Preliminary Build-out Plan for the Northeast
Executive Summary

The Integrated Ocean Observing System (IOOS®) is founded on the principal of providing ocean information to address societal issues. IOOS is a partnership of seventeen federal agencies and eleven regional associations. NERACOOS is the regional association for the waters off the Canadian Maritime Provinces of Nova Scotia and New Brunswick to those waters off Connecticut. The Integrated Coastal and Ocean Observing System (ICOOS) Act of 2009 authorized the program and required an independent cost estimate and a gaps analysis. For these, information is needed on the ideal observing system to be built out to. Each of the eleven regions developed regional build out plans with common templates and guidance to enable a national synthesis.

Knowledge of the information required to address issues is essential to an observing system designed to address the needs of those who use and manage our coastal waters. An issue driven end-to-end design approach ensured observing subsystems could be traced to issues through information requirements. First issues and the needed information were identified and then observing subsystems were designed to deliver the information.

Issues were gathered into five theme areas; (1) marine operations, (2) climate variability and change, (3) ecosystems, fisheries and water quality, (4) coastal hazards, and (5) integrated products.

In the marine operations theme information requirements are given for; safe and efficient commercial shipping and recreational boating, search and rescue, spill response, offshore energy, aquaculture, and tourism. For climate variability and change information requirements addressed; changes in ocean conditions over time, ocean acidification, and sea level change. For ecosystems, fisheries, and water quality the issues included; healthy ecosystems, productive habitats and sustainable fisheries, harmful algal blooms, hypoxia and nutrient enrichment, and minimizing impact from polluted waters. Coastal hazards needs were all driven by the requirement to provide hazard and disaster information when and where it is needed and focused on the effects of storms and inundation. Information requirements for Coastal and Marine Spatial Planning (CMSP) were examined in the integrated product theme.

A number of assumptions were used in developing the plan. Costs and system descriptions for each of the platforms were based on 2011 estimates and technology. Over the next ten years technology will advance such that costs for platforms and sensors may be reduced while capability to measure other parameters will be increased. Federal and state efforts will be continued and the plan does not specify sources of support. The plan describes an idealized system, nominally ten years from creation, and does not deal with implementation priorities or strategies.

The observing system needed to provide the required information is described in six subsystems; (1) observing, (2) modeling and analysis, (3) data management and communication, (4) product development, (5) research and development, and (6) governance and management.

Observing subsystem – The Northeast observing subsystem will incorporate a number of differing assets or platforms, both those funded by NERACOOS and by other partners in the region. The expectation is that assets funded by state and federal programs such as the National Data Buoy Center will continue to be supported in the future. The NERACOOS priorities will be to continue to support multipurpose buoys and to increase the number of nearshore or estuarine platforms, expanding the array offshore to fill spatial gaps and augmenting with additional sensors to fill data gaps. The nearshore / estuarine stations will include both buoys and shore / pier based installations. Shore based stations will also be used to remotely observe surface currents with high frequency radar, both long range units for offshore areas and short range units for high-traffic nearshore waters. Additional efforts will include a ship-based, spatially fixed sentinel station program to provide pelagic and benthic observations at greater frequency than other broader scale state and federal programs and autonomous vehicles to provide greater spatial coverage. Spatial coverage of regional water-level measurements will be increased with both fixed and moveable assets. Continued measurements of river discharge and other properties with stream gauge stations remain important. Single purpose platforms will continue to be necessary where they are cost efficient or sensors are unable to be integrated on multipurpose installations. Platforms of opportunity, both mobile and fixed, will provide access to the marine environment in an efficient and cost-effective manner, greatly expanding spatial and temporal resolution of key parameters. Examples include repeat-transects on ferries, observations by fishers with fixed fishing gear, and offshore energy installations. Satellite remote sensing will provide synoptic coverage of the region's surface waters.

The Pioneer Array of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI) will provide important and complimentary information on shelf break process south of Martha's Vineyard.

The observing subsystem is closely tied to the modeling and analysis subsystem – the two providing an information system for the region. Observations are assimilated into models, filling gaps between observations with nowcasts as well as providing future conditions with forecasts. Models can inform observational strategies to minimize model uncertainties.

Modeling and analysis subsystem – The NERACOOS Modeling and Analysis subsystem is based on the Northeast Coastal Ocean Forecast System (NECOFS), a coupled atmospheric, wave and ocean circulation model. Various other models are or are anticipated being nested with NECOFS including higher resolution models, such as one for Massachusetts Bay, Inundation Forecast Systems, water quality, and ecosystem models. Model outputs are available through interoperable web-based services such as the Thematic Realtime Environmental Distributed Data Services (THREDDS). With this, further specialized models, such as physical-biological models, are able to be initiated. A hydrological watershed model provides important input information for estuaries and nearshore waters.

To provide a more robust modeling infrastructure modeling efforts may be transitioned to Federal agencies. However, NERACOOS will maintain a more rapidly adaptable and flexible modeling capacity that is closely tied to state-of-the-art modeling efforts.

Models can inform observational strategies such that model uncertainties are minimized. Hindcasts which assimilate historical observations allow past events and trends to be studied and assessed. They also provide a range of conditions that might be expected and allow for simulation of extreme events such as hurricanes and nor'easters with changed settings such as a rise in sea level

Data management and communication subsystem – A secure, robust and cost effective Data Management and Communications (DMAC) system is required to effectively integrate, manage and distribute regional observations, nowcasts and forecasts. The DMAC system will also support the development of regional products and services developed to meet targeted end user needs. NERACOOS will adapt and develop its existing DMAC capacity to meet the emerging IOOS DMAC standards and recommendations and ultimately provide a regional capacity for data integration, management and distribution.

NERACOOS makes regional ocean information from observations and models available in a variety of ways. Robust metadata is Interoperable web-based services allow for machine to machine communications. Portals facilitate human access to real time and historical information. Examples include portals for; real-time sea surface state observations for mariners, historical climate and ecosystem information for managers, and geospatial information supporting Coastal and Marine Spatial Planning (CMSP). Partnerships are important for regional information stewardship and accessibility. Important regional partners include the Northeast Coastal Ocean Data Partnership (NeCODP) and the Northeast Ocean Data Portal Working Group for CMSP.

Product development subsystem – To enable information to support decisions products or tools need to be developed. This is an iterative process requiring scoping, development and refinement steps. Available funding limits the number of products that can be enhanced or developed in a given year. The products identified for development should come from the priorities identified within the various working groups. NERACOOS product development efforts can be classified into three levels based on several factors that include complexity to implement from a technical perspective and the amount of user input/engagement needed to develop requirements for the products.

Research and development subsystem – To develop, operate, and maintain a fully integrated observing system that achieves the societal goals of IOOS will require continued investment in research and development (R&D). This R&D includes activities to advance our knowledge of how the coastal, oceanic, and Great Lakes waters and their ecosystems function, to develop the sensors and platforms necessary to rapidly detect changes in the ecosystem and its capacity to provide goods and services, and to develop the tools necessary to predict such changes. Although IOOS is aimed at operational observing systems rather than R&D, the Regional Associations have a unique role in identifying and prioritizing the regional requirements for R&D, as well as the necessary transitions from research project to pilot project to pre-operational activities to operational systems.

Education and training subsystem – NERACOOS engages stakeholder groups through tailored training and education activities as well as product development. Education stakeholders include those in both formal (K through graduate school) and informal (museums, aquaria, and science centers) settings. Other stakeholders include marine resource managers, public health officials, energy industry, fishermen, boaters, tourism industry, emergency responders, maritime operations, real-estate and insurance industry. Training the next generation of ocean observing professionals is essential to the ongoing operation and development of ocean observing systems such as NERACOOS.

Governance and management subsystem – The administration and management of NERACOOS requires dedicated full time staff and contract support. Regular operations include administration of the organization (financial and personnel management, legal support, office space and equipment, etc.), support for the Board of Directors, Strategic Planning and Implementation (SPI) Team, and working groups, as well as management of the observing system and other duties related to the management and oversight of the organization. Staffing levels will depend on the size of the observing system.

Preliminary Build-out Plan for the Northeast

Part one: Issues and Products

1. MARINE OPERATIONS

Issue 1.1 Safe and efficient commercial shipping and recreational boating

The ocean and coastal waters of the Northeast are extensively used for commercial shipping, commercial fishing, cruise ships, and recreational boating. These maritime activities are important economic drivers for the region. The Northeast region includes several major shipping ports including: Halifax, Nova Scotia; Saint John and Saint Andrews, New Brunswick; Eastport, Searsport and Portland, ME; Portsmouth, NH; Boston, Chatham, Hyannis, New Bedford, Buzzards Bay and the Cape Cod Canal, MA; Providence, Narragansett Bay and Newport, RI; and New London, New Haven and Bridgeport, CT . The region also includes a great number of harbors and marinas for commercial fishing vessels and recreational boaters. The region is home to the US Coast Guard Sectors of Northern and Southern New England, and the Canadian Coast Guard. The safe and efficient operation of commercial shipping, commercial fishing, and recreational boating requires that mariners have access to reliable, accurate real-time observations of weather and ocean conditions through a variety communication technologies including web, mobile, and radio. While the consistent demand for accurate and accessible information is strong, the requirements for the commercial and recreational sectors vary. Key regional partners include the US and Canadian Coast Guard and Coast Guard Auxiliary, regional port safety forums, tug and pilot associations, NOAA, Port and Harbor authorities, state marine trade associations, and commercial and recreational fishing organizations.

1.1.1 PRODUCT AND SERVICES: Critical real time information for mariners
Commercial and recreation mariners require access to reliable and accurate real-time observations of weather and sea state conditions, location of other vessels, and location of endangered whales through a variety of products and services including integrated web based portals, mobile applications, and NOAA weather radio. The National Weather Service (NWS) is the primary source for weather forecasts suitable to the marine industry. Improved NWS forecasts require an expanded data collection infrastructure. Existing programs, such as the NOAA National Data Buoy Center (NDBC) and the NOAA Physical Oceanographic Real Time System (PORTS) provide real-time data utilized by commercial shippers and the public. However, the PORTS infrastructure, in particular, is limited in the NERACOOS region (no PORTS exist north of Narragansett Bay).

Real-time data portals, both web and mobile, that provide the latest and recent history for weather and sea state conditions support short-term planning needs. Recreational boaters would particularly benefit from handheld electronic applications. Commercial shippers have more sophisticated computer systems through web-based data display portals, such as those in the PORTS network. Mariners also require products that integrate weather and ocean predictions with observations. Distribution of real-time data in ports and harbors via Automatic Identification Systems (AIS) also would be useful. Historical observations in both short and longer term data products would be useful, including climatology data products that document the range of conditions over time.

Site-specific real-time information improves the efficiency of marine commerce and is essential for safe navigation in restricted locations. Reducing light-loading operations and delays offshore waiting for suitable water depths can save valuable time and money.

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Weather and sea state conditions including air temperature, barometric pressure, wind speed, gusts and direction, visibility, rainfall, water temperature, wave height, period and direction, current speed and direction, water level, bridge clearances, and water density to calculate cargo displacement. Locations of other vessels and endangered marine mammals (e.g. Right whales). Spatial scales vary from short distances in ports and harbors (~100 m) to long distances (~100 km) for open ocean shipping. In the offshore areas mariners require sufficient geographical distribution of observations to accurately characterize the weather and sea state over the long distances they will be transiting. Delivery of the information should be as near real-time as possible. Data in more congested and confined waters of ports and harbors should be rapidly updated every 6 minutes. Offshore conditions should be updated every 30-60 minutes. Remote sensing products of winds and surface water temperature are also important information sources. Open ocean shipping and planning, information about regional weather patterns is crucial.

1.1.2 PRODUCT AND SERVICES: Improved wind and ocean current forecasts

Improved wind, wave and current forecasts can be used to help develop transit routes that improve efficiency and minimize risk. Accurate, high resolution forecasts would fill this need. Increasing the number of instrumented ports and harbors and the spatial density of instrumentation would contribute to increased forecast accuracy. The NWS has the responsibility of delivering official marine weather forecasts. NERACOOS can deliver "research" forecasts to the NWS to help improve their forecasts and supplement the weather forecasts with oceanographic forecasts.

INFORMATION REQUIREMENTS:

MODEL INFORMATION: Wind, wave and current forecasts for 24, 48 and 72 hours into the future are required. Within ports and harbors, water level (tide) and current data and forecasts are required at time intervals of less than 1 hour, particularly around changing tides. The spatial resolution of the forecast should vary and the forecasts should come with a measure of uncertainty that can be understood by mariners.

Issue 1.2: Search and Rescue

All mariners in the coastal waters of the United States Exclusive Economic Zone (EEZ) potentially need the services of the US Coast Guard's (USCG) office of Search and Rescue (SAR). In 2006, 28,316 search cases were conducted by the USCG and 5,260 lives were saved (Schafer et al., 2006). Unfortunately, there were also 786 deaths. Most of these SAR cases occurred within a few miles of shore where the currents are complicated as a consequence of coastal bathymetry and congested boat traffic. These cases are often resolved quickly and target drift is limited. The search target may be moved greater distances with limited visibility and farther from shore. Predicting this drift and its uncertainty allows searchers to be more effective by reducing the search area. Coastal High Frequency (HF) radar surface current observations, in concert with the USCG forecast and search management system has been demonstrated to reduce the search areas. High resolution circulation forecast models may also reduce search areas. Real-time information on water temperature is important for determining survival time and real-time, and forecast sea-state is critical for mission planning. Improving the probability of locating the object within the constraints of limited search resources is key to successful rescue efforts.

1.2.1 PRODUCT AND SERVICES: Real-time and forecast conditions sent to the Coast Guard's Environmental Data Server

SAR operations are both costly and dangerous, but have the potential to bring large human and economic benefits. Recently, the USCG implemented a new operational tool to manage searches, the Search and Rescue Operational Planning System (SAROPS). This tool requires wind, surface current, wave measurements, water and air temperature measurements, and exploits a wide range of environmental forecasts through an Environmental Data Server (EDS). The data processing and telemetry associated with HF radar results in a delay of 1 to 3 hours in the delivery of surface current observations, and search planners need short-term statistical forecasts to predict search target drift. NERACOOS information will be integrated to the USCG SAROPS tool through the EDS.

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Operational requirements from the USCG require coverage of 80% of the area for 80% of the time of surface currents from HFR. Offshore – 6 km resolution is required (~10 HFR sites in the Gulf of Maine). Near-shore and densely populated shallow areas (Massachusetts Bay and the Sounds of southern New England) – 2 km resolution to resolve more complex currents. Historical observations are required for developing statistical current models. In-situ subsurface measurements of currents (speed and direction), wind, wave, water and air temperatures are also necessary at sufficient spatial resolution to inform SAR as well as minimizing model uncertainty. Thirty to sixty minute temporal resolution is required.

MODEL INFORMATION: A statistically derived Short Term Prediction System (STPS) is required for 24 hour current forecasts from HF radar observations. Dynamical meteorological and ocean condition models such as the Northeast Coastal Ocean Forecast System also provide forecast information to the EDS for the following 2-3 days.

Issue 1.3: Spill response

Oil and other spills have the potential to cause wide spread ecological damage and broad economic impacts, and threaten human health. Spill response personnel and groups (including federal, state, and local efforts) require up-to-date and reliable information that will allow rapid response to minimize adverse impacts and to assist in monitoring spill impact. Archived information is important for damage assessment. Key regional partners include the Emergency Response Division (ERD) of NOAA's Office of Response and Restoration (OR&R), the US Coast Guard, the Environmental Protection Agency, State Environmental Protection agencies, and Canadian oil spill response agencies.

1.3.1 PRODUCT AND SERVICES: Real-time observations and forecasts to track and predict spill trajectories and weathering, and for planning of response efforts
Information provided by NERACOOS will be integrated into partners' tools and products, specifically those of NOAA's OR&R ERD such as General NOAA Operational Modeling Environment (GNOME) and Environmental Response Management Application (ERMA). Areas of risk include major ports, especially those that receive crude oil or its products (Portsmouth, NH; Portland and Searsport, ME; Providence, RI; and Saint John and Halifax, NS). Additionally, a database providing typical patterns of circulation within estuaries and bays would give responders a sense of normal conditions.

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Surface currents (30 minutes to hourly; HFR - region wide at 6 km resolution, higher resolution for areas of risk, buoys and drifters); Surface conditions including water temperature, salinity, wave height and direction, spilled agent or proxy if possible, meteorological conditions (30 minutes to hourly; region wide spatial distribution to minimize model uncertainties); Subsurface conditions including water temperature, salinity, currents, spilled agent or proxy if possible (30 minutes to hourly; region wide spatial distribution to minimize model uncertainties). Stream gauges for river discharge. Identification of the level of stratification (pycnocline).

MODEL INFORMATION: Surface currents (STPS for HFR). Regional scale coupled meteorological- hydrodynamic models for surface and subsurface properties for large scale distribution and boundary conditions (currents, water temperature, salinity, waves, water temperature, salinity, waves, meteorological etc.; 6 km spatial; hourly temporal; 2-3 day forecast window etc.); high resolution hydrodynamic models for areas of risk (currents, water temperature, salinity, waves, meteorological etc.; ~ 100m spatial; hourly temporal; 2-3 day forecast window). Nowcast allows for extrapolation of real-time observations to a broader geographic extent. Hydrological models for river discharge. All model products should come with measures of model confidence and uncertainties.

Issue 1.4: Offshore Energy

The exploitation of tidal stream, wind, and wave ocean energy resources within the Northeast region is just getting underway. The potential is highest for offshore wind, lower for in stream tidal, and very limited for waves. In-stream tidal demonstration or initial stage energy generation projects are underway in the East River, NY; Muskeget Channel, MA; the entrance *to Great Bay, NH, Cobscook Bay, ME, Bay of Fundy, and in the Minas Passage of the upper Bay of Fundy. A wave energy demonstration site is in operation off the coast of New Hampshire and used to test prototype designs. Offshore wind energy development is the most active with state sites designed in Rhode Island (south of Block Island) and Maine (near Monhegan Island). Federal leasing is in process or completed for sites off the southern coast of RI (Area of Mutual Interest, AMI), south of Nantucket Sound, MA; and the center of Nantucket Sound, MA (permits issued Cape Wind, first in nation). The Department of Interior plans to designate specific development sites for floating offshore wind platforms in Maine waters by winter 2011-12. The Northeast region is expected to be one of the first in the nation with offshore wind energy farms and is one of the first with in stream tidal energy demonstrations. Several tidal in-stream energy turbines have been placed in the Minas Passage for testing, and commercial scale arrays are expected in 3-5 years. Key regional partners include energy developers, state coastal zone and environmental management managers, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), USCG, Army Corps of Engineers (ACOE), US Fish and Wildlife Service (FWS), the Nova Scotia and New Brunswick Departments of Environment, Canadian departments of Natural Resources (NRCan) and Fisheries & Oceans (DFO).*

PRODUCT AND SERVICES: Information to facilitate siting and engineering, power production analysis, impact monitoring, and facility operation

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: To facilitate siting, power production analysis, impact monitoring and operation of demonstration or power production facilities, buoy based observation data on surface and subsurface currents, winds (speed and direction) at surface and up to hub height (approximately 70m), solar radiation, vertical salinity and temperature structure, wave height, period and direction, sea level, tides and depth resolved current speed and direction are required. One station should be located in the vicinity of each development, as noted above. Data should be provided at 15 minute intervals and accessible from the NERACOOS web site in real-time. Archived data should also be available to facilitate statistical estimates at the sites. Proposed buoy observations are meant to be sentinel stations and provide a long-term reference for time series analysis. Energy developers and regulators will require augmentation of this basic observation system to facilitate siting, operation, and monitoring of energy development projects. This enhancement of the observation program should be their responsibility. In some cases it will involve adding additional sensors to existing buoys (e.g., ultrasonic receivers to identify bats and understand how far offshore they migrate, acoustic receivers to track marine mammal movement). Offshore installations when established may also provide platforms for integration into the regional observing system.

