stakeholder Engagement Director (P.Moore) ensures direct connectivity with the MAB stakeholder communities and leveraged engagement through partner organizations. A new position of Director of Innovation Partnerships (H.Kerkering) 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 (more in section 5 below). 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 this proposal and the regional needs identified herein.

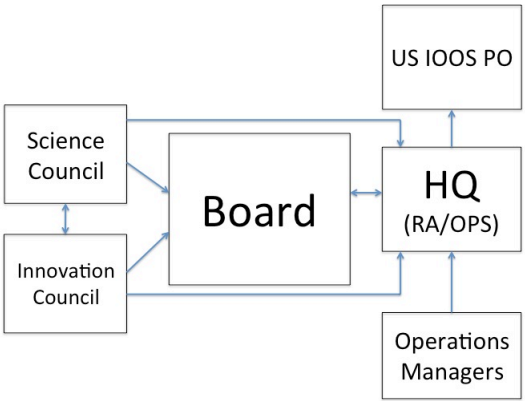

Figure 2. MARACOOS Organizational Diagram.

Based on Board and membership input, to further widen the reach and enhance the proactive nature of regional partnerships, the MARACOOS Board will transition the User Council into an

Innovation Council, with the purpose of developing and sustaining new focused partnerships under the MARACOOS umbrella (section 5). As a complement for the Innovation Council, the Science Council will advise on scientific validity and data quality assurance. This approach allows the G&M teams to maintain the core strength of MARACOOS, while providing flexibility and a pathway to engaging new partners with critical expertise, particularly those who have been unable to engage in the past. The approach will also position MARACOOS for its intention to pursue, attain, and maintain IOOS regional certification as per 15 CFR Part 997.

2. Observing (Obs) Subsystem.

MARACOOS operates three gap filling ocean observing technologies: satellites receiving stations, HF Radar, and Gliders. DMAC integrates these datasets with additional external datasets and data assimilative models. We propose to evolve the Obs Subsystem as follows.

2a. 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 forecasts for offshore wind energy and storm surge forecasts.

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.

2b. HF Radar. The HF Radar (HFR) work plan has two elements: (1) operations and maintenance, and (2) improvements and expansions. The MARACOOS HF Radar 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 HF Radar 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 HF Radar 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 HF Radar 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: HF radar 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 HF radar 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

2c. 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 forecasts 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 forecasts, 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 forecast models, enhance coastal inundation efforts, and provide data for assimilation into an operational fisheries habitat modeling system (described below).

3. Data Management and Communication (DMAC) 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 Asset Map. We are updating the Asset Map 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.

4. Modeling and Analysis (M&A) Subsystem.

In 2009 we 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 forecast 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).

We 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/forecast. 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 convergance 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 forecast 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 forecast uncertainty. For example in 4DVAR, the analysis posterior error covariance reveals uncertainty in the initial conditions (IC). We propose to generate forecast 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 forecasting capabilities by allowing the retention of remotely-forced storm surge that is captured in coastal satellite altimetry. Deliverables will include: (1) regular 3-day forecasts for Cape Hatteras to Halifax, (2) analysis and forecast skill metrics, and (3) quantified forecast 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 digitizations 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.

5. 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 current 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 has 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, 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 forecast 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.

Product User Experience Design. With guidance from a new Innovation Council, MARACOOS will continue to enhance Asset Map 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 Asset Map 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 Asset Map. 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 HF-Radar 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.

Enhancements: Innovation workshops. MARACOOS will conduct a series of focused workshops to advance specific regional partnerships under the auspices of the Innovation Council in the areas of ocean acidification, integrated animal telemetry, water quality, inundation and sea level rise, offshore energy, drawing in additional partners, with an emphasis on the private sector, to develop user-identified solutions and identify strategies for sustained funding.

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.

D2) WORKPLAN Part 2: Innovation Projects

Based on user/stakeholder feedback received during the last MARACOOS funding cycle, we have identified and describe below five major user priority areas within our existing themes that cross-cut our existing subsystems:

Ocean Acidification (OA): OA has significant societal ramifications that range from economic losses due to the decreased survival of commercially important organisms to the ecological consequences associated with altered ecosystems. Yet few time series exist to detect low pH water, specifically in coastal regions where wild stocks of scallops, clams, and other shellfish flourish. The development of the first moored OA buoy in MAB shelf waters is proposed. The mooring will be designed and built according to existing OA buoys with NOAA Pacific Marine Environmental Laboratory (PMEL) collaborators and outfitted with several sensors measuring carbonate chemistry (pH, pCO2, DIC) and other physical, biological, and water quality parameters. Data will be analyzed in context with location of shellfish habitat to identify the shellfish populations at high risk for OA. We will coordinate with the MARACOOS Stakeholder Liaison to engage and educate members of the commercial shellfish industry.

Biological Monitoring/Animal Movements: 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. We will host a workshop focused on telemetry data annotation to encourage the integration of oceanographic and telemetry data in the MARACOOS region. Based on workshop input, MARACOOS will acquire fisheries acoustic tags and glider based receivers and passive acoustic systems for sensing and reporting fish and marine mammal occurrence. In years 3-5, we will deploy acoustic and satellite tags 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).

