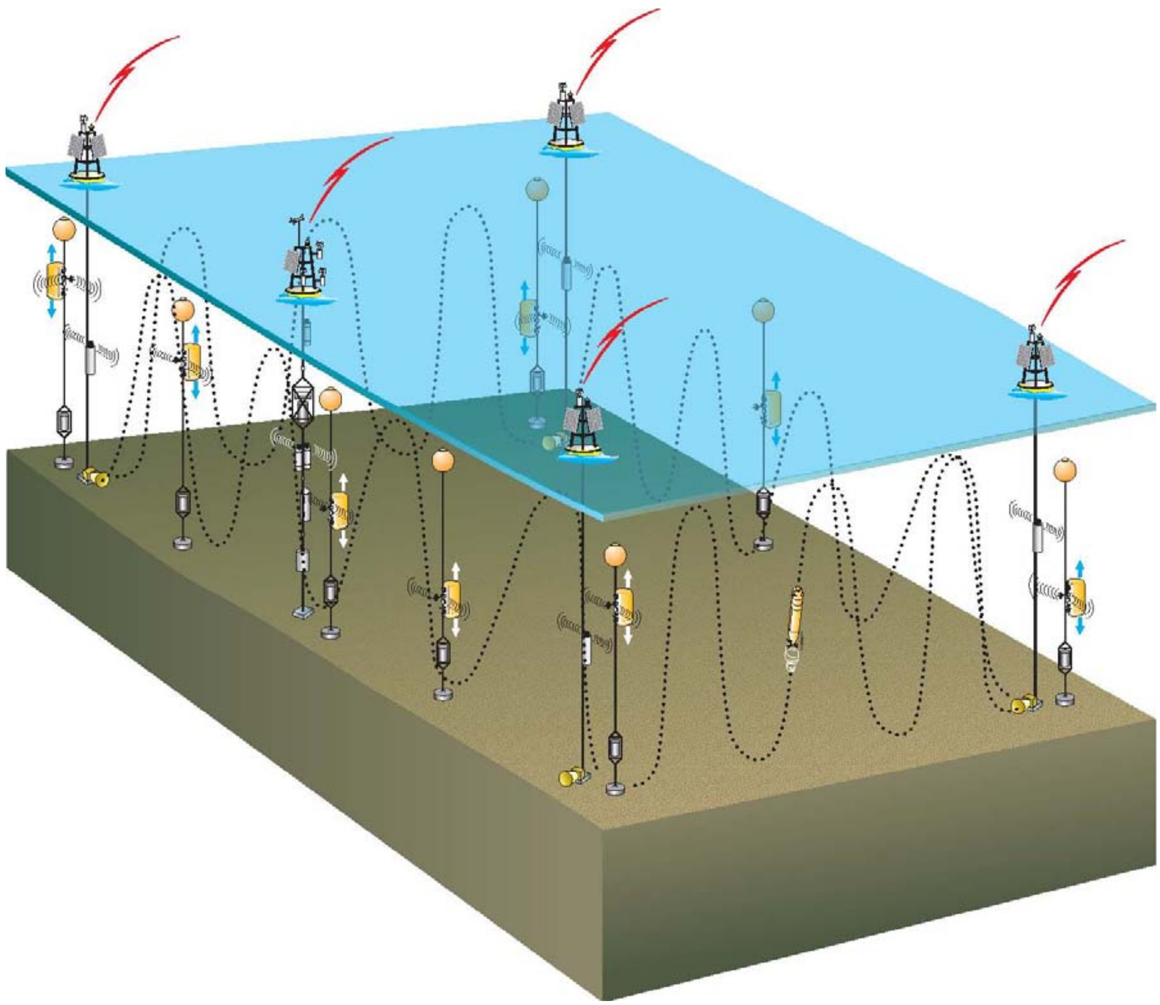
COASTAL OBSERVATORY CONCEPTUAL NETWORK DESIGN FOR ORION'S OCEAN OBSERVATORIES INITIATIVE (OOI)

Version 2.0



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Coastal Conceptual Network Design
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Key to Sub-Committees:
CSO: Coastal Scale Observatory
RCO: Regional Cabled Observatory
GSO: Global Scale Observatory
**D&I Workshop Organizing Committee*

COASTAL CONCEPTUAL DESIGN

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RECORD OF ISSUE

Issue	Date	Document Status
DRAFT 1.0	15 March 2006	Initial draft based on RFAs; October 2005 and January 2006 STAC and Engineering and Sensors Committee meetings; and iterative communications between STAC, Engineering and Sensors Committees, and RFA PIs
DRAFT 2.0	30 June 2006	Second draft revisions based on community recommendations at March 2006 Design and Implementation Workshop, April 2006 Operations and Maintenance meeting, and May 2006 STAC, Engineering, and Sensors Committee meetings

REVISIONS

Date	Nature of Change
May 27-31, 2006	Summary of input at Design and Implementation Workshop, prioritization of concepts, revised estimates of capital costs for infrastructure
June 26-30, 2006	Further prioritization of concepts, detailed descriptions of infrastructure and representative instrumentation, detailed estimates of capital and operations & maintenance costs for infrastructure and instrumentation

Coastal Observatory Conceptual Network Design for ORION's Ocean Observatories Initiative (OOI)

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Coastal Conceptual Network Design

1. Introduction

How do coastal ecosystems respond to climate variability? What role does the coastal ocean play in the global biogeochemical cycles that control climate variability? How do human activities impact the coastal ocean? What processes determine community structure in coastal ecosystems? How can we predict and mitigate coastal hazards that impact human populations? At present, scientists cannot answer these and other critically important coastal oceanographic questions because of limited understanding of fundamental processes. Limitations in understanding arise primarily from severe restrictions in the existing ability to measure essential oceanographic properties at the temporal and spatial scales required to resolve the dominant processes.

The Coastal Component of the Ocean Observatories Initiative (OOI) will enable groundbreaking advancements in our understanding of critically important coastal oceanographic processes by providing transformative observational infrastructure at scales never before realized. The OOI is administered by the Ocean Research Interactive Observatory Networks (ORION) and funded through the National Science Foundation's (NSF's) Major Research Equipment and Facilities Construction (MREFC) Account. The Coastal Component of the OOI will capitalize on cutting-edge technologies, including autonomous vehicles capable of adaptive sampling in the presence of multi-scale processes, instrumentation that provides measurements of previously unquantifiable biogeochemical properties, and seafloor cables and advanced profiling moorings that deliver high power and rapid two-way communications for continuous measurements with durations of decades.

This document presents the draft Conceptual Network Design (CND) for the Coastal Component of the OOI. The draft Coastal CND was prepared by the ORION Science and Technical Advisory Committee (STAC), which receives assistance from the ORION Engineering and Sensors Committees and reports to the ORION Observatory Steering Committee (OSC). The conceptual design task was accomplished by means of internal discussions within the STAC and extensive formal and informal communications with the oceanographic community. Formal communications with the community occurred through two mechanisms: ORION's Request for Assistance (RFA) process, initiated in February 2005, and the subsequent Design & Implementation (D&I) Workshop, held in Salt Lake City in March 2006.

The working assumption in preparing the CND has been that MREFC funds available for the Coastal Component of the OOI will total approximately $40M for fixed platforms, moveable platforms, core instrumentation, development, and installation. Costs for additional essential activities, including management, environmental impact statements, surveys, permitting and contingencies, will be covered by other OOI funds. MREFC funds cannot be used for operations and maintenance. The latest schedule for disbursement of the Coastal MREFC funds is approximately $0, $14M, $17M, $0, $0 and $9M, respectively, for fiscal years 2007 through 2012.

Of particular importance in the Coastal Component of the OOI are the concepts of "pioneer" and "endurance" elements, which are designed to serve studies with durations of years and decades, respectively. These concepts emerged from ORION meetings and workshops that preceded the RFA process (e.g., Jahnke et al., 2002; Jahnke et al., 2003; Glenn and Dickey, 2003; Rudnick and Perry, 2003; Schofield and Tivey, 2004), and were reflected in the RFA responses and the discussions at the D&I Workshop.

The remainder of this document contains a summary of coastal science drivers (Section 2), a description of the process by which the Coastal CND was developed (Section 3), a description of the elements of the proposed Coastal CND (Section 4), and a summary of linkages between the Coastal CND and the Regional and Global Components of the OOI (Section 5). An Appendix contains a description of three highly regarded concepts that are not included in the Coastal CND because of funding constraints.

2. Coastal Science Drivers

There is a critical need to advance understanding of coastal systems because they are the boundary between the terrestrial and open ocean realms and the interface at which most human-ocean interactions occur. More than 50% of the human population resides along coasts, which are susceptible to hazards such as hurricanes, tsunamis and harmful algal blooms. More than 90% of the world's fish catch is harvested from coastal waters, which also support major recreation and maritime industries. Fluxes of mass and energy across the coastal ocean exert a dominant control on major global chemical cycles and determine, for example, material exchange between the terrestrial and oceanic realms. Thus, coastal regions are a focus of human-ocean interactions and play disproportionately important roles, relative to their surface area and volume, in the ecology and biogeochemistry of the global oceans.

The OOI Science Plan (ORION Executive Steering Committee 2005) and previous workshop planning documents (Jahnke et al. 2002, Glenn & Dickey 2003, Jahnke et al. 2003, Purdy et al. 2004, Schofield & Tivey 2005) identify and discuss numerous coastal science questions. In general these can be organized into a relatively few research themes, such as: Climate Change and Biogeochemical Cycling; Ecosystem Dynamics, Turbulent Mixing and Biophysical Interactions; and Fluids and Life in Continental Margin Sediments. Example questions within these themes that were highlighted in the OOI Science Plan are:

- What processes determine the transport of carbon, nutrients, planktonic organisms, and other materials within the coastal ecosystem?
- What conditions trigger the occurrence of harmful algal blooms and regime changes in the species composition of coastal ecosystems?
- How will climate variability and human activities influence coastal ecosystems, habitats and living marine resources?

For many of these questions, there will not be a single answer. The mixes of controlling processes within coastal systems vary with the relative magnitudes of local forces and with bottom morphology. Important factors to consider include wind forcing, buoyancy inputs, tidal energy, and oceanic boundary current interactions. In addition, local morphology and bottom sediment characteristics impact process interactions by influencing bottom friction, directing bottom currents, providing habitat and substrate for organisms, and mediating a variety of biogeochemical processes. Interactions between the water column and sediments transported primarily by energetic, short-term events offer one example of the challenging temporal variability of coastal systems.

