NOPP
National Oceanographic Partnership Program

IOOS DEVELOPMENT PLAN
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THE FIRST U.S. INTEGRATED OCEAN OBSERVING SYSTEM (IOOS) DEVELOPMENT PLAN

A REPORT OF THE NATIONAL OCEAN RESEARCH LEADERSHIP COUNCIL AND THE INTERAGENCY COMMITTEE ON OCEAN SCIENCE AND RESOURCE MANAGEMENT INTEGRATION

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Preface

The Integrated Ocean Observing System, the Global Ocean Observing System, and the Global Earth Observing System of Systems

The U.S. Commission on Ocean Policy[1] and the National Ocean Research Leadership Council (NORLC)[2] identified the Integrated Ocean Observing System (IOOS) as a high priority and emphasized the importance of interagency cooperation for successful implementation. Successful implementation depends, to a great extent, on enabling connectivity between the research motivated by IOOS mission requirements and that of the ocean science community in general. Enabling this interplay is an important role of the National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology, and of the Interagency Working Group of the National Oceanographic Partnership Program, which is represented on the Subcommittee.

The IOOS is a coordinated national and international network of observations and data transmission, data management and communications (DMAC), and data analyses and modeling that systematically and efficiently acquires and disseminates data and information on past, present and future states of the oceans and U.S. coastal waters to the head of tide. "Coastal" includes the U.S. Exclusive Economic Zone (EEZ) and territorial sea[3], Great Lakes, and semi-enclosed bodies of water and tidal wetlands connected to the coastal ocean.

The IOOS is part of the U.S. Integrated Earth Observation System (IEOS), the U.S. contribution to the Global Ocean Observing System (GOOS), and a contribution to the Global Earth Observation System of Systems (GEOSS).[4] GOOS, an initiative of the Intergovernmental Oceanographic Commission, is being designed and implemented to meet the requirements of international agreements and conventions. Agreements calling for actions that address the seven societal goals of the IOOS include the Safety of Life at Sea Convention, the United Nations (U.N.) Framework Convention on Climate Change, the Convention on Biological Diversity, and the U.N. Conference on Environment and Development's Global Programme of Action on Sustainable Development. Development of the IOOS influences, and is guided by, the design and implementation of GOOS. An important step toward the realization of the Integrated Global Observing Strategy took place on 31 July 2003, when the U.S. hosted the Earth Observation Summit. At this summit, for the first time, nations came together at a political level to express the commitment of their governments to a common world understanding that sustainable economic growth can only result from linking systems into a comprehensive and sustained GEOSS. Recognizing the importance of using a common framework for development of the many GEOSS components, the thirty nations agreed to a declaration affirming the need to support the Four Principles of Earth Observations:

- Improved coordination of strategies and systems for Earth observations and identification of measures to minimize data gaps, with a view to moving toward a comprehensive, coordinated, and sustained Earth observation system of systems;
- A coordinated capacity-building effort to involve and assist developing countries in improving and sustaining their contributions to Earth observing systems, including access to and effective utilization of observations, data and products, and related technologies;
- The exchange of observations recorded from *in situ*, aircraft, and satellite networks, dedicated to the purposes of the declaration, in a full and open manner, with minimum time delay and minimum cost, recognizing relevant international instruments and national policies and legislation; and
- Preparation of a ten-year Implementation Plan (completed 16 February 2005) that is guided by the framework adopted at the Earth Observation Summit and builds on existing systems and initiatives. The Framework Document describes principle benefits of the GEOSS to a broad range of user communities and the fundamental elements to be included in the ten-year plan for its implementation.[4]

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[1] "An Ocean Blueprint for the 21st Century: Final Recommendations of the U.S. Commission on Ocean Policy" <http://www.oceancommission.gov/documents/welcome.html>

[2] "Ten-Year Strategic Plan for the National Oceanographic Partnership Program (NOPP)" <https://www.coreoceandb.org//DisplayFile.aspx?qs=3A9B53A690BA1136E5A8F08DA262794EC39>

[3] <http://chartmaker.ncd.noaa.gov/csdl/eez.htm>

[4] <http://iwgeo.ssc.nasa.gov>, <http://earthobservations.org/docs/10-Year%20Implementation%20Plan.pdf>

preface

The First IOOS Development Plan embraces these principles as guidance for IOOS design and implementation. Implementing the U.S. IOOS is a major contribution toward achieving these goals, and coordination of U.S. and international efforts to establish GOOS and GEOSS is critical. The recent history of activities leading to the effort to establish a sustained U.S. IOOS and its relationship to the GOOS is summarized in Appendix A. Appendix B provides a glossary of terms, and the conceptual design of the IOOS is described in Appendix C. The conceptual design is based on recommendations by groups of experts that culminated in an NORLC Report, *An Integrated and Sustained Ocean Observing System (IOOS) for the United States: Design and Implementation.*[5]

The First Annual IOOS Implementation Conference[6]

On behalf of the NORLC, the Ocean.US-EXCOM Enterprise (the Ocean.US Office and its Executive Committee) completed *The First IOOS Development Plan* in December, 2004 following the First IOOS Implementation Conference. This event provided a forum for the leaders of nascent Regional Associations (RAs) of regional coastal ocean observing systems (RCOOSs) to work directly with participating federal agencies to provide guidance for completing the first development plan as follows:

- Implement current plans for the global ocean component of the IOOS[7];
- Implement the plan for developing the Data Management and Communications (DMAC) subsystem of the IOOS;
- Establish RAs (consortia of data providers and users responsible for establishing, operating, and improving RCOOSs) and a National Federation of Regional Associations (NFRA) to coordinate the development of RCOOSs and represent the RAs at the federal level;
- Implement a process to select coastal ocean data assimilation experiments as pilot projects that will facilitate coordinated development of the coastal and global components.

There was also strong agreement on the pressing need to sustain existing elements of the observing subsystem for coastal IOOS, to implement the DMAC subsystem as the first step toward integrating these into an interoperable system, and to effectively link IOOS development to science education and technical training.

This document, *The First IOOS Development Plan*, is based on the results of the First IOOS Implementation Conference and recommendations received during a one-month public comment period (15 October through 15 November, 2004) announced in the Federal Register. The Plan, which will be periodically updated, makes recommendations to be used by federal agencies in establishing their priorities for contributing to the implementation, operation, and improvement of the initial IOOS.

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[5] <http://www.ocean.us/documents/docs/FINAL-ImpPlan-NORLC.pdf>

[6] "Proceedings of the First Annual Implementation Conference for the Integrated Ocean Observing System (IOOS)" <http://ocean.us/documents/docs/AnnualIOOSImpConf-PROCEEDINGS-5Oct04.doc>

[7] The Ocean Observing System Development Panel (OODSP) 1995. "The scientific design for the common module of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS): An ocean observing system for climate." Report of the OOSDP, publ. U.S. World Ocean Circulation Experiment (WOCE) Office, Texas A&M University, College Station Texas, 285 pp.; United Nations Educational, Scientific and Cultural Organization (UNESCO), 1999. Global physical ocean observations for GOOS/GCOS: an action plan for existing bodies and mechanisms. GOOS Rpt. No. 66, 50 pp. <http://ioc.unesco.org/goos/docs/GOOS_066_act_pl.htm>; Implementation Plan for the Second Adequacy Report. GCOS. 2004. Implementation Plan for the Global Ocean Observing System for Climate in Support of the UNFCC. <http://www.wmo.ch/web/gcos/gcoshome.html>

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Goals and Design Principles

The Integrated Ocean Observing System (IOOS) efficiently links observations to modeling via data management and communications in order to provide data and information needed to significantly improve the nation's ability to achieve seven societal goals:

- Improve predictions of climate change and weather and their effects on coastal communities and the nation;
- Improve the safety and efficiency of maritime operations;
- More effectively mitigate the effects of natural hazards;
- Improve national and homeland security;
- Reduce public health risks;
- More effectively protect and restore healthy coastal ecosystems; and
- Enable the sustained use of ocean and coastal resources.

Achieving these goals depends on the establishment of a robust network of operational observing activities that routinely, reliably, and continuously provides data and information on oceans and coasts, in forms and at rates specified by groups that use, depend on, manage, and study marine systems; provides multi-disciplinary data and information from *in situ* and remote sensing; fosters synergy between research and the development of operational capabilities; transcends institutional boundaries; and improves public understanding of the oceans through sustained communications and education programs. In short, the developing IOOS must make more effective use of the collective resources of the U.S. and leverage them to establish a fully integrated system that addresses all seven societal goals.

Developing an integrated system to address the seven goals and their objectives must be guided by the IOOS Design Principles as follows: (1) enable data provider and user groups to achieve their missions and goals more effectively and efficiently; (2) develop a scientifically sound system with guidance from public and private sectors; (3) begin by integrating existing assets that will improve the nation's ability to achieve the seven societal goals and regional priorities; (4) improve the IOOS by enhancing and supplementing the initial system over time based on user needs and advances in technology and scientific understanding; (5) routinely, reliably, and continuously serve data and information for multiple applications; (6) openly and fully share data and information produced at the public expense in a timely manner; (7) ensure data quality and interoperability through by meeting federally approved standards and protocols for observations, data telemetry, DMAC, and modeling; (8) establish procedures to ensure reliable and sustained data streams, routinely evaluate the performance of the IOOS, assess the value of the information produced, and improve operational elements of the system as new capabilities become available and user requirements evolve; (9) improve the capacity of states and regions to contribute to and benefit from the IOOS through training and infrastructure development nationwide; and (10) demonstrate that observing systems, or elements thereof, that are incorporated into the operational system either benefit from being a part of an integrated system or contribute to improving the integrated system in terms of the delivery of new or improved products that serve the needs of user groups.

In this context, it is important to note that the IOOS does not encompass all or even a majority of ocean observations. Its purpose is to establish operational oceanography for the public good. Most oceanographic research will continue to be performed independently, while at the same time providing an ever-growing foundation of knowledge and technology that will enable the development of operational capabilities.

Linking Observations and Models

Effectively linking societal needs for environmental information to measurements requires a managed, efficient, two-way flow of data and information among three essential "subsystems" (the "end-to-end" system) for (1) measurements (remote and *in situ* observations and data telemetry), (2) data management and communications (DMAC), and (3) data analysis and modeling. The observing subsystem is the "eyes" and "ears" of the IOOS; DMAC is the primary means of integration; and models are the primary tools of synthesis required for rapid and timely detection and prediction of changes. The term "subsystems" is used here to indicate necessary functions of the IOOS, not to indicate actual organizational entities.

A Spatial Hierarchy of Observations

The IOOS consists of two interdependent components that use both remote and *in situ* sensing to make measurements over the broad range of scales needed to detect, assess, and predict the effects of global climate change, weather, and human activities on oceans and coasts. The integrated system efficiently and effectively link models and model development to observations and establishes a sustained hierarchy of observations across spatial scales from the global ocean to coastal ecosystems.

(1) The coastal component is designed to detect, assess, and predict the effects of weather, climate, and human activities on the state of the coastal ocean, its ecosystems and living resources, and the U.S. economy. It consists of both a National Backbone and regional coastal ocean observing systems (RCOOSs) that encompass the U.S. Exclusive Economic Zone (EEZ) and territorial waters, the Great Lakes, and estuaries. Note that “coastal” refers to the nation’s EEZ, Great Lakes, and estuaries. “Estuaries” includes all semi-enclosed bodies of water (bays, lagoons, fjords, tidal wetlands, etc.) that are connected to the ocean. Development of the coastal component is critical to the design and implementation of ecosystem-based management of public health risks, water quality, and living resources. The immediate priorities for the next five years are establishing the DMAC subsystem, incorporating existing operational assets of the observing subsystem into an integrated system, establishing RCOOSs, and linking IOOS development to Earth science education, training and public outreach. Once the initial DMAC subsystem is operational, enhancements to the National Backbone can begin.

(2) The global ocean component, an international collaboration, is being implemented to improve forecasts and assessments of weather, climate, and ocean states, as well as to provide boundary conditions for the coastal component. The global component has been developed and is being implemented under the oversight of the Joint Intergovernmental Oceanographic Commission/World Meteorological Technical Commission for Oceanography and Marine Meteorology (JCOMM) and with scientific guidance from the Global Climate Observing System (GCOS) and the GCOS/Global Ocean Observing System/World Climate Research Program Ocean Observations Panel for Climate (OOPC).

Together, the global ocean and coastal components of the IOOS constitute a hierarchy of observations required to detect, assess, and predict the effects of large-scale changes in the oceans, atmosphere, and land-based inputs on coastal ecosystems, resources, and human populations.

Regional Associations (RAs) represent the interests of groups that use, depend on, manage, monitor, and study marine systems in their respective regions. For this purpose, RAs engage representatives from federal and state agencies, private sectors, nongovernmental organizations (NGOs), tribes, and academia in the design, implementation, operation, and improvement of RCOOSs that enhance the National Backbone based on regional priorities. The National Backbone consists of *in situ* observations and remote sensing, data management and modeling needed to achieve the goals and missions of federal agencies and to meet the common requirements of RAs. Establishing the National Backbone achieves economies of scale by measuring, managing, and analyzing a set of core variables needed by all or most regions. Together, the National Backbone and RCOOSs contribute to developing ecosystem-based management capabilities by (1) improving remote sensing in near shore environments by providing more *in situ* data for calibration and validation and by (2) establishing sentinel and reference stations with guidance from RAs. Both capabilities are needed for early detection of the effects of land-based inputs and of basin scale events, such as El Niño, on coastal systems.

Objectives of *The First IOOS Development Plan*

The First IOOS Development Plan addresses many recommendations of the U.S. Commission on Ocean Policy, including those for establishing an IOOS with an emphasis on regional development, developing the capacity for ecosystem-based management, and linking IOOS data and information to applications. The initial IOOS is being implemented to achieve the following objectives:

- Enable data integration by implementing the Ocean.US data management and communications plan (critical to addressing all seven societal goals);
- Establish Regional Associations (RAs) to manage the development of regional coastal ocean observing systems (RCOOSs) (especially important for addressing the goals of maritime operations, natural hazards, public health; ecosystem health and living marine resources);
- Continue implementing the global ocean-climate component of the IOOS (important for addressing the goals of climate change, maritime operations, and natural hazards);
- Begin implementing the coastal component to provide improved estimates of geophysical, biological and chemical states of pelagic and benthic environments (important for addressing all seven goals);
- Establish linkages between IOOS development and the use of IOOS data and information for education, training and public outreach; and
- Improve positive feedbacks between the Earth sciences and the development of IOOS operational capabilities.

Developing the IOOS

The global ocean component is being established by federal agencies. Establishing the coastal component will be accomplished through a collaboration between federal agencies and Regional Associations (RAs) created to manage the development of RCOOSs. Regional groups have been competitively funded to form RAs that meet criteria for governance and business plans specified herein. These include criteria for engaging user groups in the establishment of goals, objectives and priorities for ocean observations; the determination of observing system requirements based on these priorities, and the establishment of an on-going process for updating both. The development of RCOOSs must be consistent with IOOS design principles.

The First IOOS Development Plan provides a framework and guidelines for the development of RAs and RCOOSs, but it does not prescribe how RAs should be structured, the priorities and objectives that will drive RA development in each region, the infrastructure that will be needed, or which existing IOOS-related assessment should be used to build RCOOSs. For those aspects of RCOOSs that are federally funded, decisions concerning priorities and objectives should be made by the funding agencies using guidance provided by RAs that represent the interests of state agencies, industries, NGOs, academia and other stakeholders in their respective regions.

The First IOOS Development Plan has three parts: (I) Structure and Governance, (II) Integrating Existing Operational Assets, and (III) Improving the Initial IOOS through Enhancements and Research.

Part I: Structure and Governance articulates the vision of the IOOS; specifies design principles for the system's implementation and operation; recommends a process for enabling synergy among research, education, and the development of operational capabilities; recommends a governance structure for planning, implementing, operating, and improving the IOOS over time; and begins the process of establishing performance metrics.

The Ocean.US-EXCOM Enterprise prepares and periodically updates the *IOOS Development Plan*. The Plan provides guidance to participating federal agencies and RAs for implementing and improving the IOOS and for the development of recommendations for annual budget priorities.

Part II: Integrating Existing Operational Assets recommends the establishment of an initial IOOS that (1) integrates existing operational observing subsystem assets of federal agencies through the development of the DMAC subsystem, (2) enables the development of RAs, and (3) begins the process of engaging groups that use, depend on, manage, and study oceans and coasts in the development of the IOOS.

The initial IOOS is a first step in developing a fully integrated system that addresses all seven goals. When integrated, programs recommended for the initial observing subsystem will mark an important first step toward addressing the seven societal goals (Table 1).

Table 1: Variables recommended for monitoring as part of the initial IOOS and their relevance to the seven societal goals (G – Global ocean component, C – Coastal component).

PRIORITY VARIABLES	SOCIETAL GOALS						
	Weather & Climate	Maritime Operations	Natural Hazards	Homeland Security	Public Health	Ecosystem Health	Living Resources
Water Level	G,C	G,C	C	C	C	C	C
Ocean Storage & Global Transport: Carbon, Heat, Fresh Water	G,C		G,C	G	C	C	C
Air-Sea Exchange of Heat & Fresh Water	G,C	G,C	G,C		C	C	C
Extent & Condition of Pelgaic & Benthic Environments			C		C	C	C
Abundance & Distribution of Living Marine Resources		G,C		C	C	C	G,C
Freshwater Flows & Fluxes of Sediments, Nutrients, Contaminants	C	C	C	C	C	C	C

Summary

For the purposes of implementing the *IOOS Development Plan*, it is recommended that specific agencies be designated as the lead, co-lead, or a partner (Table 2).

Table 2. EXCOM sub-committees of participating federal agencies responsible for developing a coordinated budget strategy and for implementing, operating, and improving elements of the IOOS (**NOAA**: National Oceanic and Atmospheric Administration; **NSF**: National Science Foundation; **NASA**: National Aeronautics and Space Administration; **EPA**: Environmental Protection Agency; **USGS**: U.S. Geological Survey; **MMS**: Minerals Management Service; **USACE**: U.S. Army Corps of Engineers; C = Chair, CC = Co-Chair, P = Partnering agency).

Sub-Committee	NOAA	NSF	NAVY	NASA	EPA	USGS	MMS	USACE
Adminsitration	C	P	P	P	P	P	P	P
Research and Pilot Projects	P	CC	P	CC	P	P	P	P
Data Management and Communications	CC	P	CC	P	P	P	P	P
Data Analysis and Modeling	CC	P	P	P	CC	P	P	P
Global Component: Pilot Projects to Operational	CC	P	CC	P	P	P	P	
Coastal Component: Pilot Projects to Operational	CC	P	P	P	P	CC	P	P
Education/Training/ Communication	CC	CC	P	P	P	P	P	P
Assessment	CC	P	P	P	P	P	CC	PP

Part III: Improving the IOOS Through Enhancements and Research recommends enhancements and priority pilot projects that will improve operational capabilities of the initial IOOS in the longer term (decadal time scale). The initial system recommended in Part II emphasizes incorporation of existing operational assets which are most developed for meteorological and physical observations and least developed for chemical and biological observations needed to address the goals of reducing public health risks and sustaining healthy ecosystems and the living resources they support. It is expected that a comprehensive, fully integrated system that provides the data and information needed to address all seven societal goals will develop over the next decade as research increases both operational capabilities and the number and quality of products that the system can support.

To ensure efficient linkages between research (advances in scientific understanding and improved technology) and the development of operational capabilities, the IOOS encompasses a spectrum of activities from operational elements of the "end-to-end" system to research, pilot, and pre-operational projects (Part I). Transition from pilot project testing and evaluation to pre-operational status is a major step, and the joint responsibility of both research and operational communities. Final decisions concerning this transition must be made by the agency or body with responsibility for the new operational capability.

Recommended improvements in this, *The First IOOS Development Plan*, focus on five areas: (1) continued development of the global ocean component and coordinated development of the global and coastal components, (2) continued implementation of the data management and communications subsystem, (3) establishing RCOOSs, (4) continued development of the observing subsystem for the National Backbone, and (5) the development of coupled operational models (continental shelf-deep sea; physicalbiogeochemical-trophic interaction). In this context, high priorities for improving the observing subsystem are summarized in Table 3 in relation to the societal goals they are relevant to. These enhancements will be achieved through research and pilot projects, as well as through the incorporation of existing pre-operational and operational capabilities.

Engaging Data Providers and Users

Recommendations in Parts II and III are based primarily on the consensus of groups of experts from federal agencies and the academic community. As the IOOS develops over the next two to three years, it must transition from a system designed, operated and used by scientists from academia and federal agencies to one that is designed, operated, improved, and used by a broad diversity of stakeholders including state and federal agencies, tribes, industry, NGOs, and academia as appropriate. Engaging more stakeholders from both public and private sectors is critical to sustained improvements in an IOOS. Private sectors, state agencies, NGOs, and tribes, as well as federal agencies and universities, must become involved proactively in the operation and improvement of the IOOS. Therefore, two convergent and inter-related approaches are recommended:

- A *national approach* to begin serving data and information that attracts the interest of potential users and stimulates product development and

- A *regional approach* that engages, from the beginning, users from both private and public sectors in the design and implementation of RCOOSs.

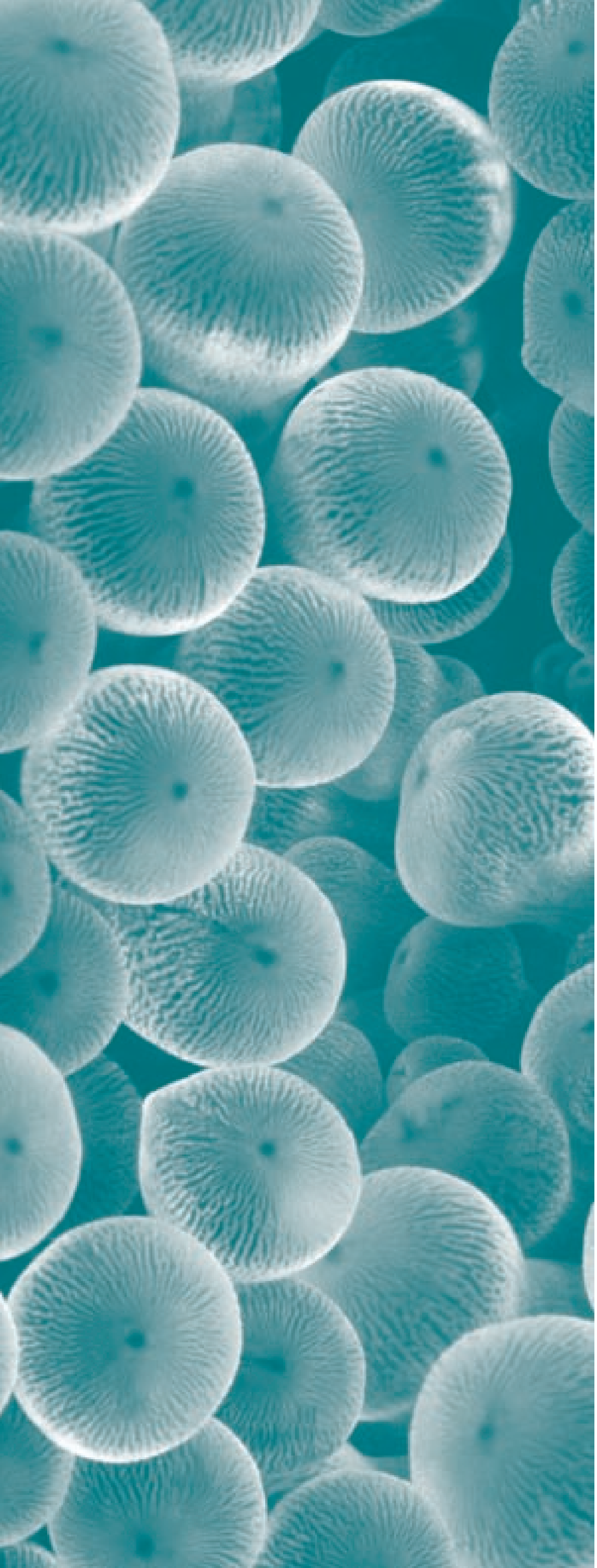
The *The First IOOS Development Plan* is concerned primarily with the national approach. The regional approach is a high priority of nascent RAs that represent the interests of user groups in their respective regions and are responsible for the design, implementation, operation, and improvement of RCOOSs.

Table 3: Coastal observing subsystem enhancement priorities and the societal goals these enhancements will address (G – Global component; C – Coastal component).

