NERACOOS: The integrated ocean observing system for the northeast region.

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Project Title: NERACOOS: The integrated ocean observing system for the northeast region

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Recipient Institution: Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS)

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3. PROJECT SUMMARY

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Project Summary:

The Northeast Region served by the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) stretches from Long Island Sound (LIS) to the Scotian Shelf including the waters of the Gulf of Maine (GoM) and is home to over 14 million people. Most of the region's economy is closely tied to the coasts and oceans including one of the United States' (U.S.) most valuable fisheries. Maritime transportation is essential for regional energy security. The resilience of coastal communities is challenged as the region is a natural breeding ground for frequent, high impact storms when compared to other locations and has become a "hot spot" for record floods and heavy rainfall in the past 10 years. There is clear evidence that the coastal environment is changing with environmental pressures affecting ecosystems. Harmful Algal Blooms (HABs) and Ocean and Coastal Acidification (OCA) threaten shellfish and other industries that rely on the health of the northeast's ecosystems. The regional economy, maritime safety and efficiency, coastal resilience, understanding of ecosystem, and climate change, all depend on accurate and timely information currently delivered by NERACOOS.

The mission of NERACOOS is to produce, integrate and communicate high quality information that helps ensure safety, economic and environmental resilience, and sustainable use of the coastal ocean. This proposal will advance the development of the multipurpose observing

and forecasting system that has been operated since 2001 and is science-based and issue-driven. Stakeholder engagement including many regional initiatives has been central to the development of requirements for the system that will;

• Support safe and efficient **Marine Operations** including commercial shipping, recreational boating, search and rescue, spill response, offshore energy, aquaculture, and tourism by: providing key observations and forecasts of surface conditions; and developing a new PORTS® (Physical Oceanographic Real-Time System) for the Cape Cod Canal.

• Inform **Coastal Resilience** efforts to help coastal communities prepare, respond and recover from hazards by: providing key observations and forecasts of surface conditions including water levels and coastal flooding; and developing a Total Water Level (TWL) Inundation Forecast System (IFS) that couples storm surge and river discharge models and visualization tools.

• Promote **Healthy Ecosystems** through supporting ecosystem based approaches to management by: providing key observations and forecasts of conditions throughout the whole water column; increasing near-shore water quality monitoring and modeling capacity; and expanding biogeochemical and biological monitoring to support regional and national initiatives.

• Increase **Operational Efficiency** by increasing coordination among observing subsystems.

• Operate an effective **Data Management and Communication** (DMAC) System by: maintaining and enhancing a robust, standards-based regional Data Assembly Center (DAC) that integrates QA/QC (Quality Assurance / Quality Control) observations and models; developing and managing systems to integrate data from regional initiatives and new observation platforms and models; developing and implementing QA/QC protocols via QARTOD (Quality Assurance of Real Time Ocean Data) for all observation data; and collaborating in national efforts to share and improve DMAC efforts.

• Continue to **Engage Stakeholders** to effectively deliver products and services that meet their needs by: sustaining stakeholder interaction through an efficient and collaborative process; coordinating and implement regional initiatives; developing and delivering products and decision support tools, including visualizations; and supporting educators to train the next generation of ocean stewards and professionals.

The proposed effort builds on a proven ability to operate an effective ocean observing system that meets multiple stakeholder and societal needs – a true example of "one system, multiple uses". This proposal meets all objectives, priorities, and national plans described in the FFO and also directly contributes to the NOAA National Ocean Service (NOS) priorities of Coastal Resilience, Coastal Intelligence, and Place-based Conservation.

Partners:

Bedford Institute of Oceanography (BIO)
Blue Urchin Consulting
Bowdoin College
Charybdis Group, LLC
Gulf of Maine Lobster Foundation (GOMLF)
Gulf of Maine Research Institute (GMRI)
Massachusetts Bays (MassBays) National Estuaries Program (NEP)
University of Connecticut (UConn)
University of Maine (UMaine)
University of Massachusetts Dartmouth (UMassD)
University of Massachusetts Boston (UMassB)
University of New Hampshire (UNH)
University of Rhode Island (URI)
Woods Hole Oceanographic Institution (WHOI)
Woods Hole Research Group (WHRG)
NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center (NOAA/NMFS/NEFSC)

4. PROJECT DESCRIPTION AND NARRATIVE

a) Background.

Regional Drivers – The regional economy, maritime safety and efficiency, coastal resilience, understanding of ecosystem, and climate change, all depend on accurate and timely information currently delivered by NERACOOS.

The Northeast Region served by NERACOOS encompasses diverse coastal and ocean environments from LIS, through the Southern New England Bight, GOM and Bay of Fundy, to the Scotian Shelf (Figure 1). In the region over 14 million people[1] live in coastal watersheds. In the U.S. portion 66% of the population live in coastal counties which contribute 71% of the states' gross domestic product[2]. The economy in the Northeast is tightly connected to marine related industries: U.S. ports in the Northeast handle $24.5 billion[2] in commercial goods; the regional commercial fishing industry is valued of over $950 million[2] (22 % of the nation's fishing industry with lobster and scallop accounting for over $660 million); the recreational boating industry is valued at $3.5 billion[3], and the region's maritime commerce routes handle 4,000 transects of commercial ships and 8,000 transits of cargo barges[3] per year. In 2011, over 29 million tonnes of cargo (approximately 90% petroleum) were shipped between major Canadian and U.S. ports in the northeast[4]. The region's energy security is reliant upon maritime transportation. Additionally, new ocean uses are being developed with the construction of the first U.S. offshore windfarm in coastal waters of RI. All of these marine related industries require ocean and weather information to operate safely and efficiently.

John Cannon and David Vallee of the National Weather Service (NWS), write "The Northeast is a natural breeding ground for frequent, high impact storms when compared to other locations. This is due to its unique proximity to the warm, high energy Gulf Stream and nearby access to cold Canadian air, which is a recipe for rapid cyclogenesis in the region. The Northeast has become a 'hot spot' for record floods and heavy rainfall in the past 10 years according to the NWS Northeast River Forecast Center, many with sustained connections to tropical cyclones. In the summer, hurricanes can pass through the region with their trail of destruction. In the winter, intense Nor'easters batter the region, which can lead to damaging ice and snow storms, freezing spray, extremely low wind chill readings, while large waves batter the vulnerable coastline, all challenging the resilience of coastal communities and marine operations."

The Integrated Sentinel Monitoring Network (ISMN), Draft Science and Implementation Plan, 2015[5] notes "There is clear evidence that the coastal environment of the Northeast U.S. is changing. Environmental pressures have and will continue to affect ecosystem services in the Northeastern region. Warmer seawater temperatures have contributed to the decline of the southern New England lobster fishery and likely the northern shrimp and Atlantic cod fishery in the Gulf of Maine. Other fish and invertebrate species are also experiencing range shifts with consequences for fisheries management. Changes in the magnitude and timing of primary production cycles have been associated with shifts in precipitation and stratification. Warming temperatures in the Gulf of Maine are predicted to reduce the abundance of energy-rich zooplankton that fuel forage fish such as herring and sand lance that are fundamental to the region's marine food web. Sea level rise is impacting the region's tidal wetlands and other

[1] National Coastal Population Report Population Trends from 1970 to 2020 (2010 data)
[2] National Ocean Economics Program - www.oceaneconomics.org/Market/coastal/coastalEcon.asp (2010 data)
[3] Northeast Regional Planning Body - http://neoceanplanning.org/projects/recreation/
[4] Research conducted by Transport Canada, R. Meier, pers comm
[5] Available at www.neracoos.org/documents

shoreline ecosystems. Ocean acidification affects the region's shellfish industries and may have other as yet unknown impacts on coastal ecosystems." Understanding, predicting and managing in this rapidly changing environment requires a system of sustained observations and forecasting.
History and status of ocean observing in northeast and NERACOOS – Initial sustained ocean observing capacity was established in the late 1990s and early 2000s. Sub-regional pilot programs included the Long Island Sound Coastal Observing System (LISICOS), the Gulf of Maine Ocean Observing System (GoMOOS), and the UNH center for Coastal Ocean Observation and Analysis (COOA). NERACOOS was incorporated as an independent, 501-c3 nonprofit organization in the fall of 2008 after a multiyear governance planning process. Building on sub-regional systems NERACOOS has become an effective regional system with its mission, updated in 2014, to "*produce, integrate and communicate high quality information that helps ensure safety, economic and environmental resilience, and sustainable use of the coastal ocean*".

