Proposal to:

Office of Naval Research

A PROPOSAL TO IMPLEMENT THE GULF OF MAINE OCEAN OBSERVING SYSTEM

APRIL 18, 2000

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Proposed Start Date:	June 1, 2000	
Proposed Duration:	24 months	
Proposed Amount:	Gulf of Maine Ocean Observing System	$5,817,650

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A Proposal to Implement

THE GULF OF MAINE OCEAN OBSERVING SYSTEM (GoMOOS)

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I. INTRODUCTION

A. The Challenge

Like most coastal waters of the United States, the Gulf of Maine supports a myriad of socio-economically vital activities. In effect, the Gulf is a busy commercial highway, a productive ranch, a bountiful source of wild stocks, and an extraordinary recreational domain. Each use of the Gulf of Maine, however, is limited by gaps in our knowledge of the physical and biological parameters that define this fertile ecosystem.

These knowledge gaps present problems that range from the inconvenient to the catastrophic. The shipping industry and harbor pilots need information on currents, waves, and meteorological conditions to bring ships safely to port. Tour boat operators lack the detailed real-time data and predictions to know whether wind, wave, and other conditions are suitable for a given trip. The livelihoods of commercial ground fishermen in the once rich Gulf of Maine are under siege, and resource managers have few tools at their disposal to effectively manage the important commercial species of the Gulf. Twice in the last three decades major oil spills have coated important ecological habitats in Casco Bay, one of the busiest oil depots on the east coast, and data still are insufficient to predict the trajectories of the spills and protect coastal wetlands and other marine habitats.

Technological and scientific expertise currently exist to produce observations and knowledge that could significantly close these gaps, thus enhancing and protecting the livelihoods and well-being of those who depend on the Gulf of Maine and its ecosystem. Deploying that technology and expertise is the immediate challenge addressed in this document.

B. The Approach

A consortium of Maine research institutions, non-profit organizations, state agencies and commercial interests has developed plans for a Gulf of Maine Ocean Observing System (GoMOOS). The rationale for a regional coastal observing system has been extensively reviewed and documented in numerous regional and national workshops and reports, and is the product of a broad-based consensus of the ocean science community. Maine's plan to implement an ocean observing system in the Gulf of Maine was galvanized by its long coastline on the Gulf, its strong economic reliance on the marine environment (transportation, fishing, recreation, tourism), and the opportunity to improve the safety and efficiency of marine operations, manage fisheries, preserve and protect the Gulf ecosystem, mitigate natural hazards, protect the public health, and stimulate regional marine research. While Maine is taking the lead in this program's development, our vision is for a regional facility with broad access and participation by scientists, managers, and the public throughout New England and the Canadian Maritime Provinces.

The Gulf of Maine Ocean Observing System (GoMOOS) is proposed as a concept demonstration of an integrated, sustained ocean observing system that will serve as a pilot component of the North East Ocean Observing System (NEOOS). The NEOOS is in turn planned as one of approximately six regional observing systems envisioned to constitute a national observing system as articulated in recent reports by the National Ocean Research Leadership Council (1999), Consortium for Ocean Research and Education (1999), and the National Ocean Partnership Program's (NOPP's) Ocean Research Advisory Panel (1999). The preliminary observational system design of the GoMOOS is based in large part upon the results of an extensive survey of operational oceanographic data requirements performed by EuroGOOS (Fischer, 1999). This initial design will be refined in response to a user survey that will be commissioned specifically for the Gulf of Maine region, and in response to early operational experience.

It is important to understand that GoMOOS is not itself a "research project." That is, its principal mission is <u>not</u> to conduct (or fund) the research that will lead to a better understanding of the workings of the Gulf of Maine. Rather, GoMOOS is more accurately thought of as a "utility": the entity that will build, deploy, operate, transmit/process/archive data, and maintain the infrastructure required to do this. The data and information produced will allow those who depend on the Gulf of Maine for livelihood and well-being, and those whose business is marine research, to undertake their pursuits and enhance the understanding of the Gulf more efficiently and profitably than ever before. This does not mean that GoMOOS won't be involved in research, but this research will be sharply focused on observational techniques and technology and on creating from the collected data the products most relevant to, and in the form most needed by, the system's clientele.

As a consortium of scientists, policymakers and industry, GoMOOS represents a novel approach to establishing a broad-based coalition for building this sustained ocean observation system. GoMOOS is designed as a service organization that augments the mission and objectives of, but does not compete with, existing institutions. The rationale for creating the consortium is to institutionalize support for ocean observing, ensure the ongoing relevancy of those observations and to create an enduring structure for sustained operations. The success of this management approach will be instructive for coastal ocean observing systems in other areas.

As a pilot demonstration for regional ocean observing systems, GoMOOS has both a responsibility and an opportunity to establish operational standards and protocols for metadata, calibration, validation, data integration and management, data dissemination, and public and educational outreach. These issues will constitute an important part of the GoMOOS concept demonstration and development. GoMOOS will work closely with the Navy, NOAA and the other NOPP agencies to collaborate on the development and transfer of observing methodologies and protocols. GoMOOS is committed to providing efficient and "user -friendly" data and data products that address the information requirements of Gulf user groups. While direct transfer of the data can be effectively handled via the Distributed Oceanographic Data System (DODS), especially for scientific users, calculated indices, data summaries, data visualization products, model nowcasts and forecasts, and simple analysis tools will be provided through a web-based Graphical User Interface (GUI). The majority of the data and data products produced by the GoMOOS will be made available in real time via a GoMOOS website. In addition, mariners and others without ready internet access will be able to access via telephone the latest meteorological, wave, current and buoy data via a menu-driven computer-voice system similar to National Data Buoy Center's (NDBC's) Dial-A-Buoy service. GoMOOS will strive to develop products suitable for distribution via mass media, such as "Spotlight on the Gulf".

C. Who Will Benefit

The focus of GoMOOS' data collection activities will be based on close interaction with several sectors that particularly depend upon the systems of the Gulf and/or whose activities have profound effects on it. An initial review follows of uses of the Gulf most likely to benefit from improved or new availability of oceanographic data. It is based on a preliminary survey of users conducted during January and February 2000. This summary is likely to change as more in-depth research into the observational requirements of users is conducted during development of GoMOOS.

- Marine shipping and oil transport: Surface current data and wave modeling products from GoMOOS will enhance the safety of marine shipping operations and increase the effectiveness of oil spill response.
- Finfish aquaculture: Observations over time by GoMOOS of currents, temperature, nutrients and dissolved oxygen, integrated with remotely-sensed information on chlorophyll and turbidity, will allow aquaculturists to assess potential grow out sites and comply with water quality standards.
- Shellfish aquaculture: Information on currents, dissolved oxygen, temperature, chlorophyll and nutrients will support efforts by shellfish farmers to avoid economic and to time spat collection activities.
- Recreational boating: The transmission of simple, ongoing observations about wave and meteorological conditions in strategic locations in the Gulf will improve the safety of whale watching cruises, passenger travel, and day sailing.
- Water quality protection: Hydrographic data (especially dissolved oxygen) from the GoMOOS buoy array, and associated modeled products, will significantly augment efforts of wastewater management authorities to assess effects of municipal wastewater discharges.
- National security: With the delivery of a variety of real-time meteorological and oceanographic conditions, military experts can both provide more accurately nowcasts and forecasts of the battlespace environment.

- Research: In addition to providing primary and contextual data to researchers, GoMOOS will provide mooring platform infrastructure for independent research projects in the region.
- Education: Real-time, spatially explicit oceanographic data from GoMOOS will be the foundation for a new generation of interactive educational products, including on line "virtual laboratories," public kiosks, and aquarium exhibits.
- Commercial groundfishing: GoMOOS will provide data on important parameters, including surface temperature, currents and phytoplankton productivity, as a foundation for understanding recruitment into the threatened fisheries of the Gulf of Maine.
- Lobster fishing: Weekly average sea surface temperatures provided by GoMOOS, in concert with real-time data on the location and status of coastal currents, are crucial to the goal of predicting recruitment into the lobster fishery.
- Marine mammal protection: With passive acoustic data from GoMOOS buoys, cetacean research groups and school children can monitor the presence and migration of endangered right whales and other cetaceans in the Gulf.

II. BACKGROUND

The Gulf of Maine is a productive, marginal sea. Like most marginal seas, its exchange with the open ocean is largely controlled by interactions with offshore currents, seasonal heating and runoff, and by the geometry of the sills and channels that characterize its open boundary. Its cyclonic general circulation pattern includes a system of offshore gyres and a complex and well-developed coastal current system (Figure 1). At present this circulation diagram is little more than a schematic without spatial or temporal detail. Similar complexity, at a smaller scale, is observed in the circulation and exchange in the many bays and estuaries that exist along this highly irregular coastline. As an example, the circulation of Penobscot Bay, one of the largest embayments in the Gulf, has been studied for several years with a real-time buoy array measuring currents, wind speed and direction, and temperature and conductivity at multiple depths. These data show that the Bay is characterized by a complex interplay of classical estuarine circulation in the inner Bay and a gyre-like exchange between the outer Bay and a filament of the Eastern Maine Coastal Current. In this case, three years of observations suggest that seasonal and interannual variation in circulation and hydrography have significant impact upon larval recruitment to the Gulf's most productive regional lobster fishery.

The extant observing system presently obtaining time series measurements within the Gulf of Maine (Figure 2) consists of three long-term sea-level stations at Boston, Portland, and Eastport, three NOAA data buoys in the western Gulf (air temperature, atmospheric pressure, wind speed and direction, sea surface temperature, and significant wave height and period) and three CMAN stations (air temperature, atmospheric pressure, wind speed and direction). In addition, there are sea-level stations at Woods Hole and Nantucket, and NOAA data buoys on Nantucket shoals and the south flank of Georges Bank. This system is ill matched to even the largest of the multiple length scales that characterize the Gulf, and it includes no direct time-series observations of the

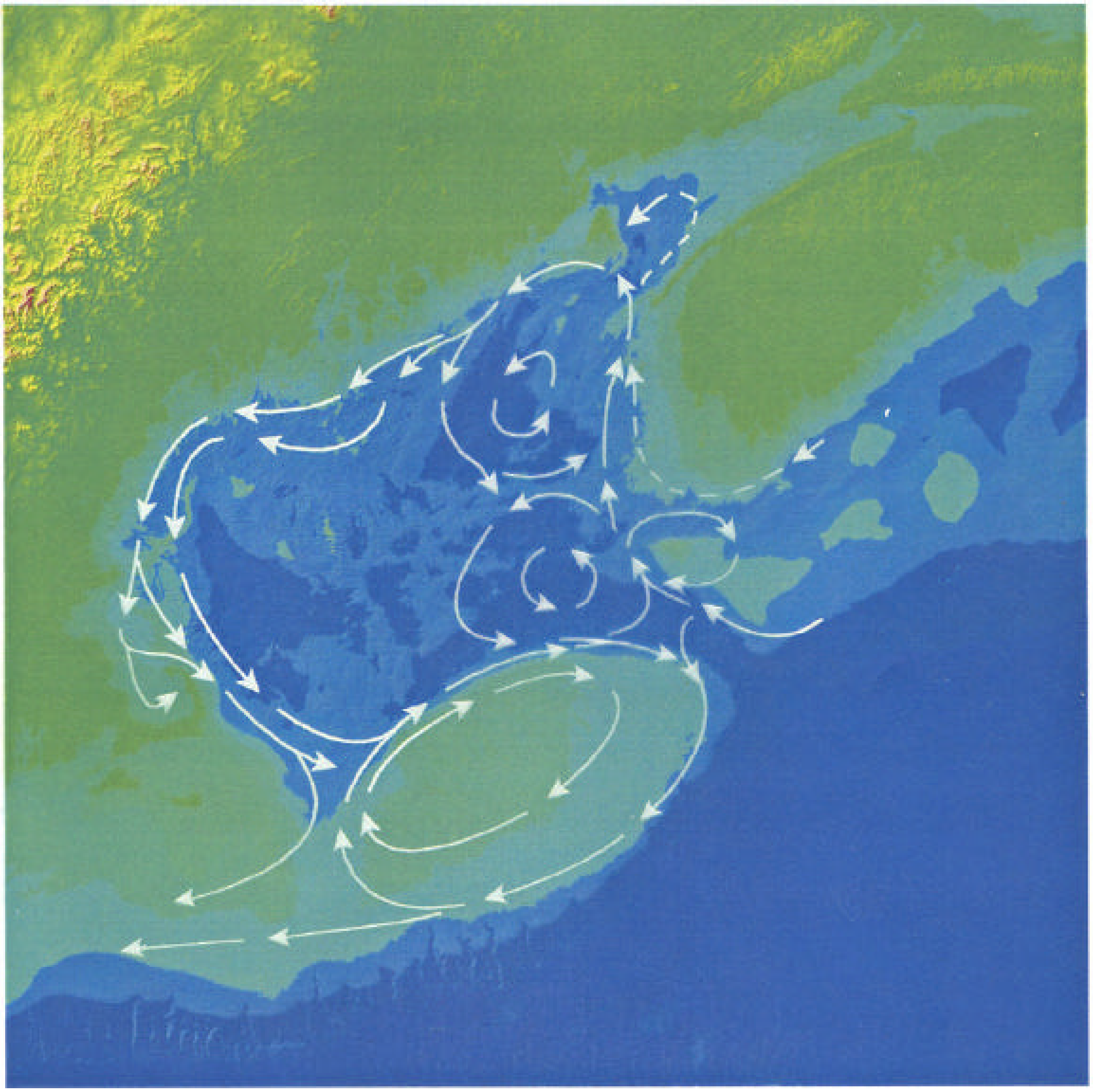


Figure 1. Schematic circulation diagram of the large-scale summer circulation in the Gulf of Maine