OBSERVING PRIORITIES	SOCIETAL GOAL						
	Weather & Climate	**Maritime Operations**	**Natural Hazards**	**Homeland Security**	**Public Health**	**Ecosystem Health**	**Living Resources**
Sustaining & Improving Satellite Observation	G,C	G,C	G,C	C	C	C	C
Increasing Time-Space Resolution of Meteorological Observation	G,C	G,C	G,C	C	C		
Increasing Number of Harbors & Estuaries with PORTS; Increasing Number & Capabilities of NWLON Stations	C	C	C	C			
Increasing Time-Space Resolution of Wave & Current Fields	G,C	G,C	G,C	C	C		
Shoreline Position & Bathy-Topographic Maps		C	C	C		C	C
Benthic Habitat Mapping					C	C	C
Developing Capability for Real-Time Measurements of Biogeochemisty	G,C	G,C	G,C	C	C	C	C

As the IOOS develops, it will become a valuable tool for science and technology learning, and the need for a skilled workforce to develop and sustain the IOOS and to utilize the information from it in many careers will grow. The Ocean.US-EXCOM Enterprise education initiative is an element of the more comprehensive ocean education initiative outlined in the U.S. Ocean Action Plan and currently being addressed by the NSTC Joint JSOST and SIMOR Task Force on Ocean Education. Within this context, IOOS education seeks to: (1) sustain a network of educators that use data and information from the IOOS and other sources to achieve their education objectives and (2) create the workforce needed to operate, improve and use the information from the IOOS.

Summary



Part I
STRUCTURE AND GOVERNANCE

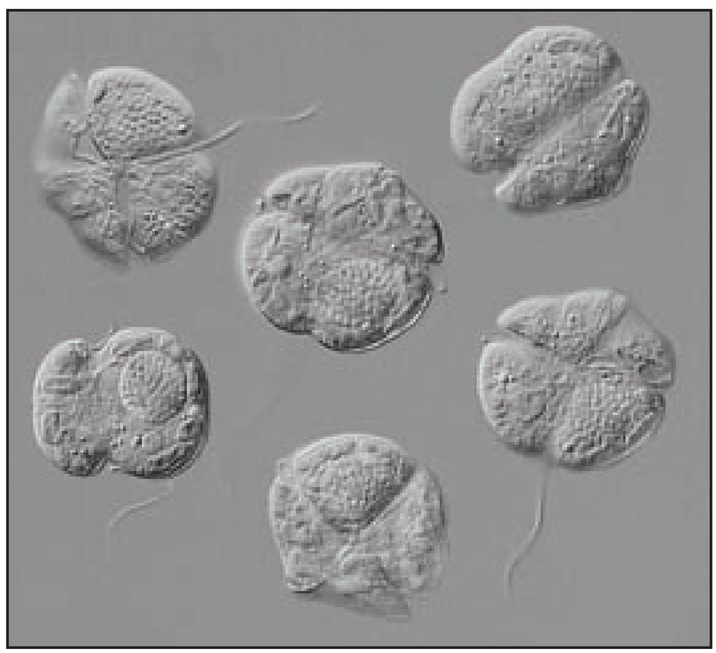
1. Background

1.1 Goals

The U.S. Integrated Ocean Observing System (IOOS) is developing as a "user-driven", integrated system of observations and data telemetry, data management and communications (DMAC), and data analysis and modeling that routinely, reliably, and continuously provides data and information required to address seven societal goals[1, 2]:

(1) Improve predictions of climate change and weather and their effects on coastal communities and the nation;
(2) Improve the safety and efficiency of maritime operations;
(3) More effectively mitigate the effects of natural hazards;
(4) Improve national and homeland security;
(5) Reduce public health risks;
(6) More effectively protect and restore healthy coastal ecosystems; and
(7) Enable the sustained use of ocean and coastal resources.

Provisional products for each of the seven goals were identified by groups of experts participating in the Ocean.US 2002 workshop (Table 1).[2]



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[1] "Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System." 1999. A report prepared on behalf of the National Ocean Research Leadership Council (NORLC) in response to a request from Congressmen Saxton and Weldon. <http://ocean.tamu.edu/GOOS/publications/sw.html>

[2] Proceedings of the Ocean.US 2002 workshop, "Building Consensus: Toward an Integrated and Sustained Ocean Observing System." <http://www.ocean.us/documents/docs/Core_lores.pdf>

Table 1. The seven societal goals and examples of products needed to achieve these goals. As recommended by experts participating in the Ocean. US 2002 workshop[2], the IOOS will provide the required data and information to serve these products. "Proof of concept" pilot projects have been initiated for the global component (GODAE and GHRSST) to demonstrate how integration of data streams from space-based and *in situ* sensors can improve the resolution of sea surface temperature fields in real-time. Pilot projects for the coastal component are recommended in Part III of this plan.

SOCIETAL GOALS	EXAMPLE PRODUCTS
Weather & Climate	(1) Improve estimates of surface fields & surface fluxes; (2) Improve predictions on seasonal & longer time scales; (3) Rapidly detect & assess the impact of climate change on the coastal zone.
Maritime Operations	(1) Maintain navigable waterways; (2) Route ships more costeffectively; (3) Improve search, rescue, & emergency response capabilities.
Natural Hazards	(1) Rapidly detect & assess physical & ecological contributions tohazard-risk; (2) Improve predictions; (3) Disseminate & provide rapid access to real-time hazards observations & warnings; (4) Complete metadata & retrospective information on all aspects of disaster reduction.
Homeland Security	(1) Improve safety & efficiency of operations at sea; (2) Enhance maritime vessel tracking; (3) Establish the capability to detect & predict the dispersion of airborne & water-borne contaminants in ports, harbors, & the littoral zone at home & abroad; (4) Support environmental stewardship; (5) Improve at-sea system performance through more accurate characterization & prediction of the marine boundary layer.
Public Health	(1) Establish nationally standardized measures of the risk of illness or injury from exposure to pathogens, toxins, hazards, & dangerous marine animals (water contact); (2) Establish nationally standardized measures of the risk of illness from consuming seafood.
Ecosystem Health	(1) Determine regional ecological climatologies for sea surface temperature, salinity, dissolved nutrients, chlorophyll-*a*, & harmful algal species; (2) Provide more timely detection & improved predictions of changes in the distribution & condition of habitats (coral reefs, sea grasses, mangroves, & tidal marshes), species diversity, distribution & toxicity of harmful algae, occurrence of invasive species, occurrence of diseases in & mass mortalities of marine animals (fish, mammals, birds), & effects of habitat modification on species diversity; (3) Monitor anthropogenic nutrients & contaminants & their effects on organisms & ecosystems.
Living Resources	(1) Provide improved & more timely prediction of annual fluctuations in spawning stock size, distribution, recruitment, & sustainable yields for exploitable fish stocks; (2) Detect changes in the spatial extent & condition of essential fish habitat more rapidly; (3) Improve predictions of the effects of fishing on habitats & biodiversity; (4) Establish & monitor the effectiveness of Marine Protected Areas.

The seven goals of the IOOS are related directly to the nine "benefit areas" of the U.S. Integrated Global Earth Observing System (IEOS) (Table 2).[3]

[3] Group On Earth Observations <http://earthobservations.org/> ; "Strategic Plan for the U.S. Integrated Earth Observation System" <http://iwgeo.ssc.nasa.gov/draftstrategicplan/ieos_draft_strategic_plan.pdf>

Table 2. Relative significance (H-High, M-Medium, L-Low) of providing the data and information needed to address the seven IOOS societal goals to achieving the nine societal benefit areas of the IEOS (a 1-way matrix assessing the impact of addressing the seven IOOS goals on achieving IEOS benefits).[a] A minimal or not yet identified impact is indicated by an empty box.

IEOS SOCIETAL BENEFIT AREAS	SOCIETAL GOALS OF THE IOOS						
	1 Climate	2 Maritime operations	3 Hazards	4 Security	5 Public Health	6 Ecosystems	7 Resources
1. Weather	H						
2. Disasters	H	H	H	M	H	H	L
3. Oceans	M	L	M	L	M	H	H
4. Climate	H		H		M	H	
5. Agriculture	H		H			H	M
6. Health	H		H	M	H	H	
7. Ecology	H		M		L	H	H
8. Water	H		H	M	H	H	H
9. Energy	H	M	M	H			L

[a] Nine societal benefits will be addressed by the U.S. Integrated Earth Observing System (IEOS): (1) improve weather forecasting; (2) reduce loss of life and property from disasters; (3) protect and monitor our ocean resources; (4) understand, assess, predict, mitigate and adapt to climate variability and change; (5) support sustainable agriculture and forestry, and combat land degredation; (6) understand the effect of environmental factors on human health and well-being; (7) develop capacity to make ecological forecasts; (8) protect and monitor water resources; and (9) monitor and manage energy resources. As the marine, estuarine and Great Lakes component of the IEOS, the Integrated Ocean Observing System (IOOS) is being implemented to provide data and information needed to address seven societal goals: (1) improve predictions of climate change and weather, (2) improve the safety and efficiency of marine operations, (3) mitigate the effects of natural hazards more effectively, (4) improve national and homeland security, (5) reduce public health risks, (6) protect and restore healthy marine and estuarine ecosystems more effectively, and (7) enable the sustained use of marine and estuarine resources.

1.2 Challenges

Although each societal goal has unique requirements for data and information, together they have many common data and information needs that can be more effectively met by sharing data among agencies and across programs. Likewise, many DMAC requirements are similar across all seven societal goals. Thus, an integrated approach to developing a multi-use, multi-disciplinary observing system is feasible, sensible, and cost-effective.

Achieving the seven goals depends on (1) developing the IOOS as an integral part of atmospheric and terrestrial observing systems (the Global Earth Observation System of Systems or GEOSS)[3]; (2) establishing a sustained IOOS that meets the data and information needs of groups that use, depend on, manage, and study marine systems (including federal, state, and local government agencies responsible for resource management, environmental protection, coastal zone management, emergency response, and homeland security; private sectors; academia; non-governmental organizations [NGOs]; and the public); (3) making more effective use of existing infrastructure, resources, new knowledge, and advances in technology for more rapid detection and timely predictions of changes in the state of oceanic and coastal systems; (4) continuously improving operational capabilities through advances in ocean science (new knowledge and technologies); and (5) enhancing public awareness and understanding of the oceans and Great Lakes, and the changes occurring in them through education and training.

The challenges are many, and it is anticipated that the development of an integrated system that addresses all seven goals will extend beyond ten years. At the same time, current observing and modeling capabilities provide an opportunity to establish an integrated system that can yield early operational successes and demonstrate economies that can be achieved through integration. To these ends, the immediate challenge is to establish a DMAC subsystem that provides the means to integrate diverse data from many different sources (across agencies, remote and *in situ* sensing, multidisciplinary) for applied purposes (blended products) is a high priority (Part II).

A longer term challenge is the design and implementation of ecosystem-based approaches to managing and mitigating the impacts of human activities, natural hazards and climate sustainable development. The U.S. Commission on Ocean Policy emphasized the importance of implementing ecosystem-based approaches that consider the effects of human activities in the context of natural variability and change in addressing the seven societal goals.[4] This is especially important for coastal systems, where the combined effects of habitat

[4] "An Ocean Blueprint for the 21st Century: Final Report of the U.S. commission on Ocean Policy" <http://oceancommission.gov/documents/welcome.html>

alterations, land-based sources of pollution, over- fishing, harmful algal blooms, and invasive species are most severe. Successful implementation of ecosystem-based approaches requires the capability to engage in *adaptive management,* a decision making process that depends on rapid assessments of current states of marine systems and timely detection and predictions (with estimates of uncertainty) of changes in them. Developing this capability depends on the development of operational ecosystem models, the specification of data and information required by the models, and the establishment of an IOOS that routinely and continuously meets these requirements. This is arguably the biggest challenge of ocean observing.

1.3 Socio-Economic Impacts

Developing the capability to rapidly assess the states of marine systems and to detect and predict changes in them in a timely manor will yield significant socio-economic benefits. Although the primary motivation for developing the IOOS is "for the public good," preliminary economic analyses estimate a $5 to $6 return for every $1 invested in the IOOS.[5] Information products enabled by new ocean data will alter decisions made in industry, recreation, and public administration, changing the economic outcome from these activities and thereby affecting economic well-being. Analyses are in progress to estimate benefits that may accrue from an investment in the IOOS by comparing outcomes of these decisions under two scenarios: the baseline situation (currently available information and products) and the possible future situation with new and improved data and products.[6] The difference in outcome between the two scenarios is the benefit derived from the new investment in ocean observation. Results from these studies will be used to help set priorities for IOOS development.

2. Design

2.1 Guidelines

Design and implementation of the IOOS should be guided by the following considerations:

(1) Addressing the seven societal goals (Table 1) requires more rapid assessments of current states of marine and estuarine systems, as well as more timely detection and prediction of changes in a broad spectrum of phenomena that characterize these systems (Appendix C);
(2) Both large scale changes in the ocean-climate system and changes in land-based inputs of water, nutrients, sediments, and contaminants cause significant changes in oceans and coasts that affect the socio-economic well being of the nation;
(3) Data management and modeling are critical to achieving the goals of integration; there is a clear need to link observations and models to user needs more efficiently, and, in the process, provide more rapid access to diverse data from many sources;
(4) Production and sale of value-added products by the private sector is to be encouraged, and data providers and users from both private and public sectors should be able to contribute to and use IOOS data and information. This policy is consistent with policies in the Paperwork Reduction Act of 1995 (44 U.S.C. §§ 3501 et seq.) and Office of Management and Budget (OMB) Circular No. A-130.
(5) Many of the building blocks of an operational IOOS already exist and are of high value to current users (e.g., the Physical Oceanographic Real-Time System [PORTS®], the National Water Level Observation Network, satellite altimetry);
(6) Many of the research, pilot, and pre-operational projects needed to improve operational capabilities are underway, making it possible to begin enhancing the initial operational IOOS early in the system's development; and
(7) Priorities for detecting and predicting changes in the marine environment and coastal systems vary among regions (e.g., priorities in the Gulf of Maine differ from those in the Gulf of Mexico, the Pacific Northwest, and Great Lakes).

In light of these factors, the IOOS is conceived as two closely linked and interdependent components: a global ocean component and a coastal component (Appendix C):

(1) The **coastal component** encompasses the U.S. EEZ, Great Lakes, and estuaries (all semi-enclosed bodies of water connected to the ocean including bays, lagoons, fjords, tidal wetlands). It is a collaboration among federal and state agencies, private sectors, NGOs, tribes, and academia. The coastal component is concerned primarily with nowcasting and forecasting the effects of weather, climate, and human activities on the coastal ocean, its ecosystems, and living resources. It consists of regional coastal ocean observing systems (RCOOSs) nested in a National Backbone of coastal observations. This National Backbone provides data and information required by most regions, links global ocean and coastal ocean observations, and establishes a framework for the development of RCOOSs. RCOOSs enhance the National Backbone in terms of the time-space resolution of measurements and the number of variables measured, based on requirements of stakeholders in the region.

[5] Kite-Powell, H.L. and C. Colgan. 2001. The potential economic benefits of coastal ocean observing systems: The Gulf of Maine. Joint publication of NOAA, Office of Naval Research (ONR), and Woods Hole Oceanographic Institution (WHOI), 13 pp; "Regional Market and Policy Imperatives as Drivers for the U.S. Coastal Global Ocean Observing System Design" <http://www.saic.com/weather/pdf/Regional_Market_and_Policy_Imperatives.pdf>

[6] A National Oceanographic Partnership Program (NOPP) sponsored Project, Coordinated Regional Benefit Studies of Coastal Ocean Observing Systems (Hauke Kite-Powell, WHOI, Lead Principal Investigator), is evaluating economic benefits of establishing regional coastal ocean observing systems (RCOOSs) in ten regions for nine sectors: beach recreation, recreational fishing, recreational boating, maritime transport (shipping), commercial fishing, search and rescue, offshore energy (oil and gas), mitigation of coastal hazards, and electric utilities. <http://www.onr.navy.mil/sci_tech/ocean/reports/docs/nopp_funded/03/22powel.pdf>

(2) The global ocean component is part of an international collaboration that is improving nowcasts and forecasts of weather, El Niño-Southern Oscillation (ENSO) events, and global climate trends, as well as providing real-time assessments of physical and biological states of the ocean. It also provides boundary conditions for higher resolution applications in the U.S. EEZ.

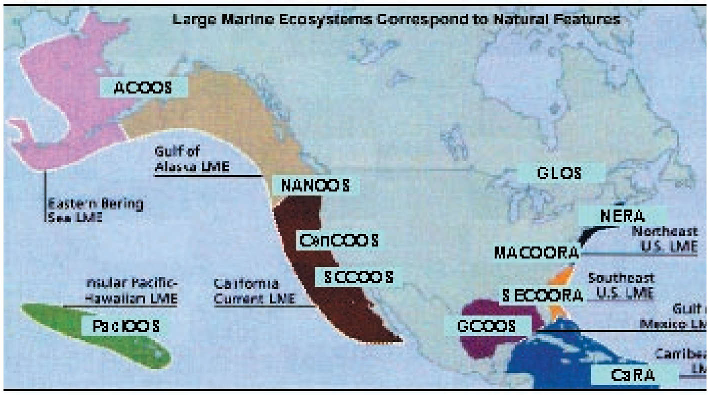


Figure 1. Regional groups are working to meet criteria for being recognized as an IOOS Regional Association (RA) in eleven regions: the Great Lakes (GLOS), the Northeast (NERA), Mid-Atlantic (MACOORA), the Southeast (SECOORA), Gulf of Mexico (GCOOS), Caribbean (CaRA), Southern California (SCCOOS), Central and Northern California (CeNCOOS), the Northwest (NANOOS), Gulf of Alaska (AOOS), and the insular Pacific (PacIOOS). The locations of these efforts are overlaid on the locations of Large Marine Ecosystems for the U.S. EEZ.

2.2 Design Principles

Rapid assessments of current states of marine and estuarine systems, and the timely detection and prediction of changes in them, depend on the establishment of an operational observing system that routinely, reliably, and continuously provides data and information in forms and at rates specified by the users. **Effectively linking user needs to measurements requires a managed, efficient, two-way flow of data and information among three essential subsystems, or the "end-to-end" system (Figure 2): (1) observing and data telemetry, (2) DMAC, and (3) data analysis and modeling** (Appendix C). The term "subsystem" is used here to indicate necessary functions of the IOOS and does not refer to actual organizational entities.

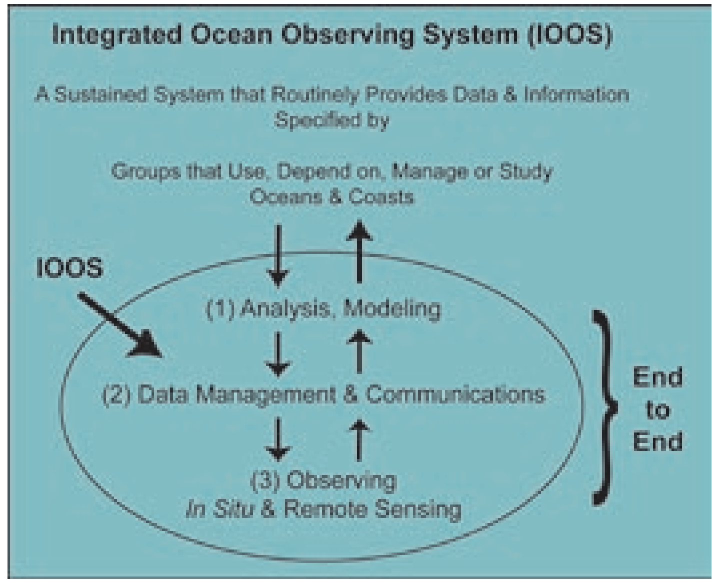
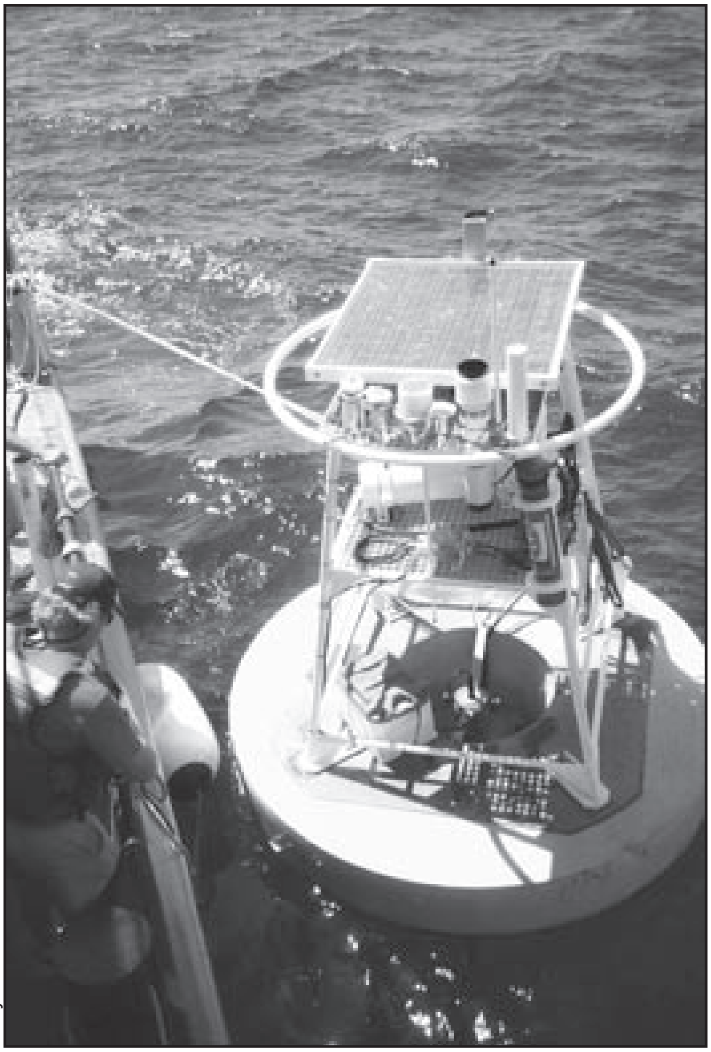


Figure 2. The IOOS is an "end-to-end" system consisting of three closely linked subsystems for: (1) analysis and modeling, (2) DMAC, and (3) observations and data telemetry. The term "subsystem" is used to represent those elements of IOOS that comprise common functional components. DMAC is the primary integrating mechanism for establishing the IOOS.

To achieve this vision, development of the IOOS must adhere to the following principles:

(1) Enable user groups from both private and public sectors to achieve their missions and goals more effectively;
(2) Develop the system with guidance, from both data providers and users from public and private sectors, that is based on sound science and encompasses a continuum of research to operational activities;
(3) Judiciously integrate existing assets that meet requirements set forth in Part I, section 2.4 and address the seven societal goals and regional priorities;
(4) Improve the IOOS by enhancing and supplementing the initial system selectively over time;
(5) Routinely, reliably, and continuously serve data and information for multiple applications that provide social and economic benefits both to the nation and to a broad spectrum of users from public and private sectors that use, depend on, manage, or study marine and estuarine environments and the natural resources within them;
(6) Openly and fully share data and information produced at the public expense in a timely manner, at no more than the cost of dissemination;
(7) Programs and activities must meet federally approved standards and protocols for observations, data telemetry, and DMAC in order to ensure data quality and interoperability;
(8) Establish procedures to ensure reliable and sustained data streams, to routinely evaluate the performance of the IOOS and assess the value of the information produced, and to improve operational elements of the system as new capabilities become available and user requirements evolve;



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(9) Improve the capacity of all states and regions to contribute to and benefit from the IOOS through training and infrastructure development nationwide; and

(10) Demonstrate that observing systems, or elements thereof, that are incorporated into the operational system either benefit from being a part of an integrated system or contribute to improving the integrated system in terms of the delivery of new or improved products that serve the needs of user groups.

Box 1: Industry's Role in the Development of the IOOS – In addition to being recipients and users of data and information provided by the IOOS, industry will play vital roles in its design and operation. This participation will not be limited to companies within the maritime arena, but will cut across many sectors. In fact, sustaining support of the IOOS will create a demand for start-up companies throughout all the participating regions, thereby creating new jobs. Examples of the roles industry will play include the following:

- Large systems integrators have already been and will be enlisted to begin to plan IOOS architecture;
- Hardware, software, and services will be provided by telecommunications, Information Technology (IT), and Information Systems (IS) firms to develop and operate the infrastructure required for data transport, collection, and distribution;
- Existing and in-place infrastructure owned and operated by industry will be critical (e.g., over 4,000 offshore platforms in the Gulf of Mexico, thousands of shore-based cell phone and radio towers, satellite bandwidth, and terrestrial and offshore communication cables);
- Sensor systems: both extant and those yet to be developed to fulfill the IOOS mission will represent an appreciable market for the ocean industry;
- Deployment: many of the assets and organic talent required to deploy complex elements of the IOOS (e.g. work boats and cable lay vessels, remotely operated vehicles) reside in the private sector;
- Operation: the IOOS will be a nationwide, 24x7 managed network; economies of scale may be achieved by enlisting some of the many companies in the U.S. that are expert, staffed, equipped, and already managing similar networks;
- Maintenance: in some regions, notably the Gulf of Mexico, there already exist numerous offshore service companies that could add the continued maintenance of the IOOS to their client list; in many other regions, however, this demand will spawn a new industry;
- End user: IOOS data, in its delivered form, will be of immediate value to a number of industries (e.g., shipping, recreation/tourism, and energy utilities); and
- Value-added resellers: there are other companies (and the IOOS is likely to encourage establishment of yet even more) who would use IOOS data to produce custom products for specific users on a for-cost basis.