To achieve this goal NERACOOS uses an integrated system design comprised of subsystems similar to those described in the federal funding opportunity (FFO). However, the design has been updated to better reflect the functional mechanisms and integrated nature of these subsystems (Figure 2), a schematic that was developed by the NERACOOS PI (Morrison) and adopted at the IOOS Summit in 2012. The main difference is that models and observations are coupled into an information subsystem and engagement replaces outreach and education.

The resulting operational observing system is the largest regional provider of publically available continuous real-time ocean information that is relied upon by those using and managing the coastal ocean. Over 50% of the publically available continuous real-time surface ocean measurements are provided by NERACOOS. Below the surface the contribution to these measurements increases to 86% and 100% below 15m.

The current NERACOOS Approach

Information subsystem (see Figure 1)

Observing subsystem – NERACOOS has managed a regional observing system by building on assets and experienced pilot programs. Multipurpose moorings, measuring surface and subsurface properties, form the system's backbone. These are cost-effective platforms (less than half the operational cost of a 24/7 glider line) capable of carrying large sensor payloads and able to resolve temporal scales of variability. The return on investment for moorings is arguably higher than any other platform as their information is used by all ocean use sectors from harbor pilots to ecosystem scientists and managers.

Offshore: Seven moorings in the GoM supported by NERACOOS (Pettigrew et al., 2011) carry meteorological sensors similar to National Data Buoy Center (NDBC) buoys and additional sensors for atmospheric visibility, surface currents, water-column current profiles, temperature and conductivity, fluorescence (for "chlorophyll a" estimation), and backscatter at multiple depths. Additional separately funded sensors, such as receivers for fish tracking (NMFS) and bats sensors (Stantec), have been added to most buoys, contributing to the national telemetry network. Two deep water buoys are located in the Northeast Channel and Jordan Basin and five coastal buoys are strategically located along the coast from Maine to Massachusetts. The mooring within Massachusetts Bay, supported with contributions from the Massachusetts Water Resources Authority (MWRA), addresses water quality concerns in the densely populated region around Boston, MA and includes additional sensors such as dissolved oxygen. In addition, the U.S. Geological Service (USGS) has recently funded near-bottom instrument packages on four coastal GoM buoys for understanding near sediment resuspension. A Coastal Data Information

Program (CDIP) wave buoy on Jeffreys Ledge provides detailed wave measurements. The NOAA Ocean Acidification Program (OAP) funds an OCA mooring off the Isles of Shoals which has provided atmospheric and in-water pCO2 time-series measurements since 2005. Nearshore / Estuarine: In LIS, NERACOOS supports three moorings that measure wind speed and direction, salinity, conductivity, temperature, pressure, currents, and dissolved oxygen near the surface, bottom and mid-depth supporting hypoxia monitoring and research used by both Environmental Protection Agency (EPA) Long Island Sound Study (LISS) and CT Department of Energy and Environmental Protections (DEEP). The Central Sound buoy also supports the only wave observations in LIS. NERACOOS also funds a highly instrumented mooring in Great Bay, NH during ice-free months and a shore-based system at the mouth of the estuary to monitor water quality, meteorology, and carbon dioxide. Shore and mooring stations of the NBFSMN are being integrated and partially supported through NERACOOS in RI. Such work has advanced knowledge of water clarity and water quality for protecting critical habitats. Tide gauges in Scituate, MA, Gloucester, MA, and Hampton, NH, provide water level information which helps validate models and is essential for emergency managers.

High-resolution (1km) satellite data provides the only complete coverage of the entire NERACOOS region for any ocean variable, is an operational, ongoing, consistently processed, unbroken time series extending back over 30 and 17 years (for Sea Surface Temperature, SST, and color respectively).

The recent IOOS Ocean Technology Transfer (OTT) program has enabled NERACOOS to assist in deploying an array of Environmental Sample Processors (ESPs) for HAB monitoring in the GoM for the last two seasons and to establish an Integrated Nutrient Observatory with nitrate sensors on offshore moorings with nitrate, phosphate and ammonium sensors in three estuaries. *In situ* nutrient measurements made by Atlantic Zone Monitoring Program (AZMP) twice yearly on a section across the Northeast Channel complement the mooring observations. Offshore nutrient measurements are critical to understanding water mass movement and have already documented interannual and longer-term variability in nutrient fluxes to the GoM and its coastal waters, and subsequent effects on plankton production (Townsend et al., 2015). Nearshore sensors provide valuable measurements for State and other water quality managers.

As part of the national surface current mapping plan, NERACOOS operates a High Frequency Radar (HFR) network at three locations in the eastern GoM. These data are ingested by the US Coast Guard (USCG) Environmental Data Server (EDS) for search and rescue. Satellite tracked drifters and bottom current meters via NOAA Environmental Monitors on Lobster Traps (eMOLT) program help to validate HFR data and surface current models.

The NERACOOS observing system compliments other US and Canadian federally funded observations and fills critical gaps in capacity (see details in Figure 1).

Modeling subsystem - NERACOOS developed the Northeast Coastal Ocean Forecast System (NECOFS) as a state-of-the-art "end-to-end" model system to produce accurate forecasts of the coastal ocean. Since 2008, NECOFS has made daily experimental 3-day forecasts of surface atmospheric forcing, water elevation, and 3-D currents and water properties (temperature and salinity) from central New Jersey to the eastern end of the Nova Scotian Shelf. The core of this system is the Finite-Volume Coastal Ocean Model (FVCOM) (Chen et al. 2003, 2006a, 2006b), which features an unstructured triangular grid in the horizontal and a generalized terrain-following coordinate in the vertical. NECOFS includes the NOAA/NCAR Weather Research and Forecast (WRF) mesoscale weather model, and added (1) an unstructured-grid version of the Simulating WAves Nearshore (SWAN) surface wave model (SWAVE) (Qi et al. 2009), (2)

modules for wave-current interaction, runup, and overtopping, (3) methods for seamless nesting of higher resolution coastal inundation forecast subdomains, and (4) updated the regional model grid. The WRF output is used to drive SWAVE and FVCOM-GOM4, which are both used to drive the higher-resolution domains. Data critical to initializing the models include National Centers for Environmental Prediction (NCEP) model, ocean tidal and WAVEWATCH III (WW3) forcing, satellite SST and radiation, river discharge, NOAA, NDBC buoys and shore stations, and NERACOOS observations. Forecasts including ship icing potential are also provided to local NWS WFOs in their preferred format.

A state-of-the-art surface wave model system also makes high-resolution accurate 2-day forecasts for marine operations and safety, especially during storms. This model system is based on the NOAA NCEP operational WW3 system, using efficient fine-resolution computational grids in the NERACOOS region, the latest physics parameterizations for wind input, wave dissipation, and related wave processes, and operational NCEP products as input. Since 2008, model forecast runs have been made four times a day and disseminated through NERACOOS.

Additionally as part of national surface current mapping, NERACOOS operates the national Short Term Prediction System (STPS) providing HFR surface current forecasts to the USCG EDS for search and rescue.

DMAC subsystem – The backbone of the Data Assembly Center for the Northeast is a standards-based Data Management Framework[6] developed and implemented by NERACOOS DMAC (GMRI). The NERACOOS Data System (NDS) is a framework for aggregation, interoperability, discovery and dissemination of observing data (gridded and observational) from the region. The NDS leverages over fifteen years of open-source software development and data management expertise by the GMRI team and is based on the suite of standards and best practices developed, tested and recommended by IOOS and the greater IOOS RA DMAC community. The NDS provides the mechanisms and protocols for the full data life cycle by integrating, aggregating and distributing data through a centralized access portal (NERACOOS.org). Following the DMAC Guiding Principles, the NDS provides the core capacity that connects and integrates observations and forecasts, making quality-controlled data discoverable and accessible to stakeholders through a wide variety of information products.