MODEL INFORMATION: Validated hindcasts (20 years or longer is optimal, 3 years is the minimum) from circulation, meteorological, and wave models for currents, winds, sea level, and waves in the vicinity of the developments will provide data necessary to generate statistical analyses for the design of energy extraction devices and their foundations, for estimating power production potential, and for planning marine operations (construction and maintenance). This data should be web accessible.

Nowcasts and forecasts from the models noted above are required to assist in design, on-site assembly and operation of the energy-extraction devices. The information will be used to incorporate safety margins for survivability, plan on-site specific steps in construction, facilitate operation of extraction devices, estimate energy generation, and identify time periods when special precautions may need to be implemented. Forecasts should be 2 to 3 days in the future. Both hindcasts and forecasts need to be at spatial resolutions on the order of hundreds of meters in the vicinity of the developments and at time steps of 15 to 30 minutes. Model simulation results can be used by energy developers as input to higher resolution models of the specific energy project necessary for permitting, understanding device interactions and their influence on energy resources, and monitoring studies require by regulatory agencies.

Issue 1.5: Aquaculture

Aquaculture, including shellfish and finfish farming, is an important industry in the Northeast region, most occurring within 3 miles of the coast. In the case of shellfish aquaculture, it occurs primarily in estuaries, rivers, and embayments. There is an experimental offshore aquaculture facility off the coast of New Hampshire and the potential for further development of offshore aquaculture for some finfish. Aquaculture siting requires accurate historical weather and ocean data. Aquaculture operations require accurate forecasts and real-time observations to improve cultivation practices, safety and efficiency. Management and regulatory agencies responsible for permitting and monitoring aquaculture operations require both historical ocean information and real-time observations to assess siting and assure operations meet regulatory guidelines. NERACOOS should develop and support products and services to deliver observations and forecasts to the operators of aquaculture facilities as well as the agencies that manage and regulate aquaculture activities to help support their decision making processes.

1.5.1 PRODUCT AND SERVICES: Information for siting, monitoring, and operations of aquaculture facilities

The development of offshore aquaculture will require accurate climatology data products that describe the probabilities of meteorological and oceanographic conditions. Aquaculture operators, especially offshore, will require web and mobile products and services that provide easy access to real-time weather and ocean conditions and forecasts near their facilities. Products are needed that can allow threshold exceedance warnings for a parameter to be generated. Agencies responsible for siting and regulating aquaculture facilities require site specific historic and ongoing information on water circulation and water quality.

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Development and siting requires accurate and long-term meteorological and oceanographic observations including air temperature, wind speed and direction, wave direction, height and period, as well as depth resolved water temperature, salinity, and current speed and direction. This data is needed to produce climatologies of the range of conditions. Operations of facilities require realtime weather and ocean observations including wind speed and direction, air temperature, visibility, water temperature (surface and bottom) salinity, current speed and direction. Water quality information (at multiple depths) is also important for aquaculture and includes pH, turbidity, dissolved oxygen, chlorophyll a, nutrients and presence and concentration of harmful algae and fecal coliforms. Also required is data about freshwater runoff and river discharge. Aquaculture operations require data close to their operation to support effective decision making.

MODEL INFORMATION: Hindcasts of weather and ocean conditions may be able to provide site-specific probabilities of meteorological and oceanographic conditions to facilitate siting. Now-casts and forecasts would be important for operational aspects. Water quality models are also important.

Issue 1.6: Tourism

Coastal tourism is a significant economic driver in the region and includes activities such as beach visits, fishing, surfing, kayaking, sailing and power boating. Tourists need up-to-date information about the weather and ocean conditions to make decisions about their tourism activities. Coastal tourism operators including whale watch operators would also benefit from this information.

1.6.1 PRODUCTS AND SERVICES: Real-time beach safety information including rip tides, waves and water quality

Tourists would benefit from having web and mobile access to the latest beach conditions and warnings information.

Information Requirements:

REAL-TIME AND HISTORICAL OBSERVATIONS: Hourly observations of meteorological and surface ocean conditions including wind speed and direction, ultra violet radiation, air and water temperature, wave height, period and direction, current speed and direction as well as nuisance species (e.g., jellyfish). Water quality information specifically of beach closures is also important. Historical conditions provide information on probabilities of finding conditions. For example, the timing of the warmest waters for planning vacations.

MODEL INFORMATION: Forecasts, weather, and ocean conditions as listed above and of dangerous conditions including rip tides, dangerous waves, and poor water quality.

2. Climate Variability and Change

Issue 2.1: Changes in ocean conditions over time

Climate variability and change affects a broad range of parameters, processes, and issues in the Northeast region including distribution, abundance, and productivity of species and habitats, sea level rise and coastal inundation, and acidification of ocean waters. To understand these changes and to develop and evaluate adaptation strategies, current climate conditions need to be put into a historical context and observations need to be incorporated into regional modeling efforts that produce hindcasts, nowcasts, and forecasts. It is necessary to make historical and current observations available in formats designed to serve an array of stakeholders including modelers, resource managers, weather forecasters, coastal managers and communities, and the public at large.

Climate effects in the region are caused by both large-scale forcing in the North Atlantic and local-scale forcing within the region. To track and forecast these effects, it is necessary to make observations on boundary forcing as well as key internal climate-system parameters. Sustained observations are necessary to provide the requisite time-series for climate scale analyses. External forcing includes freshwater input, atmospheric forcing, and advection across the northern, southern, and offshore boundaries. Key internal climate-system parameters include temperature, salinity, density, nutrients, currents, components of the carbonate chemistry system, and sea level (see section 4 for more on sea level).

2.1.1 PRODUCT AND SERVICES: Provide sustained key observations, hindcasts, nowcasts and forecasts on external forcing conditions and internal climate-system parameters

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS:

EXTERNAL FORCING OBSERVATIONS: Advection across the boundaries of the region must be quantified. Twice monthly in-situ, observations of volume transport by autonomous mobile assets are required across the northern boundary (western Scotian Shelf & Northeast Channel), the Gulf of Maine Coastal Current (perpendicular to the coast of Maine), and the southern boundary (west of Nantucket Shoals) of the NERACOOS region. The southern boundary conditions should be monitored in collaboration with MARACOOS. Higher frequency sampling and mooring deployments should be embedded into the twice-monthly autonomous mobile sampling to understand the scales of variability in volume transport. In addition, satellite altimeter volume transport estimates need to be derived for the Northeast shelf/slope consistent with estimates made further to the north along Labrador, Newfoundland, and Nova Scotia. Finally, transports across the shelf/slope boundary must be quantified through collaboration and coordination with the NSF funded OOI-Pioneer Array, which is designed specifically to measure shelf/slope boundary fluxes.

Atmospheric forcing in the region must be observed and developed into products for use by NERACOOS partners. Daily measurements of atmospheric variables are required to support a high-resolution (~10 km) gridded reanalysis and nowcast analogous to the NCEP reanalysis and WRF model nowcast and forecasts. Measurements should be made from

NERACOOS assets in the region and assembled from other platforms (e.g. airports, ships, etc.). Measurements should include wind speed, wind direction, wave characteristics, air temperature, humidity and heat flux.

Daily, watershed-level estimates of freshwater input into coastal waters are required to quantify freshwater input into the coastal ocean. These observations will be based on the USGS stream flow measurements but combined to estimate total input by watershed. Historical and current estimates will be developed and distributed. Gradients in estuaries and the coastal ocean related to freshwater input must also be quantified and tracked.

KEY INTERNAL CLIMATE-SYSTEM PARAMETERS: Measurements of key internal climate-system parameters will be made from NERACOOS assets deployed in the region including fixed and mobile platforms. Again, sustained observations are necessary to provide the requisite time-series for climate scale analyses. Parameters include depth resolved temperature, salinity, density, and nutrients. Sea-level and carbonate chemistry are also key parameters but are dealt with separately in issue 2.2 and 2.3. Both coastal and offshore, as well as surface and sub-surface observations are needed. An emphasis on gradients is necessary and developing an understanding on how these gradients change is critical (e.g. salt wedge in an estuary, boundary between coastal and shelf waters). Measurement frequency will depend on platform and emphasis will be placed on high accuracy measurements. In addition, integration of data from other sampling programs (e.g., state, NOAA) and from other platforms (e.g., satellite, ships of opportunity) is critical to provide a comprehensive view of the past, current, and potential future states of key parameters in the Northeast region. To the extent possible, key climate parameters should be measured concurrently with data on species and habitats to ensure that climate effects on ecosystems can be observed and modeled (see Section 3). Satellite remote sensing provides the ability to achieve sustained synoptic observations of surface ocean conditions.

MODEL INFORMATION: Hindcasts of historical meteorological and oceanographic conditions from the 1970s to present will provide invaluable spatial and temporal information on changing conditions throughout the region. A high-resolution atmospheric forcing reanalysis product is needed for the same time frame. These needs are currently being met with the Northeast Coastal Ocean Forecast System (scheduled to be completed in 2012). This historical database as well as the ongoing forecasts and nowcasts provide the ability to simulate and visualize a range of scenarios, for example, the effects of extreme weather events with rising sea level. Climate forecasts of future conditions downscaled to a regionally relevant resolution may also be useful.

2.1.2 PRODUCT AND SERVICES: Climate observations distribution and products

There is a need to distribute climate observations and model information in both near real-time and on a historical basis. Near real-time data will be used to support modeling and assessments of current state. Historical data will provide a statistical reference for current observations and support retrospective analyses. Forecast products will be developed in collaboration will global climate modeling centers (e.g., Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey). Five main products are required:

2.1.2.1 Climate indicators – A defined set of core climate indicators for the region is needed. These indicators must include both external forcing as well as key internal parameters. These indicators should also include large-scale climate indices used to describe basin-scale processes that are known to affect the Northeast region (e.g., North Atlantic Oscillation, El Niño Southern Oscillation). These indicators must be produced annually and reported to the public[1]. The development, storage, access and presentation of these indicators would be facilitated by the tools described below. The indicators developed/used by NERACOOS would be coupled with the NOAA Climate Normals Program to the extent possible.

2.1.2.2 Climate data catalog – A catalog of all climate related information collected in the region is needed. Several catalogs and archives exist, but none are comprehensive. This catalog will represent an ever growing accumulation of references to datasets including a set standard of metadata. The catalog will include historical datasets as well as ongoing observational programs.

2.1.2.3 Data discovery tool – Based on the data catalog, users can identify the key climate information and boundary forcing data collected in a given region. Set regions will be defined (e.g., Long Island Sound, Cape Cod Bay) and users can define their own regions (lat/long rectangles and polygons). Users can also notify NERACOOS of data not included in the catalog. The discovery tool will return user selected elements of the data catalog metadata.

2.1.2.4 Data warehouse tool – Information included in the catalog will be consolidated in a data warehouse (to the extent possible). The purpose of the warehouse will be twofold: serve as a source of data for assimilation in regional modeling efforts (see Issue 3.1) and serve as a source for data climatologies (see below) and regional retrospective analyses. A wide variety of data products will be housed (e.g., site specific temperature records, CTD observations).

2.1.2.5 Climatology and trend development tool – Based on the data warehouse, users can identify a variable (e.g., water temperature, wave height, habitat distribution, species abundance), a region, and a time frame and the tool calculates a climatology (mean), anomalies to the climatology (deviations from the mean), and completes a trend analysis based on user defined time frames (annual, monthly, weekly, daily). Specific data requirements can be programmed and provided automatically to users for incorporation into other climate variability and change products developed by users to support their specific needs (for example, the State of Connecticut could display a NERACOOS temperature climatology and trend analysis for Long Island Sound).

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[1] see OZCOASTs for an example http://www.ozcoasts.org.au/

Issue 2.2: Ocean acidification

Ocean acidification is becoming widely recognized as the "other" CO_2 problem, in that the secular increase in atmospheric CO_2 related to fossil fuel use, is equilibrating into the surface ocean, lowering its pH. In coastal regions, acidification can be can be greatly amplified by acidic freshwater inputs and eutrophication. Changes in CO_2 and pH can affect species growth, survival, and behavior. Many non-calcareous species are affected by acidification, but it is the calcifying organisms (e.g., corals, shellfish, and marine plankton) that are considered the most vulnerable. Shellfish harvesting and aquaculture are major industries throughout the Northeast. Recent research suggests that crustacean, fish and marine phototrophs may be at risk. It is vital for shellfish and finfish managers and growers to have timely knowledge about the state of ocean acidification and the impacts to living resources. It is the goal to provide information to these stakeholders but also to contribute to the NOAA Ocean and Great Lakes Acidification Research Plan. Key regional partners include NOAA (Pacific Marine Enviromental Laboratory, PMEL, and Atlantic Oceanographic and Meteorological Laboratory, AOML, National Marine Fisheries Service, NMFS, and Stellwagen Bank Marine Sanctuary, SNMS).

2.2.1 PRODUCT AND SERVICES: Information for researchers, including real-time status of pH, pCO_2 and calcite mineral saturation state, documentation of trends in acidity (over various timescales) and alerts for impending acidic conditions

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Real-time data necessary to estimate carbonate parameters including pH, pCO_2, temperature, and salinity are critical. Measurements of net community productivity are also important. These data should be at ~3 hour time resolution in order to resolve potentially important diurnal dynamics. Discharge data from USGS (or appropriate models) and depth resolved oxygen data are also necessary. Periodic in-situ sampling of carbonate parameters is important to assure accurate sensor readings. Deployment of assets should be optimized to account for critical shellfish habitat (pelagic and benthic), estuarine systems, pelagic coastal waters and fish and shellfish hatcheries. Each deployment site will likely have varying requirements.

MODEL INFORMATION: Alerts for impending acidic conditions need development but would be based on forecasts for river discharge and water conditions requiring meteorological, hydrological, hydrodynamical, and OA water quality models.

Issue 2.3: Sea Level and Lake Level Change[2]

Vemeer and Rahmstorff are projecting a sea level rise of 75-190 cm over the next 90 years. This rate will cause acceleration in the drowning of near coast lands, raise ground water table positions, cause salt water intrusion, and drowned kettleponds may become anoxic basins (Pettacumscutt River in RI and Frash Pond, in CT.). Secondary symptoms include increased flooding frequency from surge, accelerated shoreline retreat, and changes in the salt wedge position, which could impact industrial freshwater intake for cooling. Scientists and resource managers are anticipating that certain critical coastal habitats may drown such as tidal wetlands and coastal barrier beaches while increased light attenuation will cause the loss of submerged aquatic vegetation at deeper bed boundaries. Rising sea levels may alter the resonance of ocean tides (especially in locations like Bay of Fundy and Long Island Sound). Human response to flooding and erosion such as use of flood and erosion control structures have the potential to adversely impact ecosystem as in the case of "marsh squeeze". Global phenomenon such as warming of the oceans and accelerating melting of terrestrial glaciers are complex. Accurate forecasts are required and need to be downscaled to be useful to managers. Potential impacts may be felt on coastal development, ports and harbors and even cities seemingly distant from the sea like Hartford. Key users include hazard and emergency managers, resource managers (coastal, wildlife and fisheries), insurance companies, scientists and engineers.

2.3.1 PRODUCT AND SERVICES: Improved forecasts for sea level rise and land subsidence

INFORMATION REQUIREMENTS: Coastal and hazard managers need more precise predictions on sea level rise and for shorter time intervals (~20 year increments) and endeavor to achieve more consistency in numbers used by states. Wetland managers and researchers need sea level trends on intervals shorter than the metonic cycle since plans and animal responses to shorter term sea level trends. Tools are required that can translate a sea level rise forecast into an inundation simulation and visualization tool. Typically these are 'flat-water' projections but the ideal project would add modeled water levels.

REAL-TIME AND HISTORICAL OBSERVATIONS: Continued deployment of current tide gauges in the region including those deployed by NOAA CO-OPS. Additional real-time and secondary tide gauges are also needed in the region. Temporary gauge deployments are needed for calibration and validation of models forecasting inundation levels and to verify virtual tide gauge models. Streaming or providing links to real-time tide gauge data from USGS and the USACE are needed so users locate the information. NERACOOS should integrate all tide gauge data for the region and analyze, where appropriate, long-term tide gauge records that are not NOS assets (e.g., USGS and USACE).

MODEL INFORMATION: Forecast sea level for current conditions and future conditions. Inundation models and tide level models (virtual tide stations) are needed throughout the

[2] The Coastal Hazards section will address issues, observations and products specific to hazards planning and resiliency.

region to address gaps. In many instances managers want information at the scale of individual bays, embayments and tidal rivers. Models are required to forecast the fate of coastal habitats (e.g., tidal wetlands and submerged aquatic vegetation) from sea level rise. These should incorporate varying sedimentation rates across the marsh surface and consider the effects of sea level rise cycles within the lunar nodal cycle. Managers want the most accurate sea level rise forecasts for shorter intervals such as ~20 years. The downscaling products would not be produced by NERACOOS, but the outputs could be integrated with the models above. The effect of sea level rise on the tidal range in basins such as the Bay of Fundy and Long Island Sound also needs to be forecast.

3. Ecosystems, Fisheries and Water Quality

Issue 3.1 (merged with 3.2): Healthy ecosystems, productive habitats and sustainable fisheries

Information needs to support ecosystem-based approaches to management are beyond the capabilities of any one organization, yet such approaches are necessary to maintain the region's ecosystem services. The ecosystem approach requires coordination and cooperation among multiple regional institutions. An organized research-observing-modeling framework is necessary to assess and forecast the state of the ecosystem and its constituent habitats and living marine resources. NERACOOS is uniquely situated to serve a coordinating role and to fill observational and modeling gaps in the scientific support framework for the ecosystem-based approaches to management.

3.1.1 PRODUCT AND SERVICES: Support ecosystem approaches to management in the region through observing coordination and integration and provision of key observations and modeling

INFORMATION REQUIREMENTS:

Real-time and historical observations:
Sentinel, fixed-station sampling for water column and benthic properties–Relatively high-frequency biological observations are required to complement ongoing observing of the region's ocean and climate conditions. These observations will help to document changes in biodiversity and phenology related to climate change and variability, and will be used in assessments of human activity efforts on the ecosystem. Fixed station, high frequency sampling complements the broader scale seasonal surveys conducted by state and federal agencies (e.g. state trawl surveys, NMFS Northeast Fisheries Science Center (NEFSC) ecosystem surveys). The Canadian Atlantic Zone Monitoring Program uses a twice-monthly, fixed station design in the Bay of Fundy and on the Scotian Shelf; extension of this design throughout the NERACOOS region would greatly contribute to observations supporting an ecosystem approach. NERACOOS will work closely with regional partners to choose sentinel sites that could be sampled over the long-term, including estuarine, nearshore, and shelf locations. A core set of observations are required (e.g., temperature, salinity, dissolved oxygen, plankton, benthos, nutrients) using traditional (e.g., CTD, nets) and new technologies (e.g., video, genetics). Additional observations can be made based on site-specific or partner-specific needs. Co-location with other NERACOOS or regional observing activities would provide added value.