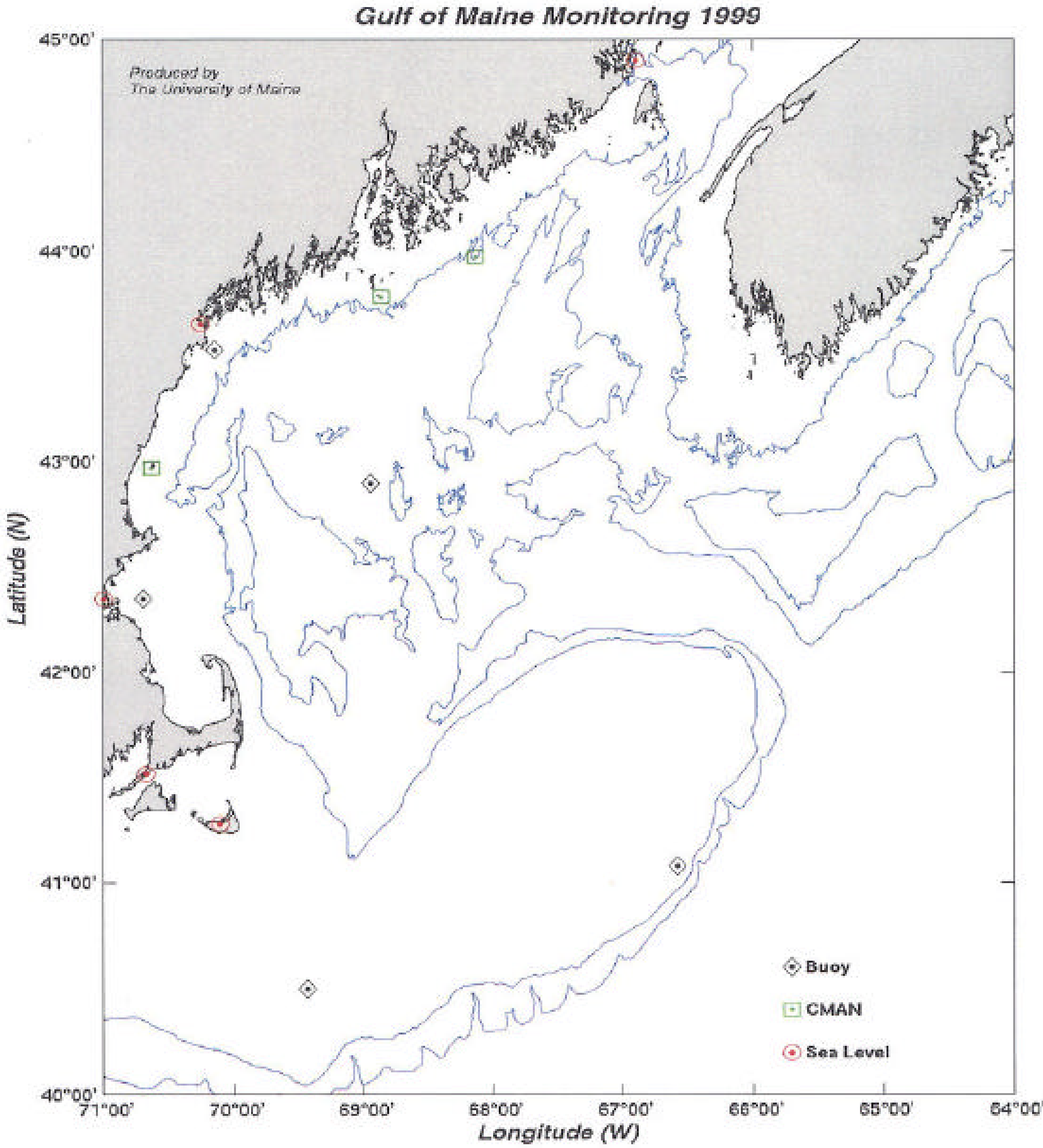


Figure 2. Locations of NDBC data buoys, C-MAN stations, and NOS coastal sea level stations currently operational in the Gulf of Maine region

general flow patterns or of subsurface water mass properties. The *in situ* observing system has been significantly augmented by satellite-derived measurements of sea surface temperature (SST) and ocean color measurements that are routinely downloaded and archived by satellite ground stations located at the University of Maine, and elsewhere. While the broad coverage and high spatial resolution of these data have greatly improved our understanding of the system, they do not measure subsurface properties and frequent fog and cloud cover, as well as weak spatial gradients in winter, make coastal regions difficult to monitor operationally via satellite data. Thus we see the need for a complementary "gray sky" observing system that can provide both remote and *in situ* information about the sea surface and the water column. The GoMOOS plan is a phased approach to establishing such an observing system.

III. GOAL AND OBJECTIVES

A. Goal

The goal of GoMOOS is to provide the data the public and private sectors need to resolve problems, predict events and to further understand the natural system relating to the Gulf of Maine.

B. Objectives

To meet this goal, GoMOOS will:

1) **Establish the infrastructure for an operational observing system** in the waters of the Gulf of Maine, make data accessible in a timely fashion, and resolutely focus the system on responding to the needs and expectations of users. The GoMOOS will establish a comprehensive and sustained ocean observation system that integrates *in situ* measurement with remote sensing; when linked to appropriate numerical models, the results can provide new understanding and ocean prediction capabilities in the Gulf of Maine.

2) **Adopt and refine an operational set of standards and protocols** for system maintenance and calibration, data management and archiving, and data and information dissemination. We will use the relevant experience of other monitoring and observing programs such as the NDBC program, the Naval Oceanographic Office and others as a starting point and tailor the GoMOOS systems to the task of providing diverse users with access to a wide range of integrated data types and products.

3) **Involve the national ocean science community** in both the design and evaluation of system structures and protocols via workshops, presentations and web-based dialog. With this approach we will begin the task of establishing operational standards and procedures for an integrated ocean observing system. Further, we have begun to assemble a team of scientists and experts from around the country who will serve as a Board of Advisors.

4) **Stimulate both basic and applied research in the region, facilitate effective resource management in the G ulf, provide commercial interests with information for decision-making and offer exceptional educational opportunities**. We foresee GoMOOS as a cornerstone of a larger regional observing system encompassing the shelf and slope waters from Cape Hatteras northward, which would constitute an important component of the anticipated integrated national system.

5) **Serve both as a test bed and germinator of new sensor technologies**. In addition to conducting field trials as new sensors become available, GoMOOS will stimulate technological development and make its buoys available to instrument designers engaged in the development or improvement of long-term monitoring instruments. The objective is to push the transition from research mode to operational monitoring mode and to calibrate and validate new developments against established technologies and techniques.

IV. INFORMATIONAL PRODUCTS FOR TARGETED USERS

A. Targeted Users

While we believe that GoMOOS will serve a variety of user groups such as those enumerated in the first section, the readiness and ability of the observation system to serve the different sectors vary; some (e.g., the shipping industry) can immediately benefit from observations that are readily achievable, while others require observations for which technologies are not yet available or affordable or for which correlations aren't yet well understood (e.g., observations relating to the recruitment of groundfisheries). The following list of targeted users is based on our preliminary user survey (see Appendix A) and surveys elsewhere, and is ordered roughly according to the likely immediacy of impact of the indicated observations on the sectors and the prominence of the issues faced in the Gulf of Maine region. GoMOOS will work with teams of industry, managers, researchers and others to refine the specific types of observations required, and to design one system that can meet the multiple needs of a diverse user community and the development of timely products. The list and the products provided are likely to change after completion of the formal survey and users' workshops. Further, we will explore the potential for the participation of nontraditional marine users, such as the reinsurance industry.

Following each category of targeted users is one or more entities within that category. In some cases (asterisked), the entities already have been approached, while in other cases they will be invited to participate. These entities will be sounding boards in the development of the observations and related products, in the tracking of their usefulness, and in making later refinements.

1. Marine shipping and oil transport industries

Major ports exist in Boston, Saint John, with feeder and specialty ports at Portsmouth, Portland, and Penobscot Bay. The transportation of petroleum by coastal barges and oil tankers is increasing in the Gulf as the Portland Pipe Line Corporation has tripled its shipment of oil to Montreal. The 1997 collision of a tanker loaded with heating oil with a bridge in Portland Harbor was a stark reminder of the vulnerability of coastal ecosystems and the lack of effective oil spill response readiness. Commercial shipping and coastal barge traffic depend upon **wind and wave data** from a few locations clustered in the western Gulf of Maine. The petroleum industry and its regulators in particular need the **real-time surface current data** and the **data assimilation capabilities** to predict spill trajectories. With data and modeling products from GoMOOS, pilots and other mariners will have access to **real time** information throughout the Gulf's coastal area that will enhance safety of marine operations and increase the effectiveness of oil spill response.

Targeted Users: Penobscot River Pilots Association*, Portland Pipeline, Clean Casco Bay, Inc.

2. Finfish aquaculture industry

Throughout the Gulf of Maine's coastal area, but especially from Penobscot Bay east to the Bay of Fundy, finfish aquaculture has become an important industry, providing a source of protein for world markets, a source of livelihood for a region of the northeast that has lagged economically for decades, and a growing source of environmental concern. The industry faces multiple challenges; among the most important are finding suitable locations for expansion, and monitoring existing sites. This need has grown as demand has outstripped the carrying capacity of traditional locations near the mouths of small coastal rivers, and has been heightened in the Gulf of Maine by recent proposals by the US Fish and Wildlife Service to list Atlantic salmon as an endangered species-- in part due to concerns that pens are located too close to rivers that still support wild Atlantic salmon. Both net pen finfish aquaculturists and marine resource and environmental regulators depend upon sporadic **dissolved oxygen and temperature measurements** and sparse **tidal current** information to evaluate potential net pen sites. Monitoring at existing sites is a growing concern as highly elevated ammonia levels are being reported in Cobscook Bay, an area of extreme tidal flushing. With **sustained time series measurements of temperature, currents, nutrients and dissolved oxygen levels integrated with remotely-sensed information on chlorophyll and turbidity,** GoMOOS will allow for more accurate assessment of the suitability of expansion sites and their carrying capacities, and compliance to clean water standards of existing operations.

Targeted Users: Maine Aquaculture Innovation Center*, Maine Department of Marine Resources,* Maine Department of Environmental Protection,* Atlantic Salmon of Maine, Inc.

3. Shellfish Industry

The wild scallop fishery in coastal Maine experiences very localized "boom and bust" cycles. The fishermen have found that successful setting of spat in a particular area occurs on a very irregular basis that appears to be related to temperature distributions and variability of the coastal circulation patterns. An effort is now underway to collect spat and transplant young seed to historical scallop beds that have been depleted by harvesting activity, rather than awaiting the episodic natural replanting of the beds. Scallop fishermen have approached GoMOOS and have requested that we work with them to determine areas of favorable **temperature profiles** and **current patterns** for successful spat collection and transplantation.