Data are acquired directly from the data providers through a Service Oriented Architecture (SOA) approach. By enabling data providers to expose data through standards-based web services (e.g. direct access to data files or connection to local Thematic Real-time Environmental Distributed Data Services, THREDDS, Data Server, TDS), redundancy and replication is reduced, therefore providing the highest quality data to end-users. The NERACOOS DMAC team works closely with the data providers to produce data in compliant format and adopt data and quality control standards and protocols. As a result, the data managed and curated through the NDS are interoperable and aggregated in region-wide products, though the data are served from distributed systems. All of the available web services have been registered with the IOOS Catalog since its inception, and are also exposed through search-engine friendly Web Accessible Folders. For data providers lacking bandwidth or capacity to serve data reliably or in compliant formats, the NDS has the capacity to ingest and store these data, and serve through standardized formats. The protocols and services of the NDS provide a roadmap to integrate new data providers quickly and efficiently (Figure 3)[7].

The NDS is entirely cloud based, deployed on an Amazon Web Services Elastic Cloud

[6] See DMF at http://neracoos.org/documents
[7] See DMF and Data Management Plan at http://neracoos.org/documents

Computing (EC2) instance for maximum cost efficiency and is backed up nightly, preserving the data, software and configuration of the machine setup for guaranteed disaster recovery. This cloud-based system has now been in place for 4 years, and the flexibility has enabled several hardware and software upgrades to accommodate the ongoing evolution of the NDS.

With level funding for the last 5 years, the NERACOOS DMAC team has been able to implement the NDS, following best practices and fully or partially adopt most of the guiding principles put forward by NOAA and IOOS.

Engagement subsystem – Engagement of key users was built into the initial governance structure with Directors derived from state government, industry, and academic organizations. A Strategic Planning and Implementation (SPI) team brings together stakeholders from various sectors to create and implement plans and priorities. Staff routinely attend meetings and conferences to further understand user needs and communicate activities. NERACOOS also helps coordinate and lead regional initiatives such as the Regional Build Out Plan (RBOP), ISMN and the Northeast Coastal Acidification Network (NECAN). NERACOOS and the Northeast Regional Ocean Council (NROC) have developed two joint working groups, one on Ocean and Coastal Ecosystem Health (OCEH) and another on Coastal Hazards Resiliency. Newsletters, social media, and an Annual Report (the first for an IOOS region) communicate programs and document success. Collaboration through the IOOS Outreach Committee leverages expertise in outreach and communications. NERACOOS also participates in the New England Ocean Science Education Collaborative (NEOSEC), of which Ms. Stymiest is the current Chair, supports the biennial NEOSEC Ocean Literacy Summit, works with educators both formal and informal, supports the NOAA NEFSC drifter program, and trains interns.

Governance and Management subsystem – NERACOOS is governed by a Board of Directors with a mandated broad and balanced membership. Established as an office in 2009, NERACOOS has successfully managed multiple multi-million dollar grants, and is currently staffed by five employees including a full-time Executive Director. National collaboration is achieved through involvement with the IOOS Association and IOOS Program Office. Binational collaboration is through the Gulf of Maine Council (GOMC, Morrison is a councilor) and with Marine Environmental Observation Prediction and Response (MEOPAR) network.

Developing the Proposal – The NERACOOS Board formed an oversight committee of un-conflicted Directors to monitor and assess the process developed by the SPI team and ensure it was open and transparent. The overall process consisted of an open call for pre-proposals (proposers had to show relevance to Strategic Priorities and stakeholders), a mail review, followed by an in person panel review.[8] The result was a prioritized set of integrated projects for the NERACOOS proposal. The slate of projects and overall process was approved by the Board.

Responding to funding announcement objectives and program priorities – The proposed effort builds on a proven ability to operate an effective ocean observing system that meets multiple stakeholder and societal needs – a true example of "one system, multiple uses". This proposal meets all objectives, priorities, and national plans described in the FFO and directly contributes to NOS priorities; Coastal Resilience, Coastal Intelligence, and Place-based Conservation.

b) Goals and Objectives

The overarching goal and mission of NERACOOS is to *produce, integrate and communicate high quality information that helps ensure safety, economic and environmental resilience, and sustainable use of the coastal ocean*. This end-user driven and science-based integrated observing system is one system with multiple uses". Specifically the proposed work will;

[8] See guidance, Strategic Priorities 2015, and review criteria at www.neracoos.org/grants

1) Support safe and efficient **Marine Operations** including commercial shipping, recreational boating, search and rescue, spill response, offshore energy, aquaculture, and tourism
    a. Produce, integrate and communicate key observations and forecasts of surface conditions (wind, waves, visibility, and water temperature, salinity and currents).
    b. Develop a new PORTS® system for the Cape Cod Canal.
2) Inform **Coastal Resilience** efforts to help coastal communities prepare, respond and recover from hazards.
    a. Produce, integrate and communicate key observations and forecasts of surface conditions; wind, waves, currents, water level, and coastal flooding
    b. Develop a Total Water Level (TWL) Inundation Forecast System (IFS) that couples storm surge and river discharge models and visualization tools.
3) Promote **Healthy Ecosystems** by supporting ecosystem based approaches to management.
    a. Produce, integrate and communicate key observations and forecasts of conditions throughout the whole water column.
    b. Increase near-shore water quality monitoring and modeling capacity.
    c. Expand biogeochemical and biological monitoring to support regional and national initiatives.
4) Increase **Operational Efficiency** by increasing coordination among observing subsystems.
5) Operate an effective **Data Management and Communication System**.
    a. Maintain and enhance a robust, standards-based regional Data Assembly Center that integrates QA/QC observations and models
    b. Develop and manage systems to integrate data from regional initiatives (ISMN, NECAN, citizen science) and new observation platforms and models
    c. Develop and implement QA/QC protocols via QARTOD for all observation data
    d. Collaborate in national efforts to share and improve DMAC efforts
6) **Engage Stakeholders** to effectively deliver products and services that meet their needs
    a. Continue stakeholder interaction through an efficient and collaborative process.
    b. Coordinate and implement regional initiatives (ISMN, NECAN, citizen science).
    c. Develop and deliver products and decision support tools, including visualizations.
    d. Support educators to train the next generation of ocean stewards and professionals.

c) Connection to Users/Stakeholders and Benefits.

Users and Benefits – NERACOOS provides highly valued data and services to the USCG, NWS forecasters, managers, mariners, scientists, engineers and developers, seafood health officials, formal and informal educators, and many more (see Appendix c). In a recent user survey, a resounding 93% of respondents indicated that if NERACOOS data were not available, it would be a serious loss or inconvenience.

The return on investment of NERACOOS observations and forecasts was conservatively estimated at 3:1 (Kite-Powell and Morrison, 2012). The various benefits of these services are best described by the customers who rely on it: Capt. David Gelinas, River Pilot, "*When making decisions about bringing in a 700-foot tanker full of fuel into port, we need the best possible ocean and weather information, which is why we depend on buoy observations and forecasts from NERACOOS to ensure safety and efficiency of these critical operations.*"[9] Capt. Brian Gilda, USCG Sector Northern New England, "*Not a day goes by where we don't use NERACOOS data. Without it we would be sending out our Coast Guard crew out uniformed and at greater risk.*" Bob Thompson, Meteorologist in Charge NWS Taunton Weather Forecast

[9] Watch Capt. Gelinas explain the importance of NERACOOS himself at http://www.neracoos.org/ioosvideo/2014

Office (WFO), "*The IOOS buoy data were invaluable for (Hurricane) Sandy.*" Matt Lyman, CT DEEP, "*The real-time data and online tools provided by NERACOOS are very helpful and informative for managers and decision makers involved in efforts to improve the health and vitality of LIS and the surrounding waters*". Mike Fogarty, NOAA NMFS, **"***NERACOOS provides an ideal gateway to relevant information for this [system-wide Integrated Ecosystem Assessment]. In particular, we routinely use information from the NERACOOS buoy array.*" Don Anderson, WHOI Senior Scientist, "*Data from NERACOOS buoys have been incredibly helpful in our efforts to diagnose the mechanisms underlying the suppressed Alexandrium blooms in 2010 and 2013.*"[10] Brandy Wilbur, STEM Coordinator at Swampscott High School in Massachusetts, *"Using NERACOOS data, building drifters, and doing real scientific research in the classroom helps build confidence in our students to become better stewards of our oceans."*

User Priority Development (Engagement Process) – The current design and proposed expansion of NERACOOS is the result of extensive consultation with users and experts in the region. The process of collecting user requirements for the observing system has been a cumulative and iterative process that seeks feedback and input from users. The SPI team, described above, was formed to expand the participation of users in the planning and implementing of NERACOOS activities, and continues to meet monthly by phone and in person to review activities and progress, and plan for future initiatives. NERACOOS first identified key needs and priorities for ocean observing in 2010 through the Regional Planning Initiative which engaged experts from state and federal agencies, private sector academia and NGOs. This process resulted in a set of regional priorities which were further vetted and refined in 2013 through the RBOP process[11] which aligned key issues with system needs.