Previous research programs, such as Coastal Ocean Processes (CoOP), recognized the need to study diverse coastal systems to examine fundamental processes. Building on this, the Coastal Observatory Research Array workshop (Jahnke et al. 2003) identified a widely distributed array of potential observatory sites to capture the broad spectrum of coastal interactions and conditions. The RFA process, the D&I Workshop, and subsequent discussions within the ORION advisory committees have been employed to focus this effort. The challenge in the coastal zone, then, is to identify the minimum number of locations that permit the study of as many of these fundamental processes and interactions as possible and which, when combined with measurements from other OOI components, provide the integrated observations needed to significantly advance understanding of coastal and ocean systems.

3. Development of the Coastal CND

3.1 Synthesis of the RFA Responses

ORION's RFA resulted in twenty-two conceptual coastal science experiments (Table 1; see also http://www.orionprogram.org/RFA/default.html), which collectively address a broad range of questions with a variety of emphases and approaches at numerous sites along all coasts of the United States. An external ORION review panel was convened, consisting of unconflicted members of the ocean research community selected by NSF OCE Program Managers, The panelists binned the proposals into three groupings based on a combination of factors, including readiness, maturity of required technologies, and proposed science. There was no prioritization of proposals within the three groupings.

Led by its Coastal Sub-Committee (see page 2 for membership), the STAC summarized the coastal RFA responses in a standard STAC format and worked with the ORION Engineering and Sensors Committees to develop cost estimates for the RFA responses. These estimates indicated that the costs represented in the tier-one responses alone totaled at least four times the coastal OOI budget. The STAC then worked with the principal investigators (PIs) of the tier-one RFA responses to reduce their concepts to the essence of the compelling new science that would be enabled by OOI infrastructure. The STAC also solicited revised cost estimates for the reduced programs from the Engineering and Sensors Committees, and identified compelling science in tier-two and tier-three RFA responses that could be enabled by tier-one designs. This process produced a reduced menu of six coastal options (Table 2), requiring, in total, approximately twice the funding available for the coastal component of the OOI.

3.2 The D&I Workshop

The reduced menu of coastal options (Section 3.1 and Table 2) was presented at the D&I Workshop for discussion, evaluation and improvement by the oceanographic community. Discussions in the Coastal breakout groups at the Workshop, summarized by Daly et al. (2006), produced at least four important outcomes. The first was nearly unanimous endorsement (among ~100 participants) of a moveable Pioneer Array, intended for process-oriented observations with durations of three to six years, and represented in the menu of coastal options (Table 2) by a shelfbreak application in the Middle Atlantic Bight (MAB) and mesoscale applications in regions of topographical variability and riverine outflows off the West Coast. Second, a Pacific Northwest (PNW) Endurance Array (Table 2) was broadened by means of extensive discussions to become a West Coast Endurance Array, through addition of assets in California, which were designed to sample different biogeographical regimes and observe propagation of interannual disturbances along the California Current System. Third, the community could not achieve a prioritization of the remaining coastal arrays—cabled endurance arrays in the Gulf of Maine (GoM), the South Atlantic Bight (SAB), and Oahu (Table 2)—but instead endorsed the idea that all three should be pursued if funding permits. Fourth, important linkages between the Coastal, Regional and Global components of the OOI were identified. These linkages include a focus on extreme events, which indicated a significant role for the hurricane-impacted SAB, and a focus on response of coastal ecosystems to climate variability, which indicated a significant role for the west coast, because of its response to interannual forcing originating in the tropical Pacific, and for the GoM, because of its responses to equatorward-propagating climate signals originating at higher latitudes.

3.3 Post-Workshop Reduction and Synthesis

Based on the RFA process (Sections 3.1 and 3.2) and the D&I workshop (Section 3.3), a consensus was quickly reached within the ORION advisory structure that a Pioneer Array and a West Coast Endurance Array are high-priority OOI concepts and should be funded at a level that ensures acquisition and installation of transformative infrastructure. A consensus was also reached that the design and initial deployment of the Pioneer Array should be based on the MAB shelfbreak application (Table 2), because of its focused scientific goals, clear dependence on OOI assets and adaptive sampling methodologies enabled by advanced autonomous vehicles, and likelihood of early success. In addition, in spite of a desire to accommodate the community consensus at the D&I Workshop that three additional endurance arrays (Oahu, GoM and SAB) should be funded if possible, the remaining anticipated funding was judged too small to establish more than one additional endurance array, because cost estimates indicated that transformative science could not be achieved if this funding were divided among two or three concepts. Prioritization of the Oahu, GoM and SAB concepts was therefore required.

The uniqueness of the Oahu Endurance Array within the coastal OOI framework and its relevance to tropical locations worldwide were clearly recognized. However, the Oahu array was deemed to be lower in priority than the GoM and SAB arrays, because the

Oahu site, although capturing important questions including internal wave propagation, benthic fluxes, and biogeochemistry of carbonate environments, offers in comparison with the GoM and SAB sites a more limited set of issues in which the broader coastal community can be engaged.

The uniqueness and importance of the GoM Endurance Array were also clearly recognized. In particular, the GoM array is in a highly productive and economically important region where ecosystem response to interannual forcing has already been inferred. The GoM is the site of a burgeoning aquaculture industry and one of the nation's richest pelagic and benthic fisheries, some of which have undergone drastic and unexplained changes within the last decade. Finally, the GoM experiences harmful algal blooms and is the summertime feeding and breeding ground for the endangered North Atlantic Right Whale.

In spite of the strengths of the GoM array, the SAB array was deemed to be of higher priority within the OOI framework. The deciding factors were (1) the diversity of compelling scientific questions associated with the dramatic and poorly understood impact of the Gulf Stream on the physical oceanography, biogeochemistry and ecosystem dynamics of the SAB shelf; (2) the role of the SAB as an analog for other systems worldwide that are directly impacted by energetic western boundary currents; (3) the presence of a productive seafloor characterized by important and poorly understood biogeochemical transformations and benthic-pelagic fluxes; (4) the unique mid-shelf and outer-shelf access offered by an existing array of surface-piercing towers, which enable measurements throughout the water column, near air-sea interface, and in the lower atmosphere; (5) frequent occurrence of extreme atmospheric events including hurricanes; and (6) the broad range of complementary interdisciplinary scientific opportunities offered by the contrast between open-shelf sites on the east and west coasts of the contiguous United States.

4. Elements of the Coastal CND

4.1 Overview

The Coastal CND that was developed by means of the process described in Section 3 has three elements: a West Coast Endurance Array concentrated in the Pacific Northwest with complementary assets off California, an East Coast Endurance Array located in the South Atlantic Bight, and a moveable Pioneer Array with an initial shelfbreak application in the MAB and subsequent applications at sites determined by the NSF peer review process. The combination of the West Coast Endurance Array and the East Coast Endurance Array capitalizes on the contrast between a narrow shelf forced by seasonal upwelling-favorable winds, a large buoyancy source and an eastern boundary current (off the West Coast) and a broad shelf forced by a western boundary current, distributed buoyancy sources and extreme wind events (off the East Coast). The two Endurance Arrays therefore provide the opportunity to address complementary interdisciplinary scientific questions in contrasting systems representing two canonical classes of coastal margins with numerous analogs worldwide. The Pioneer Array will employ adaptive sampling strategies to resolve multiple temporal and spatial scales in a variety of coastal settings. The infrastructure represented in the Coastal CND will provide an unprecedented opportunity to address broad classes of critically important coastal oceanographic problems that were identified in the RFA process, including, in particular, shelf-ocean exchange, air-sea transport, benthic processes and benthic-pelagic coupling, transport and transformations of terrestrial discharges, response to extreme events, biogeochemical cycling, and ecosystem dynamics. The infrastructure represented in the Coastal CND will enable continuous measurements by advanced sensors with durations of decades, and it will capitalize on transformative technologies including advanced profiling moorings and adaptive sampling by vehicles.

The major elements of the proposed Coastal CND are well determined, but some details could be improved by further discussion and analysis. The precise locations of fixed assets and the initial routes and timing of measurements by moveable assets should, for all endurance and pioneer arrays, be guided by Observing System Simulation Experiments (OSSEs), as recommended in the 2006 report of the ORION Modeling Working Group. The core instrumentation described here is intended to be representative, and the precise design of the core instrumentation deserves further consideration. The details of glider and AUV surveys should evolve in a manner informed by measurements and modeling.

The basic components of the infrastructure represented in the Coastal CND are surface buoys with capabilities for power generation and satellite communications, electro-optical-mechanical (EOM) moorings, profiling moorings, low-voltage (LV) and medium-voltage (MV) benthic nodes, seafloor cables, gliders, autonomous underwater vehicles (AUVs), and core instrumentation. In the present design, instrumentation for gliders includes a conductivity-temperature-depth (CTD) sensor, a set of basic optical sensors (e.g., chlorophyll fluorescence, Colored Dissolved Organic Matter), an oxygen sensor, and a motion sensor. A profiling package for deployment on profiling moorings includes a three-axis velocimeter, a CTD, an oxygen sensor, and a set of basic optical sensors. A benthic package for deployment at the seafloor near benthic nodes includes the same components as the profiling package. Fixed Acoustic Doppler Current Profilers (ADCPs) are specified for deployment at the seafloor and on selected buoys, and fixed arrays of conductivity-temperature (CT) sensors are specified for deployment on selected moorings. A meteorological package consists of a sonic anemometer, a motion sensor, a temperature-humidity-pressure sensor, solar and infrared radiation sensors, and a rain gauge. Cost estimates have been prepared by the ORION Engineering Committee and definitions of core instrumentation are consistent with the recommendation of the ORION Sensors Committee.

4.2 West Coast Endurance Array

The West Coast is characterized by a relatively narrow shelf, an energetic eastern boundary current, persistent wind-driven upwelling, a large buoyancy source (the Columbia River), a number of distinct biogeographical regimes, mesoscale variability forced by bathymetry and fluid dynamical instabilities, and interannual variability forced by fluctuations in the tropical Pacific and variations in the large-scale circulation of the North Pacific. The proposed West Coast Endurance Array (Figs 1 and 2, Table 3), in order of highest to lowest priority, consists of (1)) four shelf moorings and one slope mooring on an existing long-term sampling line off Newport, Oregon, which will be cabled by means of an onshore extension of the OOI Regional Cabled Observatory (RCO); (2) an uncabled line of four shelf moorings and one slope mooring off Grays Harbor in Central Washington; (3) an array of gliders; (4) a mooring at the cabled Monterey Accelerated Research System (MARS) node in Central California; and (5) an uncabled line with one slope and one shelf mooring in the Southern California Bight. The proposed West Coast Endurance Array will benefit from existing and evolving infrastructure associated with three Integrated Ocean Observing System (IOOS) regional associations (NANOOS, CeNCOOS, and SCCOOS; see http://www.usnfra.org/contactsRegional.jsp) and with science-driven efforts such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), the Columbia River Observation and Prediction System (CORIE) and the National Science Foundation (NSF) Science and Technology Center (STC) for Coastal Margin Observation and Prediction.