Fishers as Observers – One limitation on ocean observing is access to the ocean. Traditional platforms are expensive (moorings, AUVs, ships, satellites). The use of commercial and recreational fishing vessels as observing platforms is cost-effective, involves fishers in the observing process, and allows increased dialogue between fishers and observing systems, which will improve the development of observing products designed to build sustainable fisheries. There have been several successful pilot programs in the Northeast region, including plankton monitoring, benthic video monitoring, and the deployment of temperature probes on lobster pots and fishing trawls. These pilots are limited, however, in their engagement with fishers, in the quality of data collected, and in the time between data collection and availability. There is the regional need for involvement of fishers in ocean observing and the near real-time transfer of high quality data from fishing activities to a data warehouse. Once transferred to the data warehouse, the data would be available with other regional observations for access by a wide array of users and for assimilation into forecasts models. These models could then serve as the basis for developing products for fishers (e.g., wave forecasts, by-catch forecasts) as well as other regional stakeholders (e.g., Harmful Algal Bloom forecasts).

MODEL INFORMATION:
Species and habitat forecast system – Many activities in the marine environment require species distribution and abundance and habitat distribution and productivity information. Forecast needs include distribution of protected species for marine transportation, distribution of by-catch species for fishing operations, change in distribution of submerged aquatic vegetation for state managers, occurrences of Harmful Algal Blooms for coastal managers, and abundance and distribution of key lower trophic level species/functional groups for NOAA Integrated Ecosystem Assessments. Non-native species and vegetative habitat are also of interest. A comprehensive modeling and observation based system will be developed to provide forecasts for species of interest. These forecasts would be based on species habitat and physical-biological models that are developed based on long-term observations made in the region (and stored in the data warehouse). Data assimilative models would access the data warehouse to produce nowcasts and forecasts of oceanographic conditions. The forecasts will be short-term (1-5 days) or longer term depending on needs of specific stakeholders. This system would continually be improved through collaborator advancement in habitat modeling, data assimilation, and oceanographic modeling.

Observing System Simulation Experiments (OSSE) test-bed – OSSE's are a tool to help optimize the deployment of observing assets to address specific objectives. A model is used as truth and the sampling designs are optimized based on this truth. NERACOOS will support regional OSSE development and implementation to assist multiple stakeholders in deploying observing assets (e.g., offshore energy, government agencies) for an array of objectives (e.g., change in tidal wetland area, ground truthing satellite measures of chlorophyll).

3.1.2 PRODUCT AND SERVICES: Climate Observations Distribution and Products
Data catalog – A catalog of all ecosystem, habitat and fisheries related data collected in the Northeast region is needed. The catalog will include point, vector, and polygon data. This catalog will represent an ever growing accumulation of references to datasets including a set standard of metadata. The catalog will include historical datasets as well as ongoing observational programs.

Data discovery tool – Based on the data catalog, users can identify the key ecosystem, habitat and fisheries data collected in a given sub-region. Set sub-regions will be defined (e.g., Long Island Sound, Cape Cod Bay, western Gulf of Maine) and users can define their own regions (lat/long rectangles and polygons). This later functionally can be used to identify available data for specific Coastal Marine Spatial Planning units. Users can also notify NERACOOS of data not included in the catalog. The discovery tool will return user selected elements of the data catalog metadata. A wide variety of data types will be included such as environmental, species-specific, habitat, bathymetry, etc.

Data warehouse tool – Data included in the catalog will be consolidated in a data warehouse, to the extent possible. The warehouse will serve data to a number of stakeholders including regional modeling groups, Coastal Marine Spatial Planning practitioners, coastal managers, federal and state agencies, and the general public.

3.1.3 PRODUCT AND SERVICES: Cumulative impacts of multiple stressors
Coastal and marine ecosystems are impacted by multiple stressors including eutrophication, habitat loss, exploitation, invasive species, pollution, and pathogens. It would be extremely difficult to assess the cumulative impacts of multiple stressors, given the difficulty in assessing one stressor. There is a critical need to catalog multiple stressors and provide integrative tools for examining the spatial and temporal distribution of these stressors. Part of this need involves classifying an event in a data warehouse (e.g., report of brown tide in a particular time and place, a hypoxic event in a specific estuary). These reports can then be accumulated and tracked by stakeholders. Part of this need involves quantifying the potential cumulative stress on particular component of the ecosystem. To meet these needs NERACOOS must integrate observations made by other organizations and fill observational gaps. In addition, NERACOOS must provide tools for assessing the effect of individual stressors on specific habitats and species, and tools to evaluate the impact of multiple stressors on key ecosystem services and biological communities.

Issue 3.3 Harmful algal blooms

The waters of the Northeast region are prone to "blooms" of specific types of microscopic algae that can produce potent neurotoxins. Filter-feeding shellfish can accumulate concentrations of these toxins such that the shellfish themselves become a public health threat to consumers. Monitoring of Harmful Algal Blooms (HABs) includes testing molluscan shellfish for toxicity, as well as monitoring offshore and near shore waters for the presence of the algal species. Although Paralytic Shellfish Poisoning (PSP; causative agent Alexandrium ssp.) is perhaps the most prevalent "red tide" human poisoning syndrome in the Gulf of Maine and Long Island Sound, other syndromes can also occur in the waters of the North Atlantic, such as Amnesic Shellfish Poisoning (ASP; causative agent Pseudo-nitzchia spp) and Diarrhetic Shellfish Poisoning (DSP; causative agents Dinophysis spp. and Prorocentrum lima). Additionally, portions of Long Island experience brown tides, which turn the water deep brown, making it unappealing to swimmers and fishers alike. Although brown tides are not a public health concern for human consumption of shellfish, these algal blooms can have many adverse effects on estuarine species and ecological integrity.

HABs are economically detrimental to the region, causing undesirable water conditions and financial loss to the shellfishing and tourist industries. Approximately 3,000 harvesters and dealers in Maine depend directly upon access to healthy shellfish beds, and Maine's Department of Marine Resources (DMR) estimates total annual economic value of this industry at over $50 million, with the largest proportion of that value generated from May through August. Economic studies indicate that a one-week statewide closure of shellfish harvesting due to PSP (softshell clam, mahogany quahogs, and mussels) costs the state *approximately $1.2 million in lost harvester sales, with a total economic loss of $2.9 million. The typical duration of closures in Maine ranges from one to four months. The average annual value of economic activity generated by the Massachusetts shellfish industry is estimated to be between $135 and $180 million. Between 40% and 60% of the total revenue is generated May through September. The 2005 Alexandrium bloom was estimated to cost the Massachusetts shellfish industry $50 million. Peconic Bay on Long Island supplied about 30% of the bay scallops to U.S. markets and was a 2 million dollar industry before the first brown tide event in 1985. Brown tide also results in eelgrass declines.*

3.3.1 PRODUCTS AND SERVICES: Early information to coastal managers for when conditions are conducive for HABs (includes alerts for shellfish harvesters, growers and others)

Managers require real-time sea conditions and operational forecast systems for HAB species abundance and distribution. Near shore conditions are important. Secure communication between managers and researchers on conditions along the coasts are important due to connectivity of States and Federal waters and monitoring programs, and the sensitivity of the information. The information provided by the system is often used to inform individual State's tissue toxicity monitoring efforts as are results from neighboring State's monitoring. Efforts continue within the region to use ocean color satellite remote sensing to produce a synoptic HAB warning product.

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS: Surface currents (30 minutes to hourly; HFR region wide at 6 km resolution, higher resolution for areas of risk, buoys and drifters); Surface conditions including water temperature, salinity, wave height and direction, HAB species abundance and toxins, meteorological conditions, and nutrients (30 minutes to hourly; region wide spatial distribution to minimize model uncertainties); Subsurface conditions including water temperature, salinity, currents, nutrients, HAB species abundance (30 minutes to hourly to daily; region wide spatial distribution to minimize model uncertainties). Optical measurements may be useful for elucidating some harmful species (brown tides) in specific embayments. Ocean color remote sensing, especially hyperspectal sensors, may be useful for synoptic assessment of differing phytoplankton groups. Stream gauges for river discharge. Yearly cyst maps are important for *Alexandrium spp.* as at present they are used to initialize the forecast model.

MODEL INFORMATION: Surface currents. Regional scale coupled meteorological-hydrodynamic-ecosystem models for surface and subsurface properties that include HAB growth dynamics and toxicity for large scale distribution and boundary conditions (currents, water temperature, salinity, waves, water temperature, salinity, waves, meteorological etc.; 6 km spatial; hourly temporal; 3 day forecast window etc.; 6 km spatial; hourly temporal; 3-5 day forecast window); high resolution hydrodynamic models for areas of risk (currents, water temperature, salinity, waves, meteorological etc.; ~ 100m spatial; hourly temporal; 3-5 day forecast window). Hydrological models for river discharge and hydromet models for longer term forecast of weather patterns.

Issue 3.4 Hypoxia and Nutrient Enrichment

Nutrient enrichment and its response indicators of hypoxia, algal blooms, submerged aquatic vegetation (SAV) decline, marsh degradation and erosion, and shifts in trophic status are common features of Northeastern US estuarine and coastal waters, including many in the region. Measurements of physical, chemical and biological variables are necessary to describe effects and trends, including physical and chemical precursor conditions to algal blooms or hypoxic events. Temperature and salinity define stratification strength (a critical factor in deep water hypoxia development) and currents link nutrient sources to effects. Coastal and estuarine typology also influences system response to nutrients. Nutrient loads vary with weather and are biologically mediated on daily and seasonal scales and, under stratified conditions, can produce highly productive conditions in surface waters that feed respiration in bottom waters, creating bottom-water hypoxia and anoxia. Underlying climate trends may increase nutrient loads, alter system metabolism and strengthen stratification, thus exacerbating hypoxia and ecosystem change. Integrated monitoring in a regional or national network is necessary to provide sufficient information to quantify and predict estuarine and coastal effects of nutrient enrichment and provide guidance to managers.

3.4.1 PRODUCTS AND SERVICES: Data and information that quantifies nutrient sources effects and improves early warning and long-term predictive capability for conditions conducive to hypoxia and other nutrient enrichment effects

INFORMATION REQUIREMENTS:

REAL-TIME AND HISTORICAL OBSERVATIONS:
Nutrient Sources and Delivery – Understanding and predicting nutrient enrichment effects in estuaries and coastal waters rely on watershed assessments of nutrient sources and their processing. Mathematical watershed models provide a useful framework for relating sources to delivery and provide both quantity and quality data.

Monitoring to support models that have been applied to much of the Northeast region (e.g., Spatially Referenced Regressions On Watershed attributes, SPARROW, and Generalized Watershed Loading Function with an ArcView (AV) geographic information systems (GIS) interface, AV-GWLF) or to construct more sophisticated mechanistic models (e.g., Hydrological Simulation Program –Fortran, HSPF) is necessarily intensive for accurate calibration. Meteorological parameters, especially temperature, precipitation, wind, humidity, snow pack, cloud cover, solar radiation, dew point, and evaporation, must be continuously monitored and may be available in sufficient density from existing weather station networks (e.g., NWS, airports). Continuous wet and dry depositional monitoring of nutrients and acidifying compounds is recommended to supplement limited data provided by national efforts such as the National Atmospheric Deposition Program (NADP), the Atmospheric Integrated Research Monitoring Network (AirMon) and the Clean Air Status and Trends Network (CASTNet). Land cover (especially agriculture, developed lands, impervious cover, vegetation classes), soils, and hydrography (stream length, slope, elevation, catchment area) must be current, and land cover updated annually. Stream flow data should be continuous and ideally interpreted in a GIS database such as the USGS StreamStats system, which allows for interpolation and extrapolation to points throughout the watershed. Pollutant point sources (e.g., sewage, industry) should be monitored regularly, at least on a monthly basis for major sources. Stream water quality monitoring (See Table 1 for recommended parameters) should be paired with gauging locations at a density sufficient to capture storm water and nonpoint contributions that reflect variations in land cover, as well as consolidate entire watershed loads (e.g., Connecticut Department of Energy and Environmental Protection (CT DEEP) and USGS ambient monitoring network). Monthly water quality sampling is the minimum frequency, and targeted monitoring of catchments to reflect a range of land covers and conditions at a higher frequency across the hydrograph is essential for accurate quantification. Because some pollutants, especially nitrogen and carbon, are not conservative in the aquatic environment, studies of attenuation throughout the annual cycle and across the range of runoff conditions are critical to ensure source loads are properly related to delivered loads and management efforts are thus effectively targeted. In some areas, groundwater nutrients are important contributors to local waters (e.g., Long Island Sound embayments, south coastal Rhode Island and Cape Cod) but may undergo lengthy response lag times as legacy nutrients are flushed from soils. To be accurately quantified in models, and to improve predictive capability for the benefits of management, groundwater nutrient concentrations must be measured, and groundwater transport modeled (e.g., Chesapeake Bay and Broad Brook, CT analyses).

Response Indicators **–** Primary response indicators include dissolved oxygen (DO); area, volume and duration of hypoxia; productivity and respiration; chlorophyll-a; phytoplankton including HABs; trophic shifts; SAV loss (distribution, area, density); and marsh degradation and erosion.

Many of the response indicators useful to nutrient enrichment assessments are covered under Issues 3.1 and 3.2 (Sentinel, fixed-station sampling for water column and benthic properties) and Issue 3.3 (Harmful Algal Blooms). The dissolved oxygen (hypoxia) indicator would benefit from high-frequency monitoring (on the order of hours) at multiple depths (with temperature and salinity) to ensure an adequate profile that captures the pycnocline depth and especially bottom water condition. Sampling for DO should vary in spatial and temporal density and be more intensive during periods of hypoxia susceptibility. Relevant sampling periods and locations are reported in NOAA's National Estuarine Eutrophication Assessment, which relies on input from local experts, and EPA's National Coastal Condition Report, which relies on probabilistic, but infrequent, sampling designs, for example. NERACOOS data can complement local hypoxia monitoring initiatives, such as the Connecticut Department of Energy and Environmental Protection's (CT DEEP) biweekly surveys of Long Island Sound supported by the EPA Long Island Sound Study (LISS), providing essential short-term variations caused by diel cycles and advective movement of water that are missed by grab sampling. Light and dark bottle or stable isotope monitoring of productivity should be added and conducted periodically to define nutrient use efficiency and impact of carbon on oxygen levels, which helps calibrate models and provides a relationship to hypoxia effects. Phytoplankton should be broadly characterized through remote sensing and High Pressure Liquid Chromatography (HPLC) photopigment techniques on at least a weekly basis, with increased frequency during peak bloom periods, perhaps conducted in response to hourly fluorescence measurements and complemented with periodic, quantitative counts. SAV distribution and health parameters should be measured and mapped as an indicator of nutrient enrichment effects, on an annual basis.

MODEL INFORMATION: Estuarine and coastal eutrophication models provide analytical and predictive ability that include management scenario testing that considers source loads and hydrodynamics that lead to hypoxia dimensions or biological indicator endpoints. An example is the System-wide Eutrophication Model (SWEM) that covers the Long Island Sound –New York/New Jersey Harbor – New York Bight complex.

In variable estuarine environments, calibration data requirements are intended to capture the range of physical and chemical conditions and their interactions that define a useful range of eutrophic conditions. Accurate model calibration and validations as well as predictions of hypoxia or algal blooms are complicated by the highly variable interactions of nutrient loadings with the physical and biological factors that drive the process. Combined with source loading and delivery (above) the physical conditions as well as the chemical conditions (see Table 1) of receiving waters must be intensively monitored over a range of conditions (e.g., wet to dry periods, hot to cool, etc.) to develop an accurate predictive and analytical tool. Physical oceanographic monitoring needs are similar to those defined for other issues and are supportive of eutrophication monitoring. While parametrically complete, continuous monitoring of physical factors is necessary for calibrating the hydrodynamics of a eutrophication model; spatial density should be reviewed and focused on domains with boundary conditions necessary to accurately model areas of impact. Complementary sediment models will generally be required. A calibrated and verified model is an essential tool not only for predicting (years scale) trends and management options, targets and outcomes, but for design of a monitoring program that might provide early warning (days to weeks scale) of a hypoxia event based on precursor physical, chemical and biological conditions. This will require monitoring at a spatial and temporal frequency that provides an accuracy and skill level defined by the model and specific to the local problem.

3.4.2 OTHER PRODUCT AND SERVICES FOR HYPOXIA and nutrient enrichment

Other products and services that could be derived from NERACOOS and the National Water Quality Monitoring Network partner data, and the products defined in Section 3.4.1, would include model development (watershed and surface waters), trends analysis, and recommendations for management actions. Remote sensing information on land cover and change is essential to loading analysis and developing management priorities. Meteorological data are a key to model development, especially watershed models, and are an essential consideration in predictive tools for early warning and landscape management benefits analysis. The close link between nutrient enrichment and HABs, covered elsewhere in this plan, could also lead to better warning of blooms that might lead to public safety closures of shellfish beds and bathing beaches. Climate effects, especially changes in temperature and precipitation (amounts, intensity and seasonal distribution), are important drivers of nutrient impacts and ecosystem change that may result in unanticipated effects as well as outcomes of management actions.

Table 1 - Required nutrient parameters for National Water Quality Monitoring Network

Component	Nutrient Analyses		Related analyses	
	Tier 1	Tier 2	Response Variables	Ancillary Analyses
Rivers, Great Lakes, Estuaries, Nearshore Coastal, Offshore Coastal	Total nitrogen* Dissolved ammonium Dissolved nitrate plus nitrite Total phosphorus[+] Dissolved ortho phosphate Dissolved silica	Total dissolved nirogen Total dissolved phosphorus Particulate nitrogen Particulate phosphorus	Chlorophyll *a* Dissolved oxygen Conductivity/salinity	Dissolved organic carbon Dissolved inorganic carbon pH Total suspended sediments Photosynthetically active radiation Particulate carbon
Groundwater	Dissolved nitrate plus nitrite	Dissolved ammonium Dissolved ortho phosphate		Dissolved organic carbon
Atmospheric deposition	Dissolved nitrate plus nitrite Dissolved ammonium Dissolved ortho phosphate			Major ions pH
Wetlands (sediment only)	Particulate nitrogen Ammonium Dissolved ortho phosphate Particulate phosphorus		Chlorophyll *a*	Particulate carbon

* May be determined by analysis of total dissolved nitrogen and particulate nitrogen (TN=TDN+PN)
[+] May be determined by analysis of total dissolved phosphorus and particulate phosphorus (TP=TDP+PP)

n.b. Dissolved refers to samples that are filtered through GF/F (or equivalent) filters before analysis. Total nitrogen (or phosphorus) refers to unfitered samples. Particulate nitrogen (or phosphorus or carbon) refers to samples collected on filters which are then analyzed.

Table 1 From: Caffrey, et al. 2007. Nutrient requirements for the National Water Quality Monitoring Network for U.S. coastal waters and their tributaries. November 13, 2007 Final.