Shellfish aquaculture is an important and growing industry in the Gulf of Maine waters. Growth rates and mortality at the aquaculture sites depends critically on **temperature profiles, dissolved oxygen, chlorophyll concentrations** (phytoplankton), and **ambient flow conditions**. This information is thus important in site selection and the granting of leases. Both regulatory agencies and individual aquaculturists have expressed great interest in these data being supplied by GoMOOS.

Targeted Users: Maine Department of Marine Resources*, Stonington Fisheries Alliance*, Maine Aquaculture Association, Marine resource management agencies in New Hampshire* and Massachusetts*

4. Mariners and search and rescue personnel

The United States Coast Guard (USCG) stations in the Gulf of Maine have identified localized **visibility** as an important factor in deciding how to respond to distress calls. Most of the visibility information that is currently available comes from shore-based fog detectors that do not provide accurate information for most of the areas. Buoy-mounted fog sensors could greatly aid USCG operations. Helicopters are sometimes deployed in search and rescue operations, but cannot then be used because lack of visibility in the search area. The USCG/South Portland has suggested to GoMOOS that the decision to involve helicopters or other aerial surveillance would be aided by additional, real time information about localized visibility in the Gulf. Information on fog and other oceanographic conditions is also of use to maritime tourist activities, a growing sector of the tourist industries of New England and the Canadian Maritime Provinces. Recreational boating, tour and whale watching boats, passenger travel, and day sailing, are especially vulnerable to the lack of **real time observations on wave, current and meteorological conditions** in the Gulf. This sector would benefit greatly from the transmission of simple, ongoing observations about these conditions in coastal locations in the Gulf.

Targeted Users: United States Coast Guard*

5. Coastal managers and municipal officials

Eutrophication of Gulf of Maine estuaries is an increasing concern for environmental management agencies, municipal governments, aquaculturists and coastal residents. Last year, the Maine Department of Marine Resources denied an application for a salmon farm because of concerns about eutrophication; in 1989, Maquoit Bay experienced a catastrophic algae bloom that decimated the area's shellfishery, and the following year, Saco Bay saw a massive die-off of lobsters due to low oxygen levels.

Every year, environmental managers throughout the Gulf of Maine region issue permits for municipal treatment plants, power plants, chemical plants and other discharges into coastal waters. The hydrology of these coastal embayments is complex, varies from embayment to embayment and is poorly understood. The Massachusetts Water Resources Authority (MWRA) currently collects environmental data in the vicinity of its outfall. Data from GoMOOS will allow the MWRA to understand how concentrations of contaminants in its receiving waters are affected by "upstream" currents in the Gulf of Maine. Currently, the

Maine Department of Environmental Protection uses a percent of saturation of dissolved oxygen as a standard for determining water classification. Unfortunately, this standard fails to account for the effects of temperature and salinity. Observations on chlorophyll concentrations, primary productivity, dissolved oxygen, temperature, salinity and currents would allow such managers to determine the natural variability in coastal embayments and thereby enhance their ability to protect water quality.

Targeted Users: Maine Department of Environmental Protection, Massachusetts Water Resources Authority*, Town of Brunswick, Maine Coastal Zone Management Program*

6. Research Institutions

Pure and applied research in the Gulf of Maine is an activity that serves as the underpinning of much of the successful exploitation, regulation, and utilization of this unique resource. GoMOOS will greatly enhance and facilitate the myriad of research activities that now occur and will occur in the future by providing both a rich source of continuous contextual data and important infrastructure in terms of observational platforms and models. We expect GoMOOS to attract and stimulate new research activity in the region by making such research easier and more cost effective.

Targeted User: The member institutions of the Regional Association for Research in the Gulf of Maine* and other research organizations

7. National Security

As a result of the change in the nature of global security after the Cold War, the Navy has focused efforts increasingly in nearshore area of the world where shallow, turbid coastal water create challenges to providing ships with accurate nowcasts and forecasts of battlespace environments. **Water depth, sea surface temperature, temperature at depth, bottom type, waves, and coastal ambient noise** are needed to support modern naval operations. The Gulf of Maine provides an important analogue of cold water environments and provides an accessible and practical testing ground for the development of observing methodologies and protocols of interest to Navy operations. The development of new observing methodologies, protocols and technologies for the littoral zone can enhance the Navy's extensive observing network.

Targeted User: Oceanographer of the Navy*, U.S. Naval Oceanographic Office, Fleet Numerical and Oceanography Center, Office of Naval Research

8. Educational Institutions

Data, maps, and images accessed via informational kiosks at area aquariums, museums, park visitors' centers and other informal educational venues can provide an unprecedented look at the Gulf of Maine and explain its importance as a natural resource. GoMOOS also will provide the data necessary for the development of "virtual laboratories" that allows students to interact with oceanographic data without having to purchase expensive equipment and / or live near the ocean, such as those envisioned by the National Science Foundation and National Aeronautics and Space Administration's "Digital Library for Earth System Education" (DLESE) effort. DLESE encourages the creation of scientifically valid materials that can be easily accessed and readily used in the classroom. It also supports the development of analytical tools that are "student-friendly" and inquiry-based.

At the New England Aquarium in Boston, where 1.5 million people visit annually, a planned expansion will focus exclusively on the Gulf of Maine. A major goal is to bring the ocean into every exhibit, such that the captive animals are ambassadors for those in the wild. For example, for each seal in the Gulf of Maine Rocky Coast exhibit, the aquarium wants to have a tag on a wild seal , sending data back to the exhibit. This will be linked to GoMOOS information demonstrating the **temperature, salinity, currents** and other conditions through which the seal is traveling. This will be a powerful educational tool and provide much greater understanding the Gulf of Maine ecosystem. It is likely the Aquarium will incorporate other information into the exhibit.

Targeted Users: New England Aquarium*, Gulf of Maine Aquarium*, Island Institute*, Bigelow Laboratory*

9. Lobster fishery and management

The lobster fishery is the most valuable commercial fishery in the Gulf of Maine. The last several years has seen record catches with increasing effort and concern about overfishing. Until recently, there was little understanding of the reason for the especially rich lobster fishery in western Penobscot Bay, the most productive in the Gulf of Maine. As a result of a five-year experimental program in the bay, a collaborative of scientists, fishermen and managers, has identified the role of the Eastern Maine Coastal Current in delivering lobster larvae into the inshore region of western Penobscot Bay. In addition, a correlation between warm temperature anomalies and the degree of larval settlement has been found in this region. These two factors may play key roles in the success of the lobster fishery Gulf wide and could provide the basis for initiating a predictive model that will aid in management actions required to sustain the fishery. GoMOOS will provide the data and **modeling of variations of the coastal current** and **nearshore temperature regimes** on an ongoing basis.

Targeted Users: Maine Lobster Maine Association*, Department of Marine Resources*

10. Commercial groundfishery and management

Once an anchor of the coastal economy of New England and the Maritimes, the commercial groundfishery has diminished to the point of collapse. While fishing effort, which continues to rise world-wide, cannot be dismissed, neither can environmental forcing be dismissed in light of recent climatic fluctuations and their effects on the oceans. Indeed, El-Nino events are now believed to be responsible for transforming the open North Pacific Central Gyre, once thought to be among the least biologically productive regions of the world ocean, into an area as biologically productive as the Gulf of Maine (e.g., Karl et al., 1995, 1997). There is an accumulating body of evidence that ties fluctuations in the North Atlantic Oscillation (NAO) to plankton processes in the Gulf of Maine that could potentially impact fisheries recruitment. Among the most important parameters for understanding and, perhaps one day predicting, these fluctuations are **surface temperature, currents and phytoplankton productivity.**

Both **long-term and shorter-term temperature fluctuations** affect the fisheries in the Gulf of Maine. Fish stocks are thought to extend their range northward as a result of long-term warming embedded in longer term cycles. In addition, **shorter-term temperature fluctuations** can impact competition for the zooplankton upon which the larval cod and haddock rely. For example, the ctenophore *Pleurobrahcia* normally reach peak abundance in the Gulf in mid-summer, whereas the larval fish predominate in the spring. In 1983 the sea surface was unusually warm between January and April and the period of peak ctenophore abundance advanced from summer to spring. Frank (1986) concluded that the spring grazing of the zooplankton population by ctenophores resulted in the 1983 haddock year class being the lowest on record to date.

The seasonal **surface circulation patterns** of the Gulf of Maine are also subject to substantial variation and, in rare cases, even regime shifts (Brown and Irish, 1992). While interannual variations of the trajectory and strength of the Eastern Maine Coastal Current (EMCC) are expected (Brooks and Townsend, 1989; Pettigrew *et al*., 1998), there have been documented occurrences of when the seasonal evolution of the circulation has been so disturbed (such as an anomalously high inflow from the Scotian Shelf in 1987 (Brown and Irish (1993)), that the normal cyclonic flow pattern found in the eastern Gulf was reversed during the larval season! In view of the intimate relationship between detailed circulation features and cod and haddock larval transport in the Gulf (Townsend and Pettigrew, 1996), variations of this sort may have catastrophic impact on the successful recruitment of year classes. Long term observations will assist fishermen and managers to document such events, enhance tools for assessing and predicting groundfish stocks and inform management decisions.

Targeted Users: National Marine Fisheries Service, New England Fisheries Management Council, Groundfishermen Association

<u>11. Marine Mammal Protection</u>

The endangered northern right whale inhabits the Gulf of Maine for several months each year. It is estimated that only a handful of breeding females remain in the North Atlantic. Efforts to reduce risk to these animals from human activities has heightened the need for data on their activity in real time and over time. Real time, **passive acoustic data**, available in the vicinity of GoMOOS buoys, may allow large vessels to avoid colliding with individual animals, provide educational opportunities for school children and guide the efforts of disentanglement teams. Time series data may allow researchers to identify patterns of whale behavior that can in turn be used to refine protection strategies.

Targeted Users: Maine Lobster Association, National Marine Fisheries Service, College of the Atlantic Cetacean Research Group

The requirements of the users described above indicate that **the highest priorities for observations are: surface currents, wave data, wind speed and direction, sea surface temperature, dissolved oxygen, chlorophyll, nutrients and optical properties**. These data priorities will be reviewed and confirmed in workshops and user surveys during the start-up phase of GoMOOS. The following summarizes the data needs by user sector.

Industry Group	Issue	Wave	Wind	Current Surface	Current Column	Temp Surface	Temp Column	Salinity	DO	Chloro	Acoustics	Visibility
Shipping	Safety, efficiency	x	x	x	x			x				x
Petroleum	Spill Response	x	x	x	x	x						
Aquaculture	Siting, Water Qual.	x	x	x	x	x	x	x	x	x		
Shellfish	Spat collect, site selection	x	x	x	x	x	x	x	x	x		
Mariners	Safety, rescue	x	x	x		x						x
Coastal Mgt.	Eutrophication		x	x	x	x	x	x	x	x		
Research	Data	x	x	x	x	x	x	x	x	x	x	
Education	Curriculum Dev.	x	x	x	x	x	x	x	x	x	x	
	Exhibits											
Lobster	Recruitment Pred. Models	x	x	x	x	x	x	x	x	x		
Groundfish	Stock Assessment			x	x	x	x	x	x	x		
Marine Mammals	Endangered Species			x		x		x			x	
Military	National Security	x	x	x	x	x	x			x	x	x
TOTALS		**9**	**10**	**12**	**10**	**11**	**8**	**9**	**7**	**7**	**4**	**3**

The above list of targeted user correlates well with national and international efforts that have identified user communities and issues for which ocean observations would be helpful (EuroGOOS, 1999; Malone 1999; ORAP, 1999). The shipping industry, petroleum and oil response industries, research and educational institutions, mariners and manager rank high among the users groups most interested in observations. Regionally-specific issues include developing predictive models for the recruitment of lobsters, aquaculture siting and water quality issues, and the protection of marine mammals. The general topic areas are cited in both the international and national work but reflect the specific fisheries and concerns of the region.

B. Data Products

The results of the preliminary GOM user survey, summarized above, are consistent with an extensive survey conducted for EuroGOOS. Many of the variables listed are physical variables that represent the underlying processes driving many of the issues surveyed; they are also fundamental to the functioning of the Gulf of Maine ecosystem. The goal is to generate data products that address multiple objectives, contribute to solving specific problems, and provide a basic set of important contextual data for a broad array of regional issues and problems.