It is recognized that coordinating the required mix of platforms (e.g., ships, buoys, drifters, autonomous underwater vehicles, satellites, aircraft), data streams, data management activities, and models necessitates exceptional levels of coordination and collaboration among the managers of these resources, Regional Associations (RAs), and federal agencies. It is also recognized that user needs change regionally and that the effects of climate and human activities, which converge in the coastal zone, vary from region to region. These realities underscore the need for a regional approach in developing the IOOS and a consensus (Appendices D and E) has been achieved to establish (1) RAs that meet federally approved criteria for governance and operations (Appendix F) and are responsible for developing RCOOSs that employ IOOS design principles, and (2) a National Federation of Regional Associations (NFRA) to both coordinate the development of RCOOSs nationwide and represent regional interests at the federal level (Appendix F).[2]

2.3 Developing a User-Driven System

Many of the elements needed to develop the IOOS have emerged from the wellspring of basic research supported by our nation's federal agencies and universities. Building on these assets, successful development of the IOOS depends on engaging private sectors, state agencies, NGOs, and tribes in partnerships with universities and federal agencies in the design, implementation, and improvement of the observing system as rapidly as possible. Research and technology partnerships open to all interested parties are critical to creating a dynamic observing system that grows and improves with time (Part I, section 2.4). **During the early phases of IOOS development (i.e., over the next two to three years), the IOOS must transition into a system that continues to develop based on data and information needs of a broad spectrum of groups** and individuals that use, depend on, manage, or study marine systems, and the goods and services they support. Therefore, two convergent and inter-related approaches are simultaneously being pursued by the Ocean.US-EXCOM Enterprise:

(1) *A national approach* that focuses on coordinated development of the global ocean component and the National Backbone of the coastal component as the means to begin serving data and information that both attracts the interest of potential users and stimulates product development; and

(2) *A regional approach* that engages, from the beginning, users from private sectors, NGOs, state agencies, regional organizations of federal agencies, tribes, and academia in the design and implementation of RCOOSs.

The First IOOS Development Plan is concerned primarily with the national approach. Implementing the regional approach[7] is a high priority of nascent RAs, which are responsible for the design, operation, and improvement of RCOOSs, and for obtaining the funding to do so.

2.4 Research and the Evolution of an Operational System

The initial system is a crucial first step toward the development of a comprehensive, fully integrated system – but only a first step. System capabilities will evolve as the number of participating agencies and organizations increases. Evolution of an integrated system that is responsive to user needs requires time for an iterative process of selection, incorporation, evaluation, and improvement to develop. Successful evolution depends on:

(1) Selective incorporation of candidate operational elements into the operational observing system based on IOOS design principles (including user requirements);
(2) Selective incorporation of candidate operational elements into the operational observing system based on IOOS design principles (including user requirements);
(3) Early demonstrations of the effectiveness of integration for generating useful products;
(4) Advances in technology and understanding through the nation's investments in environmental science, in general, and the ocean sciences in particular;
(5) Synergy between the development of operational elements and the research enterprise in its broadest sense (i.e., basic and applied); and
(6) An effective and sustained program for enhanced public awareness and education.

Improvements in operational IOOS capabilities will be driven by the needs of user groups for data and information, as well as by advances in both understanding and new technologies driven by scientific inquiry and national priorities. To facilitate synergy between research and improvements in operational capabilities, the IOOS includes a spectrum of activities from operational elements to mission-driven research, pilot, and pre-operational projects (Figure 3). Research and pilot projects represent the research and development end of the IOOS. Transition from a pilot project to pre-operational status is a major step, and it is one that must be undertaken through collaboration between research and operational communities with the support of the organization that is to provide operational funding.

[7] An example of the regional approach is "A Workshop to Explore Private Sector Interests and Roles in the U.S. IOOS," held in Houston, TX on 2-4 March, 2004. <http://www.ocean.tamu.edu/GCOOS/industry/agenda.html>

Figure 3. The IOOS consists of a continuum of activities, from research to the operational system. Operational elements are funded for extended periods based on user needs and performance. Research and pilot projects have specific objectives and are funded competitively for finite periods. Projects recommended for pre-operational status are endorsed by the organization (or organizations) that will fund and operate them in a "proof of concept" operational mode. As the operational system evolves, it will benefit research and help guide the development of pilot and pre-operational projects. Research, both basic (hypothesis-driven) and applied (mission-driven), is of fundamental importance to the evolution of a fully integrated system that addresses all seven societal goals.

(1) **Research Projects** relevant to the development of the IOOS may arise from many sources, including mission-driven research to address operational priorities of the IOOS, and basic, or hypothesis-driven, research designed to achieve goals established by the scientific community. Mission-driven research is a key near-term means of enhancing IOOS capabilities as follows:

- Provide improved and/or new techniques for more rapid or accurate sensing of one or more of the core variables, more efficient DMAC, more accurate hindcasts (e.g., climatology), nowcasts (e.g., more accurate estimates of sea surface temperature, salinity, or chlorophyll fields), or forecasts of phenomena of interest (modeling);
- Establish the most efficient mix of remote and *in situ* sensing networks needed to estimate core variable fields and features; and/or
- Consistently provide data of known quality using established data management protocols and standards to achieve IOOS goals.

(2) **Pilot Projects** repeatedly test, over a range of conditions, techniques and approaches that show promise as potential elements of the operational system. Such projects may target specific elements of the IOOS (e.g., sensors, models) or the development of end-to-end observing capabilities (e.g., RCOOSs, the Global Ocean Data Assimilation Experiment [GODAE]). This process illuminates weaknesses, provides opportunities to address those weaknesses, permits a more effective understanding of how capabilities may be applied, and gains community acceptance of new techniques (from measurements to models).

- Projects or activities that meet the requirements stipulated for research may be considered for pilot projects if they conform to standards and protocols established by the Ocean.US-EXCOM Enterprise for observations, DMAC, and modeling.

Proposed pilot projects must specify (1) contributions to the development of the IOOS and benefits to potential user groups; (2) objectives and milestones that can be achieved within a specified, finite period (e.g., less than five years); and (3) a management plan with performance metrics that advance the IOOS mission.

(3) **Pre-Operational Projects** are designed to demonstrate that the incorporation of new techniques from pilot projects into the operational system leads to more cost-effective operations or improved capabilities (value-added products) and product delivery. Successful pilot projects, or elements thereof, may be considered for pre-operational status when they meet the following requirements:

- Demonstrate that incorporation improves existing products or produces new products in response to user priorities;
- Provide a cost-effective means of delivering value-added products without compromising the integrity and continuity of existing data streams and product delivery mechanisms; and
- Provide the supporting infrastructure needed to operate and maintain the capability.

Pilot projects that are candidates for becoming pre-operational projects must (1) specify how the project will contribute to the development of the IOOS and benefit targeted user groups; and (2) propose procedures for incorporation into the IOOS.

(4) **The Operational System** routinely, reliably, and repeatedly provides data and data products in forms and at rates specified by user groups. This stage is improved through the incorporation of assets that are successful in a pre-operational mode. Decisions to incorporate new or additional capabilities into the operational system must be approved by the body (e.g., federal agency or RA) that is to be responsible for operating and maintaining that capability. Successful pre-operational projects may be considered for operational IOOS status upon meeting all of the following requirements:

- Compliance with the IOOS design principles as listed in Part I, section 2.2;
- Provision of (1) data and information required by the global module of the Global Ocean Observing system (GOOS) or by one or more RAs; or (2) new or better products that enable one or more of the seven goals to be achieved more effectively or more efficiently;
- Data are quality controlled and managed in compliance with Ocean.US DMAC standards and protocols;
- Data and products are delivered on schedule according to predetermined deadlines;
- There are dedicated staff responsible for acquisition and quality control of data and dissemination of products;
- Methods are affordable and efficient;
- Expected benefits are realized on a predetermined time schedule; and
- The institution or organization that will operate the asset has a clearly identified strategy for sustained funding.

Operational activities may be conducted by government agencies, universities, private industry, NGOs, or other bodies capable of making long-term commitments and of ensuring the quality and continuity of the required data or product. In regard to the latter, continuity is sought in the data or product, not necessarily in the activity or methods.

Box 2: Examples of Observing System Assets that are Operational, Pre-Operational, and Pilot Project Stages of the IOOS

- Examples of observing subsystems elements that have progressed through research, pilot project, and pre-operational stages to become operational range from the PORTS® to the Tropical Atmosphere Ocean (TAO) array of moored instruments in the tropical Pacific Ocean. PORTS® is used to improve the safety and efficiency of ship operations in the nation's ports, while TAO is used for predicting ENSO events.

- Precise measurement of sea surface height from space is an example of an observing technology that has been proven in the research community and is emerging as a pre-operational capability. TOPEX/Poseidon was launched as a research project by NASA and Centre National d'Etudes Spatiales (CNER). Its follow-on, Jason-1, has served as a pilot project by providing a specialized Near Real-Time data stream. The next mission in the series (Ocean Surface Topography Mission) is co-sponsored by operational agencies (NOAA and the European Organisation for the Exploitation of Meteorologial Satellites [EUMETSAT]) as a pre-operational project.

- GODAE is a one-time pilot project to demonstrate the feasibility and practicality of real-time global ocean data assimilation and numerical modeling for short-range open ocean forecasts, provide boundary conditions to extend predictability of coastal regimes, initialize climate forecast models, and for research. A related sampling technology that is in the pilot project stage is the Argo project, which is deploying several hundred autonomous profiling floats to measure and telemeter temperature and salinity data for the upper ocean (0 - 2000 m).

(Nowlin, W.D., M. Briscoe, N. Smith, G. Needler, M. McPhaden, D. Roemmich, P. Chapman, and J. Grassle. 2001. Evolution of a sustained ocean observing system. Bull. Amer. Met. Soc., 82: 1369-1376.)

Existing elements or systems (regardless of origin or sponsorship) may be considered for any stage once they meet the research-to-operations criteria previously outlined. Research and development projects (stages one through three) may focus on an element of the system (e.g., sensing technology, development of sampling protocols, model development, DMAC protocols) or on the development of an integrated system (e.g., end-to-end, regional observing systems). Successful pilot projects, or elements thereof, may be incorporated into long-term time series observations for scientific purposes, become pre-operational, or both.

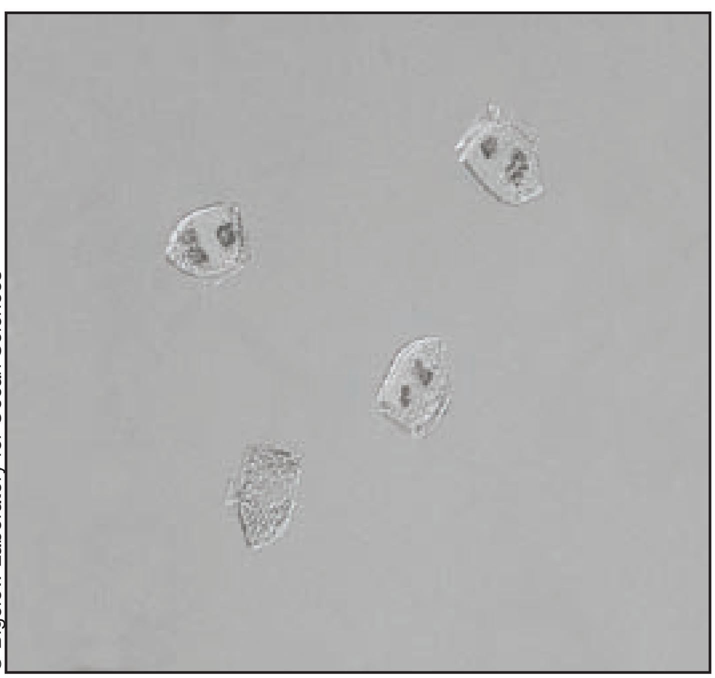
Operational capabilities of the IOOS will develop in phases. Due to prior investments by federal agencies, industries, and universities, many of the elements needed to address the seven goals are operational and provide a rich mix of capabilities that, through leveraging and integration, provide an opportunity to address the goals of improving predictions of climate and weather, improving the safety and efficiency of marine operations, more effectively mitigating the effects of natural hazards, and improving homeland security. The initial IOOS recommended in Part II capitalizes on these capabilities to ensure early and abundant successes. Establishing those aspects of the observing system that require ecosystem-based approaches to reducing public health risks, integrated coastal zone management, environmental protection, and managing living resources requires further synergy between research and the development of operational capabilities. Research priorities include the development of *in situ* and remote capabilities for rapid sensing of biological and chemical variables, formulating climatologies for chemical and biological variables, and developing data assimilating operational ecosystem models.

3. Governance

"Governance" refers to the policies and procedures by which design, implementation, operation, and improvement of the IOOS are administered and managed at both national and regional levels. The Ocean.US-EXCOM Enterprise prepares design and implementation plans (*the IOOS Development Plan*) for the IOOS and promotes coordinated implementation. **Federal agencies are responsible for implementing the global component and, in collaboration with RAs, the National Backbone of the coastal component. RAs design and implement RCOOSs.** General governance functions and roles of these bodies are outlined below.

3.1. Functions

Establishing a nationally interoperable and cost-effective IOOS requires an effective management structure for planning, funding, implementing, and improving the IOOS (Figure 4).



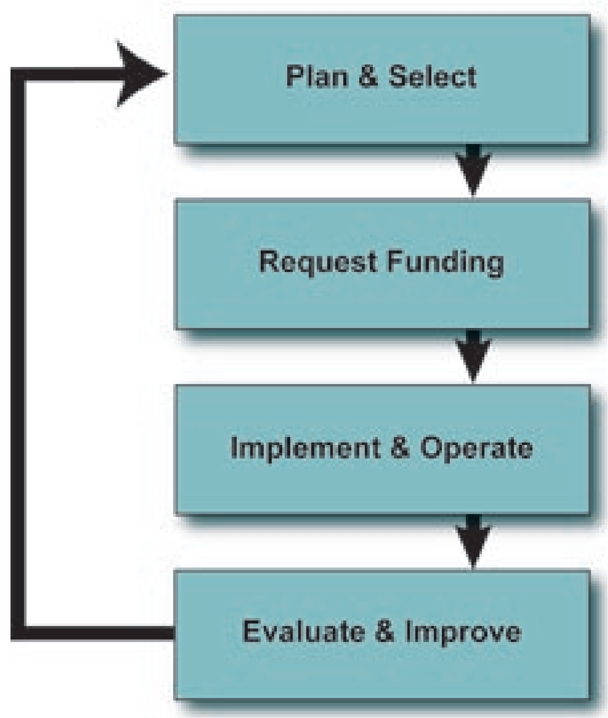


Figure 4. IOOS governance functions of participating federal agencies (including Ocean.US) that fall under the oversight of the NORLC and RAs.

3.1.1 Plan

The Ocean.US-EXCOM Enterprise is responsible for preparing and updating *IOOS Development Plan*s based on an the IOOS Strategic Plan as follows:

(1) Enable cooperation and collaboration among federal agencies and RAs to establish long-term (ten years) and short-term (two years) priorities for developing the three operational subsystems, all four stages of the IOOS (research, pilot, pre-operational, and operational), and related programs to enhance public awareness and education;
(2) Formulate and periodically update a strategic, integrated development plan to guide IOOS development based on the priorities recommended therein. The development plan is to articulate governance policies, procedures, and recommendations for the orderly and systematic development of an integrated system through coordinated contributions of participating federal agencies and RAs;
(3) Oversee the establishment of RAs that represent the interests of data providers and users in their respective regions and diversify the RA funding base; and
(4) Function as the nation's focal point ("portal") for international cooperation and collaboration in the development of ocean related activities as part of GOOS and GEOSS.

3.1.2 Fund

Federal agencies fund and the Ocean.US-EXCOM Enterprise coordinate consolidated budget recommendations as follows:

(1) IOOS Implementation

- Taking into consideration recommendations made in the *IOOS Development Plan*, participating federal agencies prepare annual budget requests for their contribution to the IOOS; and
- The Ocean.US-EXCOM Enterprise facilitates coordination of budget recommendations for the global ocean and coastal components of the IOOS based on the *IOOS Development Plan*.

(2) Ocean.US Operations

- The EXCOM secures funding commitments from participating federal agencies for the Ocean.US Office to perform the functions described herein.

3.1.3 Implement and Operate

Federal agencies are responsible for implementing and operating the global component and the National Backbone of the coastal component. Regional Associations are responsible for implementing and operating regional coastal ocean observing systems (RCOOSs) as follows:

(1) Establish national standards and protocols for observations, data telemetry, data communications, and data management;
(2) Ensure effective and efficient linkage among IOOS subsystems; and
(3) Ensure both coordinated development between the global ocean and the coastal components, and interoperability between global, national, and regional IOOS activities.

3.1.4 Evaluate and Improve

The Ocean.US-EXCOM Enterprise

(1) Oversees assessments of the extent to which IOOS data and data products are provided in forms and at rates required by users, and evaluates the efficiency and efficacy of the system in meeting the needs of user groups (see section 4); and

(2) Promotes research and development required to improve operational capabilities and the timely incorporation of new technologies and understanding needed to make such improvements.

Federal agencies and RAs

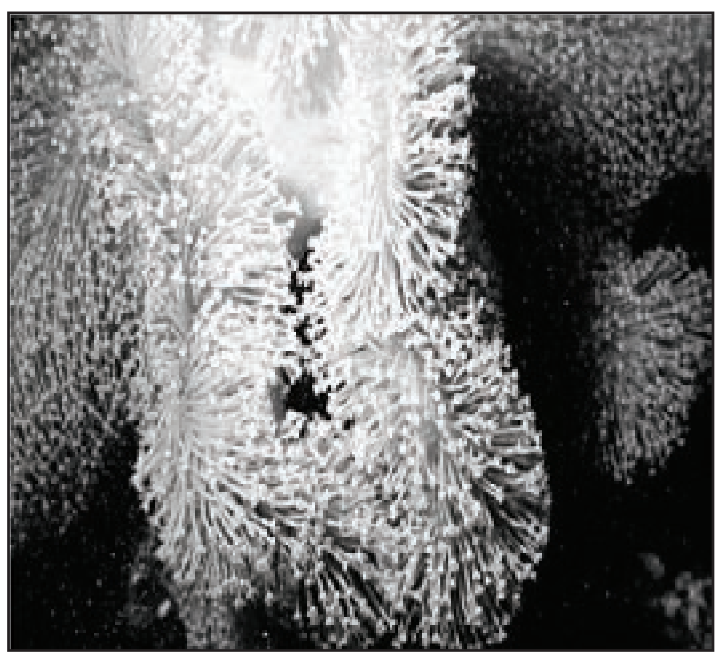
(1) Enhance existing IOOS capabilities and add new capabilities based on performance and user needs; federal agencies and RAs remove or reduce funding to those IOOS elements or programs that are not consistent with the *IOOS Development Plan*, are not meeting IOOS standards, or are not meeting user needs; and

(2) Periodically verify to the National Ocean Research Leadership Council (NORLC) that system development is in accordance with the *IOOS Development Plan*, and that funds allocated for IOOS development are used for this purpose.

3.2 The Planning Process

Implementing, operating, and improving the IOOS requires that participating federal agencies (1) specify their objectives and contributions to the IOOS using the *IOOS Development Plan* for guidance, and (2) formulate timetables with milestones for achieving these goals through coordinated, interagency implementation of their contributions. Improving the IOOS over time through integration and enhancements (Figure 5) requires an iterative process involving both performance evaluations (section 4) and the specification of requirements for new or improved products. Planning focuses on three related objectives:

(1) Establish an integrated operational system by incorporating existing operational assets;
(2) Enhance the system by incorporating additional existing operational capabilities; and
(3) Improve and expand IOOS capabilities by incorporating new assets developed through research and pilot projects (Figure 5).



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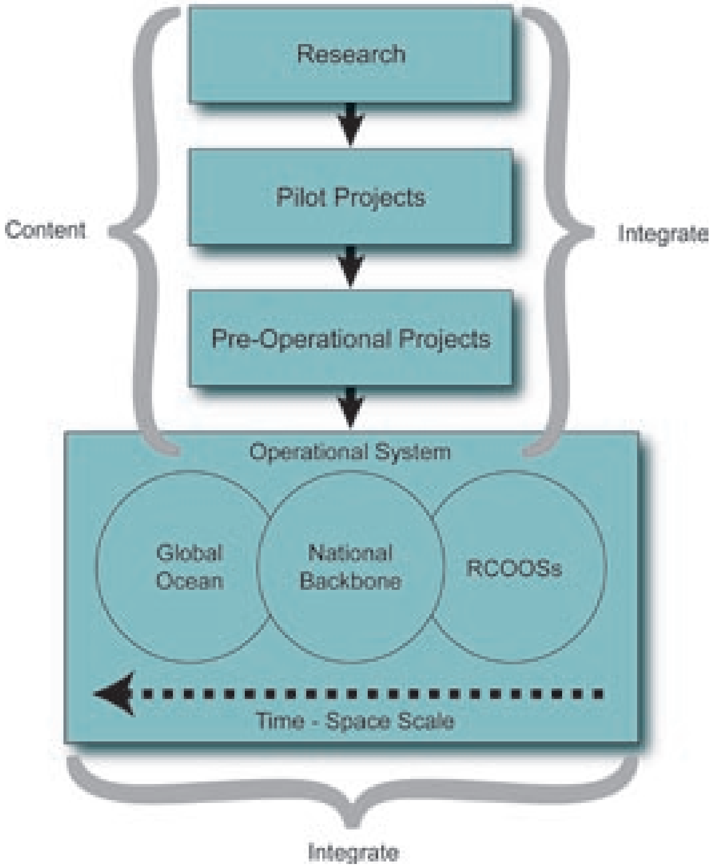


Figure 5. Operational elements of the IOOS are implemented and improved, over time, by integrating and enhancing existing operational systems to increase resolution across scales (horizontal scale), and by incorporating new operational assets developed through research and pilot projects to expand operational capabilities (vertical scale). Ocean.US promotes and coordinates the processes by which projects, programs, or elements thereof are selected and integrated into the operational system.

To achieve these objectives, planning activities of the Ocean.US-EXCOM Enterprise are coordinated with planning and budgeting cycles of participating federal agencies. In order to set priorities and update the *IOOS Development Plan*, Ocean.US collaborates with participating agencies and the NFRA in advance of the President's budget submission to Congress (Table 2). The planning process begins in March when each participating federal agency and RA provides Ocean.US with an *Annual Status and Planning Report.* The reports are used by Ocean.US to update the *IOOS Development Plan* which is transmitted to the agencies in August of each year to guide the formulation of their respective IOOS funding priorities. Periodically (e.g., every odd year), the process includes an IOOS Implementation Conference (May) that brings the federal agencies and RAs together to assess progress and recommend mutually agreed upon changes and enhancements to the *IOOS Development Plan*. Using the annual reports, results of the Conference, and other sources as appropriate (e.g. guidance from ORAP and the U.S. GOOS Steering Committee), the Ocean.US -EXCOM Enterprise prepares a new plan and submits it to the NORLC for approval prior to submission to the Executive Branch.[8]

3.3 Roles and Responsibilities

The NORLC, which oversees NOPP, leads the effort to establish and sustain the IOOS (Figure 6). To these ends, the NORLC created the Ocean.US Office and the EXCOM in 2000 (Appendix A). On behalf of the NORLC, the EXCOM provides policy guidance, approves development plans, and ensures sustained federal support of Ocean.US. In collaboration with RAs (through the NFRA), Ocean.US periodically prepares and updates a strategic development plan (the *IOOS Development Plan*). The Plan addresses the following:

(1) The long-range vision of the IOOS;
(2) Short-term and long-term objectives; and
(3) Recommendations for prioritized implementation of all three subsystems of the IOOS required to achieve these objectives.