Issue 3.5 Minimizing the Impact from Polluted Waters

Throughout the region, estuarine and coastal waters receive a wide range of contaminants from anthropogenic sources, notably 1) human pathogens, 2) toxic organic compounds such as hydrocarbons and pesticides, 3) inorganic chemicals such as elemental mercury (Hg), and 4) substances of emerging concern such as pharmaceuticals and personal care products (PCPP). Sources of these contaminants are diverse, but are primarily related to industrial and sewage discharges and stormwater and nonpoint source runoff. Human pathogens are associated with the fecal wastes of homeotherms (e.g. humans, livestock, birds, dogs, cats), and are primarily delivered as stormwater and nonpoint sources from coastal watersheds. Fecal borne human pathogens cause gastro-intestinal disease in swimmers at coastal beaches and consumers of contaminated shellfish. Toxic organic compounds are pervasive in the estuarine and marine environment. Petroleum hydrocarbons are leaked or spilled on the land, or transported via the atmosphere from combustion of fossil fuels (e.g., polynuclear aromatic hydrocarbons (PAH)), are broadcast across the land (e.g., pesticides), or are legacies of past discharge and disposal such as polychlorinated biphenyls (PCB), and find their way into runoff or are deposited directly onto estuarine and coastal waters. Many are associated with marine sediments that can be redistributed by resuspension during storms or by disposal of dredged materials. Inorganic chemicals, primarily heavy metals follow many of the same pathways as toxic organic compounds. Mercury is a widespread concern because is delivered via atmospheric deposition and from coastal watersheds, in addition to legacy point sources. When Hg is microbially transformed into its methylated form (MeHg) in estuarine and marine environments it bioaccumulates in marine food webs, leading to human health risks from fish consumption. Contaminants derived from PCPPs are primarily delivered via estuarine and ocean outfalls of wastewater treatment facility (WWTF) effluent, although groundwater from septic systems may be another important pathway in some areas. PPCPs are viewed as an *emerging rather than as an established issue, but merits exploratory monitoring to determine the level of risk to humans in addition to their documented systemic effects on wildlife from endocrine disruption. The biological activity of all of these pollutants is likely to be increased with climate-driven increases in temperature. Without adequate planning and management, their concentrations in estuarine and coastal waters will likely increase with human population densities in coastal watersheds.*

These contaminants have negative economic impacts on both market and non-market uses of estuarine and coastal resources such as beach-going, swimming, boating, surfing, fishing, shellfishing, and seafood consumption. There are also costs associated with their acute and long-term effects on human health.

Key partners include the US EPA for contaminant issues, US FDA for pathogen contamination of molluscan shellfish, Gulf of Maine Council on the Marine Environment and NOAA for Hg monitoring through the Gulf Watch program, and state and local partners for issues such as beach and shellfish bed closures.

3.5.1 PRODUCTS AND SERVICES: Early warnings for when pollution might be present (beach warnings, drinking water alerts, etc)

Pathogen Forecast Model: Appropriate short term indicator test for pathogens (current method has 24 hour delay, so not ideal for forecast modeling). Adequate sampling of pathogen delivery through stormwater, combined sewer, and nonpoint source processes and relationships to storm events. Estuarine and coastal circulation models for each estuarine/beach system to be managed.

Mercury Health Risk Model: Adequate measures of MeHg concentrations in estuarine and coastal primary, secondary and tertiary consumers. Estimates of trophic transfer of MeHg for each estuarine/coastal system to be managed to identify primary source systems of MeHg in coastal food webs. Dynamic annual forecast model marine food web MeHg tissue concentrations.

Pharmaceuticals and Personal Care Products Pilot Study: Pilot sampling of selected WWTF effluent to quantify input concentrations of targeted compounds (e.g. benzodiazepine sedatives). Assessment of indicator species effects and food web bioaccumulation risk. Review of human health risks due to contact exposure and fish and shellfish consumption.

COMMON INFORMATION REQUIREMENTS:

REAL-TIME OBSERVATIONS: Surface conditions including water temperature, salinity, wave height and direction, pollutant (e.g., pathogens and/or indicators, mercury, PCPP) levels, meteorological conditions, and nutrients (30 minutes to hourly; region wide spatial distribution to minimize model uncertainties); Subsurface conditions including water temperature, salinity, currents, nutrients, pollutant (e.g., pathogen and/or indicators, mercury, PCPP) levels (30 minutes to hourly to daily; region wide spatial distribution to minimize model uncertainties); Surface currents (30 minutes to hourly; HFR - region wide at 6 km resolution, higher resolution for areas of risk, buoys and drifters). Rainfall (including that from the Next Generation Radar, NEXRAD). Stream gauges for river discharge. Also fecal indicator bacteria counts (24 hour lag) useful for creating predictive model for forecasts.

MODEL INFORMATION: Regional scale coupled meteorological-hydrodynamic-ecosystem models for surface and subsurface properties that include HAB growth dynamics and toxicity for large scale distribution and boundary conditions (currents, water temperature, salinity, waves, water temperature, salinity, waves, meteorological etc.; 6 km spatial; hourly temporal; 3 day forecast window etc.; 6 km spatial; hourly temporal; 3-5 day forecast window); high resolution hydrodynamic models for areas of risk (currents, water temperature, salinity, waves, meteorological etc.; ~ 100m spatial; hourly temporal; 3-5 day forecast window); Surface currents . Hydrological models for river discharge and hydromet models for longer term forecast of weather patterns. Decision Support Models (e.g., multiple linear regression, Receiver Operating Curves, etc.) that need historic data to develop.

3.5.2 OTHER PRODUCT AND SERVICES FOR POLLUTED WATER: Assessment of Hg methylation processes in restoring tidal wetlands for incorporation into food web model

INFORMATION REQUIREMENTS: Contaminant source and sediment mapping (above)

3.5.3 OTHER PRODUCTS AND SERVICES FOR POLLUTED WATER: Drinking water quality- information on salt water intrusion into drinking water wells association with storm surge and sea level rise.

4. Coastal Hazards

Issue 4.1 Providing hazard and disaster information when and where it is needed

In 2004 the US Commission on Ocean Policy has made it clear that "rising populations and poorly planned development in coastal areas are increasing the vulnerability of people and property to storms, hurricanes, flooding, shoreline erosion, tornadoes, tsunamis, and earthquakes. In addition, climate change may lead to more frequent storms and sea-level rise, both of which increase coastal susceptibility. Not only can natural hazards have devastating impacts on people and property, but they may also have deleterious effects on the environment, particularly sensitive habitats." It is therefore critical to numerous groups (coastal residents, State, Federal and local emergency managers & planners, scientists, etc.,) in the region to be able to predict, understand, and manage/mitigate coastal hazards. A well-designed observing system should provide essential observations on environmental conditions for both systemic, long-term events (i.e., sea level rise) as well as episodic events (i.e., seasonal storm events, flooding, and coastal erosion) to support and leadership in this arena. In the Northeast region there is a specific need to provide data and tools to adaptively manage these issues as the population and development continues to expand within vulnerable coastal and river systems.

4.1.1 PRODUCTS AND SERVICES: Improved capacity for regional Storm Inundation forecasting and hindcasting efforts

NERACOOS currently supports the northeast coastal and ocean forecast system (NECOFS - an integrated high-resolution model system that is capable of hindcasts, nowcasts, and forecasts of circulation and key ecosystem processes in coastal oceans and estuaries.) NECOFS in part drives several operational site-specific sub-regional systems (Saco, ME, Scituate, MA, and an experimental Long Island Sound Surge model) geared towards providing local-scale flooding and erosion predictions and data. These range from simple, low-cost visualizations to more robust and complex models. As proven, useable commodities, an expansion of these tools to other key locations within the region is needed.

INFORMATION REQUIREMENTS:

- Surface currents (hourly; HFR region wide at 6 km resolution, higher resolution for targeted areas of risk, buoys and drifters);
- Surface conditions (hourly; ideally dispersed region wide to minimize model uncertainties - an example density would approximate 1 asset per 50 miles of coastline); including
    - water levels,
    - wave heights and directions as well as meteorological conditions up to 60 nautical miles (nm) offshore to support new high resolution (gridded) forecasts for the Coastal Waters
- Stream gauges for discharge in key major riverine systems.

4.1.2 PRODUCTS AND SERVICES: Storm Conditions Database

NERACOOS observational data and model outputs would be compiled for representative historic storms; observational data would be supplied to partners (NOAA, NWS, ACOE, FEMA) for forecasting predictive storms; results would be stored and managed in a centralized database for use in regional and sub-regional model validations as well as water level return period analyses (5, 10, 50, 100 year storms, etc.) This effort is required to fill a gap of similar data that is currently available and in use for rest of US East & Gulf coasts.

INFORMATION REQUIREMENTS:

- Surface currents (hourly; HFR region wide at 6 km resolution, higher resolution for targeted areas of risk, buoys and drifters)
- Modeled water level, wave output;
- Surface conditions (hourly; ideally dispersed region wide to minimize model uncertainties - an example density would approximate 1 asset per 50 miles of coastline); including
    - water levels,
    - wave heights and directions as well as meteorological conditions up to 60 nm offshore to support new high resolution (gridded) forecasts for the Coastal Waters
- Stream gauges for discharge in key major riverine systems.
- Incorporate data from any past and future storm deployments of tide and wave gauges.

4.1.3 PRODUCT AND SERVICES: Pre and post-storm conditions assessment and reporting; rapid pre-storm asset deployment

The ability to collect pre and post storm surveys of damage and overwash/splashover (erosion) are critical to help refine and validate future model projections of storm damage in addition to building a time series of data for shoreline management and emergency planning needs. These will render the region ready to mobilize in the collection of critical post storm data.

INFORMATION REQUIREMENTS:

- water level observations (high water marks);
- beach elevation profiles (neighborhood level within scope of event impact; survey assessments spread throughout the region)

4.1.4 PRODUCT AND SERVICES: Improving the Northeast Coastal Ocean Forecast System (NECOFS) for extra-tropical storm forecasting

In its current configuration, the NECOFS lacks the ability to reliably handle extra-tropical storm events, requiring the manual effort of shifting between two forecasting systems. It is therefore required, both from an efficiency as well as a data integrity/product service standpoint, to build a seamless integration of NOAA National Hurricane Center (NHC) model data into the NECOFS to support timely and accurate regional forecasting during extra-tropical storm events for both the region as a whole and for the sub-regional models driven by NECOFS. Additionally, the ability to forecast areas of potential high-impact from extra-tropical storm events will help in appropriately deploying assets of opportunity (e.g., temporary rapid-deploy USGS/ACOE tide/water level gages, or existing NERACOOS assets).

INFORMATION REQUIREMENTS:

- NOAA NHC extra-tropical storm data;
- Surface currents (hourly; HFR – region wide at 6 km resolution, higher resolution for targeted areas of risk, buoys and drifters)
- Surface conditions (hourly; ideally dispersed region wide to minimize model uncertainties - an example density would approximate 1 asset per 50 miles of coastline); including
    - water levels,
    - wave heights and directions as well as meteorological conditions up to 60 nm offshore to support new high resolution (gridded) forecasts for the Coastal Waters
- Stream gauges for discharge in key major riverine systems.

4.15 PRODUCT AND SERVICES: Regional Virtual Water Level Network
Using the NECOFS model, create and calibrate virtual tide/water level observation points to record and present predicted and historic data. These virtual stations will serve to address regional gaps in coverage where adding additional sensors is impractical. Locations to be verified/corroborated by the deployment of short-term water level gauges in a manner designed to reduce overall variance in modeled output.

INFORMATION REQUIREMENTS:
- Surface currents (hourly; HFR - region wide at 6 km resolution, higher resolution for targeted areas of risk, buoys and drifters)
- Surface conditions (hourly; ideally dispersed region wide to minimize model uncertainties - an example density would approximate 1 asset per 50 miles of coastline); including
    - water levels,
    - wave heights and directions as well as meteorological conditions up to 60 nm offshore to support new high resolution (gridded) forecasts for the Coastal Waters
- Stream gauges for discharge in key major riverine systems.

4.16 PRODUCT AND SERVICES: Regional Sea Level Rise Inundation Simulator and Viewer
Develop, using currently available and soon-to-be-delivered high-resolution elevation/bathymetric data and regional water level data, a regional approach to present sea level rise simulations beyond basic "flat-water" or "bathtub" approaches. This will take into account off-shore/on-shore water sources (coastal and riverine hydrology/hydrography) and interactions with coastal features (hardened structures, barrier beaches, etc.,) to provide a more accurate and functional representation of how changes in water levels will affect the coastal landscape of both the built and natural environments.

INFORMATION REQUIREMENTS:
- High resolution topographic elevation data;
- Bathymetric data;
- Regional oceanographic water level data (observational and modeled output)
- Stream gauges for discharge, water levels in key riverine systems.

5. Integrated Products

Issue 5.1: Northeast Ocean Data Portal to Support Coastal and Marine Spatial Planning

The 2010 U.S. National Ocean Policy calls for regional-scale coastal and marine spatial planning (CMSP) supported by a robust data management system containing coastal and marine scientific datasets and products. CMSP is a collaborative process dependent on access to a wide range of data on environmental, socioeconomic and regulatory parameters. However, many of these data have been inaccessible and scattered among different providers. In response, the Northeast Ocean Data Portal (Portal); a decision support and information system for managers, planners, scientists and industry; was developed to assist CMSP efforts for the northeast region from the Gulf of Maine to Long Island Sound. The Portal working group is endeavoring to enhance access to data, interactive maps, tools, and other information needed for decision making related to ecosystem-based management, offshore energy siting, commercial fishing, biological and habitat concerns, vessel traffic, avifauna, and ocean uses. The primary CMSP audience includes regional managers, ocean stakeholders and technical staff, although the information is useful in other ocean management and industry contexts.

5.1.1 PRODUCTS AND SERVICES: Support regional-scale CMSP through development of integrated data products

INFORMATION REQUIREMENTS:

Access- Current, credible and comprehensive data are only useful if people have ready access. The process of CMSP requires efficient access to multiple, concurrent data streams and products from widely disparate sources. The Portal is being developed as an integrated data network aimed at making pertinent information accessible for all ocean stakeholders. There is a critical need to acquire, catalogue, analyze, and develop datasets that will inform decision making, support research, and provide necessary data for advanced models and tools that can be used in the planning process. The informational requirements for the Portal are divided into four dataset categories: Administrative and Regulatory Boundaries; Ocean Uses; Biological Resources; and Physical Oceanography. The conceptual approach to Portal development has been based on: 1) the identification and collection of priority datasets (as identified by regional managers); 2) the provision of raw data to potential consumers for analysis and product development; 3) the development of data products and tools specifically for CMSP; and 4) the continued maintenance of Portal datasets and products, while encouraging data providers to serve out and maintain their own dynamic products.

Administrative and Regulatory Boundaries – Administrative and regulatory boundaries comprise a significant component of the data layers associated with CMSP, as they serve as the primary boundaries for government activities and as guides for the regulation and development of coastal and ocean resources held in the public trust. The initial development of these policy layers focuses on understanding various levels of local, state and federal marine jurisdictions, the designation of coastal barrier resources systems and an understanding of permitting areas like the outer continental lease blocks. Following the development of these initial administrative datasets, there is a need to maintain existing datasets, to identify and develop additional datasets (i.e. additional marine jurisdictions, and federal and state marine protected areas), and to continue to explore the various administrative and regulatory policies pertinent to spatial representation and CMSP.

Ocean Uses – Ocean uses refer to the management of traditional and emerging uses of ocean and coastal resources. Data layers under this category include, among others, existing or proposed utilities and infrastructure, industrial facilities, navigation and transportation corridors, recreational activities and commercial fishing. The presence of these datasets on the Portal is designed to aid in the characterization and management of human use within the northeast. Human use, socio-economics and indicators of preference for resource utilization represent a category of spatial datasets that have historically been under developed or non-existent. While significant datasets have been identified and developed to represent these uses, additional dataset development is essential to characterizing the utilization of and dependence on ocean resources and services. There is a further need to ensure the continued collection and serving of these datasets to assist with these characterizations. To date, the following datasets have been identified, are on the Portal and require continued maintenance:

- Utilities and Infrastructure: permitted Cape Wind area; LNG sites; and submarine cables
- Industrial: regulated facilities; and disposal sites
- Navigation and Transportation: wrecks and obstructions; aids to navigation; unexploded ordinance locations; unexploded ordinance areas; anchorage areas; shipping channels; and large vessel traffic from automated identification systems (AIS)
- Commercial Fishing: NMFS vessel trip report products; marine farms; and NMFS vessel monitoring system product

In addition to maintaining the datasets already on the Portal, there is a critical need to obtain and develop new datasets. Priority datasets identified by the Portal working group and regional managers include, but are not limited to: recreational boating and fishing; cultural and historic areas; demographics information; submarine cables and pipelines; energy facilities; military hazard and restricted areas; recommended shipping routes; port facilities; aquaculture sites; disposal sites; power transmission pathways; hunting areas; beach use and swimming designations; ecotourism and scenic value; aids to navigation; and anchorages.

Biological Resources – Biological resources provide an understanding of where various ocean and coastal habitats are located, and the location of these resources aids in the analysis of marine avian, mammal and fish species distributions, as well as species habitat needs and stresses. To this point, a number of these datasets have been developed and identified for the Portal, although these datasets are underrepresented and there is significant data collection needed to guide the development of new products and tools for biological resource analysis in a CMSP framework. Continued maintenance of existing datasets is also needed to accurately characterize species distributions, resilience and dependence on ocean and coastal habitats. Long-term planning involves the engagement of agencies collecting these data and encouraging them to provide products for CMSP at various time scales. Currently there are significant gaps in habitat and species composition data that should be developed for CMSP applications in the northeast. The Portal working group has prioritized the development of the following datasets: Wetlands habitat classifications; Essential fish habitat designations; Shellfish habitat/beds; Updates for habitat areas for specific fish species including Atlantic Cod and Herring; Benthic habitat characterizations; Bird habitat and nesting sites; Cetacean critical habitat and sighting information; Submerged aquatic vegetation; Primary production areas; Parks, reserves and sanctuaries; Ecological function/service classifications; and NMFS habitat areas of particular concern.

Physical Oceanography – Oceanographic modeling can provide valuable information for decision makers, such as understanding local and regional currents that help dictate habitat type. The Portal currently contains access to oceanographic time series data provided by NERACOOS buoys and tide stations, as well as data products characterizing current velocity, bottom shear stress and wind speeds. Additionally, geologic and bathymetric datasets such as depth contour, shoreline position, sediment grain size, and seabed form are available. However, in many cases, more comprehensive, higher resolution, and broader geographic data products are required to support ocean management. The Portal is designed to continue data and tool development by leveraging existing oceanographic data collection efforts and modeling approaches to compile raw data and create new spatial products, such as the effort to develop hindcast data products from the NeCOFS model that provides forecasts for the region. The portal will continue to provide access to raw oceanographic and geologic data from NERACOOS and its partners and develop data products specifically for CMSP, but significant investments are needed to further develop the tools and analyses required to make these data available.

5.1.2 OTHER PRODUCT AND SERVICES: Functionality and decision support tools for CMSP

INFORMATION REQUIREMENTS:

Functions to support and enhance data accessibility – A number of simple functionality enhancements are needed to assist with the demonstration, digestion and dissemination of the various datasets catalogued on the Portal. These enhancements will also further the development of additional data products and tools for ocean and coastal resource managers. The functionality enhancements identified as priorities by the Portal working group are:

- Enhanced data search capabilities
- Enhanced data extraction capabilities
- Web mapping service enhancements
- Enhanced geoprocessing for both data hosted by the portal working group and data served from outside sources
- Development of a media viewer to enhance access to scientific reports, underwater video, seafloor imagery, spreadsheets, and other non-traditional geospatial data
- Password protection for sensitive layers and for different levels of user access

Advanced tools to support decision making – Accommodating new ocean uses in a seascape that already includes multiple competing uses is of significant concern to practitioners of CMSP. The practical application of data sources to assist in the development of these new uses and their associated infrastructure requires: 1) efficient access to comprehensive data; and 2) tools to rationally weigh the social, biological and economic tradeoffs between competing interests.

Investment in these tools is critical to support stakeholders, managers and policy makers in identifying vulnerable habitats, gauging ocean use compatibilities and running multiple scenarios for potential siting choices to ultimately achieve the greatest overall social and economic benefit.