The assets in the West Coast Endurance Array are concentrated on the Central Oregon and Central Washington mooring lines. The purposes of these lines are to contrast shelf and slope processes in regions that are influenced in different ways by the outflow from the Columbia River (e.g., the coastally attached northward plume off Washington during downwelling events and the detached south-southwest plume off Oregon during upwelling events) and to contrast processes in a region of smooth topography (i.e., the Washington shelf) and a region with a topographic bank (i.e., Heceta Bank on the Oregon shelf). The assets on the Washington and Oregon lines will include highly capable installations with full-depth profiling, surface expressions for atmospheric measurements, and benthic nodes for intensive near-bottom measurements at the 25, 80 and 500-m isobaths, in addition to less capable installations without benthic nodes at the 50 and 150-m isobaths. The highly capable sites at the 25, 80 and 500-m isobaths were chosen to be over inner-shelf sands, outer-shelf muds, and the continental slope, respectively. The additional sites at the 50 and 150-m isobaths were chosen to resolve the dominant features of the variability over the Pacific Northwest continental margin. The shelf and slope moorings on the Washington and Oregon lines will be complemented by off-shore infrastructure associated with the RCO.

The purposes of the moorings off Central California and in the Southern California Bight are to sample different biogeographical regimes and to provide spatial measurements of northward-propagating signals originating in the tropical Pacific, which will aid in the interpretation and analysis of the more densely sampled measurements in the Pacific Northwest. The OOI installation in Central California will capitalize on the cabled MARS node and will add a full-depth profiling capability to this facility.

The array of gliders will be initially deployed to characterize shelf-wide features; over time, a subset of the gliders will be allocated to characterize smaller-scale features, in a process informed by measurements and modeling.

Scientific issues that will be addressed by the West Coast Endurance Array include the coastal carbon budget and its role in the global carbon cycle, cross-margin transport and exchange processes, fate and impacts of freshwater discharges in coastal systems, physical controls on biological variability and community structure, and the response of coastal ecosystems to interannual variability in physical forcing.

4.3 East Coast Endurance Array

The proposed East Coast Endurance Array is located in the South Atlantic Bight, a region characterized by a broad, shallow continental shelf with intense interactions between the seafloor and water column, direct forcing by a strong western boundary current (the Gulf Stream) and frequent, high-energy atmospheric events such as hurricanes. The proposed East Coast Endurance Array benefits from the existing South Atlantic Bight Synoptic Off-shore Observational Network (SABSOON), part of the Southeast Atlantic Coastal Ocean Observing System (SEACOOS), which features, in particular, an array of surface-piercing towers (owned by the US Navy) that provide unmatched mid- and outer-shelf access to the air-sea interface and water column. The main element of the East Coast Endurance Array (Fig. 3, Table 4) is a cable extending from shore to a medium-voltage inner-shelf benthic node and then to a dry node on mid-shelf tower R2 and finally to a dry node at shelf-break tower R3 (Fig. 3). The inner-shelf node will be equipped with a full-depth profiling capability. Each of the cabled towers will have a cabled profiling capability remote from the tower (by approximately 1 km) in order to minimize flow disturbances and reef effects associated with the towers. Two additional uncabled towers (R4 and R8) will be instrumented with high-frequency (HF) radars, provided with power and two-way communications by Monterey Ocean Observing System (MOOS) packages, to measure surface currents over the outer shelf and slope. Observations from an array of gliders will be used to quantify spatial variability.

Scientific issues that will be addressed by the East Coast Endurance Array include exchange processes between the Gulf Stream and the shelf; air-sea transfer processes in the presence of extreme forcing and heterogeneous atmospheric and oceanic conditions; the role of the Gulf Stream in controlling circulation, water-mass transformations, benthic-pelagic coupling and biogeochemical cycling on the shelf; the impact of extreme events on coastal circulation, ecosystem dynamics and sediment transport; and the processes controlling the transport, transformations and fate of carbon in the coastal ocean.

The infrastructure components of the East Coast Endurance Array are prioritized as follows (from greatest to least priority): (1) seafloor cable to dry nodes at towers R2 and R3, (2) benthic nodes and profilers at towers R2 and R3, (3) gliders, (4) MOOS packages and radar and HF radars at towers R4 and R8, and (5) inner shelf benthic node and profiler.

4.4 Pioneer Array

The Pioneer Array (Figs 4 and 5, Table 5) employs fixed moorings, profiling moorings, and adaptive sampling by means of gliders and AUVs to produce synoptic samples of multi-scale coastal oceanographic phenomena. The array consists of four EOM moorings with surface expressions and capabilities for local power generation and satellite data transmission, five subsurface profiling moorings with internal power and capabilities for acoustic transmission of data, four acoustic repeater moorings with internal power, three long-range (~400 km) AUVs, two AUV docking stations, twelve gliders (~ one month duration), and core instrumentation. In the present design, two EOM moorings are dedicated to bottom-mounted AUV docking stations, and two are dedicated to fixed sensors. The subsurface profiling moorings transmit data by means of the acoustic repeaters (where necessary) to the EOM moorings for satellite transmission. The AUVs sample spatially in response to two-way communications and obtain power and transmit data by means of the docking stations. Glider operations are handled by ship.

As noted in Section 3.3, the initial application of the Pioneer Array is recommended to be in the MAB, because of the scientifically compelling MAB shelfbreak application that emerged from the RFA process. The MAB is characterized by a relatively broad shelf, a persistent equatorward current originating well north of the United States, a well defined shelf-slope front, variable wind forcing, distributed buoyancy inputs by a number of rivers, and off-shore forcing by intermittent rings shed by an energetic western boundary current (the Gulf Stream). The proposed initial application of the Pioneer Array focuses on transport processes and ecosystem dynamics within the shelf-slope front, a region of complex nonlinear dynamics, intense mesoscale variability, and greatly enhanced biological productivity relative to the adjacent shelf and slope. The scientific questions center on processes controlling the transport of heat, salt, nutrient and carbon fluxes across the shelfbreak front; the relationship between variability in the shelfbreak frontal jet and the along-front structure in phytoplankton distributions; and the aspects of interannual variability that are most important for modulating shelf-slope exchange. In the shelfbreak front application, the Pioneer Array will span approximately 50 km and 40 km in the along- and cross-front directions, respectively. The AUVs will sample within the front and over the shelf and the gliders will sample the slope water.

The proposed initial application will benefit from existing infrastructure at the Martha's Vineyard Coastal Observatory (MVCO) and the New Jersey Shelf Observing System (NJSOS). For example, because of the developmental nature of AUV docking operations, docks are recommended to be deployed initially at the nearby MVCO.

After an initial deployment at the MAB shelfbreak with a duration of approximately three to six years (possibly determined by the NSF review process with an option to renew), applications of the Pioneer Array will be competed and are intended to enable studies of mesoscale and sub-mesoscale physical, biogeochemical and biological variability and processes at diverse coastal sites. The components of the recommended Pioneer Array are designed to accommodate a variety of regional studies with relatively minor modification (e.g., of mooring lines) and possible upgrades. The applications would be specified in the competed proposals and could address, for example, mesoscale physical and biological variability in regions of complex topography and riverine outflows in the Pacific Northwest, fate and impact of the buoyant discharge from the Mississippi River and related anthropogenic issues, environmentally sensitive regions with rich spatial structure such as coral reef regions, and biogeographical variability in regions of complex physical forcing (Table 1).

4.5 Prioritization

The sum of the costs of the three elements in the Coastal CND (West Coast Endurance Array, East Coast Endurance Array and Pioneer Array) is approximately $44.5M (Tables 3, 4, and 5), or approximately 11% larger than the target budget of $40M (Section 1). Prioritizations of the components of the individual arrays were discussed in Sections 4.2 through 4.4, but overall prioritizations across components were not discussed. In view of the uncertainty of the cost estimates (for example, costs of cables in the Endurance Arrays and costs of docking stations in the Pioneer Array), specifications of definite cuts to achieve a precisely balanced budget are not productive at this stage. It is worthwhile, however, to state the key elements of the program that should be preserved, and to suggest possible means by which the budget could be balanced, given updated cost estimates, while still preserving the key elements.

The key elements of the program, articulated in Section 3.3 and 4.1, are (1) endurance arrays on both the East and West Coasts of the contiguous United States, in order to capitalize on the complementary interdisciplinary scientific opportunities that are offered by these two contrasting regions; and (2) capitalization on the concepts of both endurance and pioneer arrays, which have received broad community support throughout the lengthy process leading up to the Coastal CND. These considerations dictate that the three components of the program (West Coast Endurance Array, East Coast Endurance Array, and Pioneer Array) should be preserved.

Although cuts are clearly non-optimal, each component of the program has areas in which costs could be reduced at the required level, given more precise budget estimates. In particular, the following cuts, which potentially sum to more than the $4.5M required to balance the budget, could be entertained: (1) reduction of California assets in the West Coast Endurance Array, (2) reduction of the inner-shelf presence in the East Coast Endurance Array, and (3) creative use of the MVCO and other existing assets for AUV docking capabilities in the Pioneer Array. Item (1) would retain the transformative endurance presence in the Pacific Northwest and would require use of existing or evolving assets to sample other west-coast biogeographical regimes and to observe northward propagation of signals along the California margin. Item (2) would preserve the transformative multi-scale adaptive sampling capabilities offered by the combination of moorings, AUVs and gliders. Item (3) would preserve transformative mid- and outer-shelf access to the seafloor, water column, air-sea interface and lower atmosphere in a shelf region intensely impacted by an energetic western boundary current and subject to extreme atmospheric events.