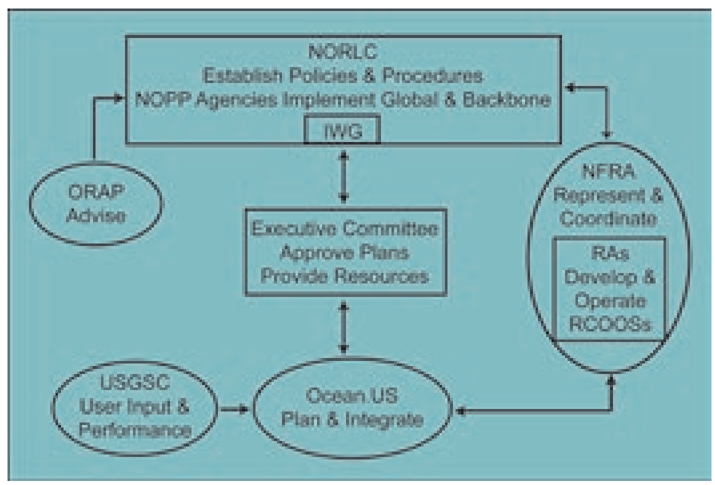


Figure 6. Governance structure for the design and coordinated implementation, operation and improvement of the IOOS (NORLC: National Ocean Research Leadership Council, IWG: Interagency Working Group, ORAP: Ocean Research Advisory Panel, USGSC: U.S. Global Ocean Observing System [GOOS] Steering Committee, RA: Regional Association, NFRA: National Federation of Regional Associations). Note that the U.S. Commission on Ocean Policy recommends that Congress amend the NOPP Act to formally establish Ocean.US under the proposed National Ocean Council.[4]

Using the *IOOS Development Plan* for guidance, participating federal agencies and RAs prepare budget requests for their contributions to IOOS development. Ocean.US then works with the agencies and RA to coordinate budget recommendations and plans for OMB and Congress. Evaluation and verification of the operational IOOS is performed periodically under the oversight of the EXCOM and its subcommittee for IOOS assessment (Table 3 and section 4).

[8] It will take approximately two years for the Ocean.US planning process to be in synchrony with the planning and budgeting cycles of federal agencies.

3.3.1 Federal

Of the federal agencies that have responsibilities for ocean observing, some are responsible primarily for basic research while others run operational observing programs, some are primarily users of IOOS data and information, and some are active in two or more of these areas. Thus, interagency coordination is essential for IOOS development, and the roles and responsibilities of each agency need to be clearly defined.

An interagency body is needed to provide high-level oversight for IOOS and an interagency program office should develop plans and requirements for that interagency body's ultimate approval. The NORLC currently provides this oversight. The Ocean.US Office is responsible for planning and coordinated, interagency implementation, but an interagency program office has not been established. The Administration, through the Joint Subcommittee on Ocean Science and Technology (JSOST) of the National Science and Technology Council and the Committee on Ocean Policy, is currently working to Part I: Structure and Governance 21 address these issues. For the purposes of implementation and operation of IOOS, the Administration recognizes the importance of having a clear point of accountability and believes NOAA should be the lead civilian agency for administration and implementation of IOOS.

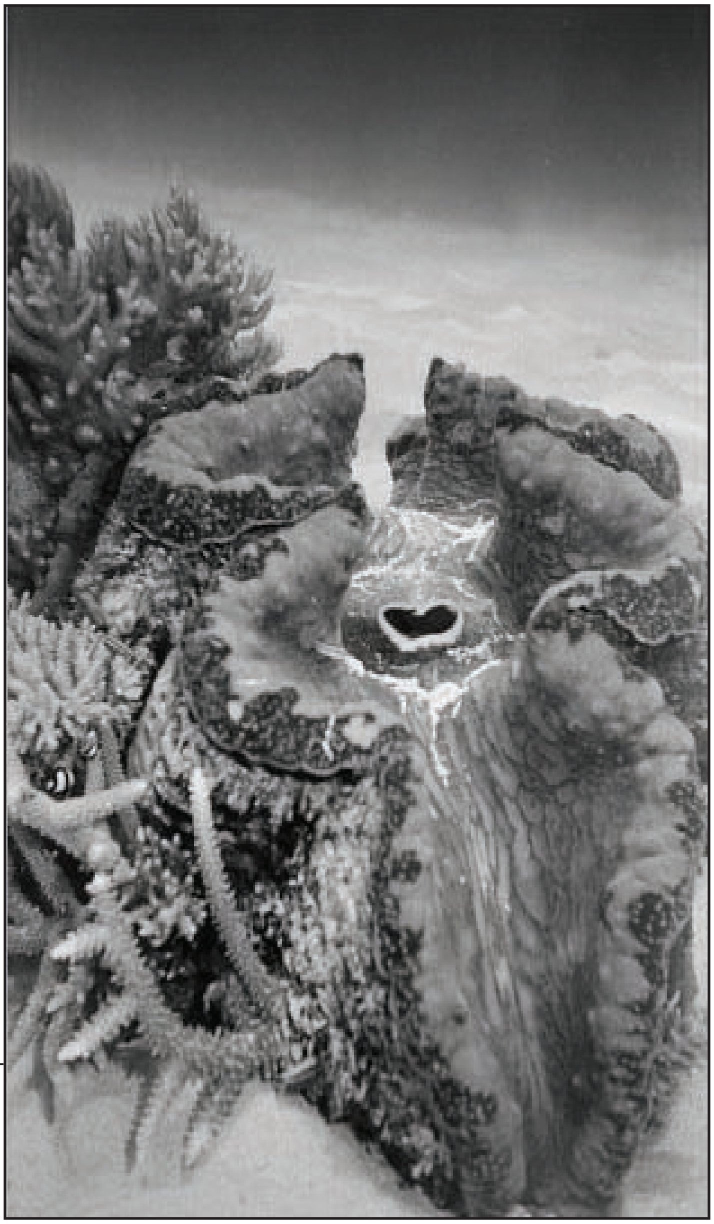
With NOAA as the lead agency, IOOS development will occur through sustained partnerships among participating federal agencies and RAs (see below). This will be achieved under the guidance of sub-committees established by the EXCOM (Table 3). The sub-committees will have agencies designated as Chairs, Co-Chairs, or partners. A primary responsibility of each sub-committee is to formulate an integrated budget strategy for each activity based on annual budget requests for participating federal agencies. For the pilot-to-operational sub-committees, this strategy will include decisions concerning the incorporation or transition of new technologies and knowledge, developed through research, into an operational mode as part of the IOOS. It is anticipated that additional agencies will become partners as the IOOS evolves, and the designations in Table 3 are likely to change accordingly.

Table 3. EXCOM sub-committees of participating federal agencies responsible for developing a coordinated budget strategy and for implementing, operating, and improving elements of the IOOS (**NOAA**: National Oceanic and Atmospheric Administration; **NSF**: National Science Foundation; **NASA**: National Aeronautics and Space Administration; **EPA**: Environmental Protection Agency; **USGS**: U.S. Geological Survey; **MMS**: Minerals Management Service; **USACE**: U.S. Army Corps of Engineers; C = Chair, CC = Co-Chair, P = Partnering agency).

Sub-Committee	NOAA	NSF	NAVY	NASA	EPA	USGS	MMS	USACE
Administration	C	P	P	P	P	P	P	P
Data Management and Communications	CC	P	CC	P	P	P	P	P
Modeling and Data Analysis	CC	P	P	P	CC	P	P	P
Research	P	CC	P	CC	P	P	P	P
Global Component: Pilot-to-Ops	CC	P	CC	P	P	P	P	
Coastal Component: Pilot-to-Ops	CC	P	P	P	P	CC	P	P
Education/Training/Communication	CC	CC	P	P	P	P	P	P
Assessment	CC	P	P	P	P	P	CC	P

3.3.2 Regional Associations

The U.S. Commission on Ocean Policy strongly recommends the strengthening of regional approaches to sustainable development in the coastal zone.[4] A regional approach to environmental management is also well documented as beneficial, and it is essential for ecosystem-based, adaptive management. [9, 10] Establishing RAs and the RCOOSs they operate is critical for engaging user groups from both private and public sectors in the specification of data and information needs, and therefore critical in the successful development of the IOOS as a whole.



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Box 3: Meeting Regional Research And Information Needs

Bridging Boundaries through Regional Marine Research, a report of the National Research Council, makes the case that enhanced regional observations and data analyses are needed to provide the data and information on oceans and coasts that are required for more effective environmental protection, resource management, and integrated coastal zone management. The U.S. Commission on Ocean Policy endorsed this approach and called for (1) research to improve understanding and technical capabilities for rapid detection and timely predictions of changes; (2) sustained data collection, monitoring, and observations; (3) development of useful information products; and (4) outreach, education, training, and technical assistance for decision makers.

The coastal component of the IOOS has embraced this approach as the most effective way of addressing the seven societal goals. RAs are being created to design and implement RCOOSs. RAs are responsible for engaging private and public sectors (state agencies, regional organizations of federal agencies, commercial enterprises, NGOs, tribes, and academia) in designing, operating, and improving RCOOSs in order to ensure the provision of data and information that meets the needs of user groups in the respective regions. **RAs are expected to perform many of the functions recommended by the U.S. Commission on Ocean Policy for Regional Ocean Councils.** In creating RAs, it is recognized that fixed boundaries are needed for funding and accountability, but that boundaries for ecosystem-based management are different, depending on the target of management (e.g., managing the salmon fishery versus managing nutrient loads to coastal ecosystems or the closure of beaches to reduce public health risks of bathing). Thus, a truly comprehensive approach to addressing the seven societal goals of the IOOS must be flexible and facilitate partnerships among regions to address transboundary issues.

"Bridging Boundaries Through Regional Marine Research" <http://www.nap.edu/books/0309068320/html/>

"An Ocean Blueprint for the 21st Century: Final Report of the U.S. Commission on Ocean Policy"
http://oceancommission.gov/documents/welcome.html

RAs represent regional interests of federal and state agencies, private sectors, NGOs, tribes, and academia in the development and operation of integrated RCOOSs. Thus, participants in national IOOS development workshops over the last four years[2, 10, 11] have consistently recommended the establishment of (1) RAs to develop RCOOSs that conform to IOOS design principles (section 2.2) and function according to established federal criteria for governance and operations (Appendices D, E,

[9] "Bridging Boundaries Through Regional Marine Research" <http://www.nap.edu/books/0309068320/html/>

[10] "Workshop on Improving Regional Ocean Governance in the United States" <http://www.udel.edu/CMS/csmp/pdf/RegionalProceedings.pdf>

[11] "Proceedings of the First Implementation Conference for the Integrated Ocean Observing System (IOOS)" <http://www.ocean.us/documents/docs/AnnualIOOSImpConf-PROCEEDINGS-5Oct04.doc>

and F), and (2) an NFRA to coordinate the development of RCOOSs nationwide and represent regional user needs at the federal level. The NFRA also coordinates the development of RCOOSs according to IOOS design principles and to criteria for the establishment of a governance mechanism and a business plan (Appendix F).

It is critical that the RAs and the NFRA be able to initiate and complete the substantial efforts involved in meeting the criteria for RA certification, including the engagement of user groups from both private and public sectors in the design, implementation, operation, and improvement of RCOOSs. RAs must be enabled, to perform the extensive outreach, economic analysis, and assessments of data and information needs of user groups that are required to become a certified RA. This priority is the highest for the regional effort and should be funded preferentially over other regional requests.

4. Performance Measures

Sustained development of the IOOS requires a systematic and rigorous process for periodic performance evaluations that ensure adherence to IOOS design principles (section 2.2). Performance metrics fall into two broad categories: (1) system performance and (2) user satisfaction. System performance includes measures of data quality, continuity of data streams, data flow from measurements to models, model skill, and the diversity of user groups. User satisfaction is primarily concerned with the provision of data at rates and in forms specified by user groups. As described in section 3.1.4, the EXCOM oversees this process. Where possible, existing federal and international measures will be adopted that assess individual components of the system (e.g., tide gauges, Box 4), achievement of objectives (e.g., long-term sea level predictions, Box 5), and achievement of the societal goals.

Box 4: Performance Measure: Sea Level Observations

Metric 1: Complete the installation of real-time, remote reporting tide gauges and co-located permanent Global Positioning System (GPS) receivers at 62 stations for long-term trends, and 30 stations for altimeter drift calibration, as part of the international Global Sea Level Observing System.

Metric 2: Establish the permanent infrastructure necessary to process and analyze satellite altimetry, tide gauge, and GPS data for the routine provision of annual sea level change reports with (1) estimates of monthly mean sea level for the past 100 years with 95% confidence; (2) variations in relative annual mean sea level for the entire record for each instrument; and (3) estimates of absolute global sea level change accurate to 1 mm per year.

These metrics were recommended by the Intergovernmental Panel on Climate Change and have been adopted by NOAA. They are for one component of the global ocean-climate component of the IOOS required to achieve the objective of improving predictions of long-term sea level rise (Box 5).

Smith, N.R. and C.J. Koblinsky (eds). 2001. The Ocean Observing System for the 21st Century. GODAE Project Office, Bureau of Meteorology, Melbourne, Australia, 604 pp.

GCOS Secretariat. 2004. Implementation Plan for the Global Observing System for Climate in Support of the U.N. Framework Convention on Climate Change. WMO, GCOS Pub. No. 92, Geneva, Switzerland, 136 pp.

Box 5: Performance Measure: Reduction in Uncertainty Of Sea Level Rise Predictions

A major goal of the IOOS is to document and predict long-term trends in sea level. One measure of success is the reduction of uncertainty in projections of sea level rise during the 21st century. The metric is to reduce the range of ensemble estimates of sea level rise as follows:

YEAR	2002	2003	2004	2005	2006	2007	2008	2009	2010
RANGE	80 cm	80 cm	70 cm	60 cm	50 cm	40 cm	30 cm	25 cm	25 cm

This metric is for an objective achievement of which will contribute to addressing the societal goal of improved predictions of long term climate change. This metric was recommended by the Intergovernmental Panel on Climate Change and has been adopted by NOAA.

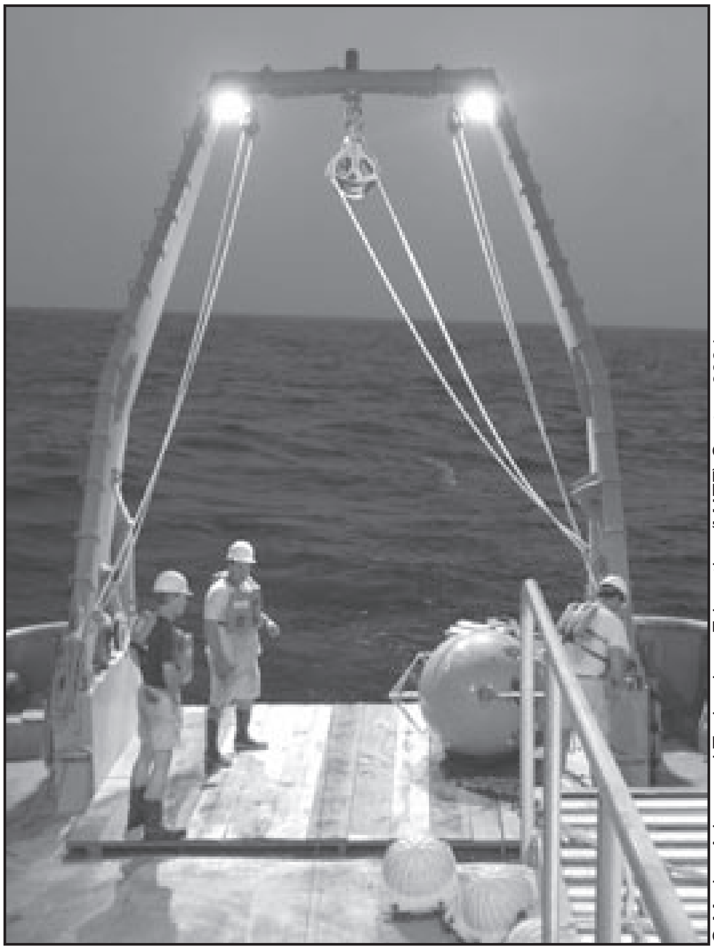
Church, J.A., J.M. Gregory, P. Huybrechts, K. Kuhn, M.T. Nhuan, D. Qin, and P.L. Woodworth. 2001. Changes in sea level, In *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I the Third Assessment Report of the Intergovernmental Panel on Climate Change, Houghton et al. (eds). Cambridge University Press, Cambridge, U.K., 881 pp.

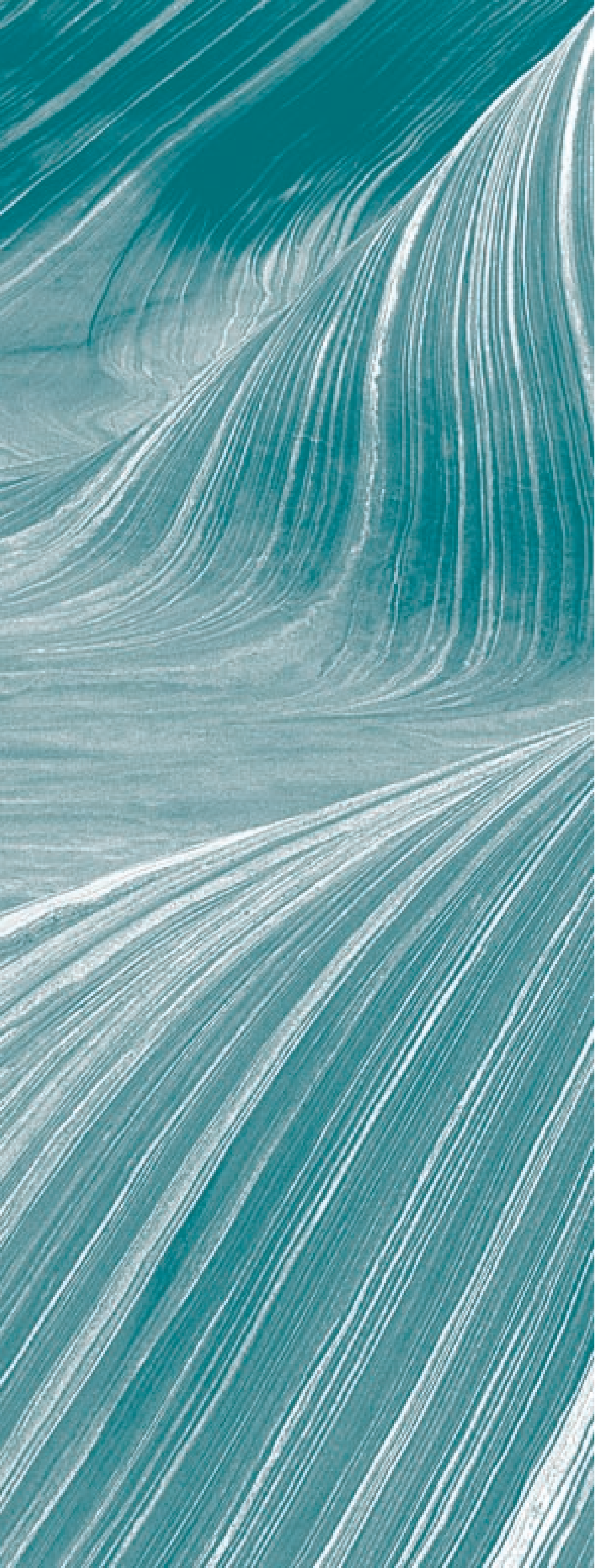
Performance measures and metrics for the IOOS as a whole (coastal and global) have yet to be adopted or developed, and a high priority should be the establishment of the IOOS Assessment sub-committee of the EXCOM to specify and oversee implementation of measures and metrics for the coastal component and the IOOS as a whole. In addition to the categories of measures described above, these should include measure of cost-benefit. Two studies have been funded by NOPP to assess economic impacts of IOOS data and information in this context:

- A two-year (2002-2004) study has been funded by NOPP to identify potential regional benefits of the IOOS. The product will be an inventory of the major users of ocean information and a set of initial region- and sector-specific estimates of benefits from improving and maintaining coastal observing systems. Using common economic methods, the study will estimate the value of more timely and accurate data and information from the IOOS in decision-making processes. Preliminary results (subject to revision) of a recently funded study of nine user sectors suggest an annual economic benefit of at least $700 million.[6]

- Environmental variability impacts the bottom line of many private sectors, including tourism and recreation, energy management, agriculture, forestry, and fisheries. A four-year study (2002-2005) is underway to determine priorities among various sectors for improved (more accurate and timely) weather, climate, and ocean information to mitigate risk.11 The sectors are divided into sub-sectors (e.g., the construction industry has separate information needs for property construction and maintenance, insurance, and emergency management). Demonstrations will be conducted to show examples of the value of the IOOS and to help determine the optimal configuration of IOOS elements. Ranking IOOS products according to their net benefit is one useful tool to help prioritize investments in an ocean observing infrastructure.

Cost-benefit analyses such as these should be an ongoing activity of the IOOS for periodically updating the value of the data and information gained by improving operational capabilities in terms of their costs. These analyses are important especially in a limited funding environment when decisions must be made to fund or not to fund various aspects of IOOS development. Thus, IOOS development should include the maintenance of data on socio-economic indicators. Standard indicators should be identified once the previously described studies are concluded, and they should be used in conjunction with performance measures of IOOS operations described above.





Part II
FISCAL YEARS 2005 – 2006
INTEGRATING EXISTING ASSETS

1. Introduction

1.1 Purpose and Organization

Part II focuses on building the Integrated Ocean Observing System (IOOS) by incorporating selected observing subsystem assets that are pre-operational or operational through the development of an integrated approach to data management and communications. Examples of current research activities that are important to IOOS development are highlighted, and the beginnings of a process for developing an education network that will benefit from and contribute to IOOS development are described.

As recommended by consensus during the First Annual IOOS Implementation Conference and endorsed by federal agencies[1], the highest priorities in Fiscal Year (FY) 2005 and 2006 for the global component and the backbone of the coastal component are as follows:

- Establish Regional Associations (RAs);
- Continue implementing the global ocean component (section 2.1.2) and coordinate its development with that of the coastal component (section 2.1.3); and
- Implement the data management and communications (DMAC) subsystem (section 2.2).

The establishment of RAs is addressed in Part I.

The selection process used to formulate recommendations for the observing subsystem of the National Backbone of the coastal component is described in section 2.1.1. Recommendations in section 2.1.2 for the global component focus on geophysical variables and are based on existing implementation plans of the international community, including the U.S. Recommendations in section 2.1.3 for the initial National Backbone of the coastal component include geophysical observations of the global ocean component and incorporate additional ecological variables and land-based inputs. Coastal priorities are to incorporate existing pre-operational and operational assets into the IOOS that are relevant to the seven societal goals and to developing ecosystem-based management capabilities. No new observing subsystem assets are recommended for the coastal component.

The DMAC subsystem is the primary integrating mechanism for the IOOS. Recommendations for developing the DMAC subsystem (section 2.2) are based on the Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems [2] recently completed by Ocean.US and endorsed by consensus at the First Annual IOOS Implementation Conference.[1]

Part II concludes with a summary of research priorities that address many of the priorities for developing IOOS operational capabilities (section 3), as well as plans for establishing education networks to provide the means for educators to benefit from and contribute to the IOOS, addressed in section 4.

1.2 Ecosystem-Based Management

The report of the U.S. Commission on Ocean Policy calls for the development of an ecosystem-based approach to environmental protection, resource management, coastal engineering, and integrated coastal zone management.[3] Implementing such an approach requires the capability to engage in adaptive management, a decision making process that depends on routine and rapid assessments of changes in the state or condition of marine and estuarine systems and on timely detection and prediction of changes in or the occurrence of phenomena of interest (Appendices B and C). **Recommended programs for establishing the initial IOOS are necessary first steps in the development of ecosystem-based approaches to mitigating the effects of human activities and achieving the goals of sustaining and restoring healthy ecosystems and marine resources** (including resource and water quality management). However, much needs to be done to develop an IOOS that provides the required data and information. Therefore, Ocean.US recommends that National Oceanic and Atmospheric Administration (NOAA) collaborate with the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), and U.S. Army Corps of Engineers (USACE) to specify observing, DMAC, and modeling requirements for the design and implementation of ecosystem-based management practices.

1.3 Terrestrial and Atmospheric Observations

In making the recommendations below, it is recognized that oceans are an integral part of the Earth system, and the development of IOOS must account for the effects of human activities, as well as interactions with the atmosphere and terrestrial environment. Thus, development of the coastal component must be coordinated with the Global Earth Observation System of Systems (GEOSS) in order to improve capabilities to monitor the movement of water, sediments, nutrients, and contaminants from land and atmosphere to the oceans and Great Lakes. Non-ocean variables that are especially relevant to achieving IOOS goals are listed in Table 1. Wind stress over water and land-based inputs are so important as drivers of change in oceans and coasts they are recommended for integration as part of the IOOS (section 2.1.3).

Table 1. Non-ocean and Great Lake variables required to quantify important drivers of change in ocean and coastal systems. Atmospheric measurements over ocean and coastal systems and measurements of surface water transports from land are considered part of the IOOS.