Tools to extract time series from modeled data – There are currently no publicly available mapping application tools that pull modeled time series data into an easily accessible viewer format. The potential benefit of these tools is the ability to generate high resolution data products for a user defined time period and geography. Recent technological and oceanographic modeling advancements have made the development and dissemination of these types of tools and databases possible. Modeled outputs are key foundational data for CMSP with numerous applications, including identifying and classifying oceanographic conditions, habitats and siting new ocean uses, such as renewable energy. The development of extraction tools for modeled time series data will have broad ranged applicability to all sectors of ocean resource management, as these data represents the conceptual foundation for developing ecological indicators. These indicators assist managers in understanding changes occurring throughout specific habitats or resource categories, and, over time, to adopt adaptive management strategies for dealing with resource resiliency, impacts and mitigation. High resolution time series data, such as for oceanographic parameters, will be broadly applicable, with potential implications towards alternative energy facility siting, marine mineral extraction, ecosystem function valuations, and habitat characterizations among others analyses.

Site suitability assessment tools – There are numerous use compatibility analyses available to inform CMSP but available assessments are typically for general demonstration purposes and therefore not specific to ocean uses and resources for a given area of interest. Assessing the potential compatibilities between uses, and among uses and resources, is an important step towards understanding and informing the tradeoff decisions that are inherent in CMSP. Initially, these assessments begin with technical and economic feasibility analyses aimed at narrowing potential siting areas, avoiding undesirable areas based on environmental variables, and minimizing costs associated with development. The development of first stage site suitability tools will allow decision makers to interactively screen locations most desirable for various activities based on their environmental and economic preferences. These potential siting areas can then be compared with existing uses and resource distributions to begin tradeoff discussions.

Stakeholder collaboration and data acquisition tools – The ability to synthesize data collection from practitioners in the field with management analysis and planning is essential to understanding the distribution and resource use of traditional ocean uses and industries. The functionality of these tools is often straight forward and provides stakeholders with the ability to inform the planning process by identifying specific areas on a temporal and spatial scale that are essential to the economic sustainability of their trade. This temporal and spatial analysis takes the form of identifying areas that are not only historical or suitable for immediate/short-term use, but also areas that may meet the long-term spatial needs and resource demands of an expanding industry or practice. Existing uses can then be compared with emerging and potential future resource characterizations and requirements to demonstrate various management scenarios, and advance stakeholder collaboration towards the development of planning alternatives. Further development of these tools is necessary to characterize the human use of ocean resources, inform CMSP and provide individuals with business dependent on ocean resources an avenue for affecting plan development.

Ecological valuation, vulnerability and cumulative impact tools – Ocean ecosystems are available for multiple activities and, although no single use may be significant in and of itself, cumulative impacts can have substantial effects. To determine the value of specific habitats, the vulnerability of those habitats to specific uses and assess the effects of cumulative impacts, it is necessary to integrate ecosystem and habitat data with spatial and temporal human use data. Development of a standard, scalable and transferable methodology for understanding habitat location, the value of that habitat and/or its associated resources, and the vulnerability of each habitat type to impacts from current or emerging uses is an important component of CMSP. The results of these analyses can be viewed at different spatial and temporal scales, depending on the level of detail in the data. Impacts associated with human uses and vulnerability analysis provide a foundation for other decision support tools such as ecosystem service tradeoff analysis because they are based on an analysis of indicators of ecosystem health. A standardized classification of ecosystems/habitats is required to make meaningful comparisons of an ecosystems' vulnerability to various human uses.

Scenario analysis and tradeoffs tool – Marine ecosystems provide essential services that people value and benefit from, including: food, recreation, jobs, transportation, wildlife viewing and opportunities for rest and relaxation. When conflicts arise over which services are more important (e.g. when whale migration routes cross cost-effective shipping channels), how do managers make informed decisions? Because these are value-based decisions, visualizing and discussing potential tradeoffs is vital to effective ecosystem-based CMSP. Ecosystem service tradeoff models integrate biological, physical, social and economic information to enhance informed decision making, and are essential tools for integrated, ecosystem-based CMSP. Several tradeoffs models and tools are currently in various stages of development. The Portal should build off these models by integrating their outputs (data and visualizations) as well as by providing direct and dynamic access to select functionality. Further work is needed to determine the appropriate use of these tools in the Portal and to develop the data and analyses necessary to define the extent, and social and economic value of key ecosystem services. Current ecosystem and socio-economic data may initially limit tradeoff modeling, but development and use of these models in the planning process will inform the prioritization of data needs.

Preliminary Build-out Plan for the Northeast
PART TWO: RCOOS AGGREGATED SUBSYSTEMS

OBSERVING SUBSYSTEM

INTRODUCTION

The Northeast observing subsystem will incorporate a number of differing assets and platforms, both funded by NERACOOS and by other partners in the region. The expectation is that assets currently funded by state and federal programs such as the National Data Buoy Center will continue to be supported in the future. The NERACOOS priorities will be to continue to support multipurpose buoys and to increase the number of nearshore or estuarine platforms, expanding the array offshore to fill spatial gaps and augmenting with additional sensors to fill data gaps. The nearshore / estuarine stations will include both buoys and shore / pier based installations. Shore based stations will also be used to remotely observe surface currents with high frequency radar, both long range units for offshore areas and short range units for high-traffic nearshore waters. Additional efforts will include a ship-based, spatially fixed sentinel station program to provide pelagic and benthic observations at greater frequency than other broader scale state and federal programs and autonomous vehicles to provide greater spatial coverage. Spatial coverage of regional water-level measurements will be increased with both fixed and moveable assets. Continued measurements of river discharge and other properties with stream gauge stations remain important. Single purpose platforms will continue to be necessary where they are cost efficient or sensors are unable to be integrated on multipurpose installations. Platforms of opportunity, both mobile and fixed, will provide access to the marine environment in an efficient and cost-effective manner, greatly expanding spatial and temporal resolution of key parameters. Examples include repeat-transects on ferries, observations by fishers with fixed fishing gear, and offshore energy installations. Satellite remote sensing will provide synoptic coverage of the region's surface waters.

The Pioneer Array of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI) will provide important and complimentary information on shelf break process south of Martha's Vineyard.

The observing subsystem is closely tied to the modeling and analysis subsystem – the two providing an information system for the region. Observations are assimilated into models, filling gaps between observations with nowcasts as well as providing future conditions with forecasts. Models can inform observational strategies to minimize model uncertainties.

Assumptions in filling out the platform templates

- Costs and system descriptions for each of the platforms below are based on 2011 estimates and technology.

- Over the next ten years technology will advance such that costs for platforms and sensors may be reduced while capability to measure other parameters will be increased.
- Federal and state efforts will be continued and the plan does not specify sources of support.
- The plan describes an idealized system, nominally ten years from creation, and does not deal with implementation priorities or strategies.

Below are summary tables for Fixed (Table 2.1), Mobile (Table 2.2), and Remote Sensing (Table 2.3) Platforms followed by more detailed descriptions of each platform in a common format.

TABLE 2.1 FIXED PLATFORMS SUMMARY TABLE

Platform name	Description	Number
Multipurpose buoy/mooring system: offshore and shelf moorings	The multipurpose moorings will provide platforms capable of measuring a suite of real-time weather and ocean parameters (physical, chemical and biological) that will meet the requirements of many theme areas. All multipurpose moorings will not necessarily have the full suite of sensors detailed below but will be capable of supporting them and will have the capacity to test new sensors. Moorings will cover a range of depths up to 300m; deeper moorings require increased instrumentation.	~15 buoys geographically spread throughout the region
Nearshore/estuarine multipurpose buoys	Designed to provide information on a number of issues but mainly focusing on port / harbor operations and water quality (hypoxia / nutrient enrichment and minimizing the impact from polluted waters).	~15 buoys with a mixture of fixed and moveable locations
Shore/pier-based systems	A shore or pier based station will collect coastal meteorological and ocean data at key locations and especially in ports and harbors with significant maritime commerce and water quality issues.	~15 Stations throughout the region
Water-level gauge: tides and water level	Water level sensors are in addition to those deployed and maintained by Federal agencies such as NOAA CO-OPS and USGS. These mainly provide coastal hazard information.	15 additional gauges including moveable ones
Coastal river gauge	A coastal river gauge will monitor river flow as well as the water quality entering the marine system.	Maintain and augment the current USGS stream gauge system and restore to previous levels if present capacity less that needed
Single purpose – Coastal Data Information	Single-purpose buoy to measure wave characteristics at a given location. Data	Sufficient to meet national waves plan but exact

Program (CDIP) wave buoy	transmitted to and processed by CDIP at the Scripps Institution of Oceanography. This program has strong links to the Army Corps of Engineers.	number is unclear and depends on location of other multipurpose platforms
Single purpose – molecular analysis buoy	Currently molecular analysis sensors such as the Environmental Sample Processor (ESP) used for HAB detection require a dedicated platform due to power, telemetry, and stability requirements.	~ 6 in the region
Single purpose – passive acoustic / listening buoys	At the moment there is an array of single-purpose Right Whale listening buoys in the Boston Shipping channel (funding from a Massachusetts Liquid Natural Gas (LNG) mitigation award.	Currently 10 in region.
Platforms of opportunity	On offshore energy installations and fixed gear such as lobster traps	~5 well-instrumented ~50 with a few sensors
Profiling moorings (future vision)	Used to provide highly depth-resolved information at key sentinel locations. They may replace some multipurpose buoys.	More development needed

TABLE 2.2 MOBILE PLATFORMS SUMMARY TABLE

Platform name	**Description**	**Number**
Gliders	Coastal gliders will help characterize the vertical and horizontal structure of the water column providing important observations to support many theme areas. Routine transects will help provide information on external forcing such as volume transport. This is particularly important at the region's northern boundary with the majority of the freshwater being delivered across the Scotian Shelf. Internal surveys are important for data assimilation into models.	7 needed to provide routine surveys at the northern boundary as well as conditions within the region
Autonomous underwater vehicles	AUVs require less time underwater than gliders due to power usage. Powered propulsion allows access to more high-energy / complex environments that gliders cannot access. Also allows more complex flight patterns including surveys at a single depth (e.g., under salmon net pens).	2 needed for specific sites and times (e.g., to monitor oxygen under and around net pens)
Ships (research and fishing)	Ships can be used to provide information that cannot easily be obtained through autonomous systems. Combinations of research ships and fishing vessels will depend on level of support and	8 stations in the region: Sentinel sites that could be sampled over the long-term, including estuarine,

	required facilities. Key fixed sentinel stations with biogeochemical, pelagic and benthic habitat components still require ships. Value can be added through common protocols with the Canadian Atlantic Zone Monitoring Program (AZMP).	nearshore, and shelf locations, ideally collocated with other regional assets (e.g., NERACOOS buoys)
Drifters	Student-built, fishermen-deployed, satellite-tracked drifters track surface currents.	Entire northeast continental shelf with typically 30 units active at any one time
Vessel of opportunity (e.g. ferry) repeating a transect for extended durations	Repeats multidisciplinary measurements (including meteorology, water quality, currents) at high frequencies (multiple times daily) for extended durations (often on repeated transects), to address multiple theme areas.	7 critical transects spanning choke points in coastal and estuarine systems typically having heavy shipping, fishing, and boating activities
Autonomous Surface Craft (Future Vision)	Multidisciplinary measurements (including water quality, currents, & potentially meteorology) multiple times daily for extended durations, along a repeat transect with full water column coverage, to address multiple theme areas.	More information is needed

TABLE 2.3 REMOTE SENSING PLATFORMS SUMMARY TABLE

Platform name	**Description**	**Number**
High-frequency radar (HFR)	Land-based short- and long-range HF radar systems will provide extensive coverage of coastal surface current speed and direction.	10 long-range HF radar shore stations (does not include the Long Island Sound systems that have historically been funded by MARACOOS) 13 short-range HF radar shore stations
Satellite	Satellites used to provide synoptic coverage of ocean conditions as well as at locations not sampled by other means. Example information includes; sea-surface temperature, ocean-color products (chl-a, CDOM, non-algal particles, phytoplankton groups and physiology), synthetic-aperture radar (SAR), satellite altimeter (for volume transport), and winds.	As available
Aerial remote sensing and autonomous	Provide spatial information of surface and shallow habitat properties (e.g., areal coverage by	Future vision (no template at present)

aircraft (future vision)	submerged vegetation).	

FIXED PLATFORMS

Observing platform-fixed **Multipurpose buoy/mooring system: offshore and shelf moorings**	The multipurpose moorings will provide a platform capable of measuring a suite of real-time weather and ocean observations (physical, chemical and biological) that will meet the requirements of many theme areas. All multipurpose moorings will not necessarily have the full suite of sensors detailed below but will be capable of supporting them and will have the capacity to test new sensors. Moorings will cover a range of depths up to 300m; deeper moorings generally require increased instrumentation required.
Theme issues addressed	1.1, 1.2, 1.3, 1.4, 1.5, 2.1,2.2, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1
Variables observed and resolution (spatial, temporal, accuracy) requirements	10-60 min measurements and finer time intervals for selected parameters. Up to 10 minutes for hurricane. Wind (speed and direction): surface Air temperature: Barometric pressure: Irradiance(Heat Flux): surface and one other depth Visibility: Wave height, period, direction, and spectrum: 30-60 minutes (2m) Relative humidity; Water temperature: 1, 2, 20, and 50 m; every 50 m below, and 1-2 m above bottom [5 or 10 levels] Salinity: same as water temp Current speed and direction: surface and water column Bottom pressure Dissolved oxygen: same as water temp Nutrients (NO_3, PO_4, others as available): - 3 depths (surface, below pycnocline, near bottom) Optical sensors (chl a, CDOM, turbidity, irradiance)–same depth as nutrient sensors. No irradiance at bottom. Molecular analysis tool (e.g., ESP)- 5 m Biological acoustic sensors: (on both multi and single purpose buoys) Acoustic tag detectors: (currently don't telemeter real time-development need?) pCO_2: 1m and bottom *Possible additional sensors:* Wind (speed and direction profile: up to 80 m above sea level) for offshore wind energy development. AIS receivers Alkalinity Total Carbon pH *Future Vision:*

	phytoplankton (abundance, classification, distribution), zooplankton (abundance, classification, distribution) Video cameras (fish)
Sensors (and number)	For a mooring in 300 m : 2 met stations, 1 visibility sensor, 1 wave accelerometer system, 1 surface ACDP, 1 long-range ACDP, 9 CTDs with DO, 3 optical sensor packages, 3 nutrient sensor packages, 1 ESP sensor, bottom pressure.
Geographic cover / location and number of buoys: • Slope, • Shelf (includes outer-shelf, mid-shelf, inner shelf),	~15 buoys geographically spread throughout the region. [This is in addition to the ~9 NDBC buoys in the region that could be augmented with an enhanced sensor suite]
Operational requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital cost: ~ 400k / buoy (need 1.5 buoys per location) Operations and Maintenance: ~40 k/ yr / buoy FTEs: 1 FTE / year / buoy (sum of multiple types of personnel skill types) 2 primary service trips per year and 2 emergency service trips per year. Cost savings are gained with multiple buoys operated by the same work group.
Development needs	Development needs include improved communications systems to support two-way communications at high data rates, improved power supply to extend deployment time and support more sensors, nutrient systems need additional development for longer-term deployments (6 mo), sensor development and refinement for more complex sensors, integration of buoy systems, etc.

Observing platform-fixed **Near-shore/estuarine multipurpose buoys**	Designed to provide information on a number of issues but mainly focusing on port / harbor operations and water quality (hypoxia / nutrient enrichment and minimizing the impact from polluted waters).
Theme issues addressed	*1.1, 1.2, 1.3, 1.5, 2.1, 3.1, 3.3, 4.1 (Other issues may be addressed if sensor suite augmented)*
Variables observed and resolution (spatial, temporal, accuracy) requirements	6-60 min measurements and finer time intervals for selected parameters. Sample every 10 min required for hurricane. Wind (speed and direction): surface Air temperature: Barometric pressure: Irradiance(Heat Flux): surface and one other depth Visibility: Wave height, period, direction, and spectrum: 30-60 min (2m) Relative humidity; Water temperature: 1 m, mid depth and near bottom [3 levels max] Salinity: same as water temp Current speed and direction: surface and water column Bottom pressure Dissolved oxygen: same as water temp Nutrients (NO_3, PO_4, others as available): -2 depths (surface, near bottom) Optical sensors (chl a, CDOM, turbidity, irradiance)–same depth as nutrient sensors. No irradiance at bottom. Molecular analysis tool (e.g., ESP)- 5m Biological acoustic sensors: (on both multi- and single-purpose buoys) Acoustic tag detectors: (currently don't telemeter real time-development need?) pCO_2: 1m and bottom *Possible additional sensors:* Alkalinity Total Carbon pH *Future Vision:* phytoplankton (abundance, classification, distribution) zooplankton (abundance, classification, distribution) Video cameras (fish)
Sensors (and number)	1 surface met station (e.g., Weatherpak) 1 CTD per depth (e.g., SBE37) 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP with currents and waves & bottom pressure (e.g., NORTEK / RDI) Nutrient sensors (e.g. Satlantic SUNA, Wetlabs Cycle-PO4)

	Wetlabs ECO triplet (CDOM, chl a fluorescence, turbidity) Satlantic HperOCR for irradiance and radiance (SAMI for pCO_2?) Ocean acidification (pCO_2, alkalinity, etc) *Future Vision:* Imaging flow cytobot type instrument for phytoplankton Video plankton recorder for zooplankton
Geographic cover / location and number of buoys:	Nearshore estuaries of national/regional importance. ~15 buoys with a mixture of fixed and moveable locations [Note: there are ~27 estuaries in the region named in the National Water Quality Monitoring Network Design. Observational needs in these estuaries will be met with a mixture of moored and shore / pier based stations. Collaboration with NERRs and Estuaries Partnerships essential]
Operational Requirements	Capital Costs: $300k Operations and Maintenance: $35k FTEs: 0.75 FTE / buoy
Development needs	Same as multipurpose off-shore buoys

Observing platform-fixed **Shore/pier based systems**	A shore or pier based station will collect coastal meteorological and ocean data at key locations and especially in ports and harbors with significant maritime commerce and water quality issues.
Theme Issues Addressed	*1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 3.1, 3.3, 4.1*
Variables observed and resolution (spatial, temporal, accuracy) requirements	6-60 min observations: Not all stations will have the full suite (depends on location) Shore based station typically measure at one depth. Wind speed and direction: Surface Irradiance Barometric pressure: Air temperature: Visibility: Rainfall: Water level: Water temperature: Salinity: Current (speed and direction) Nutrients (NO_3 and PO_4) (Note- important for NERRs if increased frequency) Dissolved Optical sensors (chl a, CDOM, turbidity) Subsurface irradiance DO pH pCO2 Video cameras
Sensors (and number)	Sensors/station: met station, water level, CTD with DO, ACDP, pCO_2, nutrient
Geographic cover / location and number of buoys:	Coastal (nearshore, beaches, coastal) and Inland (estuaries, rivers) ~15 Stations throughout the region
Operational requirements	Capital Costs: ~$200k (1.25 systems per location) Operations and Maintenance: $30k / station FTEs: 0.5 FTE / station
Development needs	Nutrient sensors need further development. Further research into bio-fouling prevention necessary.