5. Linkages of the Coastal Component with the Regional and Global Components

The Coastal, Regional Cabled (RCO), and Global components of the OOI share an overarching science theme, which is to investigate the influence of climate variability in the ocean provinces (e.g., the coastal and open ocean) and related systems. As such, the component observatories are clearly linked through a number of common scientific interests. Specifically, three of the science topics highlighted are shared by all components: investigations of air-sea fluxes, ocean circulation, and biogeochemical cycles and ocean ecosystems. Combinations of the OOI components are expected to make significant contributions to these efforts. For example, the high power and high bandwidth provided by the cable to the SAB towers will allow continuous measurements of the momentum, heat and mass exchange in a wide variety of atmospheric processes that affect the SAB shelf. Winter cyclones that impact the US east coast can develop in or cross this region, and tropical storms and hurricanes can pass through the SAB in summer and early fall. Interestingly, maximum wind speeds observed at the SAB towers to date have been associated with the passages of squall lines and thunderstorms. These extreme wind events were associated with rapid decreases in air temperature, downpours, and 6-min-averaged wind speeds of 40-60 m/s.

Likewise, the high latitude sites in the Global array will make a unique contribution to improving global estimates of air-sea fluxes at extreme wind conditions by establishing the first permanent instrumented mooring in the North Atlantic near Greenland and in the remote Southern Ocean. Additionally, the West Coast endurance array, the RCO profiling moorings, and Global mooring at Station Papa in the Gulf of Alaska will provide ample opportunities to investigate the impact of mid-latitude cyclones upon the Pacific Northwest. All of these are areas of persistent high winds and storms, which will be ideal for studies of air-sea fluxes under extreme conditions. This is particularly true of the exchange of CO_2 between the ocean and atmosphere at mid to high latitudes where CO_2 exchange may be significantly enhanced by white-capping. The primary oceanic sinks of atmospheric CO_2 over the global ocean occur at mid- to high-latitudes. Therefore, an accurate parameterization of the CO_2 flux in these regions is of critical importance for accurate estimates of the global carbon budget, climate model forecasts, and ultimately predictions of climate variability.

The Coastal components are also well situated to provide unique sites to investigate the influence of physical and biological factors on carbon cycle processes. The East and West Coast endurance arrays will permit investigators to address the coastal processing and export of carbon to the global ocean, particularly with regards to terrestrial inputs. As mentioned earlier, the two sites will provide interesting contrasts in the physical processes due to their differing shelf characteristics. However, the biogeochemical processes can also be contrasted as the Northwest is thought to be a CO_2 sink region with low anthropogenic inputs, while the Southeast has large anthropogenic inputs and its role as a source or sink of CO_2 remains an open question. Although the processes controlling CO_2 concentrations in the coastal ocean are complex, biological processes play an important role in determining the related question of whether a coastal system is heteorotrophic (supersaturated in CO_2) or autotrophic (undersaturated). To assist in these investigations, the high-power benthic nodes, moorings and towers will enable continuous measurement of nutrients, phytoplankton (using, e.g., flow cytometry) and other parameters. The power and bandwidth at the towers and benthic nodes are expected to support a wide range of other sensors to provide time series observations of phytoplankton, zooplankton, and higher trophic levels. Observations of phytoplankton to fish are required to investigate processes involved in ecological response to climate change. Therefore, these studies are expected to complement similar studies conducted in the open-ocean using infrastructure from the RCO and Global arrays. Additionally, the coastal sites will enable testing of new techniques and technology before they are deployed on deep ocean moorings.

The elements of the West Coast endurance array in the PNW are proposed to be integrated directly into the RCO, providing a coastal extension to the regional plate-scale observatory. In addition to shared resources and cyber-infrastructure, the coupled RCO-West Coast endurance array will provide infrastructure across ocean boundaries where continuous measurements have not been possible to date. Many of the scientific questions identified on the shelf and near coastal regions of the entire U.S. West Coast (ORION Executive Steering Committee 2005) are influenced and mediated by the western boundary conditions. Coupling the coastal observations with the RCO will help resolve the lateral advection and exchange on the shelf influencing benthic-pelagic coupling, biogeochemical cycles and ocean-atmosphere fluxes, mesoscale mixing, food web dynamics, and shelf transport of riverine inputs. The high frequency sampling will also serve to differentiate event time scales (i.e., episodic versus seasonal). Off-shore forcing measured by the RCO will also provide insight to the modulation and intensity of coastal current systems (i.e., California Current System and California Undercurrent), and will, over a sustained period of time, provide the necessary data to examine how these changes in forcing are linked with basin-scale oscillations such as the Pacific Decadal Oscillation (PDO). The West Coast endurance array also will provide additional opportunities to examine Earth structure and the influence of subduction processes on shelf morphology. As such, the Coastal component is expected to contribute to investigation of a fourth topic from the Global CND, Earth structure and global geodynamics, through its linkages with the RCO.

The Coastal Pioneer Array will be exceedingly useful for investigations of all of the processes described above. The flexibility afforded by this array was one of the reasons for its strong community support at the D& I Workshop. The availability of both coastal and global Pioneer Arrays presents a number of interesting possibilities for future ORION programs. For example, one could image the deployment of both arrays in the Gulf of Alaska to investigate processes that contribute to its productive ecosystems and how they are influenced by climate variability.

References

Daly, K., R. Jahnke, M. Moline, R. Detrick, D. Luther, G. Matsumoto, L. Mayer and K. Raybould. Report of the D&I Workshop, Salt Lake City, UT, 27-30 March 2006. 36 pp. http://www.orionprogram.org/di_workshop.html

Detrick, R., D. Frye, J. Collins, J. Gobat, M. Grosenbaugh, R. Petit, A. Pleuddeman, K. von der Haydt, and E. Horton. 2000. DEOS Moored Buoy Ocean Observatory Design Study, http://obslab.whoi.edu/buoy.html

Glenn, S. M. and T. D. Dickey, eds., 2003, SCOTS: Scientific Cabled Observatories for Time Series (SCOTS), NSF Ocean Observatories Workshop Report, August 26-28, 2002, Portsmouth, VA, 80 pp. http://www.orionprogram.org/PDFs/SCOTS.pdf

Jahnke, R., L. Atkinson, J. Barth, F. Chavez, K. Daly, J. Edson, P. Franks, J. O'Donnell, and O. Schofield. 2002. Coastal Ocean Processes and Observatories: Advancing Coastal Research, Report on the CoOP Observatory Science Workshop, May 7-9, 2002, Savannah, GA, Coastal Ocean Processes (CoOP) Report Number 8, Skidaway Institute of Oceanography Technical Report TR-02-01.
http://www.skio.usg.edu/coop/materials/COS_report.pdf

Jahnke, R., J. Bane, A. Barnard, J. Barth, F. Chavez, H. Dam, E. Dever, P DiGiacomo, J. Edson, R. Geyer, S. Glenn, K. Johnson, M. Moline, J. O'Donnell, J. Oltman-Shay, O. Persson, O. Schofield, H. Sosik, and E. Terrill. 2003. Coastal Observatory Research Arrays: A Framework for Implementation Planning, Report on the CoOP CORA Workshop, 12-13 November 2003, Chicago, IL, Coastal Ocean Processes (CoOP) Report Number 9, Skidaway Institute of Oceanography Technical Report TR-03-01, 77 pp.
http://www.skio.usg.edu/research/coop/cora.php

ORION Executive Steering Committee. 2005, Ocean Observatories Initiative Science Plan. Washington, DC. 102 pp.
http://www.orionprogram.org/PDFs/OOI_Science_Plan.pdf

Purdy, G. M. and D. Karl, eds., 2004, RECONN: Regional Cabled Observatory Network (of Networks), NSF Report of the Cabled Regional Observatory Workshop, October 7-10, 2003, San Francisco, CA, 64 pp.
http://www.orionprogram.org/PDFs/reconn_rpt.3.2.04.pdf

Rudnick, D. L. and M. J. Perry, eds. 2003. ALPS: Autonomous and Lagrangian Platforms and Sensors. Workshop Report, 64 pp., http://www.geo-prose.com/ALPS

Schofield, O. and M. K. Tivey, eds. 2005. ORION: Ocean Research Interactive Observatory Networks, NSF Ocean Observatories Workshop Report, January 4-8, 2004, San Juan, PR, 140 pp. http://www.orionprogram.org/PDFs/workshop_report.pdf

Table 1. Summary of Coastal RFA Responses

Lead PI	Short Title
Able	Flux of Macrofauna in Estuarine & Coastal Ocean of the Middle Atlantic Bight
Anderson	Harmful Algal Bloom Dynamics in the Gulf of Maine
Barth	Dynamics and Ecosystem Response in the Northeast Pacific
Brooks	A Hawaii Coastal Observatory
Beardsley	Air-Sea Interaction, Cyclogenesis & Ocean Response
Chang	Santa Barbara Channel and Basin Observatory
Coakley	Barrow Coastal Observatory
Dever	California Current Ecosystem Observing System
Elgar	Near-shore Sediment Transport Array
Gawarkiewicz	Shelf-break Coastal Observatory in the Middle Atlantic Bight
Geyer	Transformation & Exchange between Estuaries & Shelf
Green	Bio-acoustic Ocean Observatories
Horne	Fluxes of Pelagic Nekton
Jumars	Gulf of Maine Coastal Observatory
Klinck	Estuarine/Shelf/Ocean Exchange in the Middle Atlantic Bight
Lohrenz	Gulf of Mexico Plume Transformations Observatory
McGillis	Controls on Carbon Cycle in Middle Atlantic Bight
Pawlak	A Hawaii Coastal Observatory
Rothschild	Gulf of Maine and Georges Bank Ecosystem Observation & Prediction System
Seim	Observatory on the South Atlantic Bight Shelf and Slope
Trowbridge	Dynamics of Heat, Salt, Nutrients & Plankton
Zika	Straits of Florida Coral Reef Observing Network