NERACOOS continued to work with users to refine and update observing system requirements and developed Strategic Priorities in 2014, the basis for this proposal. The joint OCEH group has engaged the greater coastal ocean science and management community to develop the framework for ISMN that will deliver the data and services required by those studying, managing and developing policy for sustainable use of the regional marine ecosystems. NERACOOS has also developed and led NECAN, which is working closely with stakeholders who may be impacted by OCA.

Delivery of Products and Services –Easy and reliable access to near real-time observations and high-resolution regional forecasts is provided through the NERACOOS web site and tailored products and services. The web site is optimized for viewing on mobile devices which provides access at sea. Feedback from users is continually sought and received, and integrated as appropriate. New products follow an iterative design process that involves collecting user requirements, testing and refinement. Over the years, NERACOOS has collaborated with MARACOOS, SECOORA, GLOS and more recently, AOOS on product development and data sharing initiatives. The NERACOOS DMAC system relies on standardized data services, enabling the distribution of data through not only NERACOOS products but numerous other websites and apps (e.g. wunderground.com, sailflow.com, usharbors.com, and surfline.com). A recent survey shows NERACOOS data were used in at least 167 websites, many of them with commercial interests. In 2014, there were up to 1,396 visitors each day to the NERACOOS web site, and over 3.1 million page views on NERACOOS and NDBC buoy pages. NERACOOS also incorporates several social media channels including Facebook with nearly 500 fans, E-newsletters with over 600 subscribers, and Twitter which enables Text-a-buoy.

[10] For more information see NERACOOS Annual Impact Reports at www.neracoos.org/documents
[11] For more information see NERACOOS RBOP at www.neracoos.org/documents

d) Work Plan

The following work plan describes specific elements in each of the subsystems that will support the goals and objectives. These elements are incremental, building on previous sections. The work plan identifies the partner performing the task and one year funding levels at the three scenarios, $4.0m, $2.5m and $1.5m. For example, "UMaine - $712k, $678k, $498k" means the University of Maine would be funded at $712k, $678k, and $498k for the $4.0m, $2.5m and $1.5m levels, respectively. The impacts of reduced funding levels are also described in the text.

i. Marine Operations

a) Produce, integrate and communicate key observations and forecasts of surface conditions

Observations – In the GoM, an array of 7 offshore multipurpose moorings (stations A, B, E, F, I, M, N) will be maintained (UMaine - $712k, $678k, $498k) providing surface conditions similar to NDBC (wind, waves, and visibility which is unique to these moorings). At $2.5m one buoy will be removed, at $1.5m 3 buoys will be removed. In LIS, an array of 3 moorings (EXRK, WLIS, and CLIS) will be maintained by UConn ($360k, $343k, $261k). All stations will monitor the meteorological conditions with wave measurements continued at CLIS and added at WLIS. At $2.5m all stations will be maintained but recovery from outages will take longer, at $1.5m one buoy will be removed. A single purpose wave rider buoy, that provides detailed wave measurements including direction and spectra, will be supported as part of the CDIP at Jeffreys Ledge (UNH, $25k, $15k, $0k) at the $4.0m and $2.5m levels only. These buoy observations directly contribute to the national wave plan.

Surface currents will also be measured (UMaine – $125k, $125k, $0) with continued operation of HFR (CODAR) sites at Grand Manan, NB, and Greens Island, ME. A third HFR site will be relocated from Cape St. Mary to Schoodic Point, ME, to improve coverage and accuracy for HAB forecasting with operations and maintenance being a collaborative effort of UMaine and WHOI. To bridge the gap with southern New England, 3 HFR antennas (on loan from MARACOOS) in and around Massachusetts Bay will be deployed and maintained (WHOI - $75k, $32.5k, $0). WHOI will also implement advanced QA/QC processing for all systems, a first for IOOS. To provide HFR validation information and engage students, 25 drifters will be built and deployed in association with drifter building workshops for educators in collaboration with NOAA NMFS (GOMLF - $30k, $2.5k, $0). At $2.5m only 2 drifters will be deployed, and at $1.5m there will be no surface current measurements from HFR or drifters.

Modeling – Observations will be complemented with the nowcasts and forecasts of NECOFS. The NECOFS will be maintained (UMassD - $135k, $94k, $71k) as well as the capability and accuracy of NECOFS improved; continuous (1978-present) NECOFS database with annual data-assimilated hindcasts updated; and services for USCG search and rescue and NOAA spill response provided. UMassD will also: Improve the offshore regional forecast capability through nesting within a Global-FVCOM and place into 24/7 operation; improve the underlying physics and integration with NERACOOS and other data, and extend current forecast duration from 3 days to 5 days; refine and upgrade the regional model grid in the northern shelf of the GoM (horizontal resolution ~100 m in the northern coastal area); and 5); and add tools for online particle-tracking and forecast assessment. At the $2.5m level efforts will be focused on maintaining and upgrading NECOFS, at the $1.5m level only maintenance will be possible.

The WW3 wave forecast will deliver regional surface wave forecasts in near-real-time, and contribute to operational products (BIO - $11k, $10k, $8k). There are two primary tasks: continuous error-checking and resolution of difficulties in maintaining WW3 forecast operations, based on marine forecasts for winds from the navy, and implementation of new versions of the

operational model, as new code becomes available. At the $2.5m and $1.5m levels new version implementation will be reduced.

At $4.0m and $2.5m levels, the STPS forecasts will be maintained (UConn - $55k, $52k, $0) and delivered to USCG's EDS. At the $1.5m level this will not be supported.

b) Develop a new PORTS system for the Cape Cod Canal - In 2016, NERACOOS in collaboration with NOAA Center for Operational Oceanographic Products and Services (CO-OPS) will be the first IOOS region to establish a PORTS. The need for wave measurements around the Canal was established through stakeholder engagement at the Southern New England Port Safety Forum. In collaboration with the WHRG, NERACOOS and CO-OPs are securing funds to cover the majority of installation, operations and maintenance of a CDIP wave rider buoy in Massachusetts Bay from the MA Department of Environmental Protection (DEP, $444k) for five years. Additional support (WHG - $25k, $15k, $0) will secure buoy operation at the $4.0m and $2.5m levels and integrate other observations (e.g. water level and surface currents).

ii. Coastal Resilience

a) Produce, integrate and communicate key observations and forecasts of surface conditions - The NERACOOS system provides the core information needed for coastal communities to prepare, respond and recover from hazards. Wave measurements and forecasts are essential to understanding wave runup that together with storm surge causes the majority of damage from coastal storms. Three existing water level gauges will be operated and maintained (Charybdis Group – $25k, $5k, $0) at Scituate MA, Gloucester MA, and Hampton Bay, NH with leveraged funding. These locations were initially selected by local NWS WFOs and support filling gaps in the National Water Level Observation Network (NWLON). Two additional gauges will be installed in years 1 and 4, and each site will be surveyed yearly. At the $2.5m level no new gauges will be installed, at the $1.5m level this effort will not be supported.

b) Develop a Total Water Level (TWL) Inundation Forecast System (IFS) - A TWL IFS will be developed by coupling NECOFS and a river discharge forecast system. This will continue collaborative efforts with the NWS WFOs and Northeast River Forecast Center and will compliment inundation forecast and living shoreline efforts recently proposed by NERACOOS and NROC in response to the FY 2015 Regional Coastal Resilience Grants Program.