GoMOOS will provide a series of routine data products based on the preliminary user interviews which specified the kinds of data that would be most desirable to improve decision-making. Section V describes the deployment of the platforms that will be used to collect the data. These products will be refined by future work with the targeted user groups and the workshops.

1. Data Products Summary

Product	Time Interval	Platform*
Wave Products		
Wave Height	Hourly	Buoy (S,B)
Wave Trends	Hourly	Buoy (S,B)
Wave nowcasts	3-hour	
Wave forecasts	3-hour	
Meteorological Observations		
Wind	Hourly	Buoy (S,B)
Wind	4 times daily	QuickScat
Fog	Hourly	
Currents		
Surface currents maps	Daily	CODAR
Water column currents	Hourly	Buoy (N,S,B)
Large scale circ. features	Weekly	Model
Interannual variation In circ. Features		Archives
Temperature Patterns		
Seasurface temperature	4-6 times daily	AVHRR
SST composites	Weekly	DerivedArchives
Water column temp. regimes	3-hour	Buoy (N,S,B)
Salinity		
Salinity measurement	Daily	Buoy (N,S,B)
Dissolved Oxygen		
DO	Hourly	Buoy (N)
Primary Productivity		
Chlorophyll	Daily	Buoy (N,S,B)
Primary productivity	Daily	MODIS
Turbidity	Daily	Derived
Whale Sounds	Hourly	Buoy (S,B)

*N = Nearshore; S = Shelf; B= Basin

The core set of products that GoMOOS will be producing are very similar to the products identified in the EuroGOOS study and by several national studies (ORAP, NOPP, Malone et al). Information on waves, meteorological data, currents, temperature, salinity, oxygen and nutrients are cross-cutting issues for many user groups. The identification of large-scale circulation patterns and the interannual variation of those patterns provide important information for developing predictive tools within the Gulf of Maine region.

Liability issues will be an important consideration for the posting and publishing of information for public use. For example, GoMOOS will be developing an early warning tool to alert public health agencies about the potential outbreak of red tide. Such a tool will assist these agencies in determine public health issues but will not be available to the general public. GoMOOS will work with maritime legal experts to determine the best approaches for addressing issues related to liability and expects to purchase the appropriate insurance policies.

2. Display of Products

While the DODS system will serve admirably for data transfer requests for scientific users, we see the GUI systems of the Gulf of Maine Information Management System (GoMIMS) as key components for the delivery of information and data products to the general user. Remote sensing data (SST, ocean color, scatterometer winds and CODAR surface currents) will be catalogued by date and time and presented via a thumbnail browser interface. The full spatial maps will have animation and zoom capabilities, and the wind, SST, Ocean color and CODAR fields will be viewable as overlays. Individual wind and current vectors will be "clickable" with menu options of speed and direction posting, animation, and time series plots over selectable time intervals. For the CODAR maps, particle tracking through the data domain will be provided following a user-initiated tracer injection in space and past time.

Time series data from the buoy array will be served via a "clickable" map of buoy locations. Available data types, depths, and times will be displayed and selectable for visualization, statistical summary, and download via their Internet browser. For mariners or others without access to computers and the Internet, we plan to make the latest buoy data available via phone from a system akin to the NDBC's Dial-A-Buoy system. The buoys and data types will be selectable via a menu, and a computerized voice will read a text message with the latest data values.

Model nowcasts and forecasts of currents and waves will be available on the GoMOOS website in the form of graphical displays, and perhaps animation. Nowcasts and forecasts of the large-scale circulation of the Gulf will be provided on a week-by-week basis, whereas the wave modeling results will need to be provided several times per day. The website will provide Hotlinks to sites that provide regional data from other sources such as sea level, river flow or stage, waves, and meteorological data.

Data products will be refined by means of a broad-based user survey followed by workshops with targeted user groups. The survey and workshops are described in Section VII "Observing System Development and Future Design."

V. TECHNICAL PROGRAM

The following section outlines the technical approach to providing the infrastructure, data, modeling and data products that have been identified above as the highest priorities in the user survey as tabulated above. Prior to implementation of the technical program, the approach will be further refined in response to the completed user survey and via consultation with the board of advisors. The program described below is viewed as a general framework.

A. Data Acquisition

Variable: Surface current
Means: CODAR

High frequency radar units have been used for 25 years to map ocean surface currents. Each radar installation produces radial surface velocities versus range and bearing; where the signals from two or more units overlap at a sufficient angle, two-dimensional surface velocity vectors are provided. Recent advances in this technology have lead to the development of a compact and affordable 5 MHz system (Long Range CODAR) that has a nominal range of 200 km and a resolution of approximately 3 km (range) and 5^{o} (bearing). Recent comparisons of tidal currents measured by CODAR and acoustic Doppler current profilers showed rms differences of approximately 0.025 ms^{-1}. CODAR is therefore sufficiently accurate to delineate the major surface circulation features of the offshore and inshore Gulf of Maine, and to provide tidal current observations in the Gulf with an unparalleled combination of spatial resolution and accuracy.

As indicated in Figure 3, four long-range CODAR units installed along the coastline will be capable of monitoring surface currents for essentially the entire Gulf of Maine from Cape Cod to Nova Scotia. The contribution of the proposed CODAR system to the monitoring of the Gulf of Maine is hard to overestimate. These data will be available hourly at a spatial resolution similar to SST derived from NOAA's AVHRR, unimpeded by clouds and fog. As a result, features such as the Gulf of Maine coastal current system will be, for the first time, directly and continuously monitored throughout the Gulf and throughout the year. The CODAR surface current vectors are a natural candidate to be integrated with satellite SST and scatterometer winds to form geographical information system (GIS) layers.

Variables: Currents, waves, temperature, conductivity, dissolved oxygen, meteorology, optics, nutrients, visibility, passive acoustics
Means: Moored sensor array

A central element of GoMOOS is the use of Ocean Data Acquisition Systems (ODAS) in a telemetering moored buoy array. The buoy array will provide the platforms for a suite of sensors that will furnish long-term time series data on the physical, optical and bio-optical fields in the Gulf of Maine. Acoustic and nutrient sensors will also be deployed at select locations. The Physical Oceanography Group (PHOG) in the School of Marine Science at the University of Maine, and the Applied Ocean Physics and Engineering Department at the Woods Hole Oceanographic Institution, have extensive experience building and maintaining moored data buoy systems in the Gulf of Maine in the offshore, shelf, and nearshore environments. Figure 4 shows potential buoy locations superimposed upon the schematic diagram of the large-scale circulation of the Gulf. The buoys may be roughly divided into three generic types that will be referred to as Shelf moorings, Basin moorings, and Nearshore moorings. Buoy locations, and the relative numbers of each buoy type, have been selected based on a combination of the expressed needs of users and modelers. Direct data usage by targeted user communities generally varies inversely with distance from shore. All the buoys are solar-powered telemetering platforms, and are equipped with Global Positioning System

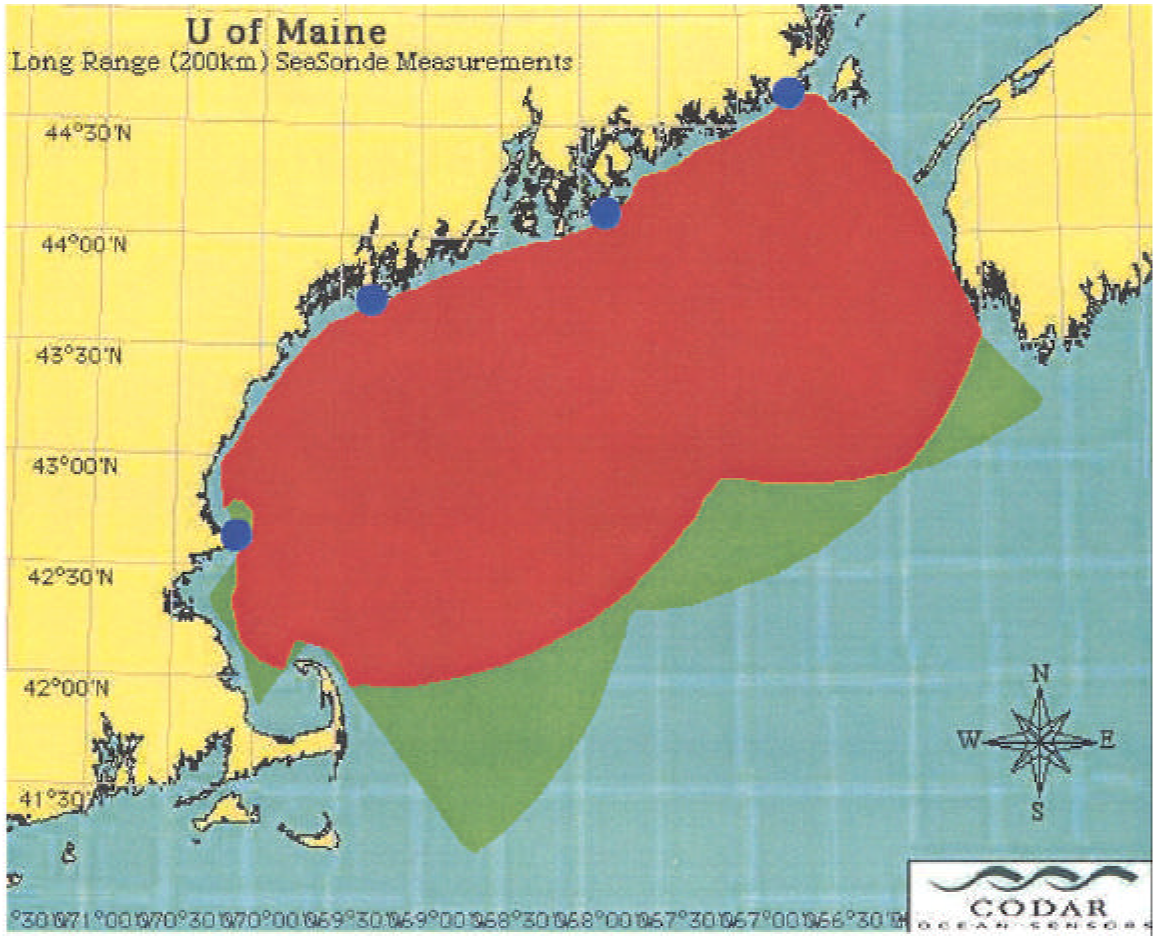


Figure 3. Projected long range CODAR coverage for the Gulf of Maine. Blue dots denote locations of the CODAR shore installations, the red shading indicates surface current vectors coverage, and the green shading indicates radial current coverage.