Table 2: Reduced Menu of Coastal Options Presented at the D&I Workshop

Array Name	OOI Elements	Selected Scientific Questions	Innovative Technology and Leverage	RFAs Enabled (Table 1; identified by lead PI)	Estimate of Minimum Cost
Oahu Endurance Array	Cable extension to 100-m node, AUV, UAV, profiler, HF radars	Permeable & biogeochemically active seafloor, mesoscale forcing	AUVs, UAVs, leveraged Kilo Nalu array	Brooks, Pawlak, Green	$2M
Pacific Northwest Endurance Array	5-element mooring lines at Washington & Oregon, 4 glider lines, HF radars	Coastal response to climate change and long term Pacific forcing	Profiling moorings; leveraged NANOOS, STC, CORIE and PISCO observation and modeling assets	Barth, Beardsley, Dever, Horne, McGillis	$15M
West Coast Pioneer Array	6 hybrid upper & deep profilers, 12 shelf mooring sets	Shelf response to buoyancy & topo, mesoscale variability	Profiling moorings	Barth, Beardsley, Dever, Chang, Geyer	$15M
Gulf of Maine Endurance Array	1 cable to 120 m with 3 nodes, 3 profiling moorings, 2 glider lines	Responses of primary production & benthic-pelagic coupling to climate change	Cable, advanced acoustical & optical instrumentation, leveraged GoMOOS array	Anderson, Jumars, Trowbridge	$10M
Shelfbreak Pioneer Array	5 surface moorings, 10 subsurface profilers, 6 repeater moorings, 3 AUVs, 2 docking stations, gliders	Shelf-ocean exchange, carbon budget	Profiling moorings, advanced AUVs & docking stations, leveraged NJSOS & MVCO Arrays	Beardsley, Geyer, Gawarkiewicz, Jumars, Klink, Lohrenz, Rothschild, Trowbridge	$16M
South Atlantic Bight Endurance Array	1 cable to 5 towers, 1 cable to 1 surface and 4 subsurface moorings, CPIES	Impact of western boundary current on shelf dynamics, biogeochemistry & ecosystem; air-sea interaction	Cables, leveraged SABSOON and SEACOOS arrays and towers	Able, Beardsley, Klinck, McGillis, Seim, Trowbridge	$20M

Acronym key. AUV: Autonomous Underwater Vehicle; CPIES: Current and Pressure Recording Inverted Echo Sounders; GoMOOS: Gulf of Maine Observing System; HF: High Frequency; MVCO: Martha's Vineyard Coastal Observatory; NANOOS: Northwest Association of Networked Ocean Observing Systems; NJSOS: New Jersey Shelf Observing System; SABSOON: South Atlantic Bight Synoptic Off-shore Observational Network; SEACOOS: Southeast Atlantic Coastal Ocean Observing System; STC: Science and Technology Center; UAV: Unmanned Aerial Vehicle.

Table 3a. West Coast Endurance Array

Item	Capital Cost	Annual O&M Cost
Central Oregon cabled mooring line (Table 3b)	$6,971,000	$1,955,270
Central Washington mooring line (Table 3c)	$5,839,000	$2,257,120
Gliders with core instrumentation (12 @ $150,000)	$1,800,000	$900,000
Central California mooring (Table 3d)	$684,000	$322,100
Southern California mooring line (Table 3e)	$1,263,000	$439,340
Total Cost of West Coast Endurance Array	**$16,557,000**	**$5,873,830**

Table 3b. West Coast Endurance Array: Central Oregon Line

Item		Capital Cost	Annual O&M Cost
25-m site:	Surface mooring with power & comms	$237,000	$78,210
	Medium-voltage benthic node	$1,000,000	$100,000
	Full-depth profiler	$200,000	$66,000
	Profiler hardware	$120,000	$39,600
	Subtotal	**$1,557,000**	**$283,810**
50-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
80-m site:	Surface mooring with power & comms	$237,000	$78,210
	Medium-voltage benthic node	$1,000,000	$100,000
	Full-depth profiler	$200,000	$66,000
	Profiler hardware	$120,000	$39,600
	Subtotal	**$1,557,000**	**$283,810**
150-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
500-m site:	Surface mooring with power & comms	$237,000	$78,210
	Medium-voltage benthic node	NC	NC
	Deep & shallow profiling	$570,000	$188,100
	Subtotal	**$807,000**	**$266,310**
Cable extension from 500-m isobath to 25-m isobath		**$680,000**	**$50,000**
Core instrumentation:			
met package at 25, 50, 80, 150, 500 m		$150,000	$50,000
profiler package at 25, 50, 80, 150 m; 2 at 500 m		$210,000	$70,000
benthic package at 25, 80, 500 m		$105,000	$35,000
ADCP at 25, 80 m; 2 at 500 m		$100,000	$33,000
CT sensors at 25, 80, 500 m		$100,000	$33,000
Subtotal		**$665,000**	**$221,000**
Non-recurring engineering		**$600,000**	
Installation (including ship time)		**$207,000**	
Annual O&M ship time:			
Maintenance (12 days small vessel)			$24,000
Mooring turnaround (9 days regional vessel)			$180,000
Service benthic (10 days regional vessel + ROV)			$350,000
Subtotal			**$554,000**
Total Cost of Central Oregon Line		**$6,971,000**	**$1,955,270**

Table 3c. West Coast Endurance Array: Central Washington Line

Item		Capital Cost	Annual O&M Cost
25-m site:	EOM mooring with power & comms	$512,000	$168,960
	Low-voltage benthic node	$161,000	$32,200
	Profiler hardware	$120,000	$39,600
	Full-depth profiler	$200,000	$66,000
	Seafloor cable with 2 connectors	$42,000	$21,000
	Subtotal	**$1,035,000**	**$327,760**
50-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
80-m site:	EOM mooring with power & comms	$512,000	$168,960
	Low-voltage benthic node	$161,000	$32,200
	Profiler hardware	$120,000	$39,600
	Full-depth profiler	$200,000	$66,000
	Seafloor cable with 2 connectors	$42,000	$21,000
	Profiler cable	$12,000	-
	Subtotal	**$1,047,000**	**$327,760**
150-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
500-m site:	EOM mooring with power & comms	$512,000	$168,960
	Low-voltage benthic node	$161,000	$32,200
	Deep & shallow profiling	$570,000	$188,100
	Seafloor cable with 2 connectors	$42,000	$21,000
	Subtotal	**$1,285,000**	**$410,260**
Core instrumentation:			
	met package at 25, 50, 80, 150, 500 m	$150,000	$50,000
	profiler package at 25, 50, 80, 150 m; 2 at 500 m	$210,000	$70,000
	benthic package at 25, 80, 500 m	$105,000	$35,000
	ADCP at 25, 80 m; 2 at 500 m	$100,000	$33,000
	CT sensors at 25, 80, 500 m	$100,000	$33,000
	Subtotal	**$665,000**	**$221,000**
Non-recurring engineering		**$500,000**	
Installation (including ship time)		**$409,000**	
Annual O&M ship time:			
	Maintenance (12 days small vessel)		$24,000
	Mooring turnaround (15 days regional vessel)		$300,000
	Service benthic (10 days regional vessel + ROV)		$350,000
	Subtotal		**$674,000**
Total Cost of Central Washington Line		**$5,839,000**	**$2,257,120**

Table 3d. West Coast Endurance Array: Central California Mooring

Item	Capital Cost	Annual O&M Cost
900-m site: deep/shallow profiling at MARS node	$570,000	$188,100
Core instrumentation: 2 profiling packages	$70,000	$23,000
Installation (including ship time)	$44,000	
Annual O&M ship time:		
Maintenance (3 days small vessel)		$6,000
Profiler (3 days regional vessel + ROV)		$105,000
Total Cost of Central California Mooring	**$684,000**	**$322,100**

Table 3e. West Coast Endurance Array: Southern California Line

Item		Capital Cost	Annual O&M Cost
80-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
500-m site:	Surface mooring with power & comms	$237,000	$78,210
	Profiler cable	$12,000	$3,960
	Full-depth profiler	$200,000	$66,000
	Subtotal	**$449,000**	**$148,170**
Core instrumentation:			
Met package at 80 and 500 m		$60,000	$20,000
Profiler package at 80 m, 2 at 500 m		$105,000	$35,000
Subtotal		**$165,000**	**$55,000**
Non-recurring engineering		**$100,000**	
Installation (including ship time)		**$100,000**	
Annual O&M ship time:			
Maintenance (4 d small vessel)			$8,000
Mooring (4 d regional vessel)			$80,000
Subtotal			**$88,000**
Total Cost of Southern California Line		**$1,263,000**	**$439,340**

Table 4. East Coast Endurance Array

Item	Capital Cost	Annual O&M Cost
Shore landing at SkIO	$600,000	
Main cable (SKIO to inner shelf node to R2 to R3)	$3,281,000	$656,200
Dry MV nodes at towers R2 and R3	$1,035,250	$103,525
LV benthic nodes at towers R2 and R3	$466,620	$93,324
Installation of cable and nodes (including ship time)	$1,756,500	
Profilers at benthic nodes at towers R2 and R3	$600,000	$200,000
Core instrumentation at moorings and towers:		
Met package at towers R2 and R3	$60,000	$20,000
Profiler package at R2 and R3	$70,000	$23,000
Benthic package at R2 and R3	$70,000	$23,000
ADCP at R2, R3	$50,000	$17,000
Gliders with core instrumentation (6 @ $150,000)	$900,000	$450,000
MOOS power and comms on towers R4 and R8	$550,000	$55,000
HF radars on towers R4 and R8	$540,500	$108,100
Inner shelf MV benthic node	$1,060,500	$212,100
Profiler at inner shelf benthic node	$200,000	$67,000
Additional core instrumentation at moorings and towers:		
Met package at towers R4 and R8	$60,000	$20,000
Profiler package at inner shelf profiler	$35,000	$12,000
Benthic package at inner shelf profiler	$35,000	$12,000
ADCP at inner shelf profiler	$25,000	$8,000
Ship time for annual O&M: 14 d regional vessel + ROV		$490,000
Total Cost of East Coast Endurance Array	**$11,395,370**	**$2,570,249**

Table 5. Pioneer Array

Item	Capital Cost	Annual O&M Cost
4 EOM moorings	$4,874,000	$1,608,420
5 subsurface profiling moorings	$1,130,000	$372,900
4 acoustic repeater moorings	$197,960	$39,592
3 long-range AUVs with core instrumentation	$3,000,000	$990,000
2 AUV docking stations	$3,250,000	$650,000
12 gliders with core instrumentation	$1,800,000	$900,000
Core instrumentation for moorings:		
Met packages on 4 EOM moorings	$120,000	$40,000
Profiling packages at 5 profiling moorings	$165,000	$55,000
Benthic packages at 4 EOM moorings	$140,000	$47,000
ADCP at 4 EOM moorings	$100,000	$33,000
CT sensors	$50,000	$17,000
Installation (including ship time)	$505,000	
Core instrumentation for moorings and AUVs	$1,250,000	$412,500
Ship time for annual O&M: 14 d regional vessel + ROV		$980,000
Total Cost of Pioneer Array	**$16,581,960**	**$6,145,412**