Atmospheric	Terrestrial	Human Use
Wind vectors Air temperature Atmospheric pressure Precipitations (wet, dry) Humidity Aerosol concentration Ambient noise Atmospheric visibility Cloud cover	River & stream flows Ground water discharge Mass transports of sediments, nutrients, and contaminants	Beach usage Point source discharges Fish & shellfish catch Commercial fish catch Recreational boating Generation of underwater sound

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[1] "Proceedings of the First Annual Implementation Conference for the Integrated Ocean Observing System (IOOS)" <http://ocean.us/documents/docs/AnnualIOOSImpConf-PROCEEDINGS-5Oct04.doc>

[2] "Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive" <http://www.oceancommission.gov/documents/welcome.html>

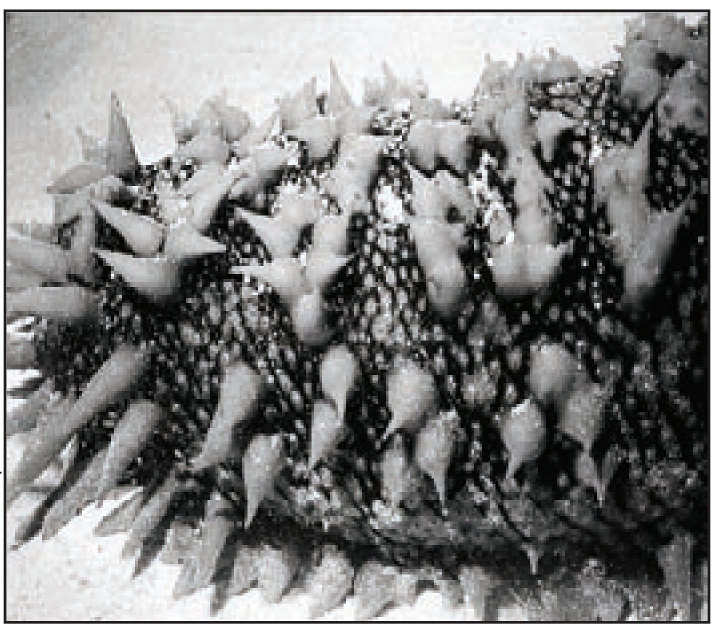
[3] An Ocean Blueprint for the 21st Century: Final Report of the U.s. commission on Ocean Policy" <http://oceancommission.gov/documents/welcome.html>

2. Integrating Existing Observing Subsystem Assets through Data Management and Communications

Plans for the initial global ocean component are completed, and implementation is underway.[4,5,6] In contrast, although operational elements for building the initial coastal component (National Backbone and RCOOSs) exist, an integrated and operational observing system for the nation's coastal waters is still in the planning stage. Design and implementation of the coastal component has lagged behind the global ocean component for a variety of reasons, including the complex nature of the land-sea interface, the challenges of developing a multidisciplinary system for multiple applications, and the need for an unprecedented level of collaboration and coordination across government agencies, academia, the private sector, and non-governmental organizations (NGOs). These challenges are being addressed; and the emphasis of *The First IOOS Development Plan* is on developing the coastal component, and doing so in coordination with the global ocean component.

2.1 The Observing Subsystem

Recommendations herein address the need to make more effective use of existing observing subsystem assets currently operated by federal and state agencies, universities, coastal laboratories, and other organizations.



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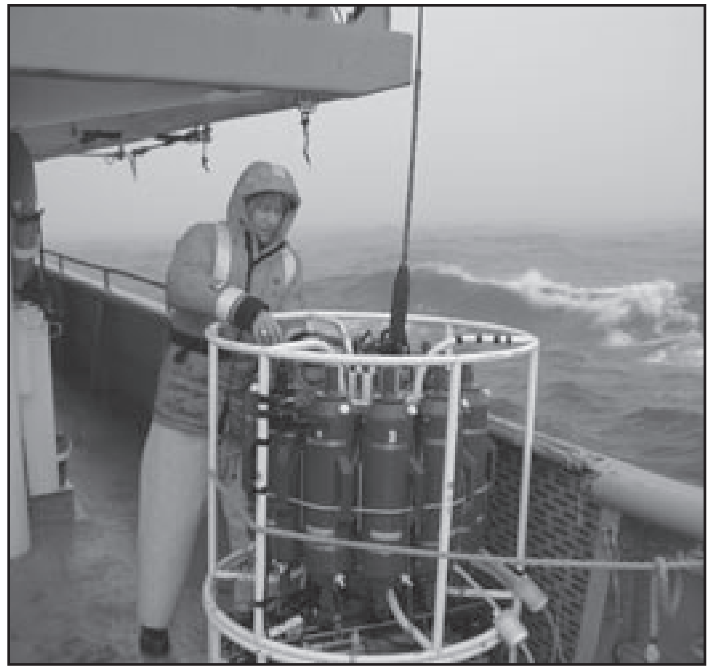

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2.1.1 Guidelines for Identifying Programs

Recommended for the Initial Observing Subsystem of the National Backbone During FY 05 and FY 06, (1) implementation of the global ocean component will continue; (2) benefits of integration will be demonstrated in terms of the cost-effective production of new or improved products; and (3) the coastal and global ocean components will develop as a manageable, interoperable, and affordable system that integrates data and information from diverse sources to improve existing product and general new products. These are first steps toward increasing operational capabilities for all seven societal goals. Improvements to the IOOS are recommended in Part III.

A primary objective of integration is to make more effective use of existing resources to address complex problems that require rapid access to diverse data from many sources. To achieve this objective, IOOS development must occur through carefully considered selection of appropriate programs and assets, especially during this formative period.

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4 The Ocean Observing System Development Panel (OODSP) 1995. "The scientific design for the common module of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS): An ocean observing system for climate." Report of the OOSDP, publ. U.S. World Ocean Circulation Experiment (WOCE) Office, Texas A&M University, College Station Texas, 285 pp.; United Nations Educational, Scientific and Cultural Organization
No. 66, 50 pp. <http://ioc.unesco.org/goos/docs/GOOS_066_act_pl.htm>; Implementation Plan for the Second Adequacy Report. GCOS. 2004. Implementation Plan for the Global Ocean Observing System for Climate in Support of the UNFCC. <http://www.wmo.ch/web/gcos/gcoshome.html>

5 Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System." 1999. A report prepared on behalf of the National Ocean Research Leadership Council (NORLC) in response to a request from Congressmen Saxton and Weldon. <http://ocean.tamu.edu/GOOS/publications/sw.html>

6 In the proceedings of the Ocean.US 2002 workshop, "Building Consensus: Toward an Integrated and Sustained Ocean Observing System," subgoals, products, and the initial suite of core variables were specified. A detailed account of the procedures used and a complete description of subgoals and products are given in Appendices V, VI, VII, and VIII of the workshop proceedings. <http://www.ocean.us/documents/docs/Core_lores.pdf>

Table 2. Provisional IOOS core variables for the National Backbone and their relevance to the seven societal goals of the IOOS (indicated by "X").[6] The core variables are nearly identical to similar suites of core variables identified in the GOOS/Global Climate Observing System (GCOS) action plan[4], the EuroGOOS survey (Fischer, J. and N. Fleming. 1999. Operational oceanography: data requirements survey. EuroGOOS Publ. No. 12, EG99.04, 59 pp.), the Coastal Ocean Observations Panel (COOP) of the IOC[10], and in the 1999 NORLC report to Congress[5]. Physical variables are ranked high because they are required to achieve all seven societal goals. Variables in **bold** were also identified by COOP as core variables using a similar procedure.[10] Note that natural hazards such as oxygen depletion and harmful algal blooms are addressed in the ecosystem health category. This list of variables is augmented by data on atmospheric, land-based and anthropogenic forcings in Table 1.

CORE VARIABLES	Weather & Climate	Marine Operations	Natural Hazards	National Security	Public Health	Healthy Ecosystems	Sustained Resources
Salinity	X	X	X	X	X	X	X
Temperature	X	X		X	X	X	X
Bathymetry	X	X	X	X	X	X	X
Sea Level	X	X	X	X		X	X
Surface waves	X	X	X	X	X	X	X
Surface currents	X	X	X	X	X	X	X
Ice distribution	X	X	X	X			
Contaminants				X	X	X	X
Dissolved Nutrients					X	X	X
Fish species						X	X
Fish abundance						X	X
Zooplankton species					X	X	X
Optical properties				X	X	X	X
Heat flux	X					X	X
Ocean color	X	X			X	X	X
Bottom character	X	X				X	X
Pathogens				X	X	X	X
Dissolved O_2						X	X
Phytoplankton species	X	X		X	X	X	X
Zooplankton abundance						X	X

Federal agencies sponsor a wide spectrum of ocean research and operational programs, a subset of which is recommended for incorporation into the initial IOOS. To begin the process of identifying programs for building the coastal component of the IOOS, participating federal agencies provided an inventory of existing ocean programs (from research to operational). The list is posted on the Ocean.US website. Products (Part I, Table 1) and core variables (Table 2) used to guide the selection of programs from the inventory were identified at the Ocean.US 2002 workshop.[6] From this list, programs recommended herein for integration into the IOOS meet the following criteria:

(1) Contribute to achieving one or more of the seven societal goals;
(2) Measure one or more of the core variables;
(3) Provide value-added benefits as part of an integrated system or contribute to the provision of required data or products (Box 1);
(4) Meet the requirements of the pre-operational or operational stages of the IOOS outlined in Part I, section 2.4; and
(5) Have identified sustained funding and agency or program sponsorship.

Box 1: Improving Products Through Integration

Remote sensing is critical for spatially synoptic observations of the ocean's surface, while *in situ* measurements are critical for observing the ocean's interior. Together, they provide a powerful means to rapidly assess current states of oceanic and coastal systems in all four dimensions of time and space. The fusion of remote sensing and *in situ* measurements provides an unprecedented ability to test physical and biological models of upper ocean processes over the past decade. Thus, with few exceptions, space-based remote sensing and *in situ* observations are best used in conjunction with each other.

In addition, the following were considered in recommending pre-operational and operational programs for building the initial National Backbone:

(1) Federal legislative mandates that can be met more effectively by implementing the coastal component (Box 1);
(2) Recommendations of the Pew Ocean Commission[7] and of the U.S. Commission on Ocean Policy[3]; and
(3) Recommendations by expert panels and commissions on indicators of ecosystem health and the implementation of ecosystem-based management of the environment and living marine resources (LMRs).[3,8]

Box 2: Legislative Mandates

Data and information provided by the IOOS will enable government agencies to meet the terms and conditions of laws that govern the use, management, and protection of oceanic and coastal systems more effectively and efficiently. Examples of these laws include the following:

- Hydrographic Services Improvement Act, Pollution from Ships Act, Rivers and Harbors Act, and Deepwater Port Act
- Disaster Mitigation Act, Harmful Algae Act, Endangered Species Act, National Invasive Species Act, and Nonindigenous Aquatic Nuisance Prevention and Control Act
- Clean Water Act, Water Pollution Control Act, Ocean Dumping Act, Oil Pollution Act, and Marine Plastic Pollution Research and Control Act
- Magnuson-Stevens Fishery Conservation and Management Act; Sustainable Fisheries Act; Marine Mammal Protection Act; Marine Protection, Research, and Sanctuaries Act; and Estuary Restoration Act
- Coastal Zone Management Act; Coastal Barrier Resources Act; Coastal Wetland Planning, Protection, and Restoration Act; and Coral Reef Conservation Act.

Building an integrated system that addresses all seven societal goals (Part I, section 1.1) takes both time and continued improvement of operational capabilities through research and pilot projects. The process begins by establishing a hierarchy of observations that serve data needed to visualize and analyze spatial and temporal variability and change across a broad range of scales (global, national, regional, and local; hours to decades). An important first step is to improve field estimates of core variables (and gradients therein) on global to local scales by integrating data from remote sensing and *in situ* measurements, and by increasing the frequency and density of observations. The former, integrating data, is addressed here, and the latter, increasing the number and type of observations, in Part III.

2.1.2 Pre-Operational and Operational Elements of the Global Ocean Component

The oceans are second only to the sun in effecting climate variability and change on seasonal and decadal time scales. Basin scale warming of the oceans and increases in sea level are important indicators of global climate change that have and will continue to have significant impacts on human society. Changes in the distribution of heat and carbon among the Earth's sources and sinks are major drivers of climate variability and change. It is estimated that the ocean stores 1000 times more heat and 50 times more carbon than the atmosphere, and is the

[7] "America's Living Oceans: Charting a Course for Sea Change" <http://www.pewoceans.org/oceans/downloads/oceans_report.pdf>

[8] The goal of ecosystem-based management is to sustain and restore ecosystem goods and services by integrating ecological and socio-economic factors into a comprehensive strategy for managing and mitigating the effects of human activities, extreme weather, and climate change on the structure and function of ecosystems over multiple scales in time and space (United Nations Environmental Programme (UNEP), 2001. "Ecosystem-based management of fisheries: opportunities and challenges for coordination between marine Regional Fishery Bodies and Regional Seas Conventions." UNEP Regional Seas Reports and Studies, No. 175; Ecological Society of America, <http://www.sdsc.edu/~ESA/ecmtext.htm>). Implementing an ecosystem-based approach depends on the ability to engage in adaptive management, a process in which decisions (e.g., control of point and diffuse inputs of nutrients, establishing catch quotas for fisheries) are influenced by knowledge of the current state of marine ecosystems and natural environmental variability (National Research Council [NRC]. 1999. Sustaining Marine Fisheries. National Academy Press, Washington, D.C., 164 pp).

source of 80% of wet deposition on land. Thus, as recommended by panels of experts[4,5,6], continued implementation of the global ocean component is needed to provide data and information required to document the seasonal to decadal scale trends in (1) sea level, (2) ocean carbon sources and sinks, (3) ocean storage and transports of heat and fresh water, and (4) air-sea exchange of heat and fresh water. High priority products required to achieve these goals include:

(1) Monthly mean sea level trends for the past 100 years, with 95% confidence;
(2) Changes in inventories of carbon, heat, and salinity in ocean basins on a decadal scale;
(3) Mean monthly sea surface temperature anomalies at 50 km resolution and 0.2°C accuracy; and
(4) Weekly analyses of precipitation and evaporation at 50 km resolution and 5 cm per month accuracy.

The full list of products can be found in United Nations Educational, Scientific and Cultural Organization (UNESCO) 1999.[4]

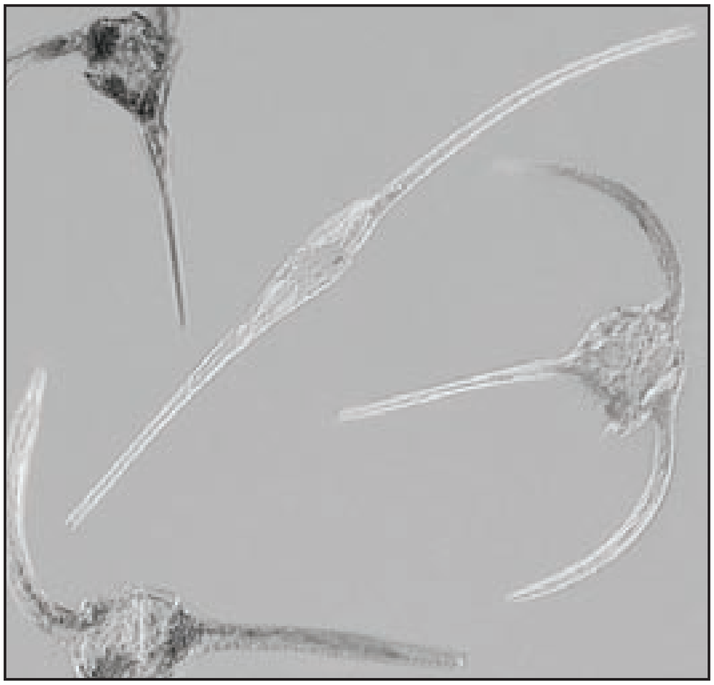
Pre-operational and operational programs that constitute the initial global ocean component are listed in Table 3. These include both *in situ* as well as satellite remote sensing programs. While the global component has focused on physical observations, it is recognized that there are operational global biological observation programs that have not yet been incorporated into IOOS plans (e.g., Box 3). These programs will be considered in subsequent updates to this plan. Enhancements to the operational system, recommended by national and international panels of experts, are presented in Part III. There are also pilot projects (e.g., Argo array of profiling floats, Global Ocean Data Assimilation Experiment [GODAE][9]) and research programs (e.g., the Aquarius satellite mission to observe sea surface salinity) that are likely to transition to pre-operational and, possibly, operational status in the future.

[9] <http://www.usgodae.fnmoc.navy.mil/>

Table 3. Pre-operational and operational programs recommended for the global ocean component of the initial IOOS, listed by core variable and by the responsible federal agency.

Core Variable	NOAA	Navy
Temperature	GOES[a] POES[b] Voluntary observing ships Ships of opportunity Dedicated Ships Moored Buoys (Tropical Array) Drifting Buoy Array Arctic flux & sea ice NWLON[c]	Integrated buoy program Ocean Survey Ships
Salinity	Voluntary observing ships Ships of opportunity Dedicated Ships Drifting Buoy Array Moored Buoys (Tropical Array) Arctic flux & sea ice	Integrated buoy program Ocean Survey Ships
Waves		Geosat[d] Follow-on Ocean Survey Ships Integrated buoy program
Currents, Sea surface topography	Drifting Buoy Array Moored Buoys (Tropical array)	Ocean Survey Ships
Winds	Dedicated Ships Drifting Buoy Array Arctic flux and sea ice Tide Gauge Network	WindSat[e] Integrated buoy program Ocean Survey Ships
Sea Level	Global Tide-Gauge Network NWLON	Geosat Follow-on

[a] Geostationary Operational Environmental Satellites
[b] Polar Operational Environmental Satellite
[c] National Water Level Observation Network
[d] Geodetic Satellite
[e] Ocean Surface Vector Winds from Space



Box 3: Ocean Biogeographical Information System (www.iobis.org)

The recommended progression of research-to-pilot-to-pre-operational projects as a means for developing operational capabilities is analogous to the classic data-to-information-to-knowledge progression. An example of an IOOS DMAC element that has progressed beyond research and into a pilot project stage is the Ocean Biogeographical Information System (OBIS). OBIS is the information component of the Census of Marine Life. It is a rapidly developing international infrastructure for accessing, archiving, and serving biological data. It provides access to data content, information infrastructure, and informatics tools (maps, visualizations, and products from models) through an on-line, dynamic, global 4-D (three space-dimensions and the time dimension) atlas of biogeographic information. Through “open access” via the Web, OBIS provides (1) a taxonomically and geographically resolved atlas on marine life and ocean environment; (2) data from museums, fisheries, and ecological studies; (3) data from all ocean environments (seabed to plankton, and coastal to deep sea); (4) interoperability with other databases; (5) access to physical oceanographic data at regional and global scales; and (6) software tools for acquiring new data, checking species names, mapping, modeling, and biogeographic analysis. The atlas will be used to reveal interesting spatial and temporal patterns, generate new hypotheses about global marine ecosystems, and guide future field expeditions. The on-line, digital atlas developed by OBIS is an important new product that will be critical to achieving the goals of sustaining living marine resources and healthy marine ecosystems.

OBIS is an Associate Member of the Global Biodiversity Information Facility and plans to work closely with the developing GOOS on data management and analysis issues. A major goal for the next two to three years is to establish an international network of national and regional nodes with common data access through the OBIS Portal. OBIS is one of the first biological portals being integrated into IOOS.

2.1.3 Pre-Operational and Operational Elements of the National Backbone of the Coastal Component

Participants in the First Annual IOOS Implementation Conference emphasized the importance of integrating physical, chemical and biological data and addressing the problem of under-sampling of core variables in time and space in coastal systems (i.e., increases in the time-space resolution of core variable measurements in coastal relative to open ocean systems).[1] Thus, to ensure a foundation for future improvements in the accuracy of field estimates and model predictions (especially for biological and chemical variables), there was widespread agreement that existing programs recommended below for the initial backbone should be sustained (as should the current investment in coastal ocean observing systems by federal agencies, states agencies, laboratories, and universities). High priority was placed on sea surface atmospheric observations (Figure 1a), water level measurements (e.g., Box 4, Figure 1b), monitoring land-based inputs of freshwater and associated constituents (sediments, nutrients, and contaminants), linking deep-ocean models to shelf and estuarine models (physical, biogeochemical, and trophic dynamics), assessing the extent and condition of key habitats (benthic and pelagic), and assessing the distribution and abundance of LMRs.

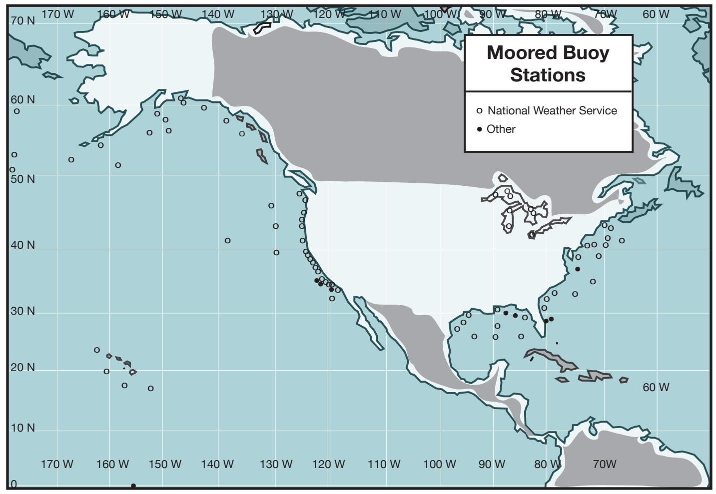


Figure 1a. The network of NDBC-Weather Service buoys, equipped with meteorological sensors for the provision of real-time data critical to weather forecasting, are a high priority for the IOOS backbone. The buoys are important not only for weather forecasting, but they also provide platforms for enhancements Part II: Integrating Existing Assets 36 recommended in Part III. This important network is a high priority for incorporation into the National Backbone of the coastal component of IOOS.

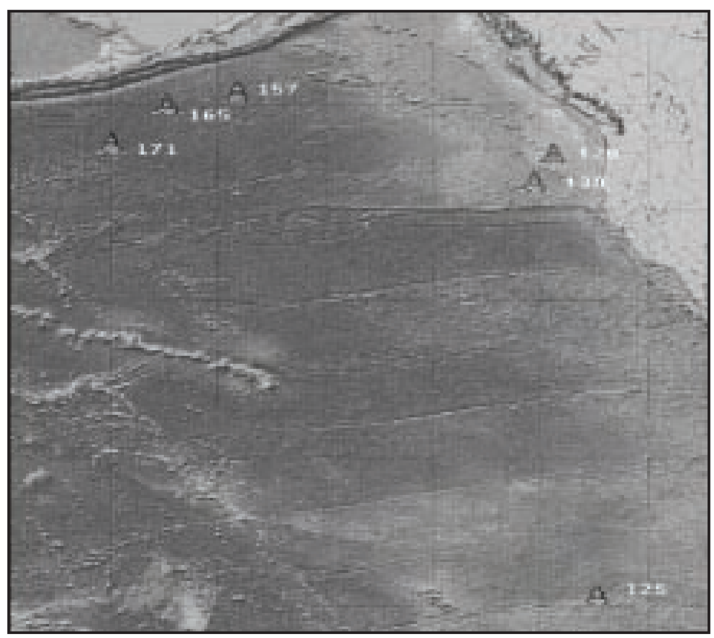


Figure 1b. The Deep-ocean Assessment and Reporting of Tsunami (DART) moorings in the North Pacific Ocean. The DART program was initiated by NOAA to maintain and improve early detection and real-time reporting of tsunamis. Currently, six DART mooring systems are deployed in the Pacific Ocean. Developed by PMEL and run operationally by NDBC as part of the Pacific Tsunami Warning System, DART moorings consists of an anchored seafloor bottom pressure recorder and a companion surface buoy for real-time data telemetry via GOES. <http://seaboard.ndbc.noaa.gov/Dart/dart.shtml>

Box 4: Tsunami Warning Systems: Protecting Public Health and Sustaining Healthy Ecosystems and Living Marine Resources

Ecosystems and Living Marine Resources Observations of geophysical variables are needed to forecast natural hazards and mitigate their effects on public health, the condition of marine ecosystems, and sustaining living marine resources. The Pacific Tsunami Warning System (Figure 1b) is an example of an important element of the IOOS that needs to be maintained, enhanced, and expanded to other ocean basins (see Part III for recommended enhancements and expansions). This observing system monitors seismic activity, sea surface height, and coastal sea level throughout the Pacific basin to provide early warning and mitigate the impacts of tsunamis on the populations and economies of 26 participating nations. As part of an international cooperative effort to save lives and protect property, the U.S. Geological Survey (USGS) operates a global seismographic network and the U.S. National Oceanic and Atmospheric Administration's (NOAA) National Weather Service operates tsunami warning centers in Palmer, Alaska and Ewa Beach, Hawaii. The latter serves as the regional Tsunami Warning Center for Hawaii and as a national/international warning center for tsunamis that pose a Pacific-wide threat. This international warning effort became a formal arrangement in 1965 when the Hawaii center assumed the international warning responsibilities of the Pacific Tsunami Warning System (PTWS).

http://aslwww.cr.usgs.gov/Stations/index.htm
http://www.geophys.washington.edu/tsunami/general/warning/warning.html

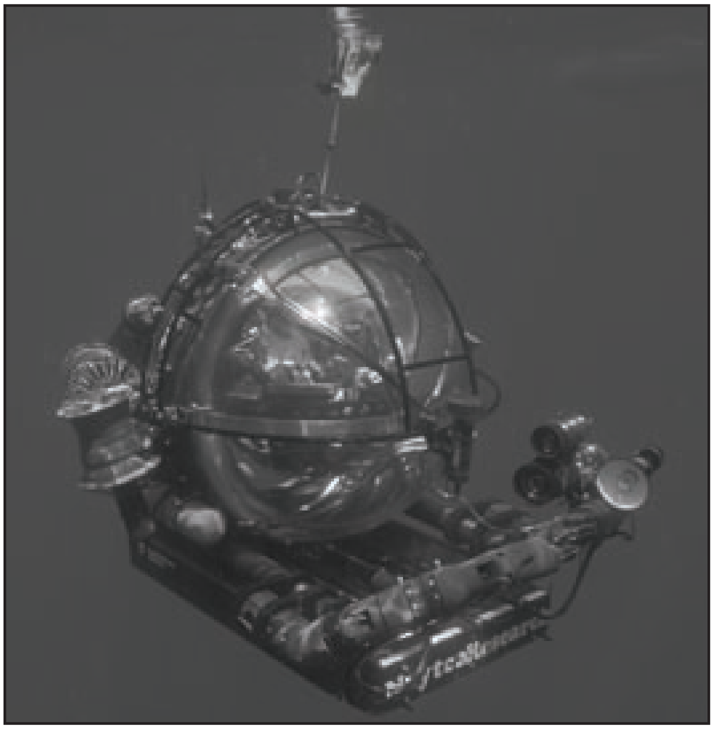
Many of the observations made as part of the global component are made in coastal waters and are needed to address the goals of public health, ecosystem health, and living resources in an ecosystem context.[5, 6, 8, 10] Thus, programs that provide estimates of distributions of geophysical variables that define the pelagic environment of coastal ecosystems and living resources are high priorities for the initial backbone:

(1) Sea surface wind vectors;
(2) Surface and interior fields of temperature, salinity, and currents; and
(3) Sea surface height and water levels.