UMassD (funds above) will maintain near street level forecast systems for Hampton, NH, Boston and Scituate, MA, and Saco, ME and continue to provide pre and post storm analyses. NECOFS upgrades will include expansion of coastal inundation domains and integration of LIS inundation system and UNH river models (see below). Sandy Supplemental investments have facilitated NECOFS to operate in the cloud during coastal storms, when the UMassD building is shut down. At the $2.5m level maintenance and some upgrades will be completed and at the $1.5m level only maintenance will occur.

To increase inundation forecasting capacity in LIS, a research FVCOM model that is nested within the regional NECOFS will be transitioned into the quasi-operational modelling system only at the highest level of funding (UConn - $30k, $0, $0).

An improved spatially distributed, time-varying discharge model will be created at the regional scale only at the $4.0 m level (UNH - $50k, $0, $0). The system will also produce coupled terrestrial heat, conductivity, and nutrient flux predictions. The information (near real-time and forecast) will be served daily. Starting in the second year the river and ocean models will be coupled to better estimate TWL in estuarine environments for inundation forecasts.

Information will be delivered to users through a temporal and spatial inundation visualization system being developed by NERACOOS with funding from the National Fish and Wildlife

Foundation (NFWF, $520k).

iii. Ecosystem Health

a) Produce, integrate and communicate information throughout the whole water column – **Observations** – As well as the surface measurements mentioned above, the moorings in GoM and LIS will continue to make subsurface measurements (currents, temperature, salinity etc.) that help document regional environmental change. In LIS and certain sites in the GoM (station A) moorings are equipped with dissolved oxygen and other water quality sensors. These moorings also provide the capacity to deploy leveraged sensors described in the background.

The satellite time-series will be continued (UMaine - $30k, $20k, $0) providing daily, 8-day and monthly SST and ocean color images, as well as derived anomaly products. Customized products and new products derived from the daily data will be created upon request for specific user groups and using field data as ground-truth from other NERACOOS groups. At the $2.5m level image availability will be reduced and customized products not created and at the $1.5m level, satellite effort will not be supported.

OCA will be monitored in the GoM (UNH - $109k, $109k, $0) with the mooring off Appledore Island, ME, established in 2005 in collaboration with NOAA Pacific Marine Environmental Laboratory (PMEL). To better understand the spatial variability between moorings, a glider (measuring temperature, salinity, dissolved oxygen, measuring chlorophyll and turbidity) will be deployed 4 times a year in the GoM (UMaine - $75k, $0, $0) contributing to the U.S. Glider Network Plan. To better understand variability a regional fishing fleet in partnership with NOAA NMFS eMOLT program will be outfitted with dozens of bottom temperature sensors and on-board real-time telemetry as well as inexpensive bottom current meters that will upload data monthly when gear is returned to dock (GOMLF - $50k, $20k, $0). The number of fishing boats outfitted will be reduced at $2.5m, and not supported at $1.5m.

Modeling – A water quality model, initially developed with MWRA funds, will be integrated into routine NECOFS operation (UMassD funds above). The combined coastal surface and groundwater nutrient flux from the river discharge model (UNH funds above) will be integrated into NECOFS to enhance regional water quality and ecological forecasting. The initial objective will be to look at the seasonal and yearly variability in nutrient flux from the region's watersheds. These modeling enhancements will only occur at the $4.0m level.

b) Increase near-shore water quality monitoring and modeling capacity - The operation of the Great Bay Coastal Buoy, that is equipped with a range of meteorological and water quality sensors, will be continued (UNH - $87k, $83k, $63k) that together with the Coastal Marine Lab (UNH - $45k, $36k, $28k) will be maintained to provide important biogeochemical measurements in the Great Bay Estuary, NH. Nearshore monitoring will be expanded with a coordinated effort in the Narragansett Bay and EPA NEPs. The two NBFSMN shore stations will be incorporated into the NERACOOS system and at minimum 4 of the 8 water quality moorings upgraded by replacing aging infrastructure (URI - $110k, $62k, $47k). UMassB ($110k, $0, $0) will build and deploy real-time water quality and meteorological systems on near-shore buoys or docks. Sites will be determined in cooperation with MassBays NEP, which will recruit volunteers to maintain buoys in Mass Bay and Cape Cod Bay (year 1), and support other NE NEPs to do the same with additional deployments (2 per year) in years 2 and 3. Continuation of the nearshore component of the Integrated Nutrient Observatory established by the IOOS OTT program will be maintained at all 3 locations, LIS (UConn - $15k, $8k, $0), Great Bay (UNH - $15k, $8k, $0), and Narragansett Bay (TBD, $15k, $8k, $0) with sensors for nitrate, phosphate and ammonium. At $2.5m support will be reduced and no support at $1.5m

c) Expand biogeochemical and biological monitoring to support regional initiatives.
ISMN – Integrated measurements throughout the pelagic ecosystem will be a first step to establishing the ISMN, facilitating unprecedented monitoring of ecosystem drivers and response that will complement regular NOAA NMFS cruises. As a follow on to the IOOS OTT Integrated Nutrient Observatory project, SUNA nitrate sensors will be maintained on 4 of the GoM moorings (various depths at E, I, M & N) (UMaine - $80k, $40k, $0). Nutrient measurements at these offshore buoys are critical to understanding already documented interannual and longer-term variability in nutrient fluxes to the GoM and its coastal waters. Autonomous measurements of phytoplankton biomass and community structure with multichannel fluorometers on GoM moorings (A, B, E, I, N) (Bowdoin College - $60k, $0, $0) will provide direct observations of the changing phenology of the base of the oceanic food web in response to hydrographic and nutrient variability. Two coordinated ship based efforts will also directly support ISMN goals through additional biological observations that are currently hard with autonomous platforms. Plankton and water column properties will be collected twice a year on three transects as part of the ongoing Canadian AZMP (BIO - $40k, $21k, $0) and monthly at the Wilkinson Basin Time Series Station (WBTS) (UMaine - $50k, $0, $0). AZMP and WBTS are identified as offshore sentinel monitoring time series sites for plankton in the ISMN plan. At the $2.5m level nutrient measurements will be supported on only 2 buoys, and measurements from only two 2 AZMP transects. At $1.5m, these efforts will not be supported.
NECAN – Coordinated expansion of regional OCA monitoring will be a first step to realizing the NECAN implementation plan to be published late in 2015. Initially 6 coastal sites will be integrated in addition to the Appledore Island OCA buoy. Carbonate chemistry measurements will be enhanced at the Great Bay Coastal Buoy, NH, the Casco Bay Observatory, ME (EPA support ends 2016), and the Mook Sea Farm in Damariscotta, ME (UNH - $75k, $0, $0). A time-series of pH measurements (with SeaFET sensors) established with internal funding at MVCO will be maintained (WHOI - $20k, $0, $0). In addition, each year one station of the NBFSMN will be equipped with a high sensitivity pH sensor by URI (funds above). At the WLIS buoy in Long Island Sound a pH and a CO2 sensors, initially purchased with EPA funds, will be maintained (UConn, funds above). At the $2.5m level only one station of the NBFSMN will be equipped with a pH sensor. All other activities will not occur.
Ecological Forecasting – HABs are the primary focus of NOAA's ecological forecasting efforts in the Northeast. Many of the above measurements provide critical observations for development, assimilation, calibration, and validation of the NOAA Gulf of Maine forecasting system which is being transitioned into operations. Measurement of HABs cells concentrations and toxicity are essential for calibration and validation of the actual threat to human health and shellfish resources. Building on IOOS OTT and other NOAA investments, 2 ESPs will be deployed for 4-6 months in the Gulf of Maine each year during the HAB bloom season (WHOI - $172k, $0, $0). HAB measurement will not occur below the $4m level. All the above will contribute to the U.S. Marine Biodiversity Network.