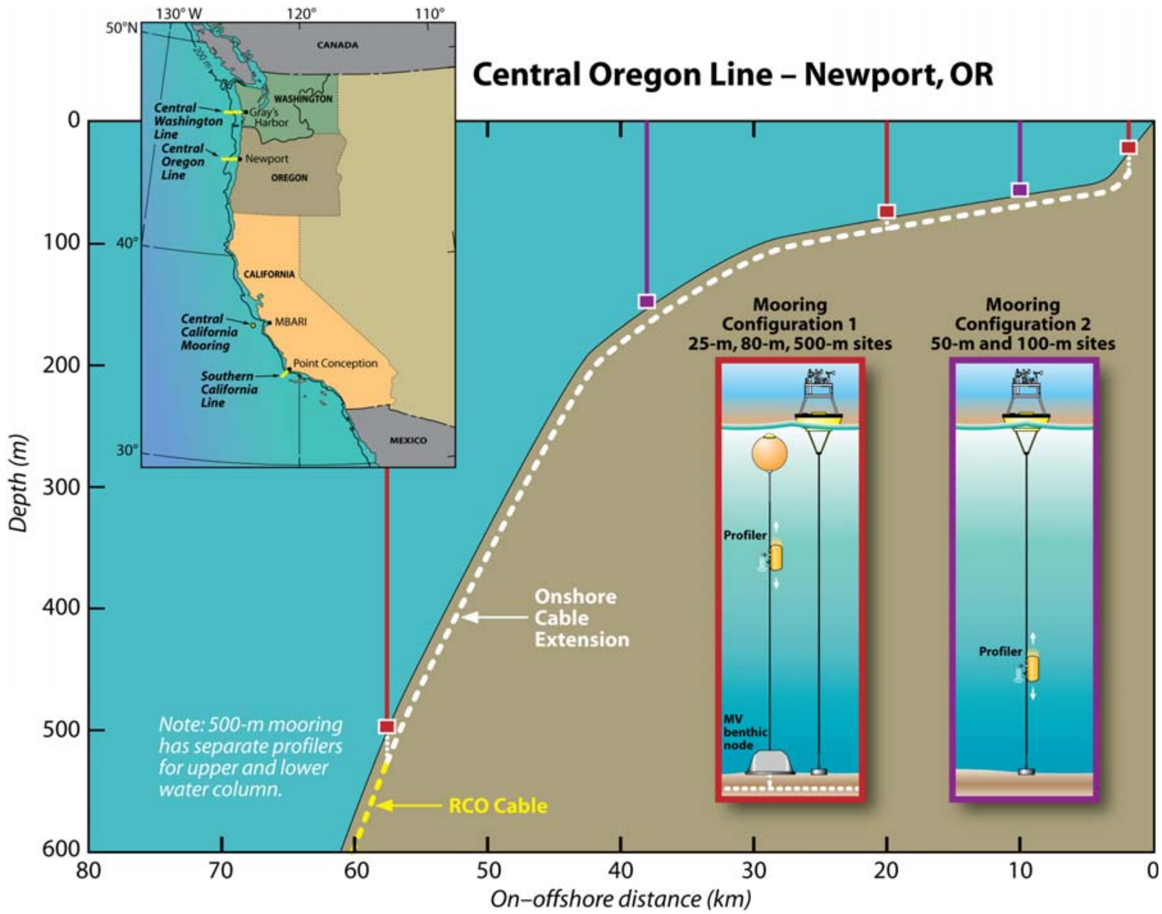

Figure 1. Map showing the West Coast Endurance Array (inset) with schematic diagram of the Central Oregon Line. The West Coast Endurance Array consists of a Central Washington Line, a Central Oregon Line, a Central California Mooring, a Southern California Line, and a glider array (not shown). At the Central Oregon Line, the RCO cable will be extended onshore to the 25-m isobath. MV benthic nodes will be connected to the cable at the 25-m, 80-m and 500-m isobaths, and these sites will be equipped with cabled surface profilers and independent surface moorings to support meteorological sensors. Surface moorings with profilers will occupy the 50-m and 150-m sites. Instrumentation and glider transects are not shown.

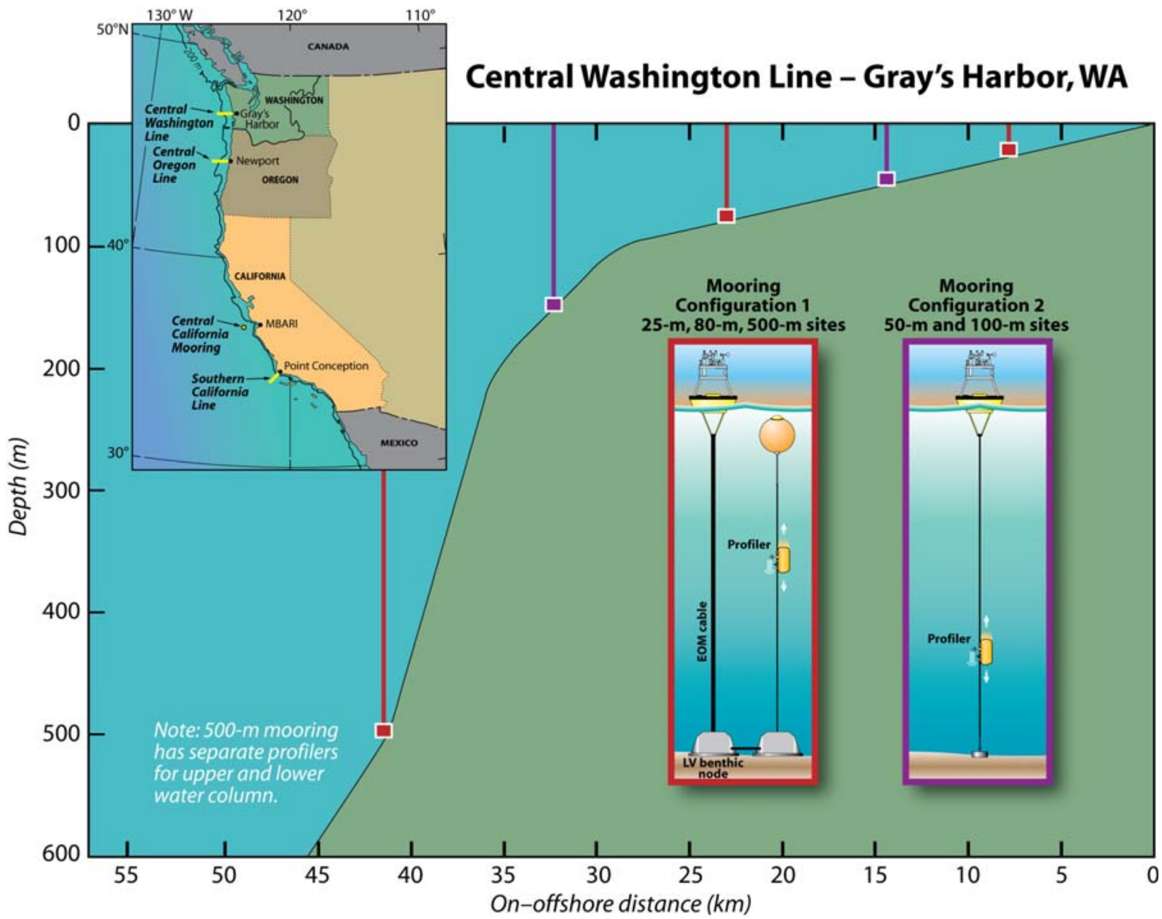

Figure 2. Map showing the West Coast Endurance Array (inset) with schematic diagram of the Central Washington Line. The West Coast Endurance Array consists of a Central Washington Line, a Central Oregon Line, a Central California Mooring, a Southern California Line, and a glider array (not shown). At the Central Washington Line, EOM moorings connected to benthic nodes and profilers will occupy the 25-m, 80-m and 500-m isobaths, and surface moorings with profilers will occupy the 50-m and 150-m isobaths. Instrumentation and glider transects are not shown.