In addition, **the initial backbone begins the process of serving data and information needed to implement ecosystem-based management by integrating data on the physical environment with biological and chemical observations that include the following:**

(1) Surface and interior fields of dissolved inorganic nutrients, oxygen, chlorophyll-*a*, and macrozooplankton abundance;
(2) Extent and condition of benthic habitats;
(3) Abundance and distribution of LMRs (including protected species); and
(4) Land-based freshwater flows and associated fluxes of sediments, nutrients, and contaminants into coastal waters.

Based on IOOS selection guidelines (section 2.1.1), programs recommended for building the initial National Backbone are listed in Table 4. Their relevance to the seven societal goals is shown in Table 5. Integrating the programs in Table 4 depends on implementing the DMAC subsystem (section 2.2).



[10] The Integrated Strategic Design Plan for the Coastal Ocean Observations Model of the Global Ocean Observing System" <http://ioc.unesco.org/goos/docs/GOOS_125_COOP_Plan.pdf>

Table 4. Pre-operational and operational programs recommended for the National Backbone of the coastal component of the IOOS listed by core variable and by the responsible federal agency. Two are non-ocean variables (winds and stream flows) that are critical drivers of changes in core variable distributions.

Core Variable	NOAA	Navy	USACE	USGS
Sea surface winds	C-MAN[a], NWLON[b] NDBC[c], PORTS®[d], NERRS[e]	Integrated buoy program		
Stream flow				Stream gauging NSIP[f], NSQAN[g]
Temperature	GOES, POES, NDBC, CoastWatch, C-MAN NWLON, PORTS®, LMR-ES[h], NERRS	Integrated buoy program		
Salinity	LMR-ES, PORTS®, NERRS	Integrated buoy program		
Coastal Sea Level-Topography	NWLON, PORTS®	ADFC[i]		NSIP
Waves	NDBC	Integrated buoy program	Coastal Field Data Collection Program	
Currents	NDBC, PORTS®, National Current Observation Program			
Dissolved Inorganic Nutrients	LMR-ES Habitat assessment, NERRS			
Chlorophyll	LMR-ES, NERRS			
Habitat & Bathymetry	Hydrographic Survey Coral reef mapping Coral reef monitoring Coastal mapping Topographic change mapping Benthic habitat mapping Habitat assessment Coastal change assessment mapping		Hydrographic Surveying	Coral reef mapping & monitoring Coastal change mapping Benthic habitat mapping
Plankton Abundance	LMR Surveys Ecosystem Surveys			
Abundance & distribution of LMRs & protected species	LMR Surveys Ecosystem Surveys Protected Resources Surveys National observer			
Population Statistics[j]	LMR-ES National observer			
Fish Catch	National observer Recreational fisheries Commercial statistics			

[a] Coastal-Marine Automated Network,
[b] National Water Level Observation Network,
[c] National Data Buoy Center (moored meteorological sensors),
[d] Physical Oceanographic Real-Time System,
[e] National Estuarine Research Reserve System,
[f] National Streamflow Information Program,
[g] National Stream Quality Accounting Network,
[h] Living Marine Resources-Ecosystems Survey,
[i] Altimeter Data Fusions Center,
[j] Population statistics = sex, weight, length, and stomach contents of fish species.

Table 5: Programs recommended for integration into the initial IOOS National Backbone (from Table 4) and the societal goals they contribute to. See Table 4 for definitions of acronyms.

Programs	Goals						
	Weather Climate	Maritime Operations	Natural Hazards	Homeland Security	Public Health	Ecosystem Health	Living Resources
C-MAN	X	X	X	X	X	X	X
NWLON	X	X	X	X		X	X
NDBC	X	X	X	X	X	X	X
PORTS	X	X	X	X	X	X	X
Integrated Buoy							
Program	X	X	X	X			
NSIP			X		X	X	X
NSQAN			X		X	X	X
GSN			X	X	X	X	X
CFDCP	X	X	X	X	X	X	X
National Current Observing Program	X	X	X	X	X	X	X
Hydrographic Surveying	X	X	X	X	X	X	X
Coastal Mapping, Shoreline change		X	X		X	X	X
Benthic Habitat Mapping & Monitoring		X	X		X	X	X
Coastal Change Assessment Mapping		X	X	X	X	X	X
Coastwatch	X	X	X	X	X	X	X
GOES	X	X	X	X			
POES	X	X	X	X	X	X	X
ADFC	X	X	X	X	X	X	X
NERRS					X	X	X
LMER-ES					X	X	X
Protected Resource Surveys						X	X
National Observer Program						X	X
Recreational Fisheries						X	X
Commercial Statistics						X	X

2.1.4 Ship, Aircraft and Satellite Requirements for IOOS

Success of IOOS depends upon ongoing assessments of ship, satellite, and aircraft requirements. Government (state and federal) and privately owned assets all have roles to play. Assessments of ship requirements have been made for the global component only. In 2001, the Federal Oceanographic Facilities Committee (FOFC) assessed the capability of the academic research fleet to meet national research requirements.[11] More recently, FOFC conducted a preliminary assessment of the ship requirements of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI)[12] and published a separate information brochure on the federal research aircraft fleet. At present, there is neither an assessment of current assets nor future requirements for the coastal component of IOOS. Although a comprehensive assessment of the mix of observing platforms that will be needed for both IOOS and OOI initiative has yet to be done, it is clear that efforts to modernize the nation's research fleet through replacements and new acquisitions will need to be considered.

Future requirements of a fully implemented IOOS are potentially significant. Therefore, the FOFC is undertaking a comprehensive assessment of the ship and aircraft assets required to support the IOOS and OOI, and it will recommend how these requirements can be met. Areas of particular concern include the availability of sufficient resources required for offshore buoy deployment and maintenance; the availability of ships and other platforms (e.g., autonomous under water vehicles) for hydrographic, benthic habitat, and fish stock surveys; and the availability of aircraft bathymetry-topography surveys across the land-sea interface (e.g., missions such as Light Detection and Ranging [LIDAR] surveys).

As discussed in the recently approved Integrated Global Observing Strategy Coastal Theme Report[13], a similar picture is emerging in terms of satellite capabilities, especially for coastal waters, where satellite observations are currently inadequate in terms of requirements for high temporal, spatial, and spectral resolution. Thus, a team of experts from NASA, NOAA, and Navy has initiated a review of satellite requirements for the IOOS, and these requirements will be addressed in the Second Annual *IOOS Development Plan*.

2.2 Data Management and Communications

The IOOS is an interdisciplinary, national network of observational, DMAC, and data analysis and modeling components that rapidly and systematically acquires and disseminates marine data and data products to be used in describing the past, present, and future states of the marine environment and ecosystems. Scales of interest range from local to global. The large number of existing and emerging monitoring and observing systems operated by federal and state agencies, academia, and the private sector encompass a diversity of disciplines and a broad spectrum of time-space scales. The existing backbone of federal, state, academic, industrial, and other observing system elements reflect the needs of many different data provider and user communities. Internationally, programs such as the Argo program of global, vertically-profiling ocean floats (among others) represent major new global contributions to the global component of IOOS. The IOOS DMAC framework links these existing efforts together with emerging systems in a seamless, interoperable data-sharing network (Figure 2). This integration increases access and use of the observational data resources, expands the kinds of data available, and reduces the overall costs to the nation. This DMAC interoperability foundation is central to the success of IOOS.

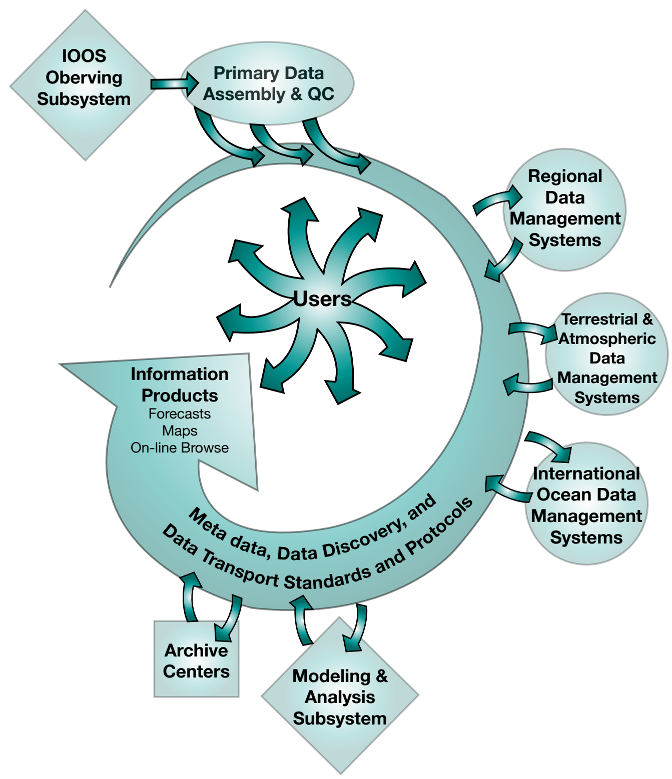


Figure 2. Schematic of the DMAC subsystem of the IOOS. Solid outlines indicate the elements of the IOOS Data Communications framework, which are detailed in the DMAC Implementation Plan.2 The arrows flowing outward from the users indicate the feedback and control mechanisms through which users ultimately direct the functioning of all parts of the system. Note that the National Data Management Systems are included in the concept of Primary Data Assembly and Quality Control.

[11] National Oceanographic Partnership Program (NOPP). 2001. "Charting the Future for the National Academic Research Fleet, A Long-Range Plan for Renewal." 40 pp. <http://www.nopp.org/iDuneDownload.dll?GetFile?AppId=141&FileID=238901&Anchor=&ext=.pdf >

[12] University-National Oceanographic Laboratory System (UNOLS). 2003. "Report of the UNOLS Working Group on Ocean Observatory Facility Needs." 54 pp. <http://www.unols.org/committees/fic/observatory/observrpt.pdf>

[13] Integrated Global Observing Strategy (IGOS) Coastal Theme Report. <http://ioc.unesco.org/igospartners/coastal.htm>

2.2.1 Formulating the Data Management and Communications Plan

In response to recommendations from the Ocean.US 2002 workshop[6], Ocean.US established a national *ad hoc* DMAC Steering Committee (DMAC-SC) to formulate a plan for developing a DMAC subsystem[14] for the IOOS. The May 2004 DMAC Plan, *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems*[2], was published electronically after an extensive external review process by national and international experts. The DMAC Plan is an evolving document containing recommended practices and standards that will be updated, as appropriate, in response to additional comments received during a final, formal 30-day public comment period announced in the *Federal Register*. Recommendations contained in the DMAC Plan relating to data and metadata standards and best management practices will then be adopted as the initial national IOOS standards guidance for data providers, users, and stakeholders.

The DMAC Plan provides the framework for interoperability among existing (and planned) previously independent, distributed, heterogeneous data management programs and activities, creating a virtual subsystem. The plan's recommendations build on existing data management activities and best practices, and lay the foundation to transition from these capabilities to a truly integrated, yet highly distributed, network. The DMAC Plan describes the proposed architecture for the DMAC subsystem; provides a technical overview of interoperable data discovery, access, and archive; and proposes a detailed development timeline with initial estimates of costs projected over a ten-year period. In summary, the DMAC subsystem will support:

(1) ***Metadata***: IOOS-wide descriptions of data sets; more specifically, adoption of a common vocabulary, agreement on minimum metadata content, and commitment to publish metadata through agreed-upon venues;
(2) ***Data Discovery***: the ability to search for and find data sets, products, and data manipulation capabilities of interest;
(3) ***Data Transport***: transparent, interoperable access and delivery of measurements and data products from computer applications across the Internet;
(4) ***Online Browse***: the ability to quickly evaluate the character of the data through common Web browsers; and
(5) ***Data Archive***: secure, long-term data storage.

2.2.2 Data Management and Communications Strategy

At the First Annual IOOS Implementation Conference[1], the Ocean.US Executive Committee (EXCOM) agencies and the emerging RAs endorsed the strategy and recommendations proposed in the DMAC Plan for achieving successful integration and interoperability across the IOOS. The principal elements of this strategy for immediate implementation in FY 05-06 are:

- ***DMAC Steering Team***: Ocean.US has established an IOOS DMAC Steering Team drawn from government, industry, academia, public, and non-profit communities to: a) coordinate and oversee the evolution of DMAC standards; b) identify and provide recommendations regarding gaps in needed standards; and, c) help ensure that the DMAC standards process is conducted in an open, objective, and balanced manner.

- ***DMAC Expert Teams and Working Groups***: Ocean.US will organize expert teams and working groups to address key information technology (IT) standards areas as identified in the DMAC Plan. Experts from the emerging GEOSS and relevant international data management standards activities will be invited to participate.

- ***Interagency Coordination***: The EXCOM agencies have agreed to establish a government-only IOOS DMAC Implementation Oversight Working Group (IOWG). Consistent with the governance guidelines outlined in Part I, the IOWG will coordinate DMAC implementation within the federal agencies. Specifically, the IOWG will provide oversight of federal implementation of relevant IOOS DMAC standards and best practices recommended by the Steering and Expert Teams; recommend to the agencies actions relating to inter-agency adoption and/or development of common standards, protocols, and shared communications software; and serve as an information resource in DMAC planning efforts.

To aid in the implementation of these processes, it is recommended that the National Federation of Regional Associations (NFRA) establish a DMAC subcommittee to oversee and facilitate coordination, communications, and data and technology exchange at the regional level. This NFRA subcommittee will also serve as a major contact point facilitating national and regional DMAC coordination, similar to the relationship between the NFRA and IOOS.

[14] The term "subsystem" is used to represent those elements of IOOS that comprise common functional components - in this case, data management and communications. This use is consistent with the approach used internationally within the UNESCO-IOC, World Meteorological Organization (WMO), and International Council for Science (ICSU)-sponsored GOOS. The DMAC subsystem will include a data and communications infrastructure that consists of standards, protocols, facilities, software, and supporting hardware systems. The DMAC subsystem links the other two IOOS subsystems, the observing and the data analysis and modeling subsystems.

The above strategy ensures that the development and implementation of the DMAC subsystem is coordinated closely with, and leverages upon, related activities in the federal agencies and other national, regional, and international Earth observing systems (e.g., GEOSS, Joint Technical Commission for Oceanography and Marine Meteorology [JCOMM], and Ocean Research Interactive Observatory Networks [ORION]). The DMAC subsystem will be planned, developed, maintained, and enhanced in a systematic, coordinated, cost-effective, interoperable manner, with support from professional systems engineering services. IOOS stakeholders will be urged to participate in the DMAC planning and assessment activities to ensure that current and future community needs and priorities are addressed.

2.2.3 Data Management and Communications Priorities for Implementation

A two-phased approach is recommended for implementing the approved DMAC recommendations. Implementation of the critical, near-term priorities during Phase 1 (FY 05-06) will establish a minimally functioning initial infrastructure of data management standards, protocols, and operating practices. This infrastructure will enable the initial integration framework among existing and emerging observing systems. Phase 2 (FY 07 and beyond) addresses the development of a comprehensive DMAC subsystem that meets the needs of the full range of IOOS partners. Many of the activities started during Phase 1 will be continued into Phase II. Phase 1 is described below, and Phase 2 is described in Part III.

Federal agencies already have an infrastructure of observing systems and associated data management infrastructures in place and are beginning to implement components of the initial IOOS as the National Backbone. Nascent RAs are rapidly organizing and beginning to develop regional coastal ocean observing systems (RCOOSs) as part of the IOOS. There is an immediate need to agree upon common standards, protocols, and software tools that will guide the coordinated establishment of an integrated, interoperable whole. Some of these standards will be drawn from present "best practices" now employed by the federal agencies, industry, state agencies, RCOOSs, academia, and elsewhere. Where gaps exist between standards needs and available best practices, standards development efforts will be required. When development is called for, these efforts will draw upon both existing programs and new initiatives.

Box 5: Regional DMAC Development

In the context of DMAC development as a whole, funding to coordinate regional DMAC development with the national DMAC strategy is a high priority for FY 05 and 06. The national strategy articulated here addresses interoperability and integration of the National Backbone, primarily among the federal agencies and other stakeholders. This effort focuses on the identification and adoption of national standards and practices, the augmentation of existing infrastructure to enable use of those standards, and the development of standards where gaps exist. The regional strategy addresses capacity building and implementation of these national standards and practices within the regions. Both efforts are needed and are unanimously supported by the participants from the regions. Investments in ensuring that the national DMAC efforts succeed are needed before regional DMAC efforts can be properly structured.

Federal agencies have begun to support some of the required IOOS DMAC activities through existing programs (e.g., quality assurance/quality control of marine buoy data), and several promising new initiatives are planned (e.g., dealing with archival of observational data, improving access to satellite data, among others).[15] Table 6 presents a summary of several existing standards and protocol-related activities identified in the DMAC Plan. However, this preliminary compilation of standards and conventions is insufficient to establish the minimal level of functionality required by the initial IOOS.

[15] For example, NOAA's Comprehensive Large Array-data Stewardship System (CLASS), now being implemented to handle satellite data archival series. <http://www.saa.noaa.gov/nsaa/products/welcome;jsessionid=C579A6EEDC7BCE657F489EFA9C762AD0>

Table 6. Candidate standards and protocols-related activities identified in the DMAC Plan

DMAC Component	Existing Element	Sponsoring Agency	URL
Metadata	FGDC[a] and GOS[b]	USGS	http://www.fgdc.gov/metadata/metadata.html http://www.geo-one-stop.gov/index.html
Data Discovery	GCMD[c] NCDDC[d] CSC[e]	NASA NOAA	http://gcmd.gsfc.nasa.gov/ http://www.ncddc.noaa.gov http://www.csc.noaa.gov
Data Transport	OPeNDAP[f] Enterprise GIS	Navy, NASA, NOAA, NSF NOAA, Navy, USGS, EPA	http://www.unidata.ucar.edu/packages/dods/ http://www.opengeospatial.org/
On-Line Browse	LAS[g] Enterprise GIS	Navy, NOAA, NASA NOAA, Navy, USGS, EPA	http://www.feret.noaa.gov/LAS/ http://www.opengeospatial.org/
Data Archive	NSF[h]	NOAA, DOE	http://www.nsf.gov/pubsys/ods/getpub.cfm?ods_key=nsf94126
Data Communications	GTS[i]	WMO and NOAA	http://www.wmo.ch/web/www/TEM/gts.html

[a] Federal Geographic Data Committee: The FGDC steering committee is composed of representatives from nineteen Cabinet level and independent federal agencies including: Department of Commerce, Department of the Interior, Department of Defense, NSF, NASA, EPA, Department of Transportation, Department of Energy (DOE), Department of Agriculture. Funding for FGDC is appropriated through Department of the Interior/USGS.
[b] The Geospatial One-Stop (GOS) is an intergovernmental project managed by the Department of the Interior in support of the President's initiative for E-government. GOS was developed to streamline access to geospatial information for users. Both GOS and FGDC support the National Spatial Data Infrastructure (NSDI) and the E-Government initiative. NSDI focuses on the technologies, policies, and people necessary to promote sharing of geospatial data. E-Government emphasizes the use of Internet based technology to simplify interactions with the Government.
[c] NASA Global Change Master Directory
[d] NOAA National Coastal Data Development Center
[e] NOAA Coastal Services Center
[f] Open Source Project for a Network Data Access Protocol
[g] Live Access Server
[h] The NSF policy statement is under revision.
[i] The Global Telecommunications System (GTS) is the worldwide terrestrial satellite telecommunications network that serves data to WMO member nations for forecast operations under the international World Weather Watch.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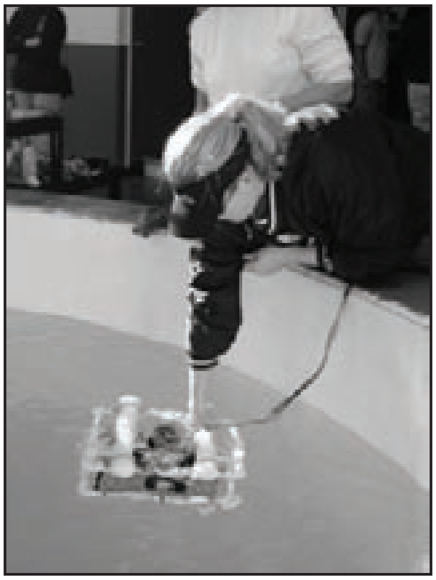
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Recommended key activities for implementation in FY 05-06, ranked in terms of priority, include the following: form community-based working groups (or expert teams) and/or conduct applied research and development activities to establish metadata and data model standards, build missing data transport components, establish community partnerships, adopt standards and protocols through the community-based process recommended in the DMAC Plan, initiate pilot projects for testing and implementation of IOOS standards, and build capacity to seamlessly link existing IOOS components across organizations and regions (Table 7). Engaging systems engineering experts to initiate well-organized documentation, centralized system coordination, and system-related life-cycle planning is also highly recommended.

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Table 7. Key activities recommended for implementation in FY 2005-2006. Recommended priority levels are given in the left column (1 – highest priority, 2 – lower priority). The multiple IOOS/DMAC functions indicated as priority 2 must be developed in a balanced way.

Priority	DMAC Function	Outcome	Activity
1	Program Management Activities	Effective system planning and coordination	• Engage services of software engineer to prepare documents • Appoint DMAC Standing Committee • Establish DMAC implementation strategy and oversight function
2	Metadata/Data Discovery[a]	Interim metadata standards Initial catalog services	• Convene/participate in community-based metadata working group • Create and publish FGDC compliant metadata • Submit metadata to GCMD, and/or CSC, and/or NCDDC
		Initial data discovery services	• Convene community-based data discovery working group • Testbed to develop distributed search capability
		Applied Research & Development (enhancement) activity	• Bi-directional linkages between data discovery, data transport, on-line browse
2	Data Archive and Access	Framework for cooperation among Archive Centers	• Convene a community-based working group of archive center representatives to identify IOOS partner organizations that will provide archive services. • Framework to inventory & assess state of marine data archives • Ensure all irreplaceable data in future/current/historical holdings have permanent archives
		IOOS Archive Centers demonstrate capability to provide DMAC data discovery and transport services	• National Oceanographic Data Center pilot projects using DMAC standards for near realtime (NRT) and real-time (RT) data sets • Pilot projects to modernize access to data sets delivered in real time.
2	Data Transport	Semantic data model	• Convene community-based expert working group
		Infrastructure development for common standards with spatial data (GIS) and biological data	• Convene community-based working group with key expertise in Open GIS Consortium and the Ocean Biogeographic Information System (OBIS)
		Initial data access/transport services	• Install servers to provide data access using OPeNDAP • Establish consistent OPeNDAP documentation and need extensions (e.g., non-gridded and time series data) • Develop resources to help train data managers • Install Live Access Server

[a] NSF and the Office of Naval Research (ONR) are supporting initial work in this area in FY 05.

3. Research

Projects currently funded or slated for funding via the National Oceanographic Partnership Program (NOPP) process (Tables 8 and 9) and by individual federal agencies (Table 10) address many of these priorities and are laying the foundation for developing and improving the IOOS. Recommended research priorities that will enhance IOOS capabilities are addressed in Part III.