iv. Operational Efficiency

NERACOOS has made significant progress in sharing expertise to improve operations. At the $4.0m further gains will be achieved by hiring an Observing System Manager who will oversee the performance and evaluation of the information and DMAC systems. Semiannual reviews of all system operators will continue at all funding levels. In addition, at the $4.0 level an effort to boost operational and economic efficiency amongst partners, both in the region and with other regions, will be initiated through a proposal process in years 2-5 (NERACOOS funds). Selected

projects may provide collaborative approaches to observations (e.g. next generation of multipurpose moorings, shared equipment pools), facilitate deployment of standard QA/QC methods such as QARTOD, or help data providers deploy common data management systems and products. Outcomes will be documented and shared as appropriate.

v. Data Management And Communications

a) Maintain and enhance a robust, standards-based regional DAC – Essential to NERACOOS is its DAC, the integration point of all observations and models. GMRI ($235k, $110k, $71k) will continue to maintain, operate and staff existing DAC infrastructure (the NDS, software, and products) at all funding levels. At the $4.0m level, the NDS will be scaled and modernized to fully adopt the DMAC guiding principles, such as full (World Meteorological Organization Global Telecommunication System) WMO/GTS integration, archiving and automation of processes and implementation of diagnostics (Figure 4). Specific tasks would include: fully implement failover processes to keep critical data services available during disasters or extreme events; develop front-end application program interfaces (APIs) to efficiently query and retrieve data from the Environmental Research Division's Data Access Program (ERDDAP)/TDS system for products; develop monitoring and notification tools for observing data streams (e.g. usage, failed sensors, etc.); develop processes to monitor usage activities; develop documentation of data lifecycle processes; and all tasks detailed in the $2.5m level. At the $2.5m level, GMRI will: ensure all IOOS supported gridded and observational data products are available through TDS and compliant services; work with data providers to produce data in required standards, upgrade as recommended by IOOS guidance, and provide support and resources for new data providers to adopt; increase integration of external partner data (gridded, observation); streamline data acquisition/integration by data type (observation, gridded) and data provider capacity (sync data files, connect to remote TDS, store data); participate in IOOS DMAC monthly calls and annual workshop; lead NERACOOS Data Providers working group; comply with IOOS DMAC requirements; and fully implement offsite archive processes for NERACOOS data. At the $1.5m level, GMRI will only be able to operate the DAC and systems will not be enhanced.

b) Develop and manage systems to integrate data from regional initiatives – At the $4.0m level, GMRI will: Scale system to integrate data from regional initiatives (ISMN, NECAN, Citizen Science); and Work with new providers in the region to integrate more data streams (e.g. gliders) into the NDS that will drive the development of new decision support tools to help end users navigate the impact of a changing climate on the valuable resources they depend on. At the $2.5m level, GMRI will include minimal integration of non-IOOS data sources. At the $1.5m level, no new sources will be integrated.

c) Develop and implement QA/QC protocols via QARTOD for all observation data - At the $4.0m level, GMRI will: participate in QARTOD workshops and cross-regional data management policy and implementation plan development; and modify of back-end systems and scripts to accommodate business rules around QC flags based on QARTOD updates (e.g. flagged data not visible on RT data products). At the $2.5m level, GMRI will: lead data providers in evaluation of QARTOD recommendations and implementation of QC flags in data streams and development of business rules for usage**.** At the $1.5m level, progress towards implementing QARTOD cannot be achieved.

d) Collaborate in national efforts to share and improve DMAC efforts– At the $4.0m level, GMRI will: refine the NERACOOS DMAC Plan; and continue to curate and develop documentation for data providers to contribute data to system, as well as sharing documentation and code for open-source software tools with other RAs. At $2.5m level, GMRI will: Work with

data providers and NERACOOS staff to consolidate and develop any further DMAC documentation needed for full RICE Certification. At the $1.5m level, RICE Certification cannot be achieved.

vi. Engagement

a) Continue stakeholder interaction through an efficient and collaborative process –At the $4.0m level, NERACOOS ($832k, $565k, $454k) staff, with support from a consultant (TBD) will conduct a stakeholder analysis to identify key users, develop strategies and targeted outreach campaign. Staff will implement these strategies which will require increased participation in key user meetings. NERACOOS will work with the IOOS Outreach Committee to build synergies for outreach and education. To measure success, GMRI (funds above) will develop diagnostics and metrics to evaluate the DMAC system (e.g. usage of products, value of data streams, and system up time). At the $2.5m level, NERACOOS will primarily engage users through attendance at meetings including stakeholder forums and research and education conferences. NERACOOS will host annual meetings with user participation and highlights, and continue communications effort in regular Facebook posts, quarterly e-newsletter, annual impact report, success stories and press releases. Participation in the IOOS Outreach Committee will also continue. At the $1.5m level, NERACOOS will need to make significant reductions including the removal of buoys, HFR stations and reduction in modeling capacity. NERACOOS staff will create a process and work directly with stakeholders to prioritize infrastructure.

b) Coordinate and implement regional initiatives – NERACOOS staff will continue to lead and coordinate ISMN and NECAN, fund an ISMN Regional Director, and stand up and support an Integrated Regional Citizen Science Network. Vast amounts of data are collected through community based, site specific, long-term monitoring efforts aimed at a multitude of issues. With decades of site-specific observations the data have the potential to provide invaluable information on trends that inform climate change, phenology, ecosystem health, and fill data gaps. NERACOOS will bring together citizen monitoring programs to develop an integrated standards-based data system and visualization tools to improve accessibility of data to the larger scientific community.

c) Develop and deliver products and decision support tools – NERACOOS staff (via focus groups, surveys, and conversations) and GMRI ($109k, $30k, $0) will develop new products based on end-user needs and data availability through an iterative process. New products at the $4.0m level may include new data access and visualization products to support PORTS-like navigation, Citizen Science, ISMN and NECAN Networks, the Drifter Program, or an Alert Tool for observation and forecast data. NERACOOS will also support development and maintenance of MyCoast tool (formerly StormReporter) (Blue Urchin - $10k, $0, $0). At the $2.5m level, new product development will be limited, with a focus on maintaining and enhancing existing products. At the $1.5m level, GMRI will only maintain NERACOOS.org web portal as the primary access point for observation and model data.

d) Support educators to train the next generation of ocean stewards and professionals – Dependent on the stakeholder analysis described above, NERACOOS will support the training of the next generation through hosting educator workshops and webinars, attending educator conferences (NMEA and NSTA), and hosting interns. These efforts will help educators integrate observing system information into their classrooms. Efforts may also include developing resources such as lesson plans and online tools in alignment with state and Next Generation of Science Standards, promote ocean literacy by participation in NEOSEC and supporting the biennial Ocean Literacy Summit. At the $2.5m level, NERACOOS will maintain its current

efforts to work with educators. At the $1.5m level, staff support will not be applied to supporting education directly.

vii. Governance and Management Subsystem

The NERACOOS Board will continue to meet quarterly with an annual meeting in the fall. A similar schedule for the SPI Team will occur before Board meetings, allowing feedback on progress to date. The Executive Director, as PI, will be responsible for the sustained management, development and operation of NERACOOS (funds above). The Director of Finance, Program Manager, Program Coordinator, and Outreach and Communications Specialist will assist in executing programmatic and administrative tasks necessary to successfully complete the award Goals and Objectives and all tasks described in this work plan. Progress reports will be written and submitted as required. In the next five years NERACOOS will further harness the potential to increase non-federal contributions through increased membership, annual campaigns, and giving programs. NERACOOS membership program, established in 2013, is an important source of non-federal funds for the organization.

NERACOOS has a strong history of participation at the IOOS national level, with the NERACOOS Executive Director being Chair of the IOOS Association and a Co-Chair of the IOOS Summit (2012). NERACOOS staff will continue to seek opportunities to participate in and lead national IOOS efforts as they arise.

e) Milestone Schedule.

Tasks (white) and milestones (pink) are given in the table below for each of the five years of the proposed work at the $4.0m level of funding.