Observing platform-fixed **Water-level gauge: tides and water level**	Water level sensors are in addition to those deployed and maintained by federal agencies such as NOAA CO-OPS and USGS. Water-level gauges mainly provide coastal hazard information. [N.B.: Water level sensors with proper maintenance and calibration will be reference stations for NOAA's tide prediction products, and serve as controls in determining tidal datums for all short-term water-level stations.]
Theme issues addressed	*1.1, 1.3, 1.4, 1.5, 2.1,2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1*
Variables observed and resolution (spatial, temporal, accuracy) requirements	Water level (tides)
Sensors (and number)	Water level measuring system
Geographic cover / location and number of buoys	Inland and coastal 15 additional gauges including moveable ones.
Operational requirements	Capital cost: $50k Operations and Maintenance: $3k / year / gauge FTEs: 0.2 FTEs / year / gauge
Development needs	None

Observing platform-fixed **Coastal river gauge**	A coastal river gauge will monitor river flow as well as the water quality entering the marine system.
Theme Issues Addressed	*1.3, 1.5, 2.1, 2.2, 3.3, 3.4, 3.5, 4.1*
Variables observed and resolution (spatial, temporal, accuracy) requirements	Water surface elevation Discharge Water temperature Conductivity Nutrients
Sensors (and number)	Flow gauge Nutrient Temperature Conductivity
Geographic cover / location and number of buoys	Inland Maintain and augment the current USGS stream gauge system and restore to previous levels if present capacity less that needed.
Operational requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	These are operated and maintained by USGS but costs were not available at time of submitting report. Capital Costs: Operations and Maintenance: FTEs:
Development Needs	

Observing platform-fixed **Single purpose – Coastal Data Information Program (CDIP) wave buoy**	Single purpose buoy to measure wave characteristics at a given location. Data transmitted to and processed by CDIP at the Scripps Institution of Oceanography. This program has strong links to the Army Corps of Engineers.
Theme issues addressed	1.1, 1.2, 1.3, 1.4, 2.1,
Variables Observed and Resolution (Spatial, Temporal, Accuracy) Requirements	Waves (height, direction, period, spectrum) Water temperature
Sensors (and number)	CDIP buoy package
Geographic cover / location and number of buoys: • Slope, • Shelf (includes outer-shelf, mid-shelf, inner shelf), • Potentially coastal as well	Sufficient to meet national waves plan but exact number is unclear and depends on location of other multipurpose platforms. Currently 3 in the region (Block Island, Jeffreys Ledge, Halifax NS)
Operational requirements	Capital Cost: $70k Operations and Maintenance: $10k FTEs: 0.125 FTEs buoy
Development needs	None

Observing platform-fixed **Single purpose – molecular analysis buoy**	Currently molecular analysis sensors such as the Environmental Sample Processor (ESP) used for HAB detection require a dedicated platform due to power, telemetry, and stability requirements.
Theme issues addressed	3.3
Variables observed and resolution (spatial, temporal, accuracy) Requirements	Harmful Algal Bloom species abundance and potentially toxicity at a single depth. Sensors are configurable for a number of molecular analyses. Potential for meteorological and water column sensors.
Sensors (and number)	1 ESP and associated power, data and telemetry hardware.
Geographic cover / location and number of buoys: • Shelf (includes outer-shelf, mid-shelf, inner shelf), • Coastal (nearshore, beaches, coastal),	~ 6 in the region
Operational requirements	Capital costs: $200k / buoy and sensors Operations and Maintenance: $30k FTEs: 0.5 FTEs / buoy
Development needs	It is hoped that sensor development in the next 10 yr will allow the next generation or two of these sensors to be incorporated into multipurpose platforms.

Observing platform-fixed **Single purpose – passive acoustic / listening buoys**	Many marine species vocalize and passive acoustic systems can provide information on their locations (and behaviors). At the moment there is an array of 10 single purpose Right Whale listening buoys in the Boston shipping channel (funding from a Massachusetts Liquid Natural Gas (LNG) mitigation award.
Theme Issues Addressed	1.1
Variables observed and resolution (spatial, temporal, accuracy) Requirements	Presence / absence of Right Whales.
Sensors (and number)	Acoustic hydrophones with associated power, data, processing and telemetry equipment.
Geographic cover / location and number of buoys: • Shelf (includes outer-shelf, mid-shelf, inner shelf),	Currently 10 in region.
Operational requirements	These are maintained and operated by Cornell University and WHOI and funded through an LNG mitigation award. Costs were not available at time of submitting report. Capital costs: Operations and Maintenance: FTEs:
Development needs	Need to incorporate acoustic sensors on to multipurpose buoys.

Observing platform-fixed **Other: platforms of opportunity**	Examples would be offshore energy installations including wind and hydro-kinetic power and powered USCG ATON buoys. A simple, modular, plug and play sensor suite that would be deployed by divers and use power and communications provided by the installation. The exact configuration of the system would depend on the type of installation and other available information. Fixed gear, such as lobster traps also provide cost-effective platforms to sample the marine environment greatly expanding spatial and temporal resolution of key parameters by working with the fishing industry. For example the Environmental Monitoring On Lobster Traps (eMOLT) program uses simple sensors to monitor bottom depth and currents.
Theme issues addressed	*1.1, 1.2, 1.3, 1.4, 2.1, 3.1, 4.1 (Other issues may be addressed if sensor suite augmented)*
Variables observed and resolution (spatial, temporal, accuracy) requirements	**Larger more complex system (offshore energy)** Hourly measurements, possibility of multiple depths, spatial resolution dependent on installation locations. Water temperature Conductivity (salinity) Pressure (depth) Bottom pressure Dissolved oxygen Depth resolved currents (speed, direction) Surface waves (height, period, direction) *Other sensors are possible including* Optical sensors (chl a, CDOM, turbidity) Ocean acidification Acoustics for fish tags HABs Cameras Etc. **Simpler more portable system (e.g., eMOLT)** 1 temperatures sensor 1 tilt current meter 1 camera
Sensors (and number)	**Larger more complex system (offshore energy)** 1 CTD per depth (e.g., SBE37) 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP with currents and waves (e.g. NORTEK / RDI) **Simpler more portable system (e.g., EMOLT)** EMOLT sensor package
Geographic cover / location and number of buoys:	**Larger more complex system (offshore energy)** Coastal and shelf depending.

• Shelf (includes outer-shelf, mid-shelf, inner shelf), • Coastal (nearshore, beaches, coastal), • Inland (estuaries, rivers)	Spatial resolution dependent on installation locations. Estimate of 5 installations with 2 systems per installation (one active, one for redeployment) **Simpler more portable system (e.g., eMOLT)** ~50 required in region Geographic coverage of fishing industry
Operational requirements • Deployment / operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of ftes) • Replacement needs (spare parts, redundant systems) • Other	**Larger more complex system (offshore energy)** Capital costs: ~$100k / unit (1.5 units required per installation) Operations and maintenance: ~$20k / unit FTEs: 0.25 FTEs / unit **Simpler more portable system (e.g. EMOLT)** Capital costs: ~$1k / unit Operations and Maintenance: ~$0.5K/unit/year FTEs: ~0.02 FTEs / unit/ year
Development Needs	**Larger more complex system (offshore energy)** Standardized system needs to be developed with the industry to facilitate easy deployment. Until then costs remain an estimate. **Simpler more portable system (e.g., eMOLT)** Need for fast transmittal of observations to data aggregation center. Real-time transmittal potential with sensors transmitting wirelessly once recovered to deck. Also need for enhanced power source on existing fixed-gear camera systems.

Observing platform-fixed **Profiling moorings (future vision)**	Used to provide highly depth resolved information at key sentinel locations. May be deployed in standalone mode (with telemetry when profiler at surface or with dedicated surface expression) or with offshore installation (e.g., MVCO/Energy site providing power and communications). They may be used to replace some of the multipurpose buoys described above, providing greater depth resolution and a potential cost saving on sensor hardware (only one set of sensors required for whole water column compared to one set per depth measured for traditional mooring). Currently seen as a future vision because profiling systems are not robust / developed enough for sustained operations.
Theme issues addressed	*1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 3.1, 3.3, 4.1 (Other issues may be addressed if sensor suite augmented)*
Variables observed and resolution (spatial, temporal, accuracy) requirements	30 min to hourly measurements, 1 m depth resolution where possible. Water temperature Conductivity (salinity) Pressure (depth) Dissolved oxygen Depth resolved currents (speed, direction) Surface waves (height, period, direction) Nutrients (NO_3, PO_4) Optical sensors (chl a, CDOM, turbidity) *Other sensors are possible including* Downwelling irradiance and upwelling radiance Ocean acidification Acoustics for fish tags Acoustics for cetaceans HABs Cameras (if sufficient band width) Etc. *Future vision* phytoplankton (abundance, classification, distribution) zooplankton (abundance, classification, distribution)
Sensors (and number)	1 CTD (e.g SBE37) 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP with currents and waves & bottom pressure (e.g., NORTEK / RDI) Nutrient sensors (e.g. Satlantic SUNA, Wetlabs Cycle-PO4) Wetlabs ECO triplet (CDOM, chl-a fluorescence, turbidity) (Satlantic HperOCR for irradiance and radiance) (SAMI for pCO_2?) *Future Vision*

	Imaging flow cytobot analog for phytoplankton Video plankton recorder for zooplankton
Geographic cover / location and number of buoys:	Coastal and shelf depending on depth. Smaller scale system may be applicable for estuaries.
Operational Requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital costs: $100-150k Seahorse ($70-100k) Wetlabs is ~$100k Operations and maintenance: Unclear FTEs: .025 FTE per unit for fieldwork, 0.25 FTE per year for DMAC
Development Needs	Profiling system and certain sensors need further refinement/ development. Autonomous vertically profiling plankton recorder (AVPPO) is an example system. Phytoplankton sensor needs further development and miniaturization.

MOBILE PLATFORMS

Mobile Platform:	Coastal gliders	AUV
Mobile: Gliders and autonomous underwater vehicles	Coastal gliders will help characterize the vertical and horizontal structure of the water column providing important observations to support many theme areas. Routine transects will help provide information on external forcing such as volume transport. This is particularly important at the region's northern boundary with the majority of the freshwater being delivered across the Scotian Shelf. Internal surveys are important for data assimilation into models.	Less time underwater than gliders due to power used for propulsion. Power propulsion allows access to more-high energy / complex environments that gliders cannot access. Also allows more complex flight patterns possible including surveys at a single depth (e.g., under salmon net pens).
Theme issues addressed	*1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 3.1, 3.3, 4.1 (Other issues may be addressed if sensor suite augmented)*	
Variables observed and resolution	Water temperature: Salinity: Dissolved oxygen Optics (chl a, CDOM, turbidity) Current (speed, direction, profile)	Same as gliders but also sidescan sonar for bathymetry mapping.
Sensors (and number)	Sensors/glider 1 CTD 1 Optical package 1 DO sensor 1 ACDP (note: shortens battery life)	Same as gliders but also sidescan sonar for bathymetry mapping.
Geographic cover / location and number:	7 needed to provide routine surveys at northern boundary as well as conditions within the region. Area sampled is limited by topography (depth). Shelf and slope.	2. Need a little vague.
Operational Requirements	NERACOOS has little experience in operating gliders and costs were not available at time of submitting report. However, MARACOOS has much experience and their costs would probably be reasonable. Capital Costs: Operations and Maintenance: FTEs:	
Development Needs	Not sure	Not sure

Mobile platform: **Ships (research and fishing)**	Ships can be used to provide information that cannot easily be obtained through autonomous systems. Combination of research ships and fishing vessels depending on level of support and required facilities. Key fixed sentinel stations with biogeochemical, pelagic and benthic habitat components. Partly based on the Canadian Atlantic Zone Monitoring Program (AZMP) with common protocols where possible.
Theme Issues Addressed	*2.1, 2.2, 3.1, 3.3, (Other issues may be addressed if sensor suite augmented)*
Variables observed and resolution (spatial, temporal, accuracy) requirements	Varying depth resolution depending on measurement. Mixture of electronic profiling sensors incorporated, net and discrete water samples. 1 m depth resolution where possible. *Pelagic core variables* Water temperature Conductivity (salinity) Pressure (depth) Dissolved oxygen Depth resolved currents (speed, direction) Surface waves (height, period, direction) Nutrients (NO_3, PO_4: surface and deep Chlorophyll a Phytoplankton (abundance, diversity, distribution) zooplankton (abundance, diversity, distribution) Optical sensors (chl-a, CDOM, turbidity) *Other sensors are possible including* Downwelling irradiance and upwelling radiance Ocean acidification and carbonate parameters (pCO_2)- sensor needed in LIS on “the bold” (?) Acoustics for fish tags Particulate organic carbon concentration HABs Cameras (if sufficient band width) Etc. *Benthic* Benthos (abundance, diversity, distribution) *Other Biogeochemical* pCO2 in air micro structure and shear
Sensors (and number)	1 CTD per depth (e.g., SBE37) 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP with currents and waves & bottom pressure (e.g., NORTEK / RDI)

	Nutrient sensors (e.g., Satlantic SUNA, Wetlabs Cycle-PO4) Wetlabs ECO triplet (CDOM, chl a fluorescence, turbidity) (Satlantic HperOCR for irradiance and radiance) $pC0_2$ sensor Bongo and vertical ring plankton nets Benthic sampling sled such as that developed for the Northeast Benthic Observatory. micro structure and shear sensor. Imaging flow cytobot type instrument for phytoplankton Video plankton recorder for zooplankton
Geographic cover:	8 stations in the region: Sentinel sites that could be sampled over the long-term, including estuarine, nearshore, and shelf locations, ideally collocated with other regional assets (e.g., NERACOOS buoys)
Operational requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital Cost: (per station): $25k for CTD and zooplankton and phytoplankton collection. Other capital costs dependent upon which sensors are added on to basic sampling design. Operations and Maintenance: (per station) Annual maintenance supply cost per station: $2.0k Annual ship time costs per station: $12k-30k, depending on vessel FTEs: (per station): 0.25 for CTD, chlorophyll and zooplankton collection and analysis. 1K for nutrient analysis; more for other sensor data; dependent on which sensors are added. Note: Centralized analysis facilities for analysis type (e.g., zooplankton, nutrients etc).
Development needs	No development needs for collection and analysis of core variables. Development needs for additional sensors dependent on sensor.

Mobile platform: **Drifters**	Student-built, fishermen-deployed, satellite-tracked drifters tracking surface currents
Theme issues addressed	Addresses components of 1.2,1.4, 2.1, and 3.3
Variables observed and resolution (spatial, temporal, accuracy) requirements	Surface currents: Combination of surface (1m) and drogued (15m) drifters deployed monthly from six locations in the coastal current ranging from Nova Scotia to Southern New England reporting hourly fixes
Sensors (and number)	150 units are built annually by local students. The $500 kit/unit materials includes a AXONN TrackPack GPS transmitter and other hardware. Students deliver the assembled units to local fishermen who deploy them at fixed locations in their routine fishing grounds. The description of the drifter is linked from http://www.nefsc.noaa.gov/drifter/. Satellite cost $0.15/fix
Geographic cover / location and number of buoys:	Entire northeast continental shelf with 150 deployments a year typically resulting in 30 units active at any one time.
Operational requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital costs: (per drifter) $0.5k / unit for parts Operations and maintenance: $0.4k /unit/year for new or refurbished drifter parts, $0.2k/unit/year for GLOBALSTAR satellite-transmission cost (~2mths) FTEs: 1 FTE (0.01 FTE /unit/year) data processor/field technician
Development Needs	Additional time to support the advanced research products would be useful. Potential to add sensors such as passive acoustic receivers, temperature, etc.

Mobile platform: **Vessel of opportunity (e.g. ferry) repeating a transect for extended durations**	Collects multidisciplinary measurements (including meteorological, water quality, currents) at high frequencies (multiple times daily) for extended durations, to address multiple theme areas. Data products useful for, e.g., real-time dissemination, model calibration and assimilative input, baseline climate characterization and climate change trend identification.
Theme issues addressed	*1.1, 1.2, 1.3, 1.5, 2.1, 2.2, 3.1, 3.3, 3.4, 3.5*
Variables observed and resolution	*Surface measurements (meteorological):* Air temperature Barometric pressure Wind (speed, gusts, direction) Incident irradiance (hyperspectral and PAR) Heat flux humidity Downwelling irradiance and upwelling radiance *(additional sensors possible)* *Near-surface water properties measurements:* Water temperature Conductivity (Salinity) Dissolved oxygen Nutrients (NO_3, PO_4, etc.) Optical sensors (chl a, CDOM, turbidity) *(additional sensors possible)* *Vertical profile measurements:* Depth resolved currents (speed, direction) Acoustic backscatter <u>Spatial coverage horizontally</u> – shore to shore between coastal ports-- usually spanning a water body through which important transport of water and materials occurs, for example a constriction near the mouth of an estuary. <u>Spatial resolution horizontally</u> – can be finer but usually averaged to about 1 km. <u>Spatial coverage vertically</u> – near-surface measurement of water quality and meteorological, full water column profile measurement of currents. <u>Spatial resolution vertically (currents & backscatter)</u> - from a few cm to a few m, depending on the water depth. <u>Temporal coverage</u> – Typically year-round for multiple years, or essentially indefinitely.

	<u>Temporal resolution</u> – Typically between twice a day and 16 times a day; long duration sampling enables effective separation of tidal and non-tidal components of variability.
Sensors (and number)	1 surface meteorological package 1 CTD 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP Nutrient sensors (e.g., Satlantic SUNA, Wetlabs Cycle-PO4) Wetlabs ECO triplet (CDOM, chl a fluorescence, turbidity) Satlantic HperOCR for irradiance and radiance
Geographic cover / Location and number of buoys:	7 Critical transects spanning choke points in coastal and estuarine systems typically having heavy shipping, fishing, and boating activities.
Operational Requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital Costs (per unit): Full sensor system \$50k per unit; initial installation \$25k per unit. There is one deployment, scheduled for a planned drydocking of the vessel that requires coordination among ferry operator, machine shop, marine architect, shipyard, and Coast Guard. Operations and Maintenance: \$10k /unit/year (calibrations, repairs) FTEs: 0.2 FTE /unit maintenance, 0.2 FTE DMAC
Development Needs	Additional sensor development, e.g., optical phyto/zooplankton species identification. Additional data product development, e.g., creating tidal currents and non-tidal currents data products, and providing them in near real-time.

Observing platform-mobile **Autonomous surface craft** **Future vision**	Multidisciplinary measurements (including water quality, currents, & potentially meteorological) multiple times daily for extended durations, along a repeat transect with full water column coverage, to address multiple theme areas. Emphasis on measurement of water and material transport and how it is distributed vertically/horizontally in the transect plane. Data products useful for, e.g., real-time dissemination, model calibration and assimilative input, baseline climate characterization and climate change trend identification. ASCs are similar to gliders in their capacity for sustained long-duration observations at relatively low cost. When equipped with ADCP and winching system, they can collect essentially the same suite of measurements the gliders gather. However, ASCs carry certain important advantages over gliders, particularly in shallow coastal areas with strong currents and heavy vessel traffic. Compared to gliders, ASCs are capable of higher speeds, better able to stay on a transect in the face of strong currents; can provide more power to sensors; and can mitigate collision risks better, due to their sustained surface presence enabling radar and AIS.
Theme issues addressed	*1.1, 1.2, 1.3, 1.5, 2.1, 2.2, 3.1, 3.3, 3.4, 3.5*
Variables observed and resolution	*Surface measurements (Meteorological):* Air temperature Barometric pressure Wind (speed, gusts, direction) Incident irradiance (hyperspectral and PAR) Heat flux humidity Downwelling irradiance and upwelling radiance *(additional sensors possible)* *Vertical profile measurements:* Water temperature Conductivity (Salinity) Dissolved oxygen Nutrients (NO_3, PO_4, etc.) Optical sensors (chlaa, CDOM, turbidity) Depth resolved currents (speed, direction) Acoustic backscatter *(additional sensors possible)* <u>Spatial coverage horizontally</u> – Typically a 10-20 km transect arbitrarily specified in a coastal or estuarine area-- for example across-shelf line, arc enclosing an estuarine outflow, or along/across-estuary transect.