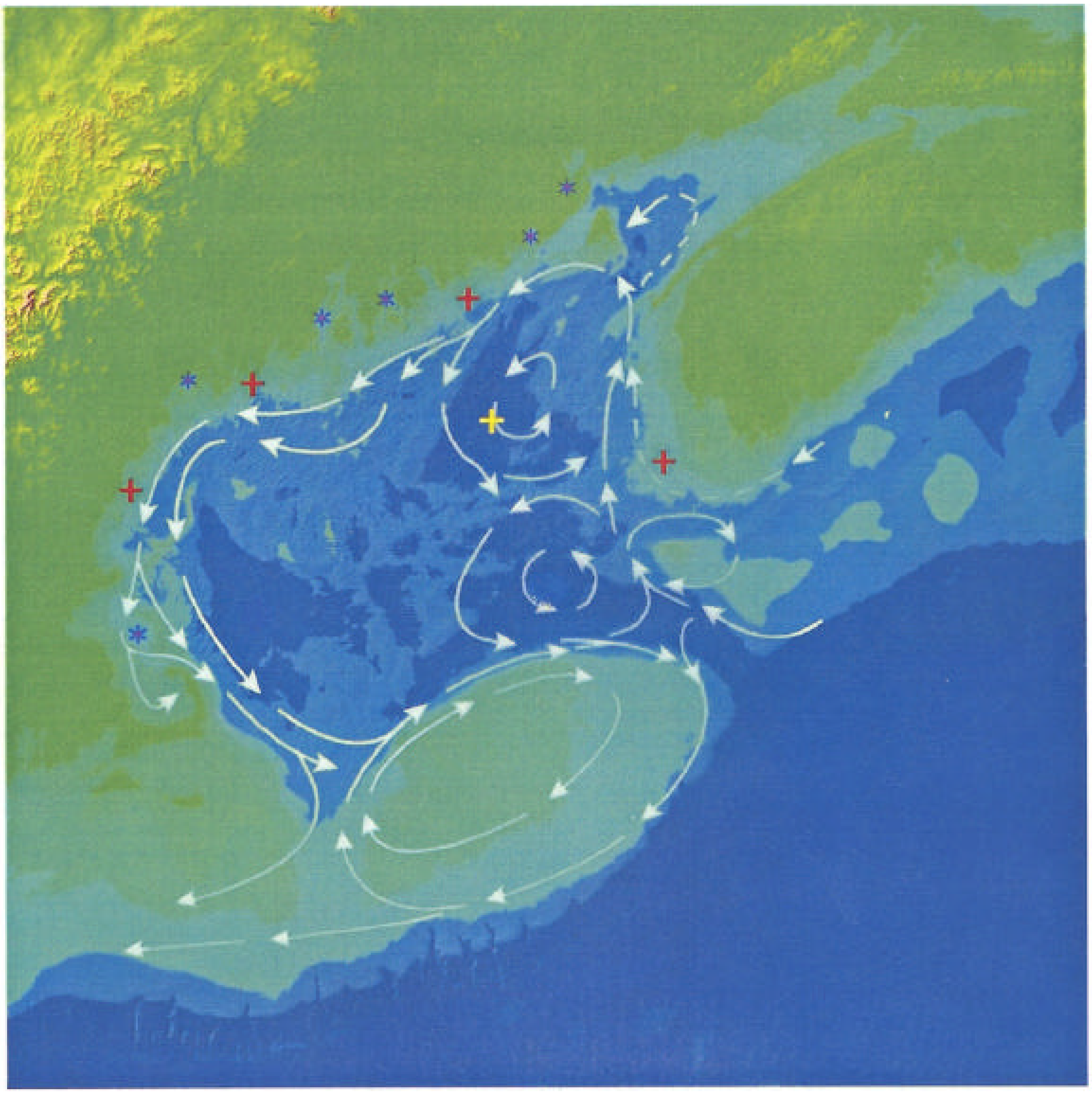


Figure 4. Schematic mooring locations for GoMOOS. The yellow cross represents the basin mooring that measures optics, temperature and conductivity at multiple depths, surface currents, surface waves, meteorology, visibility, and whale sounds. The red crosses represent the shelf moorings that include a Doppler current profiler in addition to the sensors included on the basin mooring. The purple asterisks indicate the shallow coastal moorings that measure temperature, conductivity, fluorescence, and dissolved oxygen at multiple depths, and meteorology and surface currents.

(GPS) and drift detection software. The data telemetry system is based on cellular phone with a 1200 baud modem. These systems have proven very successful in long-term deployments in nearshore and shelf waters of the Gulf, and have a data rate more than adequate to handle economically the estimated hourly data stream. The basin buoy will be based on a GOES transmitter since cellular coverage may be unreliable at that distance from shore. Subsurface data will generally be transmitted to the buoy telemetry system via inductive modem. Platforms and sensors will be replaced on a staggered deployment/recovery schedule requiring 50% redundancy in equipment.

The shelf moorings (within the coastal current system) will be the most heavily instrumented of the moorings. They are instrumented with both a near-surface acoustic current meter and a Doppler current profiler to provide current measurements throughout the water column. Temperature and conductivity sensors (Seabird SeaCats or MicroCats) will be deployed at near-surface, near-bottom, and mid-depth. Also included will be multi-channel radiance and irradiance sensors, fluorometers, hydrophones (whale sounds), forward scatter visibility, and in two cases, transmissometers and spectral absorption/attenuation sensors. The mooring farthest east on the Maine shelf will have tri-axial accelerometers for wave measurement.

The basin mooring will be heavily instrumented with MicroCats to monitor the water mass evolution in the interior of the Gulf; it will also carry surface current meters, multi-channel radiance and irradiance sensors, fluorometers, visibility, meteorology sensors, wave accelerometers, and a hydrophone.

Nearshore moorings are viewed as special-purpose moorings tailored to user-specific needs.. While the suite of sensors and the number of sensors will tend to reflect the site-specific missions of the buoys, standard features will include telemetry and GPS, a near-surface current meter, dissolved oxygen, fluorometers, and a SeaCat TC pair. For several applications, notably the wild shellfishery and aquaculture applications, targeted users (Maine Department of Marine Resources, Maine Department of Environmental Protection, and the Stonington Fisheries Alliance) and have expressed a strong desire for shorter-term deployments at multiple sites rather than continuous monitoring at a fixed site. In response to these requests we have planned for three nearshore moorings (not shown in Figure 4) as a pool of buoys to be deployed for shorter periods at the highest priority "sites of the moment". These moorings will be smaller, less expensive, and easier to deploy, recover, and replicate.

Physical Sensors -- Standard operational physical oceanographic sensors will be used on the moored data buoys. We have nearly a decade of experience building the telemetering data buoys and have interfaced most standard sensors to the buoy data system. The following sensors are tentatively identified for incorporation into the GoMOOS Buoy array:

Surface currents – Nobska MAVS acoustic current meters
Water Column Currents – RDI 300 KHz Workhorse ADCPs
Temperature & Conductivity – Seabird Instruments SeaCats and MicroCats
Meteorology – R M Young wind speed, direction, and air temperature sensors
Passive Acoustics – Eng. Acoustics E200 hydrophones
Waves- Crossbow tri-axial accelerometers

Optical Sensors -- Standard operational optical sensors will be used on the moored data buoys. We have over a decade of experience working with optical instrumentation, including deployment, calibration, validation and interpretation. In concert with PHOG and the appropriate vendor, the instruments will be optimized for moored deployment on selected GoMOOS buoys.

- Surface radiance reflectance – Satlantic OCI & OCR, 7 channel 20 bit digital irradiance and radiance sensors
- Light penetration depth – Satlantic OCI-200, 7 channel 20 bit irradiance sensors
- Near surface spectral absorption and attenuation – WETLabs ac9, a nine wavelength absorption/attenuation meter
- Near surface spectral backscattering – WETLabs ECO-VSFS a shuttered three angle backscattering sensor
- Euphotic zone chlorophyll biomass – WETLabs WETStar and ECO-DFLS chlorophyll fluorometers
- Mixed layer nitrate/nitrite – WSOceans NAS-2E moored nutrient analyzer
- Hydrocarbon detection – SeaTech flash fluorometer
- Visibility – Qualimetrics 8463E

Variables: Spatial fields of conductivity, temperature, dissolved organic matter, inorganic nutrients
Means: Shipboard surveys

Substantial shipboard activities will be necessary to support the automated ocean data array. The ODAS will be deployed and recovered on a staggered six-month schedule requiring cruises every three months during which half of the moorings will be replaced. Service of the buoys, sensors and mooring components will be accomplished in the University of Maine buoy facility between cruises.

Hydrographic surveys will be conducted in conjunction with all mooring cruises. The survey pattern will be determined by the final array design, and the hydrographic data will become part of the GoMOOS archive. Conductivity Temperature Depth (CTD) casts will be made at all mooring locations prior to mooring recovery/deployment for calibration and validation purposes. Discrete water samples will be analyzed for chlorophyll and pheopigment concentrations, spectral absorption coefficients by phytoplankton and colored particulate and dissolved organic matter (CPOM and CDOM, respectively) at Bigelow Laboratory and inorganic nutrients at the University of Maine using a Technicon Auto Analyzer.

Variables: Seasurface temperature, winds, chlorophyll
Means: Satellite remote sensing

Together with CODAR, satellite data are a principal means of obtaining operational synoptic coverage of the GOM region, thus helping to place *in situ* time series measurements in spatial context. In addition, historical archives of satellite data provide a temporal context for *in situ* data of shorter duration and make possible comparisons of real time observations to a climatological database. We have over 15 years experience processing, analyzing and archiving time series of satellite data for oceanographic investigation.

Four satellite data streams are viewed as critical to GoMOOS (AVHRR, SeaWiFs, MODIS, QuickSCAT). These data streams provide sea-surface temperature, ocean color, and surface wind monitoring capability. The choice of these four data streams is based upon a combination of their suitability for monitoring signals critical to the program, the maturity of the data products that result, and the ease and cost of access and handling. NOAA AVHRR data are available 4-6 times daily at 1 km resolution. These data will be provided in real time from the University of Maine Satellite Data Laboratory ground station, and eventually augmented in the archive by the higher quality PATHFINDER data as they become available from University of Rhode Island (URI) 12-18 months later. NASA SeaWiFS data provide multispectral measurements of ocean color, suitable for calculating surface chlorophyll concentration and extinction coefficients. These data are available on a daily basis at 1 km resolution, however real-time access requires purchase of a license from Orbimage. One month old data are available free of charge to NASA-registered investigators. These data are presently delivered to the University of Maine Satellite Data Laboratory from the NASA Goddard Space Flight Center archive and will be acquired, processed, archived and disseminated through the GoMOOS data system. NASA MODIS data will become available in early 2000 providing daily 1 km resolution co-registered ocean color and SST data. The ocean color data from MODIS is potentially of higher quality than that of SeaWiFS. These data will be available at full resolution from the University of Miami and/or the University of South Florida, and GoMOOS will acquire, process, archive, and distribute the data for the Gulf of Maine region in as near real-time as is possible with the delivery / software systems. Should the MODIS system not be online when GoMOOS becomes operational, we will consider purchasing real-time SeaWiFS imagery should as an interim measure. Surface wind measurements are available from the NASA QuickSCAT mission. These measurements provide daily coverage and will be acquired from the mission science team as available and subset to the Gulf of Maine region and archived in formats suitable from comparison and overlay on the other satellite, modeling, and CODAR data products.

B. Numerical Modeling

Numerical modeling and assimilation of data into models are key components of the proposed Ocean Observing System. The great strengths of model simulations from the observatory perspective are interpolation, extrapolation, integration, and prediction. The GoMOOS modeling program is focused on applying operational numerical models to the Gulf of Maine region, making model results available via the web in real time in nowcast mode, producing forecasts by coupling the circulation and wave models with available meteorological forecast models, and producing model products. The models will run on dedicated machines, and their output will form a powerful part of the GoMOOS product and outreach effort.

1. Circulation Modeling

There are two principal circulation models presently operational in the Gulf of Maine. We have chosen the model based on the Princeton Ocean Model (POM) for use in the implementation phase of GoMOOS. The decision was based upon the following considerations. The National Center for Environmental Prediction (NCEP) is running POM for operational forecasts of the coastal ocean off the east coast (Coastal Ocean Forecasting System (COFS)), and the existing Gulf of Maine POM model (Xue *et al*. 2000) is presently embedded in the COFS in that the COFS provides open boundary condition for the Gulf of Maine model. Researchers at Princeton University, NCEP and elsewhere are planning to implement more sophisticated two-way nesting schemes to improve the COFS operational forecast with finer resolution in the Gulf of Maine, Chesapeake Bay, Straits of Florida, western Florida shelf and Louisiana/Texas shelf. The operational forecasts will soon include routine assimilation of SSH and SST and span the US Gulf Coast and Eastern Seaboard. Other advantages include the fact that there are operational high resolution models of Penobscot Bay and Massachusetts Bay imbedded within the POM Gulf of Maine model. We note that models and modeling methodologies are undergoing rapid advancements. GoMOOS will encourage collaborative approaches to ocean modeling so that the advantages of various methods can be explored and possibly combined in new ways. Just as we intend to incorporate future advances in sensor technologies, our modeling strategy will be adaptive and responsive to changes in the field.

The assimilation of CODAR-measured sea-surface velocities over virtually the whole Gulf of Maine will provide a unique opportunity. It has been shown that the assimilation of CODAR velocities increases greatly the predictive skill of the southern New Jersey Coast nowcast and forecast model. Modelers in the University of Maine's School of Marine Science have an ongoing collaboration with scientists at Hong Kong University of Science and Technology to assimilate CODAR measurements in a POM-based model of the Pearl River estuary. This experience will significantly expedite the task of assimilating CODAR data in the GoMOOS circulation model.