Table 8. IOOS-related NOPP research projects (as of 2003) most relevant to the development of the global ocean component. Although the development of sensor technologies is not specific to global or coastal components, it is included here, in part because much of the work has been done in the open ocean, where biofouling problems are less severe.

NOPP Project	Academic Partners[b]	Private Sector Partners	Government Partners[c]
Argo: An Integrated System for Real-Time CTD[a] Profiling Float Data on Basin Scales	SIO, UW, WHOI, LDEO	Seascan, Inc Webb Research Corp.	NOAA-AOML, PMEL
Establishing a NOAA Operational Data Center for Surface Currents Derived from Satellite Altimeters and Scatterometers; Pilot Study for the Tropical Pacific Including the Hawaiian and U.S. Territorial Islands	FSU, USF	Earth and Space Research	NOAA-NESDIS, NMFS, NWS, NCEP NRL
Scatterometer-derived Operational Winds, Surface Pressures, and Rain	FSU, CSU, HU	SeaScape Corporation Microwave Remote Sensing Consultants	NASA - Wallops Flight Facility NOAA-NESDIS Navy – Fleet Numerical Met OCN CTR NRL, NAVOCEANO
Operational Utilization of High Resolution Ocean Surface Wind Vectors (25km or better) in Marine Forecasting Environment	BYU	OCENS	NOAA-NESDIS, NWS, NCEP NRL
Prototype Operational System – Inverse Synthetic Aperture Radar (ISAR) - Temperature Instrumentation for the Volunteer Observing Ships (VOS) fleet	RSMAS, SIO	Remote Sensing Systems Royal Caribbean International International SeaKeepers Society Brittany Ferries, UK Wallenius Lines, Sweden	BNL, NOAANESDIS NAVOCEANO USCG UK Met Office
Design Study for NEPTUNE: Fiber Optic Telescope to Inner Space	UW, WHOI		NASA-JPL NOAA-PMEL
Ocean Acoustic Observatory Federation	SIO, UW		NPS NOAA-PMEL

Incorporation of Sensors into Autonomous Gliders for 4-D Measurements of Bio-optical and Chemical Parameters	UM, UW, OSU	WET Labs, Inc. Sea-Bird Electronics, Inc.	King County Department of Natural Resources Washington Department of Ecology
Long-Term Surface Salinity	WHOI	Epaint, Inc. Clearwater Instrumentation, Inc.	
Observational Technique Development- Float Technology Development	UW	Sea-Bird Electronics, Inc. Webb Research Corporation	
Accelerating Electronic Tag Development for Tracking Free-Ranging Marine Animals at Sea	HMS, UCSC, OSU, USA	Wildtrack Telemetry Systems Wildlife Computers Lotek Monterey Bay Aquarium Research Institute (MBARI)	NOAA-NMFS
Developing Gene-Based Remote Detection	UofM		NOAA-AOML
Multi-disciplinary Ocean Sensors for Environmental Analyses and Networks	UCSB, BBSR, UH, USF	MBARI WETLabs	NOAA-AOML NOAA-PMEL
Renewal for Incorporation of Sensors into Autonomous Gliders for 4-D Measurement of Bio-optical and Chemical Parameter	UW, UM, OSU	WET Labs, Inc. Sea-Bird Electronics, Inc.	King County DNR Washington Dept. of Ecology
The Environmental Sample Processor (ESP): A Device for Detecting Microorganisms In Situ Using Molecular Probe Technology		MBARI	NOAA/NOS

[a] Conductivity-Temperature-Depth

[b] **BBSR**: Bermuda Biological Station for Research, **BYU**: Brigham Young University, **CSU**: Colorado State University, **FSU**: Florida State University, **HMS**: Hopkins Marine Station Stanford University, **HU**: Hofstra University, **LDEO**: Lamont-Doherty Earth Observatory, **MBARI**: Monterey Bay Aquarium Research Institute, **NRL**: Naval Research Laboratory, **OSU**: Oregon State University, **RSMAS**: Rosenstiel School of Marine and Atmospheric Science, **SIO**: Scripps Institution of Oceanography, **UCSB**: University of California Santa Barbara, **UCSC**: University of California Santa Cruz, **UH**: University of Hawaii, **UofM**: University of Miami, **USA**: University of St. Andrews, **USC**: University of Southern California, **USF**: University of South Florida, **USM**: University of Southern Mississippi, **UW**: University of Washington, **WHOI**: Woods Hole Oceanographic Institute

[c] **AOML**: Atlantic Oceanographic and Meteorological Laboratory; **BNL**: Brookhaven National Laboratory; **JPL**: Jet Propulsion Laboratory; **NAVOCEANO**: Naval Oceanographic Office; **NCEP**: National Centers for Environmental Prediction; **NESDIS**: National Environmental Satellite, Data, and Information Service; **NMFS**: National Marine Fisheries Service; **NOS**: National Ocean Service; **NRL**: Naval Research Laboratory; **NWS**: National Weather Service; **PMEL**: Pacific Marine Environmental Laboratory; **USCG**: U.S. Coast Guard

Table 9. IOOS-related NOPP research projects (as of 2003) relevant to the development of the coastal component. Although projects for the Ocean Biogeographic Information System (OBIS) are not exclusively coastal, most activity occurs in the coastal realm and, as such, is listed as a coastal project.

NOPP Pilot Projects	Academic[a]	Private Sector[b]	Government[c]
Sea Net: Extending the Internet to the Oceanographic Research Fleet	CU, LDEO, WHOI	Omnet, Inc., JOI	U.S. Naval Postgraduate School
Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean	UD, OSU, SIO, WHOI, NCSU, UMi		NPS NRL
Modeling and Data Assimilation for the Study of Puget Sound, WA	UW		King County Department of Natural Resources Washington State Department of Ecology
Models of the Coastal Ocean off the West Coast of North America: A Comparative Study and Synthesis of Observations	UCB, UCLA, OSU, RU, SUNJ, SIO		JPL NRL NOAA-Pacific Fisheries Environmental Group NOAA-PMEL
Planning for a Coupled Physical-Biological Modeling Node: A 'Phase A' National Node	URI, OSU, UofM, VIMS, MIT, RU, SUNJ, ODU, WHOI		NRL NOAA NASA
A Biotic Database of indo-Pacific Marine Mollusks		California Academy of Sciences	Australian Museum Museum National d'Histoire Naturelle, France Academy of Natural Sciences
Application of an Integrated Monitoring and Modeling System to Narragansett Bay and Adjacent Waters Incorporating Internet-Based Technology	DU, URI, BU	Applied Science Associates	Rhode Island Department of Environmental Management Rhode Island Transportation Center NOAA-NOS
Biogeoinformatics of Hexacorallia (Corals, Sea Anemones, and their Allies): Interfacing Geospatial, Taxonomic, and Environmental Data for a Group of Marine Invertebrates	UK, NU, UoW	Bits and Parity Land-Ocean Interaction in the Coastal Zone (LOICZ) (IGBP) International Center for Living and Aquatic Resource Management (ICLARM)	Shirshov Institute of Oceanology Australian Institute of Marine Science NOAA, Biogeography Program Natural History Museum, Smithsonian Institution
Census of Marine Fishes (CMF): Definitive List of Species and Online Biodiversity Database		FishBase, ICLARM Integrated Taxonomic Information System Department of Ichthyology, California Academy of Sciences	
Development of a Dynamic Biogeographic Information: A Pilot Application for the Gulf of Maine	USC	System Science Applications	BIO, Department of Fisheries and Oceans (Canada) Atlantic Reference Center, Huntsman Marine Science Center (Canada)

Development of an Integrated Regional, National and International Data System for Oceanography	URI, OSU, UWi, UCAR, MIT, TAMU, UMd	SAIC, ESRI,	USGS(Coastal and Marine Programs) NASA-JPL-Goddard Space Flight Center NRL NOAA-Coastal Services Center National Geophysical Data Center - GIS NOAA-PMEL State of Maine Department of Marine Resources Meteo-France Bureau of Meteorology Research Centre MMS
Diel, Seasonal, and Interannual Patterns in Zooplankton and Micronekton Species Composition in the Subtropical Atlantics	VIMS, WHOI, Russian Academy of Sciences, BBSR		Museum of Natural History, Smithsonian Institution
Expansion of Cephbase as a Biological Prototype for OBIS	UT, Dal		Smithsonian Institution
Limited Area Coastal Ocean Models: Assimilation of Observations from Fixed Platforms on the Continental Shelf and Far-Field Forcing from Open Ocean Models	DC, UNC, WHOI, Skidaway	North Carolina Supercomputing Center	NOAA-NWS
Modeling the Central California Coastal Upwelling System: Physics, Ecosystems and Resource Management	UCLA, UCSC, UM, Duke	HOBI Labs MBARI	NOAA Monterey Bay National Marine Sanctuary NASA-JPL NRL Naval Postgraduate School
The Fishnet Distributed Biodiversity Information System	UK, Cornell, USM, Harvard, SIO, UT, Tulane, UA, UMi	American Museum of Natural History Bernice P. Bishop Museum Canadian Museum of Nature Field Museum of Natural History, Chicago Natural History Museum of Los Angeles County Florida Museum of Natural History Philadelphia Academy of Sciences Royal Ontario Museum	Australian Museum Museum National d'Histoire Naturelle Swedish MNH Smithsonian Institution
ZooGen, a DNA Sequence Database for Calanoid Copepods and Euphausiids: An OBIS tool for Uniform Standards of Species Identification	UNH, UW, WHOI		NOAA-NMFS-NEFSC National Institute of Water & Atmospheric Research, Ltd., Wellington, New Zealand Australian Institute of Marine Science

Planning for a National Community Sediment Transport Model	WHOI, VIMS, Rutgers	HydroQual, Inc TetraTech, Inc.	USGS NOAA
			Rutgers University NATO SACLANT
Digital Archive of Marine Mammal-Bird-Turtle-Data for OBIS	Duke, UCSD, UW, Sir Alistair Hardy, SIO, Cat, SAU	Cascadia Research Collective Clymene Enterprises E.S.R.I. Systems Science Applications	British Antarctic Survey NOAA-NMFS-Southeast Fisheries Science Center

[a] **BNL**: Brookhaven National Laboratory, **BU**: Brown University, **CU**: Columbia University, **Dal**: Dalhousie University, **DC**: Dartmouth College, **DU**: Drexel University, **ESRI**: Environmental Systems Research Institute, Inc, **JOI**: Joint Oceanographic Institutions, **MIT**: Massachusetts Institute of Technology, **NCSU**: North Carolina State University, **NU**: Nova University, **ODU**: Old Dominion University, **RU**: Rutgers University, **SAIC**: Science Application International Corporation, **SUNJ**: State University of New Jersey, **TAMU**: Texas A&M University, **UA**: University of Alabama, **UCAR**: University Corporation for Atmospheric Research, **UCB**: University of California Berkeley, **UCLA**: University of California Los Angeles, **UD**: University of Delaware, **UK**: University of Kansas, **UM**: University of Maine, **UMd**: University of Maryland, **UMi**: University of Michigan, **UoW**: University of Wales, **URI**: University of Rhode Island, **UT**: University of Texas, **UWi**: University of Wisconsin, **VIMS**: Virginia Institute of Marine Science.

[b] **ESRI**: Environmental Systems Research Institute; **HOBI**: Hydro-Optics, Biology and Instrumentation Laboratories; **JOI**: Joint Oceanographic Institutions; **SAIC**: State Administration for Industry and Commerce

[c] **NEFSC**: Northeast Fisheries Science Center

Table 10. IOOS-related research projects funded by individual federal agencies listed by focus areas. For the purposes of implementing the initial IOOS, research activities are limited to those that are clearly related to research and development needed to improve the operational IOOS.

NSF	NASA	Navy	NOAA	USACE	USGS	MMS
Hawaii Ocean Time Series Bermuda Time Series Ocean Instrumentation Bermuda Testbed Mooring Regional Observatories Relocatable Buoys Monterey Accelerated Research System	Seastar Science[a] Ocean Surface Topography[b] MODIS Ocean Science[c] RADARSAT[d] Physical Ocean Modeling[e] Ocean Biogeochemistry[e] Global Ocean Research[e]	UUV development[f] Near shore & coastal processes Remote Sensing Applications Surface Current Mapping Ocean Instrumentation Acoustic Sensing of Fish Migrations Ocean Modeling	Marine Boundary FOCI[g] Fish LIDAR	Nearshore Processes[h]	Coastal Modeling	Surface Current Mapping[i]

[a] This research program relies on satellite missions for sustained remote sensing of ocean color (SeaWiFS).

[b] This research program relies on satellite missions for sustained remote sensing of sea surface height and waves (TOPEX/Poseiden, Jason-1, Ocean Surface Topography Mission [OSTM]).

[c] This research program relies on satellite missions for sustained remote sensing of ocean color and sea surface temperature (SeaWiFS and MODIS).

[d] This research program relies on satellite missions for sustained ocean imaging using synthetic aperture radar.

[e] These research programs rely on satellite missions for sustained remote sensing of sea surface temperature and ocean color (SeaWiFS, MODIS), sea surface height and waves (TOPEX/Poseiden, Jason-1, OSTM), winds (QuikSCAT), and salinity (Aquarius).

[f] Unmanned Undersea Vehicle

[g] Fisheries Oceanography Coordinated Investigation (Pacific Northwest and Gulf of Alaska)

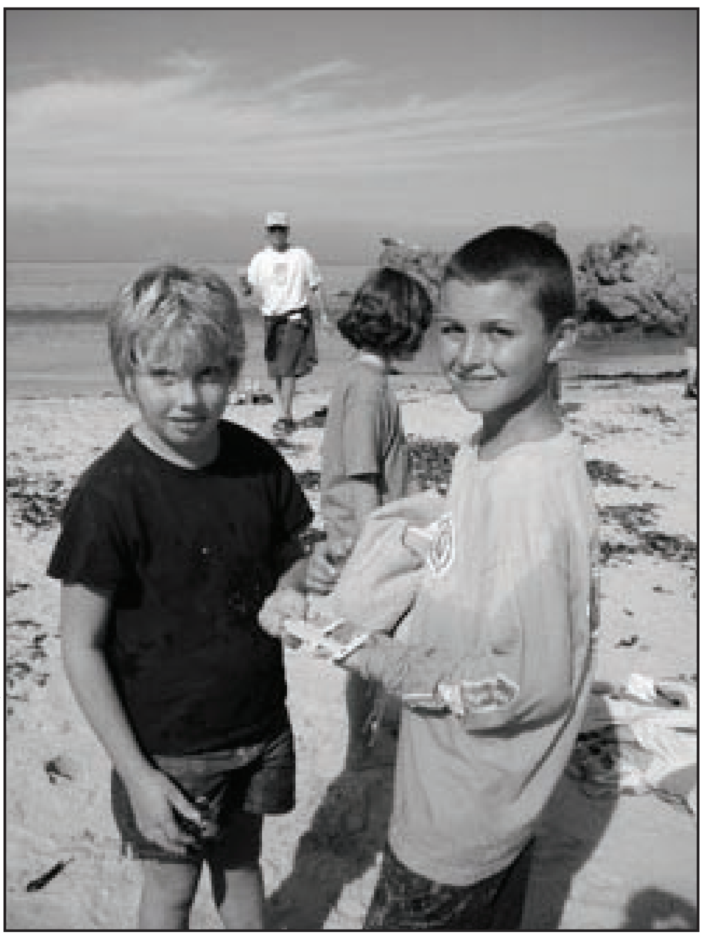
[h] USACE has several research programs to measure, model, and predict nearshore processes.

[i] MMS has been involved in surface current mapping in the past in their Alaska and Pacific Regions. Funds are available this FY and possibly in FY 05 for an effort in Alaska.

4. Education

The IOOS education initiative aims to establish an education network that will enable (1) improvements in lifelong science and technology education through the use of IOOS data, information, and applications, and (2) creation of the science, technology, and operations workforce that will be needed to develop and sustain the IOOS and allied enduser industries over time. These objectives are consistent with the NOPP Strategic Plan and with recommendations of the U.S. Commission on Ocean Policy, both of which emphasize the importance of science and technology education and the participation of science and technology organizations in those efforts.

Those activities that will benefit most from the IOOS include classroom learning (i.e., primary, secondary, post-secondary and continuing education), informal learning at indoor and outdoor sites (e.g., aquaria, seaports, sanctuaries, and parks), informal learning using multiple media (e.g., the internet, radio, and television), and youth groups such as scouts. Many ocean science education activities funded by federal agencies serve as a rich source for initial IOOS education efforts (Table 11).

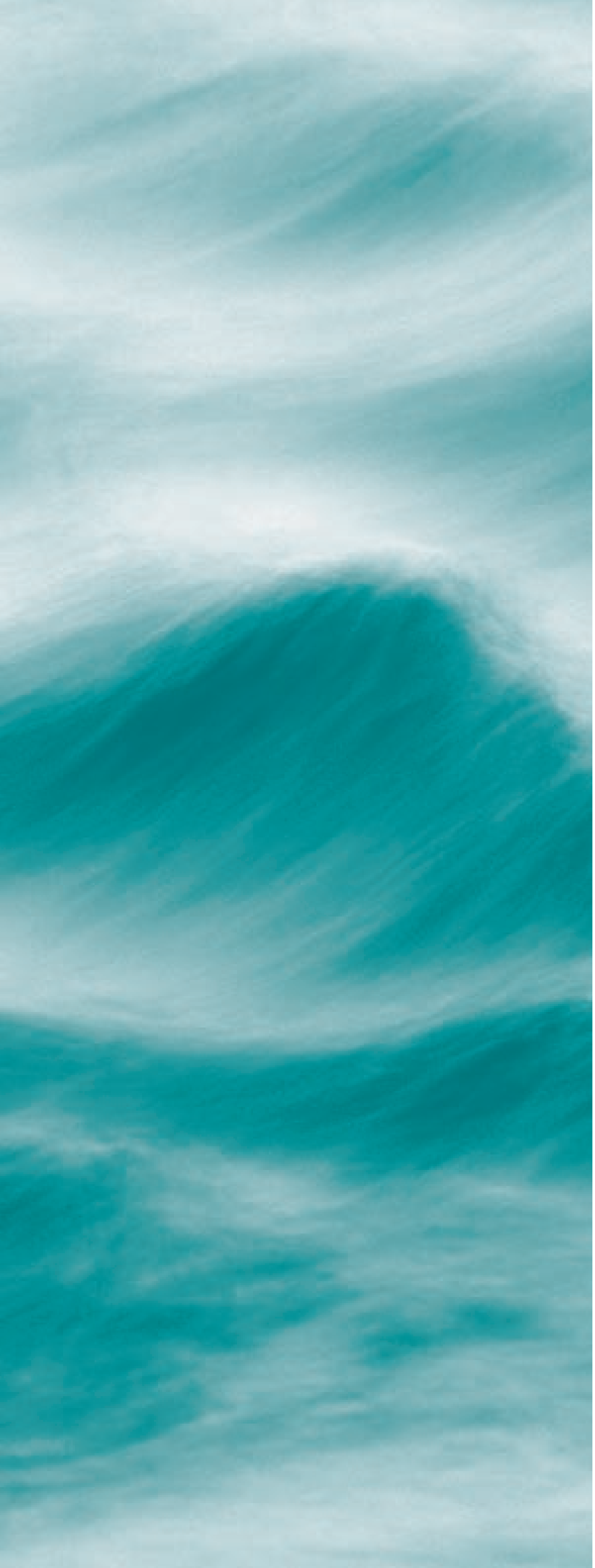


In March 2004, ocean educators signed a resolution to "collaborate with Ocean.US to initiate a national education network integral to IOOS" (Appendix G). Signatories represent a broad cross-section of the ocean education and observing system community, including developers of the IOOS, formal and informal educators, professional societies, and ocean and Earth science education programs. The workshop launched an effort to network these programs for more effective information exchange and to make more effective use of data and information on the oceans and ocean technologies for education and training. Four working groups were formed to address specific high priority needs and to provide recommendations for IOOS education: (1) develop and shape work force recommendations, (2) formulate key messages and themes for IOOS education, (3) build capacity to use satellite remote sensing in IOOS education, and (4) specify website best practices and establish guidelines for evaluating performance.

Table 11. There are many education networks, projects and programs (as of 2003) that are relevant to the development of education activities that utilize IOOS data and information. These examples of sustained education networks and those projects that have left a legacy, are prime candidates to contribute to the initial IOOS education efforts.

Programmatic Area	Agency	Program
Networks of watershed, coastal, ocean, and Earth system educators	NSF	Centers for Ocean Science Education Excellence (COSEE)
	NOAA	Sea Grant Education/Communications
	NOAA	Sea Grant Extension
	NOAA	National Marine Sanctuaries (NMS) Education
	NOAA	National Estuarine Research Reserve System Education (NERR)
	NOAA	National Estuarine Research Reserves (NERR) Capacity Building
	NOAA/Navy	American Meteorological Society (AMS) DataStreme Ocean and Project Maury
	NOAA	American Meteorological Society (AMS) Project Atmospheres and Water in the Earth System projects
	NOAA	Teacher at Sea Alumni
	NOPP	JASON IX: Descending the Ocean Ladder - Expanding Student and Teacher Access to Ocean Science Research
	NASA	Earth System Science Education in the 21st Century (ESSE-21)
	NASA	Earth Explorers Network
	NASA	Minority University Space Interdisciplinary Network (MUSPIN)
	NASA/NSF	Global Learning and Observations to Benefit the Environment (GLOBE)
	NOPP	National Ocean Science Bowl
Individual legacy watershed, coastal, ocean, and Earth education efforts	NOPP	Enhancing K-12 Science Education Via Satellite-Televised Interactive Technologies
	EPA	Watershed Academy
	NOAA	Office of Exploration-Ocean Exploration
	NASA	SeaWiFS, SeaWinds, Topex/Posiden/Jason-1, Aquarius education and public engagement efforts
	NOPP[a]	*The Bridge,* a marine education on-line clearinghouse
	NOAA[b]	Oceans for Life (Geography scope and sequence)
	NOPP	Bringing the Ocean into the Precollege Classroom Through Field Investigations at a National Underwater Laboratory (morphed into a COSEE)
	NOPP	COAST: Consortium for Oceanographic Activities for Students and Teachers (morphed into a COSEE)

[a] Joint with the National Marine Educators Association
[b] Joint with the National Geographic Society



Part III
IMPROVING THE IOOS THROUGH ENHANCEMENTS AND RESEARCH

1. Introduction

The initial Integrated Ocean Observing System (IOOS) described in Part II is the first step of many in the phased development of an integrated system that fully addresses the seven societal goals. Part III presents recommended enhancements and research initiatives to improve IOOS capabilities over the next ten years. These recommendations will be periodically revised and updated in IOOS planning documents as described in Part I.

1.1 Advances in the Ocean Sciences and IOOS Development

Development of the observing system that provides timely nowcasts and forecasts of the weather was, and is, based on sound meteorological and physical oceanographic science. At the same time, the sciences of meteorology and physical oceanography have been, and are, enabled by operational data and information served by the National Weather Service. A similar synergy is emerging between the ocean sciences and operational oceanography due in part to a common need for long-term, time series measurements of biological, chemical, geological, and physical variables over a broad spectrum of time scales. Thus, Part III not only focuses on enhancements using current operational capabilities, but also on priority research areas and pilot projects that will improve operational capabilities of the IOOS for addressing the seven societal goals.

In this context, it must be emphasized that the IOOS, from mission-driven research to operational capabilities, does not encompass all of the ocean sciences. While benefiting from IOOS development, much, if not most, of the ocean sciences will continue to be funded to advance our understanding of the oceans and their role in the Earth's climate system.

1.2 Targeted Areas for Enhancing the IOOS

Participants in the Ocean.US 2002 workshop[1] and the First Annual IOOS Implementation Conference[2] identified the following six areas as priorities for enhancement:

(1) Regional coastal ocean observing systems (RCOOSs, section 2);
(2) Observing subsystem of the global ocean component (section 3.1);

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[1] "Building Consensus: Toward an Integrated and Sustained Ocean Observing System" <http://www.ocean.us/documents/docs/Core_lores.pdf>

[2] "Proceedings of the First Annual Implementation Conference for the Integrated Ocean Observing System" <http://ocean.us/documents/docs/AnnualIOOSImpConf-PROCEEDINGS-5Oct04.doc>

(3) Observing subsystem for the National Backbone (section 3.2);
(4) Coordinated development of the global and coastal components (section 3.3);
(5) Data telemetry (section 3.4);
(6) Data management and communications (DMAC) for the IOOS as a whole (section 4); and
(7) Modeling for the IOOS as a whole (section 5).

Together, these six areas are those targeted for enhancing the initial IOOS as outlined in Part II. Development of operational capabilities in these areas involves enhancements through four tracks:

(1) Increasing the time-space resolution of current operational measurement programs;
(2) Incorporating additional operational sensors on existing platforms;
(3) Incorporating additional measurement programs that are currently operational (which may achieve 1 or 2 above); and
(4) Investing in research and pilot projects that will increase the IOOS operational capabilities in the future.