Water Quality: The MAB 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 in our region, most are located in estuaries and along the coast. This localizes the need and application of water quality product development. We propose to facilitate the connection between the regional IOOS with the work of local stakeholders to fill local needs with a specific focus on the major bays within MARACOOS (Chesapeake, Delaware, Hudson, Long Island, and Narragansett). In Years 1-2, the Water Quality Working Group will host meetings at these five locations to develop local strategies to best leverage MARACOOS assets to fill existing gaps. These meetings will develop the implementation strategies and priorities that will be deployed during Years 3-5. This strategy would guarantee the measurements and accessibility to meet local needs while also providing the foundation for standardization of sampling protocols and QA/QC across the region.

Coastal Inundation Modeling: 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 forecasting and information delivery to save lives and property in future storms. We will utilize local scale models, including the unstructured FVCOM (Finite-Volume Community Ocean Model) model and the New York Harbor Prediction System (NYHOPS) to predict storm surges along the open coast of Mid-Atlantic Bight and major estuaries. High-resolution inundation simulations will be conducted at high-risk areas such as New York/ New Jersey Harbor, Barnegat Bay, N.J., Norfolk, V.A. and the Eastern Shore of Maryland. The hydrodynamic models will be forced with an ensemble of weather forecasting models (such as GFS, NAM and WRF models) to produce an ensemble prediction of storm surges and coastal inundations. ArcGIS and Google Earth software will be used to visualize the location, depth, and duration of inundation in static and animated images that can depict inundation at street level.

Offshore Wind: WeatherFlow Inc. will act as a private sector partner with specialized expertise in coastal marine weather observations and modeling. They will be 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 the model ensemble output. They will also run statistical performance verifications on the ensemble members, using WeatherFlow and selected other observational data to compare forecasted versus observed values as a way to assess model performance. WeatherFlow will run the analysis

scripts and processes on its own infrastructure and provide the resulting statistics to MARACOOS for display on its system.

E) MILESTONE SCHEDULE

Informed societal decision-making, enabled by the growing suite of user-defined, ocean and coastal data products, is the vision of MARACOOS. Toward this vision, all MARACOOS efforts will focus on the outcome of increased use of high quality data products by specific user groups and decision-making authorities. Inputs include *sustained real-time operations* of our Obs, DMAC, and M&A subsystems that are prioritized according to agency/partner strategies/roadmaps/initiatives, proactive partner engagements, year-round OSE&E team outreach, and a coordination fabric consisting of weekly conference calls, quarterly board meetings, 3 innovation/education meetings per year, feedback/guidance on 6-month progress reports, and annual stakeholder meetings. Outputs will be characterized by user-friendly data accessibility, user need-based, quality data products, active and functioning partner relationships, user-guided product improvement, and ongoing need assessment. Users/authorities in each thematic area include: *maritime safety:* search and rescue personnel, maritime transportation operators, and recreational boaters; *ecological decision support:* fisheries managers, fishermen, and living marine resources managers; *water quality:* federal and state shellfish authorities, and beach / recreational use managers; *inundation:* federal, state, local, and private entities for infrastructure protection and flood control, and federal and private weather entities; *offshore energy:* federal and state renewable energy entities, private energy companies, and private wind energy developers. The following inputs/outputs will contribute directly to the outcome of increased use of higher quality data products:

MARACOOS Milestones 2016 - 2021

MILESTONE		TIMELINE (Yrs)
Maritime Safety		
Ensure 80/80 coverage of HFR		1-5
Enhance data quality:	Integrate the bistatic vector measurements into the regional products	1-2
	Increase the Lagrangian trajectory modeling skill of the radar network	3-4
	Develop and apply additional QA/QC procedures, including QARTOD	1-5
	Commence real time automated QA/QC of the radial and total surface current measurements	1-5
Maintain data product availability via HFR DAC, STPS, NDBC, and enhance Asset map to expand functionality and access		1-5
Develop & execute engagement/ed. plans/tutorials w/ USCG & maritime pilots to ID changing needs & increase data use		1-5
Monitor data product use through automated reporting and user surveys		1-5
Ecological Decision support		
Target engagement with fishermen & mgrs.to ID areas/species for enhanced/new data products & training/tutorials		1-5
Establish and support MATOS Integrated Animal Telemetry Users Council		1-5
Enhance data quality:	Refine Doppio domain for the data-assimilative ocean model	1-2
	Regular 3-day forecasts for Cape Hatteras to Halifax initialized via ROMS 4DVAR DA	1-5
	Continue quantitative skill assessment of the entire system	1-5
	Quantify forecast uncertainty using intra-model ensembles	1-5
	Deploy 3 gliders during the stratified season each year	1-5
	Develop and apply additional QA/QC procedures, including QARTOD	1-5
Deploy and maintain enhanced Asset map to expand functionality and access		1-5
Water Quality		
Convene 5 local workshops to ID water quality needs		1-2
Plan user need ID and product training:	Support intergovt. pilot for L.I. Sound H2O Quality database for Vibrio forecast	2-3
	Convene partners toward Mid-Atlantic Ocean Acidification Network	1-2
	Plan Choptank Habitat Pilot adaptation for other reg'l watersheds	3-5
Enhance data quality:	Leverage 3 glider deployments per year measuring water quality parameters	1-5
	Develop and apply additional QA/QC procedures, including QAPP and QARTOD	1-5
Deployand maintain enhanced Asset map to expand functionality and access		1-5
Coastal Inundation		
Develop engagement plan for identification of user needs and product use training/tutorials		1-3
Enhance data quality:	Add realism in model physics (surface wave effects, atmospheric pressure influence)	1-5
	Develop and apply additional QA/QC procedures, including QARTOD	1-5
Deploy and maintain enhanced Asset map to expand functionality and access		1-5
Offshore Wind		
Develop engagement plan for identification of user needs and product use training/tutorials		1-5
Enhance data quality:	Leverage regional atmospheric prediction models to form the MARACOOS ensemble	1-5
	Provide validation stats on ensemble components based on fed, state, industry network	1-5
	Develop and apply additional QA/QC procedures, including QARTOD	1-5
Deploy and maintain enhanced Asset map to expand functionality and access		1-5