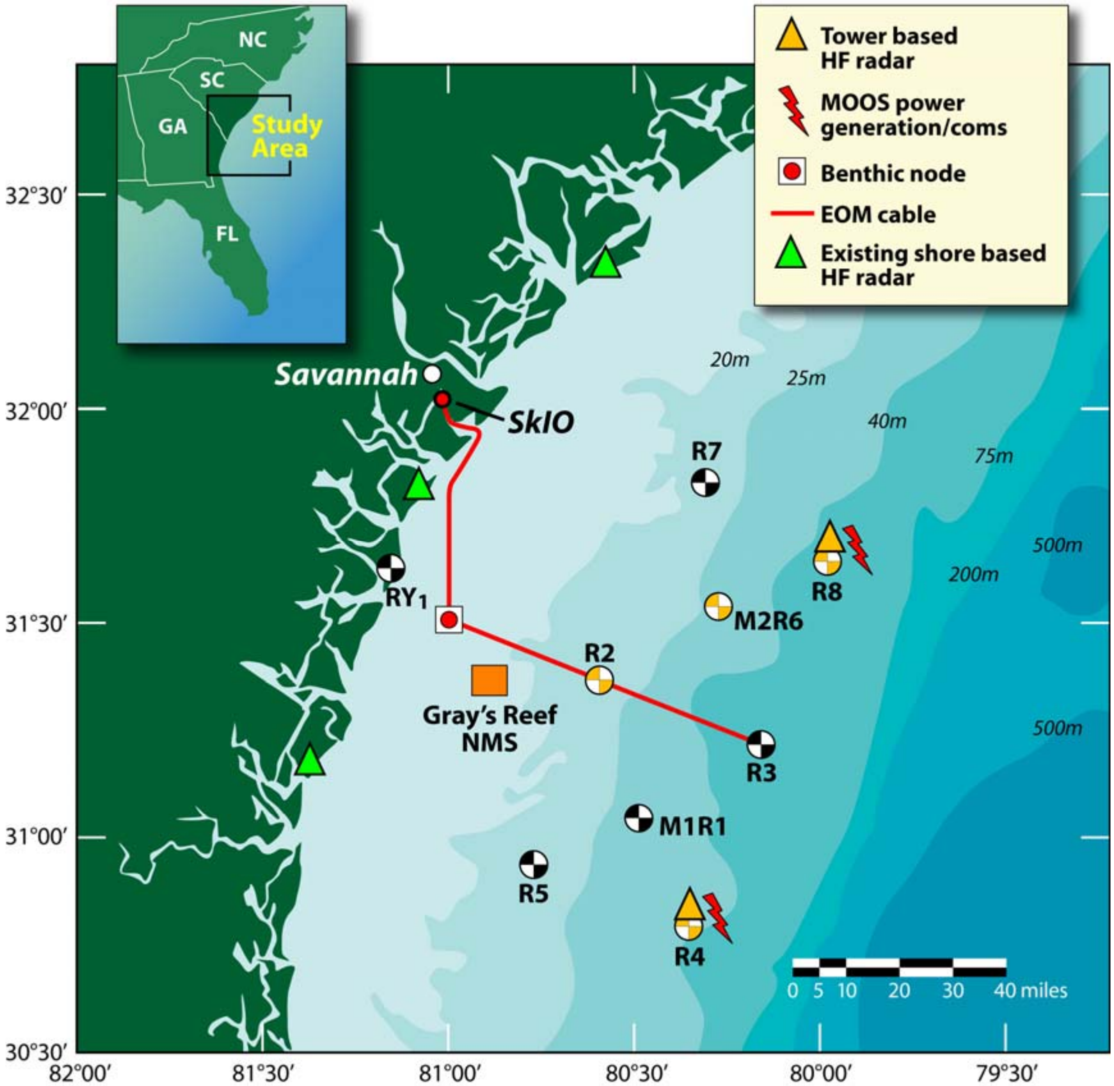

Figure 3. Map showing the elements of the SAB Endurance Array. Also shown are the existing Navy towers R2, R3, R4, R5, R7, R8, M1R1 and M2R6, some of which are part of the ongoing SEACOOS and SABSOON programs. The seafloor cable will extend from a shore landing near Skidaway Institute of Oceanography to a seafloor node near 31.5N, 81W and then to towers R2 and R3, which will be equipped with dry nodes, benthic nodes, and water-column profilers (not shown). High-frequency (HF) radars will be placed on towers R4 and R8, which will complement existing shore-based HF radars, and Monterey Ocean Observing System (MOOS) units on towers R4 and R8 for power and two-way communications. Glider transects (not shown) will complement the fixed assets.

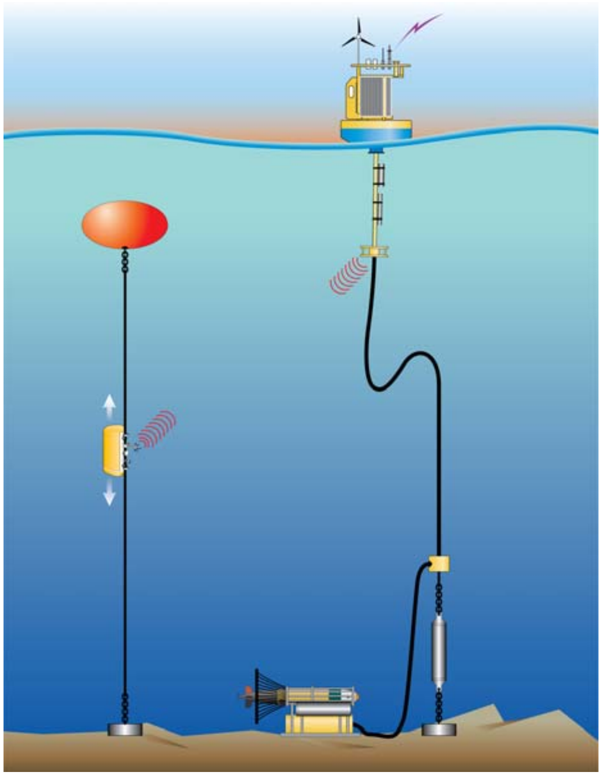

Figure 4. Schematic diagram of selected components of the Pioneer Array. EOM moorings (with surface expressions equipped with capabilities for power generation and satellite transmissions) provide power and two-way communications to an AUV fleet by means of a bottom mounted docking station, while also providing two-way communications to a sensor suite on a nearby internally powered profiling mooring, by means of acoustic telemetry. Other elements of the array are EOM moorings (with surface expressions equipped with capabilities for power generation and satellite communication) that are devoted to instrumentation on the mooring itself, repeater moorings for longer-range acoustic transmissions, and gliders for spatial sampling that complement the AUV measurements (Fig. 5).

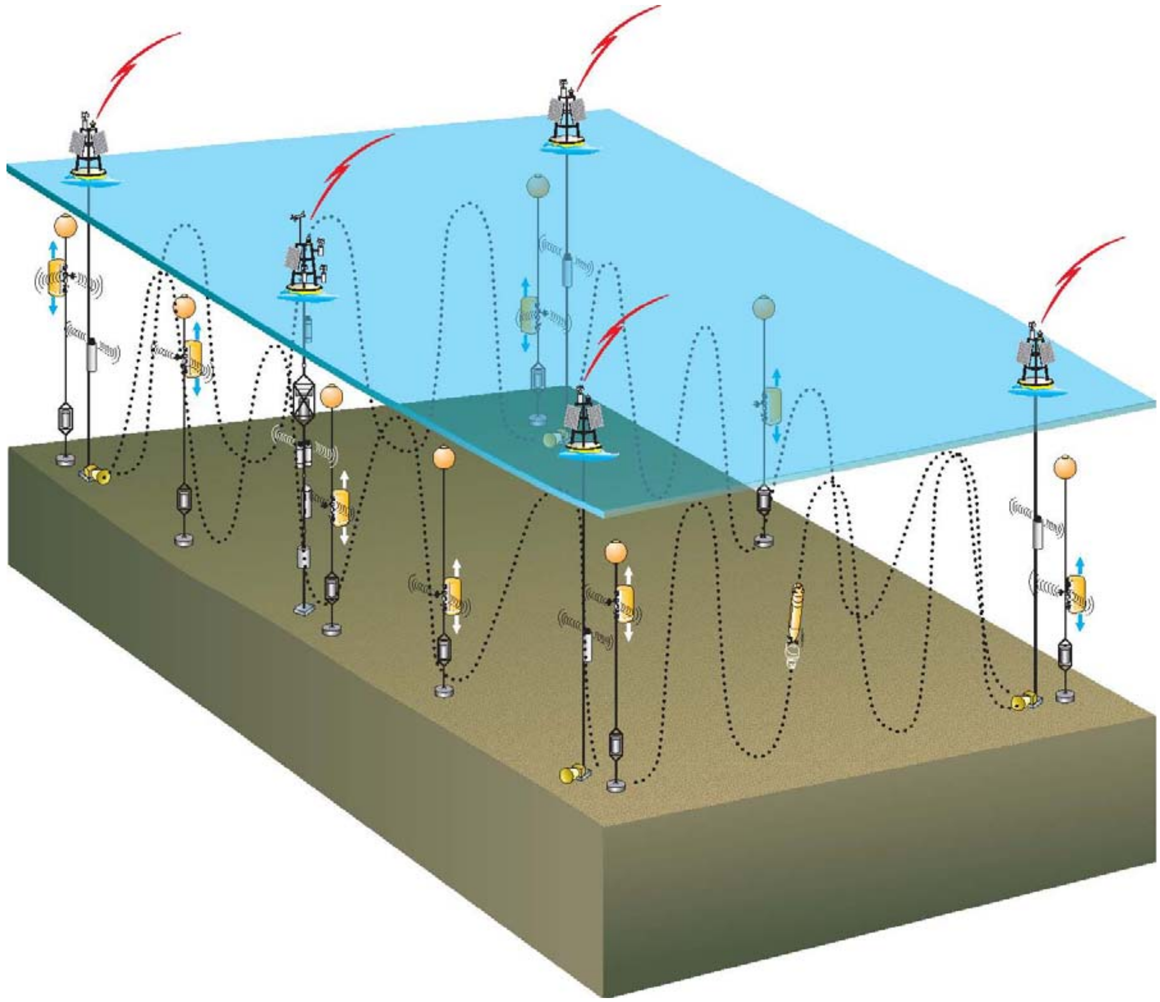

Figure 5. Schematic diagram of the pioneer array, showing EOM moorings with surface expressions, subsurface profilers, acoustic repeater moorings, and AUV transects. Glider transects (not shown) will sample off-shore and onshore of the mooring array.

Appendix: Other Highly Regarded Coastal Concepts

Because of funding constraints, a number of excellent concepts that emerged in the RFA process and D&I Workshop could not be included in the Coastal CND that was presented in Section 4. The following is a brief description of three particularly compelling concepts, which should be considered if additional funding for the Coastal Component of the OOI becomes available.

A.1 Gulf of Maine Endurance Array

The Gulf of Maine (GoM) is a highly productive, semi-enclosed basin characterized by a combination of deep depositional basins surrounded by a shallow shelf and exchanges with the open ocean through well defined channels, a heterogeneous bottom with persistent and intense nephloid layers, and a persistent buoyancy-driven equatorward coastal current that is driven by a distributed river system. The engaging scientific questions focus on the effects of climate variability on ecosystem dynamics, and in particular the dependence of phytoplankton community composition on water column stability and nutrient ratios (which appear to be directly controlled by large scale forces operating on oceanic water masses entering the Gulf of Maine), dependence of phytoplankton productivity on storms and episodic events, carbon fluxes as a function of phytoplankton composition, nonlinear response of functional groups to environmental forcing, and benthic-pelagic coupling. A proposed OOI array (Figure A1) benefits from the existing Gulf of Maine Observing System (GoMOOS) and consists of a seafloor cable with benthic nodes equipped with profiling moorings and benthic boundary layer packages, in addition to a glider fleet. The transformative aspects of this program were stimulated by the design of the cable-requiring benthic sensors which included bottom-mounted multi-frequency radially-scanning sonars, bubble scanners and combination holographic-particle imaging velocimeters to assess an expected developing reef effect, benthic production events, and to quantify near bed particles and organisms on the same scales as bottom boundary layer dynamics. These benthic observatories are to be coupled to profiling moorings to assess water column ecosystem dynamics in a very dynamic coastal current. Revisions of this original design (discussed at the D&I Workshop) aim to replace the extensive cable infrastructure with additional moorings and glider lines to maintain controlled volume observations and to better characterize both hydrographic and biogeochemical properties of the water column.

A.2 Oahu Endurance Array

The Oahu site is unique within the OOI context because of its subtropical coral reef environment, seafloor sediment composition and exposure to forcing by processes characteristic of the deep ocean. The scientific issues include (1) benthic exchange processes across a range of bottom conditions in the presence of a highly permeable and biogeochemically active seafloor, (2) interactions and links between off-shore and near-shore geochemistry under variable physical forcing driven by internal tides and mesoscale eddies, (3) transformation between off-shore baroclinic tidal energy and near-shore currents, (4) biochemical response in the water column to physically driven sediment fluxes of nutrients, and (5) dynamics of the carbonate system in the surface water and the consequent effects of ocean acidification on coral reef ecosystems. A possible array (Figure A2) benefits from the existing Kilo Nalu Near-shore Reef Observatory and includes, in addition to a cabled system, autonomous vertical profilers, a high-resolution near-bed turbulence profiler, and shipboard, AUV and unmanned aerial vehicle (UAV) surveys.