	Spatial resolution horizontally – can be finer but usually averaged to about 1 km. Spatial coverage vertically – near-surface measurement of meteorological; full water column profile measurement of water properties and currents. Spatial resolution vertically - from a few cm to a few m, depending on the water depth. Temporal coverage – Year-round. Temporal resolution – Completes a 10-20 km repeat transect four times daily; long duration sampling enables effective separation of tidal and non-tidal components of variability.
Sensors (and number)	1 surface meteo package 1 CTD & winching system 1 DO sensor (e.g., Anderra / Seabird) 1 ADCP Nutrient sensors (e.g. Satlantic SUNA, Wetlabs Cycle-PO4) Wetlabs ECO triplet (CDOM, chl-a fluorescence, turbidity) Satlantic HperOCR for irradiance and radiance
Geographic cover / location and number of buoys:	Transects selected for importance of water and material transports. Each transect about 10-20 km long with 10-20 virtual stations at which the sensor package will be winched through the water column.
Operational requirements	Capital Costs: $250k (per prototype) Operations and Maintenance: $40k /unit/year (repairs, batteries, calibrations) FTEs: 0.5 for fieldwork, 0.25 DMAC
Development needs	The key needed improvements to ASC capabilities, which are underway, include their seaworthiness in high sea states, and the durations of their unattended operations. One-month duration in coastal ocean conditions are feasible in the next few years, and frameworks for their use are under development by the Coast Guard.

REMOTE SENSING

OBSERVING - Remote Sensing High Frequency Radar (HFR)	Land based short and long range HF Radar systems will provide extensive coverage of coastal surface current speed and direction.
Theme Issues Addressed	1.1, 1.2, 1.3, 1.4. 1.5, 2.1, 2.2, 3.1, 3.2, 3.3,3.4.3.5, 4.1
Variables Observed and Resolution Requirements	Surface Currents : Hourly vector maps at 2 km spatial resolution in selected bays and estimated 6 km resolution offshore with uncertainty
Sensors (and number)	10 Long range HF Radar shore stations (does not include the Long Island Sound systems which have historically been funded by MARACOOS) 13 short range HF Radar shore stations www.codar.com
Geographic cover / Location and number of buoys	Coastal and Shelf Portable systems may be useful for rapid response.
Operational Requirements • Deployment / Operations • Maintenance • Personnel • Replacement needs • Other	Costs were not available at time of submitting report. MARACOOS costs for HFR may be reasonable. Capital costs : (per unit) Operations and Maintenance: (per unit) FTEs: (per unit)
Development Needs	1. Need to develop redundant power and communications systems to support transition to operational system. 2. Need to improve accuracy of current estimates using new CODAR processing software as shown by A.Kimirk (?) (WHOI). 3. Then implement this into regional center of CODAR data assimilation via NERACOOS server. 4. Study of value of portable systems for rapid response to events such as spills. Understand errors in the actual data

Remote Sensing - Satellite	Satellites used to provide synoptic coverage of ocean conditions as well as at locations not sampled by other means. Examples information includes; sea surface temperature, ocean color products (chl a, CDOM, non-algal particles, phytoplankton groups and physiology), synthetic aperture radar (SAR), satellite altimeter (for volume transport), and winds.
Theme issues addressed	*1.1, 1.3, 2.1, 2.2, 2.3, 3.1, 3.3 (Other issues may be addressed if product suite augmented)*
Variables observed and resolution (spatial, temporal, accuracy) requirements	Sea surface temperature (short and long range radiation) Ocean color products (chl-a, CDOM, non-algal particles, phytoplankton groups and physiology) Surface slicks (SAR) Sea surface height (satellite altimeter)
Sensors (and number)	Current: MODIS, MERIS, AVHRR, etc. GEOS-E Scaterometry for winds Future:
Geographic cover:	Entire region
Operational requirements • Deployment / Operations (boats, etc) • Maintenance (# of service trips/year) • Personnel (# of FTEs) • Replacement needs (spare parts, redundant systems) • Other	Capital Costs: Operations and Maintenance: ~10k /year FTEs: 1.5 FTE
Development Needs	

MODELING & ANALYSIS SUBSYSTEM

INTRODUCTION

The NERACOOS Modeling and Analysis subsystem is based on the Northeast Coastal Ocean Forecast System (NECOFS), a coupled atmospheric, wave and ocean circulation model. Various other models are or are anticipated being nested with NECOFS including higher resolution models, such as one for Massachusetts Bay, Inundation Forecast Systems, water quality, and ecosystem models. Model outputs are available through interoperable web-based services such as the Thematic Realtime Environmental Distributed Data Services (THREDDS). With this, further specialized models, such as physical-biological models, are able to be initiated. A hydrological watershed model provides important input information for estuaries and nearshore waters.

To provide a more robust modeling infrastructure modeling efforts may be transitioned to federal agencies. However, NERACOOS will maintain a more rapidly adaptable and flexible modeling capacity that is closely tied to state-of-the-art modeling efforts.

The observing subsystem is closely tied to the modeling and analysis subsystem – the two providing an information system for the region. Observations are assimilated into models, filling gaps between observations with nowcasts as well as providing future conditions with forecasts. Models can inform observational strategies such that model uncertainties are minimized. Hindcasts which assimilate historical observations allow past events and trends to be studied and assessed. They also provide a range of conditions that might be expected and allow for simulation of extreme events such as hurricanes and nor'easters with changed settings such as a rise in sea level

Note: The Short Term Predication System (STPS) that uses a statistical model to forecast surface currents from HFR measurements was not included in the NERACOOS modeling and analysis section as this is implemented at a national scale and is not regional.

MODEL REQUIREMENTS

NECOFS

Model Name	Northeast Coastal Ocean Forecast System (NECOFS)
Type of Model (see above – e.g. circulation model)	Coupled Dynamical atmospheric (WRF) – surface wave (SWAVE) – ocean circulation (FVCOM 3.5+) model system
Geographic Domain (entire region, specific harbor, etc)	Entire NERACOOS domain (New England Shelf/Georges Bank/Gulf of Maine/Scotian Shelf)
Themes/Issues Addressed	all
Important Variables to be modeled (see terms	Surface weather: wind, air temp, RH, barometric pressure, icing potential

and definitions**)**	Surface forcing: wind stress, heat flux, moisture flux (E-P) Surface wave state: significant wave height, dominant period, directional wave spectrum, bottom stress Ocean state: surface temperature, elevation, 3-D currents, temp, salinity, tracers, wave-current interaction, bottom stress
Spatial (horizontal and vertical requirements)	Horizontal: Regional: 1.0-15 km; Coastal: 0.1-1.0 km, estuaries, inlets, harbors: 10 m to 0.5 km Vertical: 40 layers, hybrid coordinate: in the regional deeper than 80 m, a s-coordinate with 10 uniform thickness layers from the surface and above the bottom, respectively. In the regional shallower than or equal to 80 m, a sigma-coordinate is used, where the maximum layer thickness is 2 m or less.
Temporal	Hourly output for most applications, higher frequency output available
Computing infrastructure, including redundancy of operations	A linux cluster: uses 24 nodes (each node includes 8 processors) for operation of all components of NECOFS. Note: this does not include remote infrastructure system, which is described in Note 1 below.
Personnel (FTEs/year)	The system is operated automatically. A full time research associate effort to maintain and upgrade the system.
Expected Initial and Boundary conditions	NECP North American Weather Forecast; NCEP North Atlantic wave forecast (WWIII); UMassD Global Ocean forecast; Coastal freshwater input (USGS, UNH, NOAA) Data for forecast assessment and hindcast/update. See Table 1: NECOFS Forecast Assessment/Update Data (below).
Development Needs	1. Add localized FVCOM inundation forecast systems as requested 2. Develop FVCOM wind-driven overtopping module (with ACE) 3. Help transition NECOFS elements to NOAA NOS CO-OPS for operational forecast use 4. Improve coastal freshwater input source term and forecast used in NECOFS (UNH) 5. Work with NWS Advanced Hydraulic Prediction Service to use NECOFS to improve coastal river flood forecasting. (pilot project -

	Connecticut River) 6. Nest with global ocean model: Global-FVCOM and Global HYCOM 7. Improve the data assimilation efficiency. 8. Develop a two-way nesting for multi-scale domains and ocean-atmospheric models.

Note 1: Backup Infrastructure and Development Needs

NECOFS is presently run on Chen's Linux cluster located in the UMASSD SMAST facility. This facility is located on the southern end of New Bedford outside on the New Bedford Hurricane Barrier. Because of the exposed SMAST location (ground floor elevation ~ 11 ft above MSL), the UMASSD administration policy is to shut power off and evacuate the SMAST facility in advance of extreme weather events that could cause flooding. This occurred on Friday August 26 before Hurricane/Tropical Storm Irene. As a result, NECOFS was shut down, and the 3-day forecasts of surface atmosphere/wave/currents/elevation and potential inundation conditions stopped. NECOFS forecast data are also used in the NWS/IOOS "splash-over" forecast tool for Saco, Portland, and Scituate, so this information was lost.

It is clear that NECOFS needs a hurricane/power outage proof facility for backup operations so that it can function 24/7 in all conditions. Here are some initial ideas about potential facilities:

1. SMAST AT&T Building (200 Mill Road, Fairhaven, MA) may have suitable space and power for a Linux cluster, plus high-speed internet connections. It is located behind the Hurricane Barrier and away from the water, with ground floor elevation ~ 37 ft above MSL.

2. Massachusetts Green High-Performance Computing Center (MGHPCC) is presently being built at UMASS-Amherst (Holyoke, MA) by a consortium between UMASS, MIT, HARVARD, Boston University, and Northeastern University. MGHPCC web site is http://www.mghpcc.org/. Rich Signell contacted Chris Hill (EAPS, MIT), a co-chair of the research committee, who wrote:

"The 2011 MGHPCC Seed Fund RFP is soliciting research proposals for computer and computational science. Pre-proposals are due October 1st, 2011. A total of $500K is available with anticipated award sizes in the range of $50K – $150K. Proposals must involve investigators from two or more of Boston University, Harvard University, the Massachusetts Institute of Technology, Northeastern University and the University of Massachusetts system."

3. NOS: CO-OPS presently is using FVCOM 3.5 as part of its Northern Gulf of Mexico shelf forecast system. The system is in development and being setup to run on the new NCEP IBM system. This suggests that it would relatively straight forward to run NECOFS on the CO-OPS facility.

Hurricane Irene also highlighted a major shortcoming with NECOFS. The surface weather/forcing used in NECOFS is produced using our regional WRF mesoscale model. WRF is unable to simulate directly the very intense hurricane/tropical storm systems. Instead, a hurricane wind model must be used (embedded in a regional WRF system) to produce the surface forcing during a hurricane/tropical storm event. Chen in collaboration with Kerry Emanuel (MIT) has hindcast Hurricane Bob using such a blended forcing with excellent results. What is needed now is to set up NECOFS system to automatically switch to embed the NHC (or similar) hurricane model forecast fields into the regional WRF forecast fields to drive NECOFS during such events.

Assuming that the NHC (or similar) hurricane forecast fields could be obtained online in real-time, both SMAST AT&T facility and the MGHPCC could be considered for setting up a backup facility for NECOFS. One possibility is to submit a proposal to MGHPCC to 1) setup NECOFS for remote 24/7 operation, 2) improve assimilation efficiency, 3) reduce time for forecast cycle from 24 hr to 12 hr (or even 8 hr), 4) develop and implement adding hurricane model output into operational status, and 5) provide additional computing power as more inundation forecast systems are developed. The investigators could include C. Chen (UMASSD), K. Emanuel (MIT) for the hurricane component, and perhaps someone who could focus on the data assimilation problem.

Table 1: NECOFS Forecast Assessment/Update Data

Variables	Data sources	Time scale	Approach
Wind speed and direction	*NOAA buoys*	*Hourly*	*Daily when the online data available*
Air pressure	*NOAA Buoys*	*Hourly*	*Same above*
Significant wave height and peak period	*NOAA Buoys*	*Hourly*	*Same above.*
Wave spectra	*NOAA Buoys*	*Hourly*	*Same above*
Sea level	*Tidal gauges*	*Hourly*	*Same above*
Water currents	*NERACOOS buoys*	*Hourly*	*Same above*
Water temperature and salinity	*NERACOOS buoys*	*Hourly*	*Same above*
DO	*NERACOOS sites and other surveys*	*Monthly*	*Monthly*
Nutrients	*NERACOOS sites and other surveys*	*Monthly*	*Monthly*

FVCOM Inundation Forecast System

Model Name	FVCOM Inundation Forecast System (IFS)
Type of Model	Coupled dynamical atmospheric (WRF) – surface wave (SWAVE) – ocean circulation (FVCOM 3.5+) model system
Geographic Domain	Scituate (MA), Saco (ME), rest of region to be added as requested, and all CT with UCONN Model
Themes/Issues Addressed	4.1
Important Variables to be modeled	Surface weather: wind Surface forcing: wind stress, moisture flux (E-P) Surface wave state: significant wave height, dominant period,

	directional wave spectrum, bottom stress Ocean state: elevation, 3-D currents, wave-current interaction, bottom stress Coastal flooding: water flow onto (otherwise) dry land and over coastal structures and subsequent draining
Spatial (horizontal and vertical requirements)	Horizontal: minimum ~ few m's Vertical: minimum < 1 m
Temporal	Hourly output for most applications, higher frequency output available
Computing infrastructure, including redundancy of operations	A Linux cluster: 10 nodes (with 8 processors per node) are required for each region. (See Note 1)
Personnel (FTEs/year)	3 months/year
Expected Initial and Boundary conditions	Local FVCOM IFS driven by nesting with NECOFS
Development Needs	1. Add localized FVCOM inundation forecast systems as requested 2. Develop FVCOM wind-driven overtopping module (with ACE) 3. Help transition FVCOM IFSs to NOAA NOS CO-OPS for operational forecast use

NECOFS-Ecosystem

Model Name	NECOFS-Ecosystem
Type of Model	Ecosystem/water quality model system (system structure and parameters can be easily changed for different applications)
Geographic Domain	Mass coastal waters operational; other sections of NERACOOS domain added as requested
Themes/Issues Addressed	3
Important Variables to be modeled (see terms and definitions**)**	Nutrient concentrations, phytoplankton and zooplankton concentrations, dissolved oxygen,
Spatial (horizontal	Can be adjusted to meet application

and vertical requirements)	
Temporal	Hourly output for most applications, higher frequency output available
Computing infrastructure, including redundancy of operations	A Linux cluster. It should be driven offline using NECOFS output. It requires the same nodes (24) used for NECOFS for operation.
Personnel (FTEs/year)	Share with the time for NECOFS operation: 6 months/year.
Expected Initial and Boundary conditions	All boundary conditions supplied by NECOFS or higher resolution subdomains of NECOFS (e.g. Mass coastal waters).
Development Needs	1. Identification and specification of applications 2. Boundary inputs of nutrients (e.g., output of GM-WICS) 3. Validation for a long-term simulation

UNH Gulf of Maine Watershed Information and Characterization System (GM-WICS)

Model Name	UNH Gulf of Maine Watershed Information and Characterization System (GM-WICS)
Type of Model	Hydrological: Watershed freshwater and nutrient forecast model system
Geographic Domain	Gulf of Maine watershed (Nantucket Sound – western end of Nova Scotia)
Themes/Issues Addressed	1,2,3
Important Variables to be modeled	River and groundwater flux of freshwater and nutrients into coastal ocean.
Spatial (horizontal and vertical requirements)	On Land: 6 minute (~ 1 n mile)
Temporal	Daily precipitation, temperature, and downwelling radiation;
Computing infrastructure, including redundancy of operations	

Personnel (FTEs/year)	~0.5, plus initial model calibration and validation efforts
Expected Initial and Boundary conditions	Various NOAA products
Development Needs	Community validation is needed.

Bedford Institute of Oceanography Wave Watch IIIModel Name	Wave Watch III version 3.14
Type of Model	Wave forecast
Geographic Domain	Three nested grids – North Atlantic, East Coast and Gulf of Maine
Themes/Issues Addressed	1.1, 1.2, 1.3, 1.4, 1.5. 1.6, 2.1, 3.1, 3.3, 3.5, 4.1, 5.1
Important Variables to be modeled	Significant wave height, peak and mean wave period, peak and mean wave direction, peak wind-sea period and direction and water-level
Spatial (horizontal and vertical requirements)	.1 degree finest grid, 0.2 degree intermediate grid and 1.0 degree coarse grid
Temporal	Hourly outputs for most applications
Computing infrastructure, including redundancy of operations	linux cluster, 16 processors ideal
Personnel (FTEs/year)	1.25 FTE
Expected Initial and Boundary conditions	Primary input bottom depth and wind components (COAMPS) we can also include input water level (tide and storm surge), and currents.
Development Needs	Water level input (tide and storm surge), currents and accurate elevation / water depth allowing flooding and drying.

Synthesis Table for Cost Estimation

Model	Modeling	Variables	Computing	*Geographic	Associated	FTE

Name	Subsystems	Modeled	Resources	Cover/Locat ion	Theme/Issue(s)	
NECOFS	*Coupled atmos-wave-circulation models*	*Surface weather, forcing, wave and ocean states*	*Linux cluster, 24 nodes (8 processors per node)* *(See Note 1)*	*Regionwide*	*1,2,3,4*	*1*
FVCOM Inundati on System	*Coupled atmos-wave-circulation models*	*Surface forcing, wave and ocean states, and coastal inundation*	*Linux cluster: 10 nodes (with 8 processors per node) are required for each region. (See Note 1)*	*1. Scituate (MA)* *2. Saco (ME)* *3. Rest of region* *4. CT already covered*	*4,1*	*.25*
NECOFS-Ecosyste m	*Ecosystem / water quality model system*	*DO, nutrient, phyto- and plankton concentrations*	*Same as NECOFS: Linux cluster, 24 nodes (8 processors per node)* *(See Note 1)*	*Regionwide*	*All four*	*0.5*
JCOOT Hydrolog y *FRAMES (constitu ent flux, temp)*	*Discharge, Nutrients, DOC, Temp*	*Discharge, Nutrients, DOC, Temp*	*Modest*	*Regionwide*	*All four*	*2 for first year, then 1/yr*
BIO Wave Watch III	*Coupled atmos-wave*	*Surface weather forcing, wave and ocean states*	*Linux cluster, 16 processors*	*Gulf of Maine* *East Coast* *North Atlantic*	*All four*	*1.25*

DMAC SUBSYSTEM

INTRODUCTION

A secure, robust and cost effective Data Management and Communications (DMAC) system is required to effectively integrate, manage and distribute regional observations, nowcasts and forecasts. The DMAC system will also support the development of regional products and services developed to meet targeted end user needs. NERACOOS will adapt and develop its existing DMAC capacity to meet the emerging IOOS DMAC standards and recommendations and ultimately provide a regional capacity for data integration, management and distribution.

NERACOOS makes regional ocean information from observations and models available in a variety of ways. Robust metadata is Interoperable web-based services allow for machine to machine communications. Portals facilitate human access to real time and historical information. Examples include portals for; real-time sea surface state observations for mariners, historical climate and ecosystem information for managers, and geospatial information supporting Coastal and Marine Spatial Planning (CMSP). Partnerships are important for regional information stewardship and accessibility. Important regional partners include the Northeast Coastal Ocean Data Partnership (NeCODP) and the Northeast Ocean Data Portal Working Group for CMSP.