F) PROJECT BUDGET. Our budget target is $4M/yr for 5 years, with the annual budget prioritized into Tier 1 ($1.5M/yr), Tier 2 ($1.0M/yr) and Tier 3 ($1.5M/yr) activities. Tiers 1 & 2 combined constitute the Base Support ($2.5M/yr) required to sustain the essential functions of MARACOOS. Tier 3 is approximately evenly split into enhancements plus new innovations. Funding levels beyond Base will remain evenly split. Cuts below Base will be distributed by our standard formula, where maintaining G&M activities are our first priority (0 shares), observation time series are second (1 share), and all other base-level functions are third (2 shares each).

1. G&M. Maintaining critical RA functions at the increased level required for certification prompted our first G&M increase in 10 years. The Chair and Vice-Chair have reduced their funding so that they now split 1 month of PI support, shifting what we can to support a full time Executive Director (Kuska in Tier 1) and a part time Technical Director (Crowley in Tier 2).

2. Observing. This sustains existing IOOS operations for HF Radars, Satellites & Gliders. HFR site support ($10 K/site for 41 sites) is at the recommended annual level. Technicians operate from 3 HFR Technologies Centers (North (UMass & UConn), Central (Rutgers) & South (ODU)) and are managed by a regional coordinator (Roarty). Satellite Technology Centers (Rutgers (L-Band, X-Band), UDel (X-Band, Geostationary) are responsible for maintaining direct-broadcast data downlinks and require site license fees. The rapid growth of MAB glider activities has prompted expansion to 5 Glider Technology Centers (UMass, Rutgers, UDel, UMaryland, VIMS) to broaden capabilities. Requested budget includes 3 dedicated fisheries support flights each summer with itemized tasks distributed through the 5 glider operators.

3. DMAC. The DMAC team includes a coordinator (Howlett), curator (Crowley), and developers (ASA & Rutgers) responsible for the lifecycle management of the data streams and their integration via the Data Explorer user interface. Communication is through our website (Crowley). DMAC team is also centrally engaged in the NSF OOI (Crowley, Howlett, Kerfoot).

4. M&A. Through a multi-year series of model evaluation studies, the Tier 2 modeling effort has been refocused on sustained real-time operation of the data assimilative ROMS model expanded to cover the full Northeast U.S. LME and nested within the European global model. NYHOPS has transitioned to local funding, and HOPS has transitioned to a validation effort for long term reanalyses to support fisheries. The weather ensemble remains external supported as it has been.

5. OSL&E. Expanding on the successes of the part time Stakeholder Liaison, we have transitioned to an integrated OSE&E team that increases support for the Stakeholder liaison, refocuses the education team on user interactions with products, and now also includes the new position of Innovation Liaison to develop new activities from a wider range of funding sources.

6. Enhancements. (1) A second half month each for the Chair and Vice-Chair, and additional support to bring the Technical Director up to half time; (2) Addition of geostationary satellite data to the existing polar-orbiting data stream; (3) Storm Glider rapid-response deployments by RU & UMaryland; (4) DMAC support for model metrics ($40K yrs 1&2) and mobile apps ($25K/yr); (4) Historical Gulf Stream analysis for model validation (UMass) and OSSEs to further inform glider flights (Rutgers); (5) establishing Stakeholder Liaison as full time and Innovation Director as half time positions; (6) 3 workshops per year, 2 for innovation, 1 for education; and (7) Continuing education course development for targeted user communities.

7. Innovations. (1) Establishment and maintenance of first ocean acidification buoy in shelf waters of the MAB; (2) Animal telemetry and tracking to inform fishery and conservation efforts; (3) Integration of existing and new near-shore water quality data to support models for water quality forecasting; (4) Model forecasts for coastal inundation in estuaries with PORTS; and (5) Integrating weather data and forecast ensembles for offshore wind.