A.3 Middle Atlantic Bight (MAB) Endurance Array

As noted in Section 4.4, the MAB is characterized by a relatively broad shelf, a persistent equatorward current originating well north of the United States, a well defined shelf-slope front, variable wind forcing, distributed buoyancy inputs by a number of rivers, and off-shore forcing by intermittent rings shed by an energetic western boundary current (the Gulf Stream). A compelling science problem for this region is to understand the biological and physical controls on the overall carbon balance. Specific tasks related to this objective include continuous measurements of the spatial and temporal distributions of the carbonate system (O_2, N_2, CDOM, pH, chlorophyll, atmospheric forcing and bubble concentration); cross-shelf transect measurements of CO_2, O_2, N_2, pH and other quantities; measurement of the spatial and temporal variability of near-surface ocean turbulence and waves; and direct measurements of the air-sea gas flux. Relevant infrastructure (Figure A3) capitalizes on the existing MVCO and NJSOS observatories and includes cross-shelf mooring lines and glider transects, deployments of the Pioneer Array, and moorings in the entrances to major estuaries.

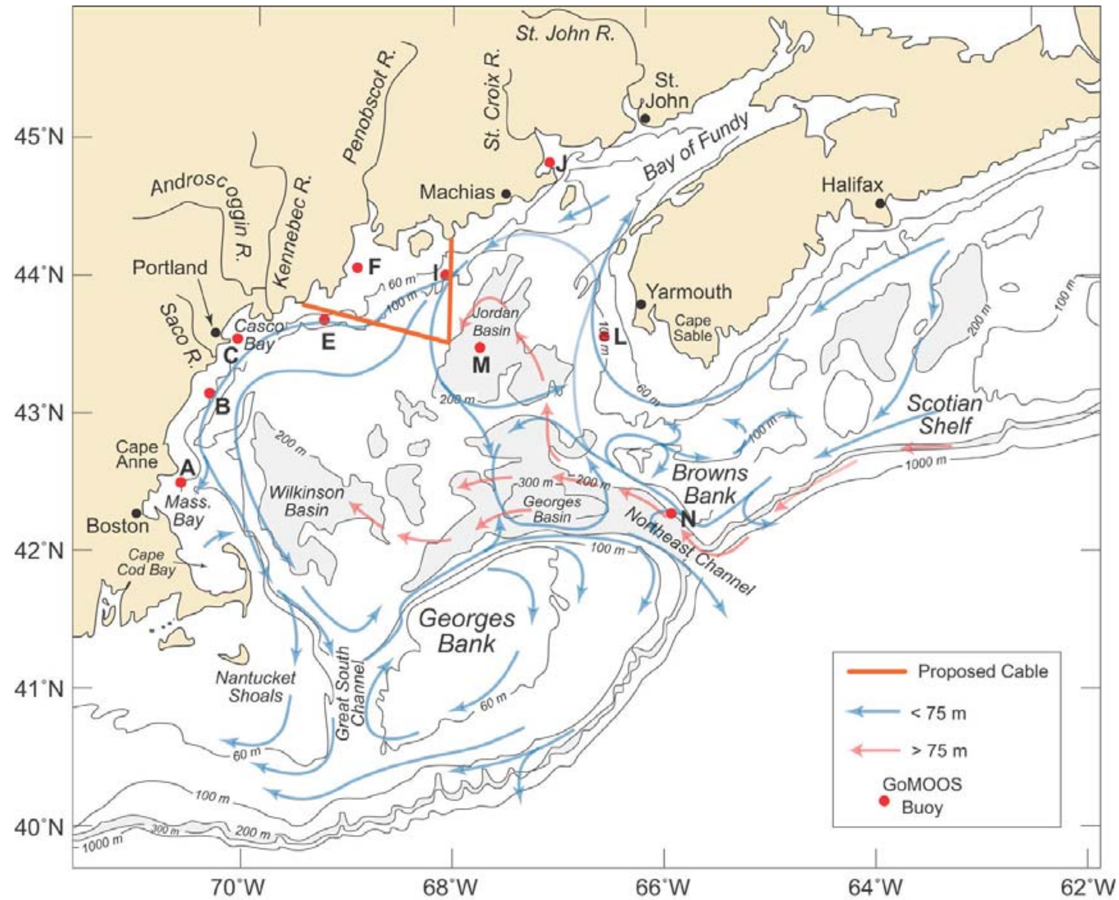

Figure A1. Schematic diagram of a possible cabled endurance array in the Gulf of Maine. See text for details. Possible modifications were discussed at the D&I workshop.

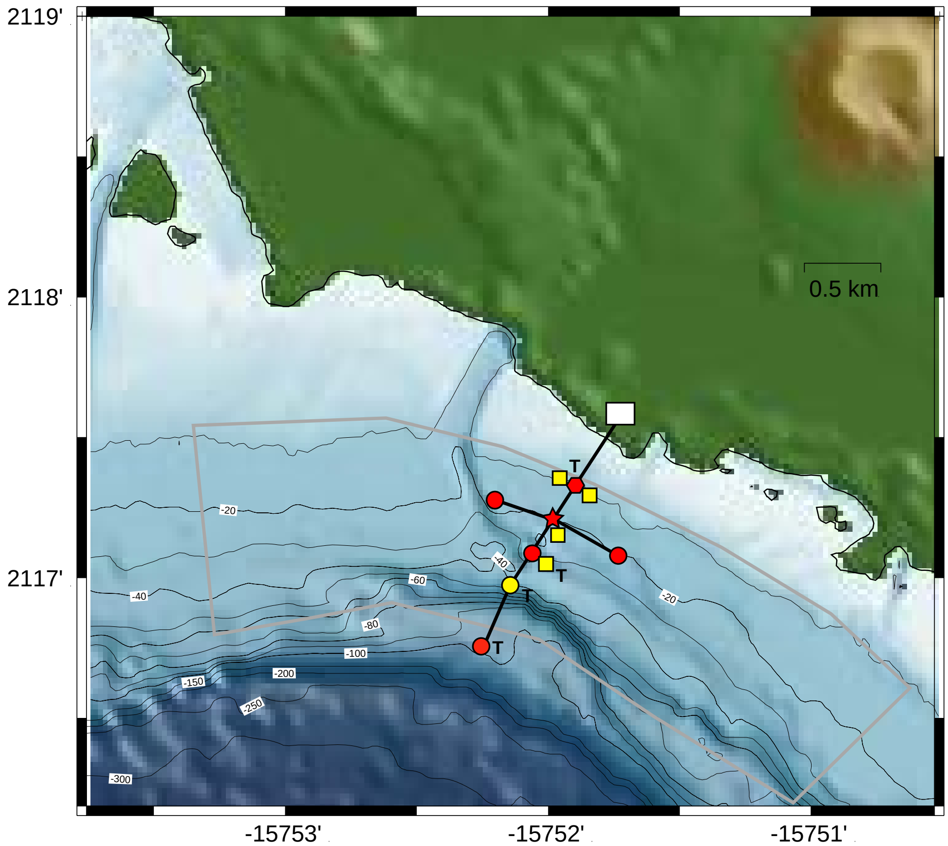

Figure A2. South Oahu bathymetry and Kilo Nalu observational array with possible enhancements (bottom), including 10-m node with lateral sandy and reef bed sites, 20-m node with lateral sub-nodes, 30-m node, 40-m sub-node, and 100-m node, with geochemistry sites (yellow boxes), thermistor chains (T), autonomous profiler (star), and ADCPs (red symbols).

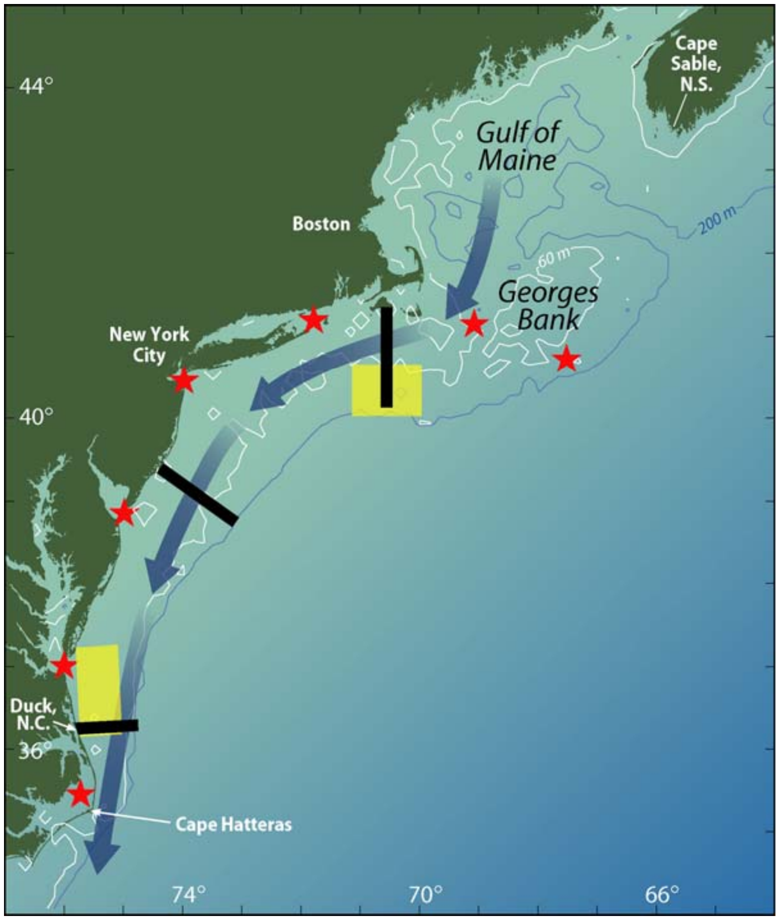

Figure A3. Schematic diagram of a possible endurance array in the Middle Atlantic Bight (MAB). Array elements include cross-shelf glider and mooring lines off Massachusetts, New Jersey, and North Carolina, and moorings (red stars) in the mouths of major estuaries. Potential Pioneer Array deployments (yellow squares) are near the shelf break and the Chesapeake Bay outflow.