OPERATIONAL REQUIREMENTS

General description of DMAC Operations to be compliant with IOOS Standards **(**as described in Whitepaper and includes discovery, QA/QC, archives)	NERACOOS is comprised of several sub-regional observing systems of fixed ocean platforms and modeling groups. Each provides Data Management And Communication services and products locally. NERACOOS also maintains a region-wide Data Aggregation Center (DAC) with region wide services and products. The regional DAC will eventually provide access to all NERACOOS observation and model products as well as integrate other federal and state observations and forecasts and provide a comprehensive regional ocean data portal. IOOS compliant web services, Sensor Observation Service, THREDDS Data Server (TDS), Web Mapping Service (WMS), and Web Coverage Service (WCS) exist at the regional and many of the sub-regional systems. We envision all of the sub-regional systems along with the DAC maintaining IOOS compliant web services for access to observation and model outputs. These web services provide a pathway to the production of robust access and discovery metadata via the SensorML and ISO 19139 standards and eventually to emerging QA/QC process chain descriptions as outlined by QARTOD. As well they will enable archiving at the NODC. The NODC has established guidelines and developed NetCDF CDM compliance templates and advocates TDS to automate the archiving of observation and model outputs. Given that the IOOS DMAC guidelines are a work in progress the establishment of these web services require on-going software maintenance and updates. The SOS standard is also undergoing significant changes by the IOOS and will require updates. Establishment

	of web services at all the sub-regional levels would ensure the ability to establish a robust regional DAC providing a gateway to the national and global IOOS efforts.
Regional Data Management Enhancements	NERACOOS through it's partnership with the Northeast Coastal and Ocean Data Partnership (NeCODP) has begun work on developing region wide conventions for ISO Metadata to enable Dataset Discovery. This work should be continued and further workshops need to be developed to spread tools to the region. XML encoding designed to leverage JSON and AJAX requests have also been adopted which provide an interoperable pathway with many web services and visualization tools. To maintain a robust infrastructure redundancy for critical data servers have been implemented. To ensure the widest possible use of IOOS Web Services we will need to develop easy to use tools and "cookbooks" providing guidance for implementation and upgrade paths.
Maintenance Actions	The Service Oriented Architecture (SOA) of SOS and TDS systems need to be maintained and in operation 24/7 for the priority areas of Marine Operations, Coastal Hazards and Climate Change monitoring. This will ensure ready access to real-time in-situ observations and the development of long time-series of observations. As mentioned above, the software tools, libraries and packages need to be consistently maintained and periodically upgraded to keep up with emerging IOOS standards, data formats and conventions. Current Annual IOOS Regional DMAC meetings include: ➢ Annual NeCODP meeting ➢ QARTOD (hopefully these will be restored) ➢ IOOS DMAC Team (several NERACOOS members are participants) ➢ Product Workshops ➢ There is a need for more region wide DMAC oriented workshops and meetings (SOS, TDS, QA/QC, Metadata, etc.) to ensure coordination and maturity of the DMAC systems.
Development Needs	Via the DAC all these systems are registered with the national IOOS. As the guidance is developed we will face the task of ensuring that all these systems are certified and monitored. Arrangements must be negotiated with the NODC for an automated archiving process and then replicated at each sub regional system. Efforts are needed to ensure that all the sub-regions have SOS and TDS servers installed and configured and that the DAC has the latest versions installed as well.

	Many of the existing sub-regional TDS are old and need to be upgraded and reconfigured to support the many new plugin additions such as ncWMS (support for WMS for visualizing gridded data) ncISO (support for producing ISO 19115 metadata for NetCDF files) and even ncSOS (support for SOS from NetCDF files). These upgrades and work on the metadata front utilizing ncML will greatly increase the goals of making data available in IOOS recommended interoperable formats. ncML can also be utilized to ensure regional NetCDF files are CF conventions compliant per IOOS guidelines.

SYNTHESIS TABLE FOR COST ESTIMATION

DMAC Needs	Computing Resources Required	FTE
IOOS-compliant DMAC	Dedicated servers at data provider facilities, which are ideally located in a secure facility with redundant power to ensure 24/7 operations.	1
Regional Data Management	Dedicated web server and database server at hosted facility with 24/7 operating capacity. Includes 2 FTEs dedicated to CMSP activities.	3
Maintenance		1
Development Needs	Dedicated development server at hosted facility.	1

Product Development Subsystem

Introduction

To enable information to support decisions products or tools need to be developed. This is an iterative process requiring scoping, development and refinement steps. Available funding limits the number of products that can be enhanced or developed in a given year. The products identified for development should come from the priorities identified within the various working groups. NERACOOS product development efforts can be classified into three levels based on several factors that include complexity to implement from a technical perspective and the amount of user input/engagement needed to develop requirements for the products.

FTE Roles

- **Product developer** – performs user outreach, compiles requirements. Works with content teams to understand need and develop potential products, develops content.
- **Graphic designer –** develops prototypes and visual interface elements
- **Programmer –** writes code, integrates data, develops functionality
- **Product tester –** interacts with products in beta mode to identify bugs and problems. Works under direction of product developer.

Levels of product development			*FTE requirements*	
Simple	Extension to existing products: ($5-$10k)	• Addition of new sensors/obs platforms to existing product (sensors are similar to what is already being served) • Extension of product to new location (e.g. splashover tool) • Maintenance/troubleshooting of existing products (factor some amount for each product to deal with bugs, user difficulty, customer support, upgrades to software, etc) • Requires minimal user needs/testing	Programmer - .04 FTE Product Developer - .03 FTE	If staffed up with a full-time staff that includes the roles listed above, the number of products to be developed at the Simple level could be between 20-25 per year, not including other DMAC services or less complex products.
Medium	Complex extension to existing product, new straightforward product	• Addition of new type of sensor/obs platform (e.g. right whale buoys) • Integration of data • Requires some level of user needs/testing	Programmer - .15 FTE Product Developer	If staffed up with a full-time staff that includes the roles listed above, the number of products to be developed at

	($10-$50k)		- .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	the Medium level could be between 6-8 per year, not including other DMAC services or less complex products.
Complex	New product requiring user input ($50-$100k)	• Multi-variate (model plus observation) • High functionality (graphing, data analysis) • Complexity of data (data products for atlas work) • Custom product for one user type (boater's app) • Requires high level of user needs/testing	Programmer - .25 FTE Product Developer - .25 FTE Graphic Designer - .15 FTE Product Tester - .15 FTE	If staffed up with a full-time staff that includes the roles listed above, the number of products to be developed at the Complex level could be between 3-4 per year, not including other DMAC services or less complex products.

A general year-to-year recommendation might be to develop 1 Complex product, 3 Medium products, and 8 Simple products. Efforts should be made to balance the needs from the various focus areas so that each area can benefit from the development of new products and decision support tools over the course of several years.

These figures are rough estimates based on budgets from previous development efforts for the region. Cost savings can be found relatively easily by leveraging existing products, sharing ideas and code with the other RAs, and generally not reinventing the wheel unless absolutely necessary. Ideas such as the development of an IOOS product registry/code repository/app store should be investigated and implemented. Well-documented products could be adapted to new regions with greater efficiency and minimal effort to reduce development costs for the individual RAs. This will allow for more needs to be met by the IOOS community at larger with a smaller budget.

Earlier this year, NERACOOS formed a product development working group. This group works to understand the needs coming out of the individual work groups and determine what products could be developed to meet those needs. A draft list of potential products was developed by this group and is outlined below.

SYNTHESIS TABLE FOR COST ESTIMATION

Product Name	Development	Computing Resources	*Geographic Cover/ Location	Associated Theme/ Issue(s)	FTEs	Description
Coastal Erosion and Flooding **SIMPLE/ MEDIUM**	Determine areas to extend product, collect storm datum, identify and acquire model output and forecast feeds. Modify code and display.	Model feed integration Data feed integration Web software development Graphic design	Point specific, not for entire region. Can be extended to as many locations as needed if the information is there.	Coastal Hazards	Programmer - .04 FTE Product Developer - .03 FTE	Extension of existing tool to new areas, addition of real-time data, fail over models and beach erosion forecast.
Regional Indicators **MEDIUM**	Determine scope and requirements	Data feed integration Web software development Graphic Design	TBD	Climate Change	Programmer - .15 FTE Product Developer - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	migrate selected NERACOOS information into customized, value-added environmental and economic indicators (documents, graphs, synthesis reports, and online tools)
Environmental Events Reporting Tool **MEDIUM**	Determine scope and requirements	Data feed integration Web software development Graphic Design	NERACOOS region	Coastal Hazards	Programmer - .15 FTE Product Developer - .13 FTE Graphic Designer - .05 FTE	Display real-time warnings, allow users to access and view a history of warnings, and sign up for alerts

					Product Tester - .04 FTE	
Beach Water Quality Tool **COMPLEX**	Determine scope and requirements	Model feed integration Data feed integration Web software development Graphic Design	Point specific locations	Coastal Hazards	Programmer - .25 FTE Product Developer - .25 FTE Graphic Designer - .15 FTE Product Tester - .15 FTE	Estimate pathogen levels at Scituate, MA, and Saco, ME (selected because they both have multiple beaches and shellfish areas, the availability of sufficient publically-available data and the high resolution NECOFS sub-models)
Hydrological river discharge forecast **MEDIUM**	Determine scope and requirements	Model feed integration Data feed integration Web software development Graphic Design	Point specific locations	Ecosystems	Programmer - .15 FTE Product Developer - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	

Virtual tide stations and wave buoys **SIMPLE**	Determine scope and requiremen ts	Model feed integration Data feed integration Web software development Graphic Design	Point specific locations extended to entire region	Integrated Products	Program mer - .04 FTE Product Develop er - .03 FTE	
Model inter compariso n **MEDIUM/ COMPLEX**	Determine scope and requiremen ts	Model feed integration Data feed integration Web software development Graphic Design	Entire region	Integrated Products	Program mer Product Develop er - .25 FTE Graphic Designer - .15 FTE Product Tester - .15 FTE	
High resolution forecast for at risk ports **MEDIUM**	Determine scope and requiremen ts	Model feed integration Data feed integration Web software development Graphic Design	Point specific locations – ports	Marine Operations	Program mer - .15 FTE Product Develop er - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	
Vessel tracking **MEDIUM**	Determine scope and requiremen ts	Data feed integration Web software	Entire region where data is available	Marine Operations Coastal	Program mer - .15 FTE Product	

		development Graphic Design		Hazards	Develop er - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	
Climatolog ies from buoy data **MEDIUM**	Determine scope and requiremen ts	Data feed integration Web software development Graphic Design	Entire region	Marine Operations Coastal Hazards	Program mer - .15 FTE Product Develop er - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	Develop display and access to climatologies for all buoy locations that have enough data
USCG 24 hr wind analysis **MEDIUM**	Determine scope and requiremen ts	Data feed integration Web software development Graphic Design	Entire region	Marine Operations Coastal Hazards	Program mer - .15 FTE Product Develop er - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	Provides USCG alert and/or analysis when 24 hr winds reach a certain threshold
Wave data display	Determine scope and requiremen	Model feed integration	Entire region	Marine Operations	Program mer - .04	Provide wave data display similar to

SIMPLE	ts	Data feed integration Web software development Graphic Design		Coastal Hazards	FTE Product Developer - .03 FTE	NDBC or CDIP for NERACOOS buoys
Product user guides and description **SIMPLE**	Determine scope and requirements	Develop pages to support use of products. Minimal web development needed	Entire region	Integrated Products	Programmer - .04 FTE Product Developer - .03 FTE	Provide how to guides for NERACOOS products and explanation of different forecasts provided
USGS historical near-bottom current, temperature and turbidity data **MEDIUM**	Determine scope and requirements		Point specific could be extended to entire region	Integrated Products	Programmer - .15 FTE Product Developer - .13 FTE Graphic Designer - .05 FTE Product Tester - .04 FTE	
Regional Products Directory **SIMPLE**	Identify products, develop content	Build pages and directory Minimal web programming, some design	Entire region	Integrated Products	Programmer - .04 FTE Product Developer - .03 FTE	

Research and Development

Introduction

To develop, operate, and maintain a fully integrated observing system that achieves the societal goals of IOOS will require continued investment in research and development (R&D). This R&D includes activities to advance our knowledge of how the coastal, oceanic, and Great Lakes waters and their ecosystems function, to develop the sensors and platforms necessary to rapidly detect changes in the ecosystem and its capacity to provide goods and services, and to develop the tools necessary to predict such changes. Although IOOS is aimed at operational observing systems rather than R&D, the Regional Associations have a unique role in identifying and prioritizing the regional requirements for R&D, as well as the necessary transitions from research project to pilot project to pre-operational activities to operational systems.

Operational requirements

- Personnel to gather R&D requirements
- Forums (e.g., workshops) on R&D requirements
- Concept development for pilot projects

Synthesis Table for Cost Estimation

R&D Need	Associated Theme	Personnel and other costs	RA Role	Role of Others	Adoption Process
Determination of stakeholder requirements needing R&D	All	.25	Gather regional information and prioritize requirements		
Sponsored workshops or other forums on R&D needs		$30k every three years	To identify needs and solutions		
R&D Need 1 Broad scope Sensor development (HAB, nutrients, pathogens, phytoplankton, Zooplankton,	All		Recommend or endorse project. Provide testbed access to platforms.	Partner and fund unless IOOS funding expands	

etc.)					
R&D Need 2 **Biofouling prevention**	All		Recommend or endorse project. Provide testbed access to platforms.	Partner and fund unless IOOS funding expands	
System, power, data management, and telemetry improvements	All		Recommend or endorse project. Provide testbed access to platforms.	Partner and fund unless IOOS funding expands	
Platform / system development (e.g. Profiling moorings, autonomous surface craft, platform of opportunity systems)	All		Recommend or endorse project. Provide testbed access to platforms.	Partner and fund unless IOOS funding expands	
Improvements to NECOFS - General	All		Recommend or endorse larger scale projects including developing hardened infrastructure. Also small improvements as part of system development.	Partner and fund unless IOOS funding expands	
Improvements to NECOFS Inundation Forecast System – adaptation for	4.1, 2.3		Recommend or endorse larger scale projects. Also small improvements	Partner and fund unless IOOS funding	

other locations			as part of system development.	expands	
Improvements to NECOFS Ecosystem / Water quality 1. Identification and specification of applications 2. Boundary inputs of nutrients (e.g., output of GM-WICS) 3. Validation for a long-term simulation	3		Recommend or endorse larger scale projects. Also small improvements as part of system development.	Partner and fund unless IOOS funding expands	
UNH Gulf of Maine Watershed Information and Characterization System (GM-WICS)- Further development of system into more operational system	All		Recommend or endorse larger scale projects. Also small improvements as part of system development.	Partner and fund unless IOOS funding expands	

Training and Education Subsystem

Introduction

NERACOOS engages stakeholder groups through tailored training and education activities as well as product development. Education stakeholders include those in both formal (K through graduate school) and informal (museums, aquaria, and science centers) settings. Other stakeholders include marine resource managers, public health officials, energy industry, fishermen, boaters, tourism industry, emergency responders, maritime operations, real-estate and insurance industry. Training the next generation of ocean observing professionals is essential to the ongoing operation and development of ocean observing systems such as NERACOOS.

Target Audiences

- **Stakeholder groups** (e.g., marine resource managers, public health officials, energy industry, fishermen, boaters, tourism industry, emergency responders, maritime operations, real-estate and insurance industry)
- **Formal educators and Ocean Education Partners** (K-Graduate School)
- **Informal education audiences** (museums, aquaria, science centers)
- **Internal-Professional development** for RA staff/council and committee members

Operational And Information Requirements (Briefly Describe By Product Or Service)

Synthesis Table for Cost Estimation

Target audience	Product or Service	Development Costs	Distribution Costs	FTEs
Stakeholder groups	Continue stakeholder workshops to understand information needs Facilitate "think tank" meetings for data providers and product developers to foster the development of novel products, avoid duplicity of efforts, and establish redundancies where needed. Create a directory of IOOS Experts (points of contact) available for specific topics, and willing to speak or participate at various venues. Provide technical training to appropriate audiences when			2 FTEs

	products launched Create stakeholder-specific displays or presentations to share at appropriate venues Develop kiosks that make RTD available at public places (e.g., marinas, fishing piers, boat ramps, beach side hotels and restaurants, dive shops, etc.)			
Stakeholder (Decision Makers)	Development of training materials and training on how to use / implement decision support products (workshops, webinars, tutorials, etc.)	$10K	$10K per workshop	
Stakeholder (R&D partners)	Engagement to define regional priority research and development needs. Workshops, webinars etc, R&D and OL- engage scientists, broaden participation. Work with COSEE on Broader Impacts initiative. Fellowships for training next generation of ocean observing professionals	$50k per fellowship (salary and travel)	$ 10K for meeting travel etc	
Stakeholder (Audience Seekers – Elected officials)	Educational meetings and supporting materials	$20k for consultants to assist with elected official education	$ 5K for meeting travel etc. Meeting scheduling and tracking, develop materials, print materials, etc	
Stakeholder (Audience Seekers – Media and Public)	Press releases, media events etc. Website Newsletter Consistent Messaging- implement communication	$20k to develop and conduct events $10-20K for web development		

	strategy			
Formal educators and Ocean Education Partners (K-Graduate School)	Workshops to develop and share lesson plans Visits / webinars with classes and teachers etc.	$25K/workshop	Website	
	Training for technologies and products i. Workshops, webinars ii. Tutorials iii. Training materials			
	Collaboration with ocean education partners (local, regional, and national). Support partnerships through: i. Attend meetings (NMEA, NSTA, etc) ii. Participate in projects (COSEE, OOI, etc)	$10k travel and registration		
Informal education audiences (museums, aquaria, science centers)	Exhibit development and maintenance, develop one exhibit every three years in science center or public space Program development and training Meetings to bring awareness to IOOS (ex. Fishermen Forums, Port Safety Meetings, etc.) Provide Professional Development opportunities for staff and docents Create a community of Citizen Scientists that take ownership of specific waterways	$50-100K / exhibit Program training $10K		
Internal-Professional development	Professional development for RA staff/council and committee members	$5k professional development		

for RA staff/council and committee members	Facilitate dialogue among councils and committees to enable development of a fully integrated Regional Operations Center Create an IOOS tool box that will enable all IOOS educators to communicate consistent messages, share successful data applications and extend successful programs beyond individual RAs			
Cross Cutting	Establish routine Public Broadcasting messages about the region News stations broadcast IOOS information on a daily basis Public radio messages include IOOS information Newsletter Website			

GOVERNANCE AND MANAGEMENT SUBSYSTEM

INTRODUCTION

The administration and management of NERACOOS requires dedicated full time staff and contract support. Regular operations include administration of the organization (financial and personnel management, legal support, office space and equipment, etc.), support for the Board of Directors, Strategic Planning and Implementation (SPI) Team, and working groups, as well as management of the observing system and other duties related to the management and oversight of the organization. Staffing levels depend on the size of the observing system.

SYNTHESIS TABLE FOR COST ESTIMATION

	Office Space*	**Office Equipment and Supplies**	**FTEs**
Board and Organization Support and Management	*90 ft²* *60 ft²* *60 ft²*		*1 Executive Director* *1 Program Coordinator* *1 AA*
Observing System Management	60 *ft²*		*1 Technical Director*
Financial, Legal, Personnel Management	60 *ft²*		*1 Business and Grants Manager* *.20 Legal contract* *A133 annual audit (~$17K in 2011)*
Other Meeting Space Evaluation (contractual) Communications Meeting support Membership fees Travel	 150 *ft²*		 0.25 FTE ~$5k in 2011 ~$6,500K in 2011 ~ $10K in 2011 ~$40K in 2011
Total	480 *ft²*	~$15K in 2011	