State of Maine funding has been obtained to convert the serial POM Gulf of Maine/ Penobscot Bay code to a parallel version with a Message Passing Interface suitable for Beowulf clusters. This development assures that the model may be run in real time in a cost effective manner. The University of Maine Gulf of Maine circulation model is coupled with an ecosystem model to predict inorganic nutrient distributions and phytoplankton concentrations. Preliminary results compare favorably with SeaWiFS ocean color data. With more sensitivity tests and process studies, the coupled physical-biological model will soon be capable of nowcasts and forecasts of plankton biomass in the Gulf. The circulation model is a keystone in the central GoMOOS mission of integration of spatial and temporal data spanning the physical, chemical and biological characteristics of the ecosystem and provides a powerful tool for prediction and resource management.

2. Wave Modeling

Calculations using buoy and satellite data in the Gulf of Maine show that significant wave heights (average of the highest third) of about 15 m (translating to maximum wave heights of about 30 m) occur 2% of the time each year. Waves of this magnitude pose a serious threat to marine operations. Thus, there are serious economic and public safety reasons for including wave products as part of GoMOOS. While there are few wave buoys maintained in the Gulf of Maine, their usefulness can be greatly extended through wave modeling.

Three sophisticated wave models, known as WAM, SWAN, and WAVEWATCH, have been developed in recent years for calculating unsteady wave conditions resulting from wind-induced growth, energy exchange, breaking, and refraction. Of these, WAM is perhaps the most mature and has the widest base of users worldwide. It is used by NOAA and the Navy on a global or ocean scale. The unsteady version of SWAN is still in its infancy, however it is essentially a mini-WAM with certain technical features that render it more suitable to somewhat smaller length scales with greater complexities (e.g., Gulf of Maine or coastal regions). The steady state version of SWAN (like its predecessor HISWA) also has a large user base and has been rigorously validated for many applications in the North Sea. WAVEWATCH, which provides a higher level of user control than the other two models, is now finding increased usage in the United States (e.g., at NCEP, Army Corps of Engineers, etc). At present, DoD and NOAA scientists are attempting to determine the merits of these models.

GoMOOS will use one of the above models to produce wave nowcasts on a three-hour time interval, which will be displayed on the website. GoMOOS will assimilate data from the buoy array and satellites and develop wave forecasts once the nowcast model is fully operational. In determining model selection, GoMOOS will work closely with national experts such as Dr. Robert Jensen of the Army Corps of Engineers and Dr. Linwood Vincent of NRL in selection of the model. (The PI has experience applying WAM's predecessor HYPA to the Gulf of Maine (Panchang et al. 1990), as well as with SWAN and its predecessor HISWA (Panchang and Bondzie,1993); the postdoctoral assistant who will work on this project also has unique expertise, having coupled WAM to a storm-surge model in the Bohai Sea (Baoshu and Panchang, 2000)).

The preferred wave model will be applied to the Gulf of Maine with a grid spacing of 3km. Its performance will be in the nowcast mode using available meteorological and wave buoy data. The grid pattern will be constructed to make maximum use of available satellite data. Boundary conditions for the model will be procured from NOAA/NCEP (Dr. H. S. Chen and Dr. H. Tolman) or Navy/FNMOC large-scale simulations of the North Atlantic. The model will be model inputs will be validated and evaluated.

Various data assimilation schemes are available for refining model performance. In recent years, variational adjoint inverse schemes have been widely used in Europe to incorporate buoy and/or satellite measurements into WAM simulations (e.g., Des Les Haras et al. 1995). In a flow model context, the PI has devised such variational assimilation schemes (Panchang and O'Brien, 1990; Panchang and Richardson, 1993). However, data assimilation using the adjoint scheme is inherently unstable when the degrees of freedom exceed a threshold and/or when the problem is nonlinear. Further, it is extraordinarily time-intensive. For the GoMOOS project, therefore, we expect to use simpler data assimilation schemes based on "sequential" methods such as optimal error-interpolation (e.g. Bauer et al. 1992; Lionello et al. 1992; Koorrips et al. 1999) as needed. The success of these methods is not expected to depend on the wave model selected.

Throughout this effort, we will collaborate with Dr. Robert Jensen of the US Army Engineering Research and Development Laboratory in Vicksburg, VA, who has kindly agreed to provide expert guidance on all modeling issues.

C. Research and Development

Several research and development (R&D) efforts have been identified as high priorities based on the user needs described earlier. Time series information on nutrient cycles, phytoplankton concentration and species composition, and natural variability in dissolved oxygen, are all high priority products that have recently become within technological reach. The technical ability to produce these data will substantially enhance Gulf of Maine resource management activities focused on aquaculture, water quality, fisheries management and reduction of the risk of eutrophication in nearshore waters.

We intend to aggressively promote, assist, and facilitate the development and testing of new sensors for use in GoMOOS and other oceanographic applications. In some cases instrument development will be directly supported through GoMOOS and, in other cases, GoMOOS will serve as a test bed for new techniques nearing the operational stage.

Time series measurement of dissolved oxygen in nearshore regions of the Gulf is a very high priority. Eutrophication has become a serious problem in recent years, with massive fish kills and blooms of noxious algae becoming a regular event. The growing practice of netpen aquaculture has raised the stakes. One of the primary factors used by state regulatory agencies in evaluating lease site applications and determining compliance with clean water standards is the impact on dissolved oxygen during the high feed (summer) season. Long-term, real-time stable measurements of dissolved oxygen are now feasible using antifouling measures and the pulsed technology of YSI. GoMOOS nearshore buoy array and the servicing cruises will provide the opportunity to evaluate the long-term performance of these systems as compared and calibrated with oxygen levels determined from chemical analysis of water samples.

We will support the development of a moored version of the FlowCAM system that uses imaging and epi-fluorescence optics to count, size, and identify particles down to the size of microplankton. These data along with the images themselves are stored on disk. Recent advances in the image processor and frame grabber technology have made the moored version a feasible short-term goal, and anti-fouling and pump technology can be easily adapted from existing oceanographic sensor systems.

The FlowCAM is a mature shipboard and dockside product that has been developed over the past five years. It has been used successfully on three research cruises and in continuous operation at dockside. In the present configuration, the microscope section is in a weatherproof module that resides on a dock float. This is connected via a weatherproof cable to the computer/internet server. It is running unattended for a week at a time with file management and 10 minutes of bleach flushing being the only weekly maintenance. This configuration has been in use for the past seven months and has been very robust. Further information is available at the FlowCAM website (http://flowcam.bigelow.org).

For algal species identification, the FlowCAM can provide identification down to the genus level in most cases and in some cases such as *Dinophysis norvegica*, to the species level. The instrument has a 3 micrometer resolution limit so it cannot resolve the important plate structures in organisms such as *Alexandrium tamerense* or *Pseudonitzchia sp.* It will detect and image each passing cell and measure the size and pattern match of each cell with target organisms as well as the chlorophyll and phycoerythrin fluorescence. These fluorescence signatures are very useful for additional species recognition, especially for *Dinophysis norvigeca* and *Mesodinium rubrum*.

The areas in which the FlowCAM needs further development for mooring deployment are 1) power management, 2) data compression and 3) anti-fouling. To address these needs, we propose the following milestones:

1) Develop power management strategy for long term deployment. For situations where the FlowCAM is to be powered by solar panels or batteries, power consumption by the computer and laser must be carefully controlled and monitored. Appropriate strategies must be studied and developed. (2 person months)

2) Develop appropriate data compression and representation for relevant telemetry**.** In an onshore deployment during bloom conditions, the FlowCAM can generate up to 100Mbytes of images and data per day. This raw image data can be compressed by a factor of 10 to one just by using a different image format. The cell spreadsheet data may be only 500Kbytes per day in raw format. Proper representation of relevant data trends (e.g., cell type counts) need to be developed to boil this data down to be the most meaningful and smallest size. We propose to generate 100Kbytes per day for a good representation that can be telemetered to shore. (2 person months)

3) Develop anti-fouling strategy for long term deployment. To prevent fouling in the marine environment, the tubing and pump of the FlowCAM unit must be made with anti-fouling materials that are commercially available. (2 person months)

Fluid Imaging Technologies (FIT) is interested in participating as a partner in the GoMOOS program. As such, FIT intends to cost share the development expense of the new moored version of the FlowCAM. This cost sharing by would be in the form of a 50 percent match in research engineering hours and the associated overhead.

Moored monitoring of inorganic nutrients has also recently become feasible. We intend to purchase an automated nutrient analyzer for deployment in Cobscook Bay, where high nutrient levels have been observed that may be related to fish-pen aquaculture. The performance of this instrument will be evaluated and validated with standard sampling and laboratory techniques. Our hope is that this technology will prove feasible at other GoMOOS sites.

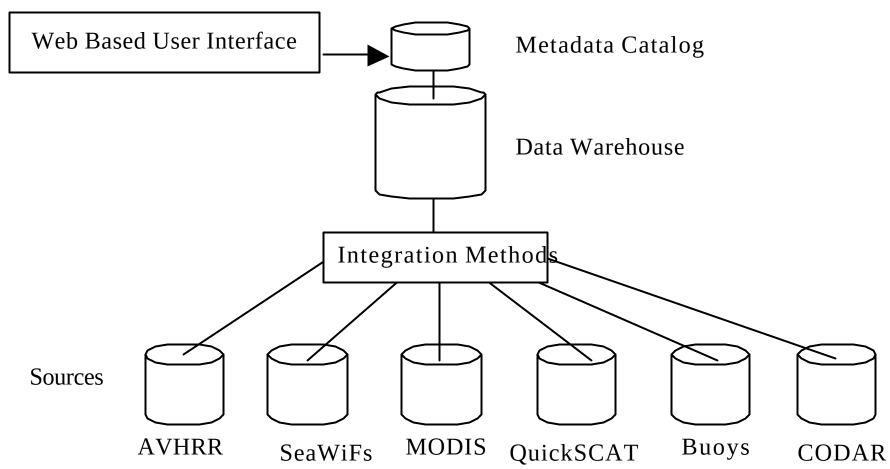
Some of the optical sensors proposed above for GoMOOS have seen limited use on long-term moorings. We will compare the performance of the WETSstar fluorometer attached to the SeaCat pumped system fitted with anti-fouling tubes, and the newer ECO-DFLS protected by a copper shutter system. We will also explore and test technical solutions to fouling on the radiance and irradiance sensors and the spectral absorbtion/attenuation sensors. Dr. Tommy Dickey of USCB has agreed to serve as a technical advisor in this effort. If the research activity in his group permits, the copper shutter and poison cell components will be fabricated in his laboratory.

The nominal CODAR coverage shown for the longshore CODAR array in Figure 3 makes an extraordinary contribution to GoMOOS; nearly covering the entire Gulf of Maine region at roughly 3 km resolution. The chief limitations of the system in terms of GoMOOS goals are the lack of nearshore coverage due to the fact that the nearshore radials from adjacent CODAR units are nearly parallel, and the lack of sufficient range to cover Georges Bank. These limitations can theoretically be overcome by the so-called bistatic HF radar configuration (Barrick, 1972). The envisioned bistatic radar system, which would consist of a pair of relatively inexpensive radar transmitters on Buoys offshore of a pair of standard shore-based CODAR transmitter/receiver pairs should allow current vectors to be calculated right up to the coast, while at the same time extending the coverage in both the alongshore and offshore directions. Development of the bistatic CODAR system has been proposed to ONR by Scott Glenn of Rutgers and Don Barrick of CODAR Ocean Sensors, Ltd. In the future, we propose to team with the Rutgers and CODAR groups to test a version of the bistatic CODAR in the longrange GoMOOS CODAR array. We will propose to deploy the bistatic transmitters on two of the GoMOOS continental shelf moorings in the GoMOOS buoy array, and evaluate their performance after the implementation phase of GoMOOS.

Fisheries are extremely important to the entire Gulf of Maine region. GoMOOS must provide data useful to fishermen, managers and researchers so that linkages between the environment and fisheries can be better understood and the knowledge effectively used in managing harvests of living resources. Development of the most efficient and broadly useful monitoring techniques requires, *a priori*, a thorough consideration of the ongoing survey programs for fisheries and zooplankton in the Gulf. This includes Canadian efforts (Therriault et al. 1998) and an extensive program by the U.S. National Marine Fisheries Service (NMFS), Woods Hole. NMFS conducts three fisheries and six plankton surveys of the GOM each year at approximately 30 stations. In addition, there is a Continuous Plankton Recorder (CPR) Survey, which is conducted aboard a ship of opportunity on a monthly trip from Boston to Halifax (data collection is terminated at Cape Sable, northeastern end of the GOM). This survey has a long history: CPR records from 1961–present; continuous surface salinity and temperature and periodic bathythermograph (XBT) records (every 1-2 h) since 1978; and surface fluorescence in the last few years. Processing of survey results is virtually up to date and publicly available in digital form (J. Jossie, NMFS, Narragansett, RI, pers. comm.). Records such as these have provided tremendous insight into biological fluctuations in the North Atlantic and Gulf of Maine (e.g., Planque et al. 1997, Mountain 1999). The temporal and spatial properties of the GOM fisheries and zooplankton data will be evaluated to determine how they might be integrated with remotely sensed data, and what techniques should be used. This will be done in partnership with the Canadian Department of Fisheries and Oceans (DFO) and NMFS (see letters of support) through this proposal. Findings and future recommendations for monitoring (a collaboration among GoMOOS and the federal labs) will be a major topic at the RARGOM Workshop and in one of the Working Groups to follow.