	Milestones		Year 1	Year 2	Year 3	Year 4	Year 5
Observations	Sensors purchased or aqcuired by leverage	Buoys, Stations, Gliders	X	X	X	X	X
	Sensors and systems prepared and deployed	Buoys, Stations, Gliders	X	X	X	X	X
	Water samples taken and analyzed	Buoys, Stations, Ship surveys	X	X	X	X	X
	Site surveys conducted	Water level gauges, HFR	X	X	X	X	X
	Real time data sent to provider's data center	All	X	X	X	X	X
	Real time data made available through NERACOOS.org	All	X	X	X	X	X
	QA/QC completed	All	X	X	X	X	X
	QA/QC processing improved	Buoys, Stations, and HFR	X	X	X	X	X
	Historical data made available through NERACOOS.org	All	X	X	X	X	X
	New system established	PORTS, eMOLT, WBTS, NEP	X	X			
Modeling	Maintain modeling systems	NECOFS, WW3, TWL, STPS	X	X	X	X	X
	Models run	NECOFS, WW3, TWL, STPS	X	X	X	X	X
	Routine error checking completed	All	X	X	X	X	X
	Data added to archive	NECOFS	X	X	X	X	X
	Modeling systems improved		X	X	X	X	X
	Underlying information improved	NECOFS			X	X	X
	Update codes when available	WW3	X	X	X	X	X
	Forecast duration extended from 3 to 5 days	NECOFS					X
	Water quality model integrated	NECOFS				X	
	Particle tracking and forecast assessment available	NECOFS					X
	Total Water Level (TWL) Inundation Forecast System developed	NECOFS			X		
	Near street level forecast systems maintained	NECOFS	X	X	X	X	X
	Coastal inundation domain expanded	NECOFS					X
	LIS FVCOM model transitioned into quasi-operational status	NECOFS and LIS FVCOM			X		
	River discharge model developed	UNH TBD		X			
	River and ocean models coupled	NECOFS/UNH TBD		X			
	Forecasts delivered	NECOFS, WW3, TWL, STPS					
DMAC	Maintain DMAC system, including products	GMRI	X	X	X	X	X
	Full WMO/GTS integration achieved	GMRI		X			
	Archiving and automation of processes achieved	GMRI	X				
	Certification application submitted	GMRI		X			
	Long term operations	GMRI			X		
	Implementation of diagnostics	GMRI			X		
	New data streams integrated into DMF and NDS	GMRI	X	X	X	X	X

Engagement	Stakeholder analysis conducted	NERACOOS	X				
	Strategies developed for key users	NERACOOS		X			
	Evaluation and metrics program established	NERACOOS		X			
	Maintain social media	NERACOOS	X	X	X	X	X
	Citizen Science Network established	NERACOOS		X			
	New products developed	NERACOOS	X	X	X	X	X
	Workshop for educators conducted	NERACOOS		X		X	
	Resources for educators developed	NERACOOS		X	X	X	X
	NEOSEC Ocean Literacy Summit supported	NERACOOS	X		X		X
GMS	Office maintained	NERACOOS	X	X	X	X	X
	Board meetings (Quarterly and Annually) held	NERACOOS	X	X	X	X	X
	Observing System Manager hired	NERACOOS	X				
	Performance reviews conducted (Semi annually)	NERACOOS	X	X	X	X	X
	Operational efficiencies improved	NERACOOS		X	X	X	X
	Progress reports submitted (as required)	NERACOOS	X	X	X	X	X

f) Project Budget.

The total overall project budget is given in the table below with costs broken down by SF-

Total Project Costs: FY2016 IOOS (June 1, 2016 to May 31, 2021)

		TOTAL
Contractual	University of Maine	5,356,919
	University of Connecticut	2,299,800
	University of New Hampshire	2,031,800
	Gulf of Maine Research Institute	1,768,999
	Woods Hole Oceanographic Institution	1,333,902
	University of Massachusetts Dartmouth	675,000
	University of Massachusetts Boston	550,000
	University of Rhode Island	549,999
	Gulf of Maine Lobster Foundation	369,507
	Bowdoin College	299,987
	Bedford Institute of Oceanography	254,500
	Charybdis Group, LLC	125,000
	Woods Hole Research Group	125,000
	Blue Urchin Consulting	50,000
	TBD (RI Nutrient work)	75,001

Description of work: NERACOOS will maintain office and regional initiatives and lead stakeholder engagement. NERACOOS will work closely with the following project partners to conduct the proposed work. UMaine will operate and maintain buoys, HFR, gliders, WBTS, and satellite work. UCONN will operate and maintain buoys, STPS, and modeling work. UNH will operate and maintain buoys and shore stations, OCA monitoring, and modeling work. GMRI will operate and maintain DMAC system and lead product development. WHOI will operate and maintain (with UMaine) HFR work, deploy ESPs, and maintain OCA monitoring. UMassD will maintain and enhance NECOFS model. UMassB will lead the development of monitoring system in Mass Bays for NEPs. URI will integrate NBFSMN data into NERACOOS and add OCA monitoring. GOMLF will provide supplies and satellite fees for drifters, bottom temperature sensors, and bottom current sensors. Bowdoin College will monitor phytoplankton community in GoM. BIO will maintain WW3 model and support AZMP monitoring. Charybdis Group, LLC will operate and maintain water level gauges as well as deploy new gauges. Woods Hole Research Group will operate and maintain wave buoy in Cape Cod Canal. Blue Urchin Consulting will maintain and enhance MyCoast web tool. TBD for nutrient sensor work in RI is reserved for a contractor to be determined.

5. APPENDICES:

a) Figures

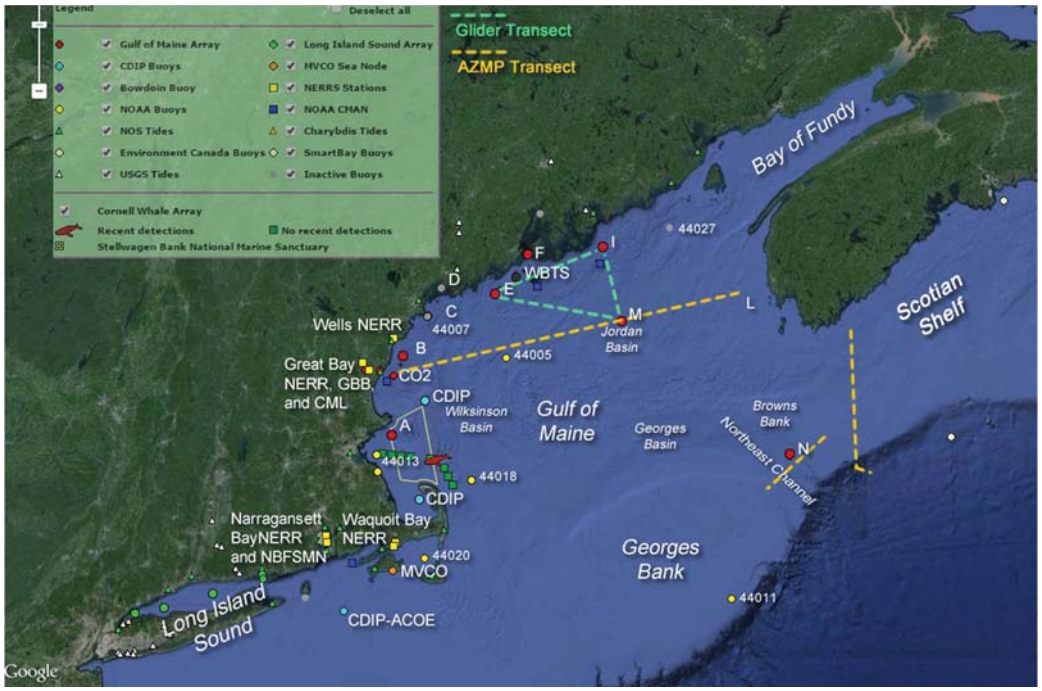
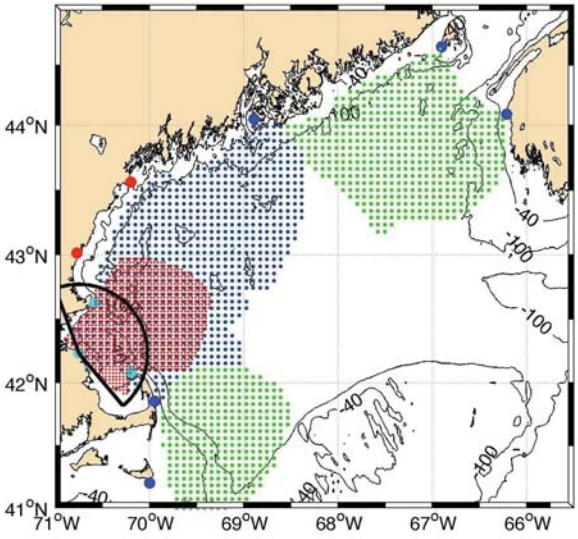


