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.

	Temporal resolution – 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.

	<u>Spatial resolution horizontally</u> – can be finer but usually averaged to about 1 km. <u>Spatial coverage vertically</u> – near-surface measurement of meteorological; full water column profile measurement of water properties and currents. <u>Spatial resolution vertically</u> - from a few cm to a few m, depending on the water depth. <u>Temporal coverage</u> – Year-round. <u>Temporal resolution</u> – 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/Location	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 Inundation 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-Ecosystem	*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 Hydrology *FRAMES (constituent 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 Develop er - .03 FTE	NDBC or CDIP for NERACOOS buoys
Product user guides and descriptio n **SIMPLE**	Determine scope and requiremen ts	Develop pages to support use of products. Minimal web development needed	Entire region	Integrated Products	Program mer - .04 FTE Product Develop er - .03 FTE	Provide how to guides for NERACOOS products and explanation of different forecasts provided
USGS historical near-bottom current, temperatu re and turbidity data **MEDIUM**	Determine scope and requiremen ts		Point specific could be extended to entire region	Integrated Products	Program mer - .15 FTE Product Develop er - .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	Program mer - .04 FTE Product Develop er - .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 ft^2* *60 ft^2* *60 ft^2*		*1 Executive Director* *1 Program Coordinator* *1 AA*
Observing System Management	60 *ft^2*		*1 Technical Director*
Financial, Legal, Personnel Management	60 *ft^2*		*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 *ft^2*		 0.25 FTE ~$5k in 2011 ~$6,500K in 2011 ~ $10K in 2011 ~$40K in 2011
Total	480 *ft^2*	~$15K in 2011	