D. Data Management System

The Gulf of Maine Information Management System (GoMIMS) will be designed to serve both the immediate and future missions of Ocean Observing Systems. As the first operational observing system, special effort needs to be expended by GoMOOS to assure that a flexible modular design structure is developed that is both compatible with current systems and amenable to evolution as information technology changes. The system must provide users with search and discovery capabilities and provide seamless access to any information within the system. GoMIMS must be capable of integrating with other Ocean Observing Systems, with historical data archives for the Gulf of Maine, and a range of heterogeneous distributed sources. GoMIMS will use a client server architecture that manages data through a data warehouse and supports the dissemination of GoMOOS data and products over the Internet. A warehouse approach involves assembling data from various sources, integrating them and storing then in a central repository. An alternate approach is a mediated approach in which data reside at their source location and are extracted from the sources by a form of middleware in response to a query. In the warehouse approach data are integrated, restructured and packaged into a common format for efficient query processing. One advantage of such an approach is that computations on this data do not interfere with the operational sites from which data are assembled.



The diagram above shows a proposed architecture for the system featuring the major data sets. Several distributed sources contribute data to the warehouse first passing through an integration step. In the integration step data may be structured, normalized, checked for inconsistencies and derived products created. The warehouse itself must be capable of storing heterogeneous data types including structured data plus text, imagery, video, and potentially audio. The metadata catalog, roughly analogous to a card catalogue, provides a frontline interface to the user. It contains summaries of the data contained in the warehouse including brief entries for data sets or observations that note times, spatial locations, and depths. Additionally the catalog may include thumbnail versions of images, histograms, time series plots, model descriptions and images of model results. The catalog thus contains abstract representations of the full data sets contained in the warehouse. The development of the data warehouse will involve development of warehouse services and metadata services. Warehouse services will be built on top of a commercial database system that supports spatial and temporal data types and indexing over these data types. The metadata services will require development of software tools to automate a substantial portion of the metadata creation and update.

The data warehouse server must support easy loading of new data sets, multiple indexing over the data sets and summaries of new data that can be passed up to the metadata catalog. The warehouse server should be able to support potentially large numbers of users with optimal query performance across a range of query types.

On the client side, one or more Graphical User Interfaces (GUI's) designed for a range of users from scientists and mariners to K-12 students will provide a flexible web-based front end to the system. The GUI's at a minimum will support the following functionality:

- Viewing of now-time conditions

Graphical displays of near real time conditions for measured variables: sea surface temperature, wind speed, ocean color, surface currents, scatterometer winds, and buoy data will be made available. Users should be able to easily navigate and request the variables of their choice and zoom and pan functionality will be supported for these displays. For mariners, or others without access to computers and the Internet, the latest buoy data should be available via phone from a system akin to the NDBC's Dial-A-Buoy system. The buoys and data types will be selectable via a menu and a computerized voice will read a text message with the latest data values.

- Downloading of now-time data

Both NEOOS and GoMOOS intend to adopt the Distributed Oceanographic Data System (DODS). DODS is a client-server system that uses http as the low-level communication protocol. It was designed to make oceanographic data of virtually all descriptions available over the Internet. Data providers install DODS servers on their system and any client program that can read DODS data has access to the served data. This system provides the low-level infrastructure needed to integrate the various data collected by GoMOOS. This will be extended to support data delivery for common desk top applications.

- Search and browse of the archive

In addition to supporting display and download of now-time data, users should have access to the GoMOOS archive. To support access to the archive, the GoMIMS system will support flexible and efficient search and retrieval. Search functionality should allow for search over the spatial dimension (e.g., near shore, Massachusetts Bay, a region specified in latitude and longitude, depth, etc.), the temporal dimension (e.g., data from last year, from last January, from last summer, etc.) and topical criteria (e.g., sea surface temperature, currents, dissolved oxygen).

In a very large archive a query paradigm is not adequate since the user will likely not have sufficient information to formulate a query. In this case, users need the capability to quickly browse the archive for information of interest. Browsing capability is a particularly useful feature for investigating image archives. Browsing will be supported by summary information on the archive contents. Thumbnail versions of images stored in the metadata catalog will be accessible to users to quickly check for presence of features of interest or presence of cloud cover. The goal is to sort the thumbnail images by date and time and have similar presentation formats for efficient visual comparison. When a data set of interest is discovered the system will allow the user to down load the data and pertinent metadata in formats that can be used in desktop applications.

The GUI component will consist of a web-based front end developed in Java for platform independence. The Java front end will provide intuitive access to the warehouse services that support query, browse and retrieval of information from the archive.

A fully functional data management system as envisioned by the GoMOOS team is not available as an off the shelf product. The challenge will be to design an effective data management system that will allow for the display and dissemination of real-time information, include an archive and retrieval system that meets the needs of sophisticated and non-sophisticated users, and is compatible with other data systems. GoMOOS will draw on experts throughout the country to assist with the design of the data system and will ensure that the system is part of the National Ocean Partnership Program's Virtual Ocean Data Hub effort. The data system implementation will be sent out for commercial bid through an Request for Proposals (RFP) process as three component pieces: data warehouse services, metadata creation services, and the client GUI. Vendors may bid on all three components or a single component. Commercial database vendors (e.g., Oracle), spatial data warehouse providers (e.g., Cubewerx, ESRI, CARIS) and metadata software developers are examples of types of firms capable of bidding on such an RFP. GoMOOS will retain critical tasks involving coordination and oversight of the design and modification of the system in order to insure flexibility and standardization with other observing systems as they evolve. Should no acceptable proposals be received in response to the RFP, a system manager, programmer and two graduate research assistants will be hired to carry out the data management system development with supervision from the GoMOOS team.

VI. PUBLIC AWARENESS

Building public awareness of, and support for, ocean observing is a central mission of GoMOOS. GoMOOS is an exciting new experiment in ocean observing, attempting to provide oceanographic information on a regional scale to a variety of user groups. To ensure GoMOOS reaches it full potential as a user-driven system, GoMOOS will implement a creative and effective public awareness campaign.[1]

GoMOOS will design and develop engaging public awareness material including superb visualizations, animations, "movies" and graphics that can be used to design compelling electronic and print presentations for telling the GoMOOS story. These materials will form the backbone of a public awareness strategy that will include meeting with regional groups

[1] GoMOOS makes a distinction between public awareness and public education. GoMOOS is a service organization dedicate to the delivery of high-quality and timely information on the Gulf of Maine. Such information will augment the efforts of others in fulfilling their missions. The Gulf of Maine region is blessed with excellent public education organizations (e.g. New England Aquarium, Gulf of Maine Aquarium, Island Institute, Bigelow Laboratory, etc.). GoMOOS will supply excellent oceanographic information and data products that can be utilized by these organizations to develop exceptional education opportunities. GoMOOS, itself, will not develop educational materials.

(professional meetings, trade organizations, media groups, managers, non-profits and others), formal presentations at meetings and conferences and informal networking opportunities.

The mass media presents one of the most powerful tools to tell the "Gulf of Maine" story via press release material. To facilitate this exposure, we will convene a group of media representatives from local and regional newspapers (e.g., Portland Press Herald, Boston Globe), television and radio stations and media experts to discuss and design a GoMOOS product that would have mass appeal and be suitable for broad distribution through the television market, local papers or radio. The goal is to develop a product that can be shown on nightly news programs or in the daily paper about the state of the Gulf.

VII. Observation System Development and Future Design

The implementation of the observational subsystems and the data storage and dissemination subsystems will be a staged incremental process. Research, development, and review (R&D&R) are thus acknowledged to be an integral part of the execution of the proposed observing system. GoMOOS will incorporate R&D&R into the fabric of its overall approach in the form of new sensor field-testing, workshops and surveys to evaluate the systems, standards and protocols.

An important objective of this proposal is to provide for transition of the startup program into a regional facility. In the first year we will develop membership throughout the New England area; we will seek and share technical and programmatic ideas with all appropriate and interested parties; and we anticipate that future funding will support additional investigators and contractors from around the region and beyond. This evolution will be accomplished through workshops, and meetings with research institutions, industry and managers throughout the region.

As a demonstration project, GoMOOS will be active in the effort to establish the key elements of a national network of observing systems and will work the NOPP agencies and other regional observing efforts to discuss common concerns and the development of protocols and standards that will allow for seamless communication among the observing systems. It is anticipated that GoMOOS will host one to two working group meetings on specific topics as well as attend and participate in meetings and conferences on relevant topic areas. The topic areas for these workshops will be determined in consultations with ONR/NOPP, the Board of Advisors and others involved in ocean observations.

The working group on HF radar systems planned by Dr. Scott Glenn for May 2000, with Drs. Hans Graber, Mike Kosro, Jeff Paduan, Neal Pettigrew, and Libe Washburn participating is an example of the kind of activity in which GoMOOS will participate. HF radar systems are becoming more prevalent in the measurement of ocean currents, and, as they become central elements in a national network, issues of common antenna calibration protocols, data exchange formats, and data processing procedures will need to be standardized.   GoMOOS also anticipates participating in the first of an ONR-sponsored series of HF radar workshops is being planned by Dr. Hans Graber for the fall of 2000. Thus, GoMOOS will participate in and support an ongoing national dialog aimed at establishing interoperability, and standardization of data handling and analysis procedures for HF radar facilities.

The Board of Advisors will be serve as an important link to regional and national observing efforts. Since this is not simply a Gulf of Maine project but a national pilot, we expect to involve a number of individuals with national and other regional expertise in workshops described under section. (A list of confirmed members is in Section VIII.)

GoMOOS expects to work with the Oceanographer of the Navy, ONR and potentially the Naval Oceanographic Office to explore opportunities for collaboration including the exchange of data, methodologies and protocols. GoMOOS hopes to formalize this relationship by having a representative from the operational Navy serve on the Board of Advisors.

To guide the way from the start-up phase to an operational system, GoMOOS will complete a five-year business plan. The business plan will prepare for the long-term operation of the system and for the possible migration of certain duties from the principal investigators in the start up phase to the corporation at some point in the future. The business plan will identify sources of support necessary to sustain the operations of the observing system and outline a process for ensuring its long-term viability

To ensure relevance of data products, GoMOOS will establish a forum for on-going communication with users and principal investigators. To begin this process, a survey of user groups will be conducted. Representatives the shipping industry, oil and gas industry, telecommunications industry, marine engineering; harbor pilots; hazard mitigation industry; fishing industry; fishery and environmental managers; port authorities; recreational industry; researchers and educational groups; aquaculture; military experts, construction, and the biotechnology industry will be included in the survey. This survey will build on the previous work done to identify user needs (EuroGOOS, 1999) but be directed to the specific market demands of the Gulf of Maine region.

The results of the written survey will be augmented by 3-4 workshops with targeted industry groups to solicit specific ideas for operational products that will assist them in solving problems and facilitate their business, management and research. The industries likely to benefit from observational products will be diverse. Instead of one workshop to bring together tanker captains concerned about ballast water and as well as shellfish harvesters concerned about red tide closures, GOMOOS will conduct a series of workshops targeted to specific industries or groups of industries. The workshops will serve the additional purpose of informing the various constituencies of the form, function, and purpose of the ocean observing system.

The synthesis of these focus groups will be accomplished through workshops, and working group meetings and reports carried out by a partnership with the Regional Association for Research in the Gulf of Maine (RARGOM)[2]. Workshops will better define user needs, evaluate the extant observing system, and make recommendations for changes/additions for the future. Working groups will evolve from the workshop deliberations to advise on the future

[2] RARGOM has existed for a decade to promote and facilitate research in the Gulf of Maine and to increase effective links between science and management (Wallace and Braasch 1997, Migis Workshop Report 1997, Incze et al. 1998). RARGOM comprises 21 member and associate member organizations from government, academia and the private sector in the U.S. and Canada.

development and management of the system and its related programs and will contribute to written reports.