Figure 1: A) NERACOOS Asset Map. A map of the spatial extent of NERACOOS from the waters of Long Island Sound to those of the Scotian Shelf. The image was derived from the interactive NERACOOS website (neracoos.org) with the addition of AZMP and proposed glider transects. As well as NERACOOS funded assets, the website includes important existing Canadian and US federal assets include the buoys of Environment Canada and the US NOAA National Data Buoy Center (NDBC), the NOAA Coastal Marine Automated Network (C-MAN) weather stations, the National Water Level Observation Network (NWLON) of NOAA Center for Operational Oceanographic Products and Services (CO-OPS), the NOAA National Estuarine Research Reserves (NERRs), the NOAA NMFS Ecosystem Monitoring (ECOMON) and bottom trawl cruises, the USACE CDIP wave buoy off Block Island, and the United States Geological Survey (USGS) river and tide gauges. The NSF OOI Pioneer Array will also provide important information when publically available.



B) High Frequency Radar (HFR) locations. Existing (green) and proposed additional (blue) coarse resolution HF radar coverage along with proposed high resolution (red) coverage of the western GoM and Mass. Bay. Locations for all GoM sites are shown in (blue) for present-day sites, (red) near-term expansion using equipment on loan from Rutgers, and (cyan) higher frequency sites. The ideal coverage area for the standard range site proposed here is shown in black.

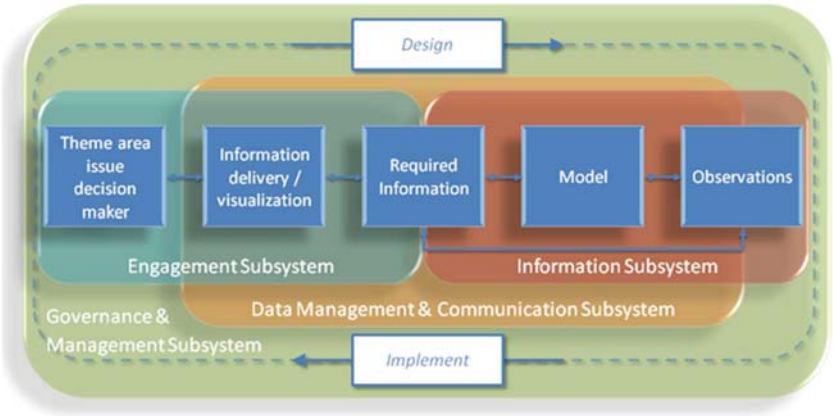


Figure 2: **Observing System Design Schematic**. This updated schematic better reflects the functional mechanisms and integrated nature of these subsystems, an approach adopted at the IOOS Summit in 2012. The main difference is that models and observations are coupled into an **Information** subsystem. Observations are assimilated into models, filling gaps between observations with nowcasts as well as providing future conditions with forecasts. Models inform observational strategies to minimize model uncertainties. Outreach and education, both implying one-way delivery of information, are replaced with the two-way **Engagement** subsystem to work iteratively with stakeholders to understand their requirements, implement analyses, and develop products, tools, and training to meet their requirements. The **Data Management and Communications** subsystem effectively couples the two previous subsystems by aggregating, managing, curating, and distributing coastal and ocean information. The **Governance and Management** subsystem provides the organizational structure to bring the whole together, ensuring that the observing system is designed and implemented to meet the region's diverse stakeholder needs.

Figure 3: NERACOOS DAC schematic. The data managed and curated through the NDS are interoperable and aggregated in region-wide products, though the data are served from distributed systems. The protocols and services of the NDS provide a roadmap to integrate new data providers quickly and efficiently.

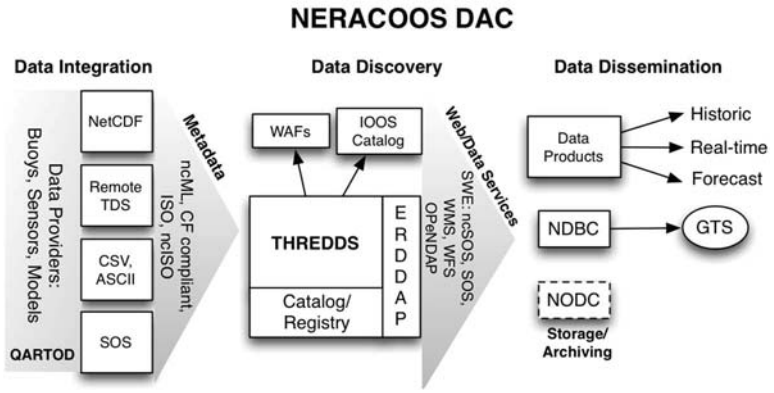
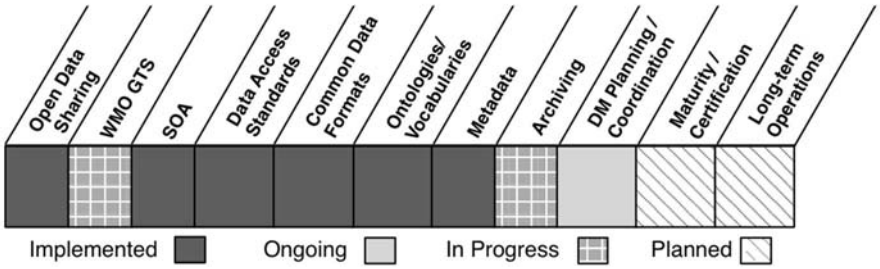


Figure 4:
Status of Implementation of DMAC Subsystem Guiding Principles.



b) References

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c) Users and Letters of Support

NERACOOS users (applications and occupations) determined through a survey in 2013 include: Coastal manager, Commercial fisherman or other harvester, Commercial ship operator or pilot, Communicator (writer, radio, etc.), Educator (K-12, higher ed., and informal), Educator (K-12), Emergency manager, Energy industry, Engineer (contractor, surveyor, or similar), Environmental consultant, Environmental manager, Ferry rider, Fisheries manager, General public, Harbormaster or marina operator, Insurer, Island resident/caretaker, Law enforcement, Lives on a boat, Meteorologist/Forecaster, Military or Coast Guard, Racing, Recreational boater, Recreational fisherman or other harvester, Research scientist, Scuba diver or instructor, Student, Surfer, Tourism, and Tourism owner/operator.

The following letters of support (listed below and preceding this section) further detail the value and benefit of NERACOOS to a sample set of our users:

- Bar Harbor Whale Watch
- Connecticut Department of Energy & Environmental Protection
- Gulf of Maine Council on the Marine Environment
- Long Island Sound Study
- Maine EPSCOR, Sustainable Ecological Aquaculture Network
- Maine Lobstermen's Association, Inc.
- Maine Port Authority
- Marine Environmental Observation Prediction & Response Network
- Marine & Oceanographic Technology Network
- Massachusetts Bays National Estuaries Program
- Massachusetts Lobstermen's Association, Inc.
- Massachusetts Water Resources Authority
- Mook Sea Farm
- National Estuarine Research Reserves
- New England Ocean Science Education Collaborative
- NOAA's National Marine Fisheries Service, Northeast Fisheries Science Center
- NOAA's National Ocean Service Office of National Marine Sanctuary's, Stellwagen Bank National Marine Sanctuary
- NOAA's National Ocean Service, Office of Response and Restoration
- NOAA's National Weather Service, Eastern Region
- Northeast Regional Ocean Council, Integrated Sentinel Monitoring Network
- Northeast States Emergency Consortium
- Ocean Tracking Network
- Penobscot Bay & River Pilots Association
- Portland Pilots Inc.
- Rhode Island Department of Environmental Management
- The Commonwealth of Massachusetts, Office of Coastal Zone Management
- The State of New Hampshire, Department of Environmental Services
- U.S. Department of Homeland Security, United States Coast Guard
- U.S. Environmental Protection Agency Region 1
- Weatherpredict