Based on the above, GOMOOS will identify and design (or facilitate design by the private sector) useful products that can be derived from the ongoing observations. Such products might include predictive indices, interpretive maps, and assimilation of data that can be used by those who work and depend on the Gulf of Maine.

VIII. PROJECT ADMINISTRATION

This proposal is submitted to ONR/NOPP on behalf of GoMOOS by Evan Richert, President of the GoMOOS Board of Directors. GoMOOS will be responsible for overseeing and administering the grant. Mr. Richert, Director of the Maine State Planning Office, or his successor as President of the Board of Directors, is the Principal Investigator. A national search for an Executive Director for GoMOOS will be launched when and if funding for this proposal is awarded. Once the Executive Director is hired, GoMOOS will negotiate with ONR/NOPP to have the Executive Director replace the President of the Board of Directors as Principal Investigator.

GoMOOS is a not-for-profit corporation committed to: (i) providing resource managers, harvesters, military experts, industry, researchers, educators and others with integrated, remotely-sensed and *in situ* information about the Gulf of Maine and related ecosystems for use in real or near real time, so that they may better understand the cold water environment, manage ocean and littoral resources, and develop commercial uses of marine resources, data and information; (ii) helping to anchor a national ocean observing system; (iii) developing new sensor technologies; and (iv) stimulating innovation by supporting new and expanded business opportunities in such areas as biotechnology, information technology, and living marine resources. GoMOOS was incorporated in November 1999; the by-laws are attached as Appendix B. Charts describing the organizational structure of GoMOOS and its implementation are attached as Appendix C.

GoMOOS is explicitly designed to reflect a corporate organizational model. The ocean observing system envisioned by GoMOOS is not a research project; it is an operational, long-term monitoring program driven by the needs of a wide range of users of the Gulf of Maine. GoMOOS is drawing upon the expertise of the research community in designing the plans for an ocean observing system, but the goal of the system will be to serve the needs of its customers: resource managers, military planners, environmental regulators, fishermen, aquaculturists, mariners, biotechnology interests, and specialists in real time, spatial, oceanographic data. In the process of serving these needs, GoMOOS will also support and stimulate research and help leverage additional funding for research.

Operationally, GoMOOS will draw upon a distributed network of service providers to establish an ongoing flow of data products of use to a broad range of users. It will be managed from a market-oriented, results-driven perspective ensuring that the needs of user groups remain the top priority of the organization.

In order to serve as broad a constituency as possible, including unforeseen users, GoMOOS is designed as a membership organization open to any institution willing to pay an annual membership fee. To date, members include public interest non-profits, private sector spatial information companies, state agencies and research and academic institutions. We will expand the membership in two ways: first, to include other user groups such as shipping interests, fisheries groups, biotechnology companies and others who have expressed strong interest in the system, and, second, to include institutions from throughout the Gulf of Maine region. The benefits of membership include: making a civic contribution to an effort of tangible benefit to the citizens and economy of the region, a well-defined role in GoMOOS' governance, participation in GoMOOS' linking of value-added providers and user groups, and favorable terms on certain value-added products.

The Board of Directors that oversees GoMOOS is elected by the membership. GoMOOS decision-making is ultimately tied to its membership to ensure that GoMOOS is responsive to the needs of those who will benefit from the data and information it provides. The power of a membership organization is that it fosters participation by a range of participants, some of whom can be identified today, others of whom are currently unanticipated, who will use ocean observation in a variety of ways. GoMOOS will work for a much broader constituency than the military and other Federal agencies who have been the traditional market for oceanographic data and information.

The Founding Board of Directors of GoMOOS are drawn from a diverse array of interests in ocean observing including non-profit organizations, mapping companies, aquarium, research institutions and government agencies. This Board has been instrumental in articulating the purpose of the organization, shaping GoMOOS into an organization that is responsive to the needs of user communities and defining the unique niche GoMOOS fulfills in the Gulf of Maine region. Founding Directors include:

President
Evan D. Richert, Director
Maine State Planning Office

Vice President
Dr. Louis 'Sandy" Sage
Bigelow Laboratory for Ocean Sciences

Treasurer
Philip D. Conkling, President
Island Institute

Secretary
Dr. James Page, President
James W. Sewall Company

Members
Daniel J. Dwyer
Vice President for Research
University of Maine

Mark A. Jadkowski, PhD, Vice President
MapTech, Inc.

Linda P. Mercer, Director
Bureau of Resource Management
Maine Department of Marine Resources

Donald W. Perkins, Jr., President
Gulf of Maine Aquarium Development Corporation

Joel B. Russ, President
Maine Science & Technology Foundation

The Founding Directors will be replaced in September 2000 by the first Board of Directors that will include representation throughout the Gulf of Maine region and broader participation from industry.

A Board of Advisors comprised of experts in appropriate fields provides technical expertise to the Board of an advisory basis. The membership of the Board of Advisors is currently incomplete; it will shortly be broadened to include a diverse range of disciplines. Thus far, the board includes:

Dr. Scott Glenn, Rutgers
Dr. David Mountain, National Marine Fisheries Service, Woods Hole
Dr. Tommy Dickey, University of California, Santa Barbara
Dr. Robert Weller, Woods Hole Oceanographic Institution
Dr. A.D. Kirwan, University of Delaware
Dr. Peter Smith, Bedford Institute of Oceanography

The Chief Scientist and Project Scientists throughout the region, drawing on the resources of their home institutions, will be responsible to the President, and subsequently the Executive Director when hired for the initial implementation of the technical aspects of the observing system. Ongoing review by representatives of the user community will ensure the relevancy of the observing system.

The Board of Directors will hire an Executive Director to be the Chief Executive Officer of the corporation. The Executive Director will be responsible for conducting the business activities of GoMOOS, for implementing its policies and programs, for maintaining its user focus, for coordinating and communicating with member institutions, for managing the scientific aspects of projects and programs, for serving as a liaison with federal agencies and other regional observing systems, for the fiscal management, for employing and supervising staff members and for building public awareness of GoMOOS' activities. An individual will be selected who has strong leadership and management skills, an understanding of the technical and scientific issues, a proven ability to foster partnerships with the private sector, and experience in working with Congress and state and federal agencies. It is anticipated that an Executive Director will be hired by December 31, 2000.

IX. CHIEF SCIENTIST AND PROJECT SCIENTISTS' RESPONSIBILITIES

Neal Pettigrew (Chief Scientist): Physical oceanography, buoy assembly & deployment (coastal and shelf buoys), ship schedules, central coordinator for all technical aspects of the program
Mary Kate Beard-Tisdale (Project Scientist): Request for proposals for data management system
Lewis Incze (Project Scientist): Zooplankton and fisheries
James Irish (Project Scientist): Buoy assembly & deployment (basin buoys), wave measurements
Vijay Panchang (Project Scientist): Wave modeling
Collin Roesler (Project Scientist): *In situ* ocean optics
Andrew Thomas (Project Scientist): Satellite remote sensing
David Townsend (Project Scientist): Nutrients
Huijie Xue (Project Scientist): Circulation modeling

X. PROJECT TIMELINE AND IMPLEMENTATION SCHEDULE

Our plan is to implement the GoMOOS technical program in a phased manner. Modeling efforts will begin immediately after funding is secured. We will deploy a prototype of each of the three buoy types (basin, shelf, and nearshore) within a few months of funding. This early deployment strategy will allow us to test our designs, begin to develop the data handling and delivery protocols, and begin data assimilation efforts early in the demonstration project. We expect the full array to be in place in the spring of 2001. Satellite remote sensing data will be one of the first products served by GoMOOS. We will also begin installation of the CODAR system for surface current measurement, as soon as funding is available and will begin to gain experience with the data handling and development of data products.

Optical sensors will be phased into the mooring array. While the required servicing of many of the sensors in the Gulf of Maine are well established, servicing and anti-fouling measures required in the Gulf on others will need to be determined empirically. Our strategy will be to deploy optics early when we have few buoys and servicing can be more frequent. The results of this early experimentation may be that a few buoys in the final array will be heavily instrumented will optical sensors and these buoys may to be serviced at shorter time intervals.

Before initiation of the project, GoMOOS will develop a formal management schedule with milestones, timeline, budgets and contingencies using a conventional project management system that is suitable for managing large, complex projects.

	1st Quarter Jun-Aug	2nd Q Sep-Nov	3rd Q Dec-Feb	4th Q Mar-May	5th Q Jun-Aug	6th Q Sep-Nov	7th Q Dec-Feb	8th Q Mar-May
Outreach								
Needs Survey	Conduct	Finalize						
User Workshops	Planning	Focus groups	RARGOM/synthesis	Preliminary recomm.	work group	w groups	w groups	final report
Nat'l workshops			Workshop			Workshop		
Public Awareness	Design Materials	On-going	************	***********	************	***********	***********	************
Moored Array								
Prelim. Moorings	Deploy	service						
Offshore				deploy		service		service
Shelf Moorings				deploy		service		service
Coastal Mooring				deploy		service		service
CODAR			************	************	************	************	************	Shoreland Zoning
Remote Sensing								
AVHRR	*************	***********	************	**********	***********	***********	***********	***********
SeaWIFS	*************	***********	***********	***********	***********	***********	***********	***********
MODIS			***********	**********	***********	***********	***********	***********
Quickscat	************	***********	***********	***********	***********	***********	***********	***********
Modeling								
Circ. Modeling	*************	***********	***********	***********	***********	************	************	************
Wave Modeling	Develop	***********	***********	***********	***********	************	************	************
Data System								
Develop RFP	********							
Issue RFP	*****							
Issue Contract		*						
Develop System			**********	***********				
System Functioning					**********	***********	************	************
Data Products								
Wave					************	***********	***********	************
Meterological					************	************	************	************
Currents					*************	************	************	************
Temperature					*************	************	************	************
Salinity					*************	************	************	************
Dissolved Oxygen					*************	************	************	************
Turbidity							************	************
Primary Produc.							************	************
PSP Index								************
Whale accoustics					************	************	************	************
Nutrients								************

XI. BUDGET

The budget is summarized below. Budget details can be found in Appendix D.

Summary by Expense	FY 1	FY 2	Total
Total Personnel Costs	$654,494	$799,652	$1,454,146
Permanent Equipment sensors, buoys, CODAR, computers and laboratory equipment	1,767,499	492,780	2,260,279
Expendable Supplies, Analyses and System Maintenance	112,100	113,300	225,400
ShipTime	94,000	243,000	337,000
Contractual/Project			
Data Management System	270,000	130,000	400,000
Surveys, workshops, etc.	164,000	100,000	264,000
Liability Insurance	10,000	10,000	20,000
Travel	30,350	43,800	74,150
Other Direct Costs			
material and supplies	26,771	95,500	122,271
rental and utilities	12,500	12,500	25,000
office supplies	4,500	5,500	10,000
computer maintenance	6,000	6,000	12,000
telecommunications	26,500	30,700	57,200
Total Direct Costs	$3,178,714	$2,082,732	$5,261,446
Indirect Costs	$316,604	$239,908	$556,204
Total Costs	**$3,495,318**	**$2,322,332**	**$5,817,650**
	FY00	FY01	Total

Summary by GoMOOS Component	FY 00	FY01	Total FY 00-01

Shelf and shallow buoys, CODAR and shiptime (Pettigrew)	$1,806,137	$1,077,590	$2,883,727
Offshore buoys and waves (Irish)	$201,943	$151,712	$353,655
Optics (Roesler)	$268,026	$222,636	$490,662
Satellite Remote Sensing (Thomas)	$144,858	$110,904	$255,762
Nutrients (Townsend)	$65,915	$50,611	$116,526
Circulation Modeling (Xue)	$170,835	$89,503	$260,338
Wave Modeling (Panchang)	$129,478	$122,608	$252,086
Data Management System (Beard)	$17,698	$18,820	$36,518
Biological Monitoring (Incze)	$77,427	$57,485	$134,912
Administration and Outreach (Richert)	$603,655	$429,809	$1,033,464
Total Costs	$3,485,972	$2,331,678	$5,817,650

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