Part III begins with the establishment of RCOOSs (section 2) and recommendations for improving operational capabilities of the observing subsystems of the global component and the National Backbone (section 3) as recommended by federal agencies and participants in the Ocean.US 2002 workshop[1] and the First Annual IOOS Implementation Conference.[2] Recommendations for DMAC and modeling are given in sections 4 and 5, respectively. Part III concludes with sections on research priorities (section 6.1), pilot projects (section 6.2), and education (section 7).

2. Developing Regional Coastal Ocean Observing Systems

Regional groups are in the early stages of forming Regional Associations (RAs). As these groups meet the requirements for being certified as RAs and determine priorities for developing their respective RCOOSs, they will enhance the National Backbone to meet regional priorities and they will contribute to building the Backbone itself. Consequently, distinctions between the National Backbone, regional contributions to the backbone, and enhancements to the backbone through regional development are evolving and are not defined in detail here. Nevertheless, as summarized in Table 1 and articulated at the First Annual IOOS Implementation Conference[2], there is an emerging consensus among nascent RAs on priorities for enhancing the National Backbone. The high priority given to the development of "integrative models" reflects, in part, the importance placed by the regions on developing operational capabilities for ecosystem-based managements (Box 1). These priorities are reflected in the recommendations for enhancements to the initial National Backbone (section 3.2).

Table 1. Summary of regional priorities for the operational, National Backbone of the coastal component. Requirements for long range (LR), high HF radar, coastal remote sensing, and elements of bathymetric (Bathy) – topographic (Topo) surveys of the near shore coastal zone are addressed in Section 6.2. These capabilities are high priorities of the regions for incorporation into the operational backbone as they meet operational criteria over the next five years.

Region	Data Buoys	NWLON	C-MAN	LR, HF Radar	NASQAN	Bathy-Topo, Shoreline position	Integrative Models	Remote Sensing
Arctic[a]	X[b]		X		X	X	**X**	**X**
Gulf of Alaska[d,e]	X[c]		X	X	X		**X**	**X**
Pacific NW[f]	X[c]			X		X	**X**	**X**
Central and Northern CA[g]	X[h]	X	X	X			**X**	**X**
Southern CA[i]	X			X		X	**X**	
Gulf of Mexico[j]	X	X	X	X	X		**X**	
SE – West FL								
Mid Atlantic[f,k]	X			X				**X**
Gulf of Maine[l]	X	X		X	X		**X**	
Great Lakes[m]	X[c]	X[c]	X[c]	X	X	X	**X**	**X**
Hawaii								
Caribbean								
TOTAL	**9**	**4**	**3**	**6**	**4**	**4**	**6**	**4**

[a] Additional priorities: RADARSAT ice cover, remote sensing-ground truth, Navy submarine access
[b] Ice capable with solar radiation sensors
[c] Enhance with sensors for biological and chemical variables
[d] Includes the Bering Sea
[e] Additional priorities: Status of fish stocks and ecosystems
[f] Additional priorities: Biological surveys, stream sampling and gauging, sea level sites, HAB identification, sensor technology
[g] Additional priorities: Offshore telemetry, more *in situ* observations (ship surveys, gliders), California Cooperative Oceanic Fisheries Investigations (CALCOFI), Autonomous Underwater Vehicles (AUVs), drifters, and floats
[h] Enhance to measure more variables
[i] Additional priorities: Buoys for nearshore transport and fate of pollutants and sediments; monitor ship traffic and offshore hazards, biological sampling, glider fleets
[j] Additional priorities: Wave direction, visibility, ecosystem observations, HABSOS support, sentinel stations
[k] Additional priorities: fleet renewal
[l] Additional priorities: Improve National Centers for Environmental Prediction (NCEP) forecasts; new coastal satellite
[m] Additional priorities: interconnected waterway sampling; flow metering, and enhanced remote sensing

Box 1: Implementing Ecosystem-Based, Adaptive Management

There are many challenges to the development of ecosystem-based management practices, ranging from the need for *in situ* sensors that rapidly detect changes in habitats (both benthic and pelagic) and the abundance of living resources, to the need for operational, data assimilating, hydrodynamic-ecosystem models that can be used to predict changes in water quality (e.g., the spatial and temporal extent of bottom water anoxia) and related changes in the abundance and distribution of targeted populations of living resources. Sensors for geophysical measurements (e.g., near surface winds and air temperature, water temperature, and salinity) are operational. Sensors for some chemical (e.g., partial pressure of CO_2, dissolved oxygen, and dissolved nitrate) and biological (e.g., *in vivo* fluorescence) are in pilot project or pre-operational stages of development, depending on water quality (e.g., pre-operational in low nutrient, open ocean waters; pilot project in eutrophic coastal waters where sensor deployment periods are limited by biofouling). Sensors for detecting organisms from microbes to fish are high priority research projects. Likewise, operational models for predicting changes in water quality are in the early stages of development while operational models for ecosystem-based management of fisheries are high priority research projects. Thus, considerable research and development is needed to develop operational capabilities for ecosystem-based management. However, research on marine and estuarine ecosystems and long-term time series observations in both the Pacific and Atlantic Oceans clearly shows that real-time observations of pelagic environmental conditions (e.g., temperature, salinity, dissolved oxygen, currents) and more rapid and repeated assessments of the spatial extent and condition of benthic habitats (e.g., coral reefs, seagrass and kelp beds, tidal wetlands, hard and soft bottom substrates) will be needed to implement ecosystem-based management practices effectively.

3. Enhancing the Initial Observing Subsystem

Integrated approaches to observing oceans and coasts depend on both the coordinated development of the global ocean and coastal components, and on increasing the capacity of the IOOS to integrate (blend) data streams from remote and *in situ* sensing to produce more accurate, more frequent, highly resolved estimates of the distributions of core variables. While *The First IOOS Development Plan* emphasizes *in situ* observations, enhancing remote sensing capabilities for coastal observations in general, and ecosystembased management in particular, are high priorities.[3] Thus, a team of experts from the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Navy have initiated a review of satellite requirements for the IOOS that will be addressed in the *Second Annual IOOS Development Plan* in 2005. Refinements and additions to these enhancements will be identified as IOOS planning and implementation continue in the future.

3.1 Global Ocean Component

The goal of the global ocean observing system is to build and sustain the ocean component of a global observing system that addresses the long-term observational requirements of operational forecast centers, international research programs, and major scientific assessments. The system includes (1) deployment and maintenance of observational platforms and sensors including ships, satellites, aircraft, and supporting infrastructure; (2) data delivery and management; and (3) routine delivery of ocean analyses. Consistent with the development of the global ocean and coastal modules of the Global Ocean Observing System (GOOS), the goals of public health, ecosystem health, and living marine resources (LMRs) for the oceans as a whole are addressed by the coastal component.

Over the last decade, the U.S. and its international partners have begun to build an integrated, sustained global ocean observing system. These efforts culminated in the ratification of a plan for an integrated system of space-based and *in situ* observations by over 300 scientists from 26 nations in 1999.[4] As of 2004, approximately 45% of the planned *in situ* elements (drifting buoys, profiling floats, moorings, tide gauge stations, etc.) were globally implemented. The U.S. has committed to funding and operating about 60% of the *in situ* elements and is a major contributor to the space-based elements of the global ocean component. The long-term goal of the U.S. is to maintain approximately 50% of the global system.

Currently, the global component is comprised of eleven complementary *in situ* and spacebased observing subsystem elements: (1) global tide gauge network; (2) global surface drifting buoy array; (3) global ships of opportunity network; (4) tropical moored buoy network; (5) Argo profiling float array; (6) integrated polar observing systems; (7) ocean reference stations; (8) full-depth ocean surveys and ocean carbon monitoring; (9) dedicated ship operations; (10) satellites for sea surface temperature (SST), sea surface height (SSH), ocean color; sea ice and surface vector winds; and (11) data and assimilation systems such as now being developed under the Global Ocean Data Assimilation Experiment (GODAE). With the exceptions of the Argo array, GODAE, and satellites for SSH, ocean color, and vector winds, all of these elements are operational.

[3] Integrated Global Observing Strategy (IGOS) Coastal Theme Report <http://ioc.unesco.org/igospartners/coastal.htm>

[4] OCEANOBS 99. Proceedings of the International Conference on the Ocean Observing System for Climate, GCOS/GOOS/World Climate Research Program (WCRP) Ocean Observations Panel for Climate and the Climate Variability and Predictability (CLIVAR) Upper Ocean Panel, Saint-Raphael, France, October 1999. <http://www.bom.gov.au/OceanObs99/Papers/Statement.pdf>

Two key operational components of the global component are the tropical moored buoy program and the global drifting buoy program. Together, they presently provide over 1,000 daily SST observations used in the operational production of the global, blended (remotely sensed plus *in situ*) SST products assimilated into models for numerical weather prediction. These programs are implemented through international collaboration with the drifting buoy program implemented by 14 nations.

The Argo array of profiling floats is a collaborative pilot project involving over 20 countries that buy, build, and deploy floats, and process their data. Argo is becoming the mainstay of both climate and ocean researchers, and of operational weather and climate centers in many countries. Begun in 2000, the array reached its half way point in 2004 with 1,500 operating instruments in all ocean basins providing 55,000 profiles of temperature and salinity of the upper ocean (down to 2,000 m) annually. In 2004 over 800 floats will have been deployed. With a design lifetime for the floats of 4 years, 800 is the number of floats that will need to be deployed annually to maintain the array. The array is expected to approach its 3,000 float target and become operational in 2007.

3.1.1 Space-based Observations

Maintaining continuity and enhancing satellite remote sensing of the oceans are critical components of the IOOS. Integral in every remote sensing system is the requirement to maintain a sensor validation and continuous calibration program that ensures delivery of functional data to users. The global ocean observing system depends on space-based global measurements of SST, SSH, surface vector winds, ocean color, and extent of ice cover:

Box 2: IOOS and the Unique Vantage Point of Space

One of the grand challenges of ocean observing has been overcoming the sparseness of observations in the vast space of the oceans. The advent of satellite-based ocean remote sensing in the 1970s revolutionized oceanography by empowering global oceanography with a nearly synoptic view of the ocean surface from various Earth orbits. In the U.S., NASA leads the development of these capabilities. Research and development of satellite observing capabilities for sea level, ocean vector winds, sea surface temperature, sea ice extent, and chlorophyll-*a* have made possible pre-operational and operational products and services. These products and services depend on the assimilation of satellite data into models for boundary conditions, initial conditions, and validation. However, many of the data streams required to deliver operational products and services are provided by satellites as part of research missions that are of finite (but multiyear) durations. Assuring a long-term commitment (operational) to remote sensing capabilities of the IOOS remains a significant challenge, one that is the subject of an ongoing discussion among NASA, NOAA, Navy, and the NPOESS IPO.

(1) High-resolution SST data are provided by both infrared and microwave techniques. A combination of the two techniques is required, as they have different coverage and error properties. *In situ* observations are necessary for providing calibration and validation of satellite data and bias corrections.

(2) The value of space-based measurements of SSH has been clearly demonstrated in seasonal forecasting by providing realistic model initializations. The precision altimetry data from TOPEX and Jason 1, when calibrated precisely with tide gauge measurements, have provided the ability to monitor the rate of sea level change with a projected accuracy of one to two millimeters per year. Continuation of the precision altimeter missions in the TOPEX/Poseidon/Jason orbit is necessary for sustaining this level of accuracy in monitoring long-term sea level change. Although adequate for many other applications, altimetry from the planned National Polar-orbiting Operational Environmental Satellite System (NPOESS) will not achieve this level of accuracy.

(3) Synthetic Aperture Radar (SAR, a Canadian asset) and visible imagery are used to monitor the extent of sea ice. Determination of ice volume from satellite observations remains a research question. A key element in monitoring ice extent is the maintenance of a robust calibration system.

(4) The best method of sustaining uninterrupted satellite measurements of adequately resolved surface vector winds and ocean color remains an open question at this time. Over the early part of the implementation of the IOOS (e.g., first five years), Ocean.US will collaborate with NOAA, NASA, the NPOESS Program Office, and other groups to determine the long-term strategy for the implementation and continuance of systems that can provide these key ocean observations.

3.1.2 *In situ* Observations

The First IOOS Development Plan is founded upon the international design formulated by over 300 scientists from 26 countries in1999[4] and a report issued by GODAE.[5] The highest priority for the global component of the IOOS is sustained, global coverage (Figure 1). The Plan calls for working with national and international partners on a tenyear, phased implementation with specific, defined objectives and detailed metrics given below:

[5] Observing the Oceans in the 21st Century. 2001. Edited by Chester J. Koblinsky and Neville R. Smith. GODAE Project Office, Bureau of Meteorology, Melbourne, Australia, ISBN 0642 70618 2. <http://www.bom.gov.au/bmrc/ocean/GODAE/ocean_book.html>

(1) Global Tide Gauge Network: In cooperation with international partners, the U.S. will maintain a global climate network of 170 tide gauge stations, establish the permanent infrastructure necessary to process and analyze the tide gauge and global positioning system (GPS) data, and deliver routine annual sea level change reports. The initial goal will be the complete installation of real-time, remote reporting tide gauges, increasing from the present 39 GPS sites to 86 sites globally.

(2) Global Surface Drifting Buoy Array: The U.S., together with international partners, will extend the global SST/velocity drifting buoy array to data sparse regions, increasing from 900 to 1250 buoys, while adding wind, pressure, and precipitation measurement capabilities.

(3) Tropical Moored Buoy Network: The global tropical moored buoy network will be expanded from 79 to 115 stations and will ultimately span the Pacific, Atlantic, and Indian Oceans.

(4) Global Ships-of-Opportunity Network: Improve meteorological measurement capabilities on the global ships-of-opportunity (SOOP) fleet for improved marine weather and climate forecasting. Concentrate on a specific subset of high accuracy SOOP lines to be frequently repeated and sampled at high resolution for systematic upper ocean and atmospheric measurement. A climate-specific subset will build from 29 lines presently occupied to a designed global network of 41 lines.

(5) Argo Profiling Float Array: The Argo profiling float array is designed to provide essential broad-scale, basin-wide monitoring of the upper ocean heat content. Three thousand floats will be deployed worldwide, with the U.S. providing one-half of the array. The Argo array presently consists of Lagrangian instruments. Strong circulation patterns in ocean boundary currents often transport these instruments out of the general deployment region over their lifetime, requiring more frequent reseeding of those regions. Glider technology offers the ability to control instrument movements and should be used to complement the Argo array in coastal systems.

(6) Integrated Arctic Observing System: Increase the present 11 ice-tethered buoys and bottom-mounted moorings to monitor the drift of ice and its thickness to 51.

(7) Ocean Reference Stations: Working with international partners and the National Science Foundation's (NSF) Ocean Research Interactive Observatory Networks (ORION) program, the U.S. will implement a sparse global network of 29 ocean climate reference stations to measure changes in full depth ocean and surface atmospheric conditions to the highest possible accuracy (6 moorings are in place as of 2004; 28 are scheduled to be operating by the end of 2008). In addition, a network of 58 ocean time series stations is planned to monitor key locations for deep ocean circulation that could signal possible abrupt climate change.

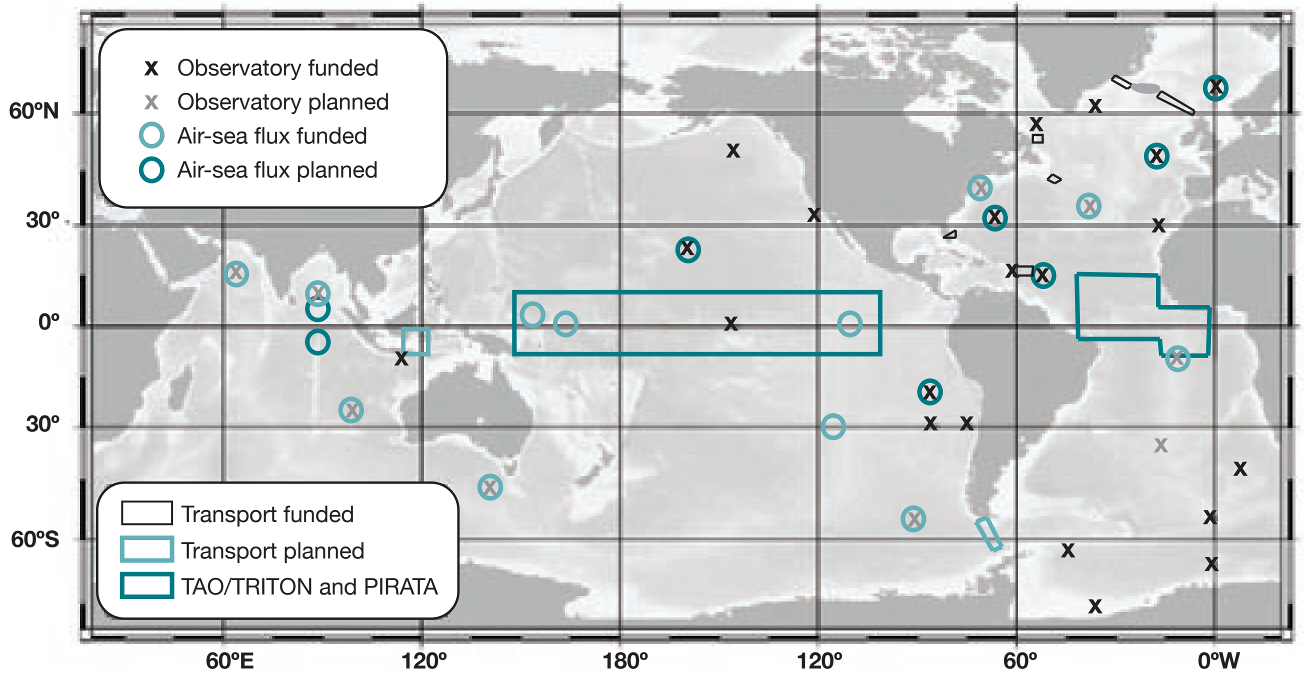
(8) Full Depth Ocean Surveys and Ocean Carbon Monitoring: A program is underway to implement a global survey of 25 trans-oceanic full depth sections, repeated every ten years by dedicated research ships, for inventory of ocean heat content and ocean carbon; add autonomous carbon dioxide sensors to the moored arrays and ships of opportunity.

(9) Dedicated Ship Operations: Presently the U.S. provides approximately 660 days of ship time annually in support of ocean observations (slightly less than one-half the global contribution). This contribution will expand to nearly 1500 days out of a global total of approximately 3,100 days.

(10) Data and Assimilation Subsystems: The U.S. IOOS DMAC Implementation Plan[6] integrates data transport, quality control, data assembly, limited product generation, metadata management, data archeology, data archival, data discovery, and administrative functions. The principal vehicle for producing marine products and the use of observations for forecasting is GODAE. The global component of the IOOS will provide the funding to implement the results of GODAE within some operational centers.

[6] "Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive" <http://www.dmac.ocean.us/dacsc/imp_plan.jsp>

Oceanographic Time Series



Courtesy of Uwe Send, IfM Kiel.

Figure 1. Locations of funded and planned time-series stations as of 2004.

3.1.3 International Implementation

For implementing the global ocean-climate component, the U.S. is a participating member of the Joint Intergovernmental Oceanographic Commission (IOC)/World Meteorological Organization (WMO) Technical Commission for Oceanography and Marine Meteorology (JCOMM). JCOMM is striving to ensure that consistent standards and formats are used by all collaborating nations so that data can be easily shared and that consistent quality can be expected from all platforms, regardless of their national origin.

3.2 The National Backbone of the Coastal Component

Recommended programs for an initial IOOS that serves data and information to provide improved products listed below are summarized in Tables 3 and 4 of Part II:

(1) Fields of surface winds over water, surface atmospheric pressure, and waves;
(2) Sea and water level;
(3) Surface and interior fields of currents, temperature, salinity, dissolved nutrients, dissolved oxygen, chlorophyll-*a*, and carbon;
(4) Heat, water, and carbon fluxes across the air-water interface;
(5) Ice distribution and volume in coastal and oceanic waters;
(6) Inputs of freshwater, sediments, nutrients, and contaminants from land-based sources;
(7) Distribution and abundance of phytoplankton, zooplankton, and LMRs in the context of environmental (water depth, temperature, salinity, dissolved oxygen, flow, and wave fields) and habitat conditions; and
(8) Spatial extent and condition of benthic habitats (benthic mapping).

Based the Ocean.US 2002 workshop[1], the First Annual IOOS Implementation Conference[2], and direct input from participating federal agencies and nascent RAs (Box 3), enhancements to the initial Backbone are recommended here (Tables 2 and 3). As a group, these enhancements will improve operational capabilities of the IOOS to achieve the seven societal goals. As the number of user groups increases, data requirements become more rigorously defined, priorities evolve, and new technologies and knowledge come on line, these recommendations will be refined and improved with each iteration of the *Annual IOOS Development Plan*.

Box 3: Regional Priorities for Developing the National Backbone of the Coastal Component

The following priorities are reflected in recommendations given below for the initial observing subsystem:

(1) Increase the density of NDBC buoys and equip them with temperature and salinity sensors and with ADCPs;
(2) Implement the surface current mapping initiative in all regions;
(3) Increase the number of PORTS that are in operation nationwide;
(4) Increase the number NWLON stations and equip tide gauges with GPS, meteorological sensors (surface wind vectors, air temperature, barometric pressure) and oceanographic sensors (temperature and salinity);
(5) Conduct repeated LIDAR surveys of the coastline from 30 m below to 30 m above mean low water;
(6) Improve satellite-based remote sensing of coastal waters by increasing the time, space, and spectral resolution of observations, and by increasing access to data streams and products; and
(7) Increase the number of stream gauge stations and equip them with sensors for measuring concentrations of inorganic nutrients and suspended sediments.

In all cases, federal agencies responsible for operating fixed platforms, tide gauges, and stream gauges, should consult with nascent RAs in determining where these should be located in order to optimize the sampling network.

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Table 2. Recommend
for achieving the seven goals by increasing the density of *in situ* measurements.

Program - Enhancements	Weather & Climate	Marine Operations	Natural Hazards	National Security	Public Health	Healthy Ecosystems	Sustained Resources
NDBC - Increase to 350 stations	NOAA	NOAA	NOAA	NOAA			
NDBC - Increase number of stations measuring directional waves		NOAA	NOAA	NOAA			
NWLON - Increase to 300 stations		NOAA	NOAA	NOAA			
NWLON - Make all stations realtime reporting		NOAA	NOAA	NOAA			
NWLON - Increase the number of stations making meteorological measurements	NOAA	NOAA	NOAA	NOAA			
NWLON - Incorporate water level gauges operated by other agencies		NOAA	NOAA	NOAA			
PORTS - Increase number of estuaries served	NOAA	NOAA	NOAA	NOAA			
National Current Observation Program - Increase measurements and surveys		NOAA	NOAA	NOAA			
National Current Observation Program - Survey 35 high priority sites per year for tidal current predictions		NOAA	NOAA	NOAA			
LMR - Improve resolution of surveys spatially and temporally					NOAA EPA	NOAA EPA	NOAA
LMR – Survey Abundance of Juvenile Fish					NOAA	NOAA	NOAA
Coastal Field Data Collection Program - Increase the number of stations measuring directional waves		USACE	USACE				
NSIP - Increase number of stations by 200			USGS	USGS	USGS		
NASQAN - Increase stations to 60 with new stations in coastal watersheds			USGS	USGS	USGS		

Table 3. Rec
sensors on existing platforms to improve operational capabilities for achieving the seven goals.

Program & Enhancements	Weather & Climate	Marine Operations	Natural Hazards	National Security	Public Health	Healthy Ecosystems	Sustained Resources
NDBC – Add vertical profiles of currents and temperature to buoys	NOAA	NOAA	NOAA	NOAA	NOAA		
NWLON - Selectively add measurements of temperature, salinity, and current velocity	NOAA	NOAA	NOAA	NOAA	NOAA		
PORTS® - Add side-looking and bottom mounted ADCPs		NOAA	NOAA	NOAA			
Mapping and Surveying - Increase spatial and temporal resolution of all mapping and surveying		NOAA, USGS	NOAA, USGS	NOAA, USGS		NOAA, USGS	NOAA, USGS
Hydrographic Surveying - Increase spatial and temporal resolution of bathymetric and topographic surveys		USACE	USACE	USACE			
NASQAN - Add side-looking ADCPs to stations in or near the tidal zone		USGS	USGS		USGS	USGS	
NASQAN - Increase stations to 60 with new stations in coastal watersheds and add contaminant measurements					USGS	USGS	USGS

A high priority for enhancing the initial IOOS is to begin addressing the problem of under-sampling in space and time. The recommended enhancements are made with the understanding that under-sampling will remain a chronic problem. These enhancements are steps that will begin to reduce the magnitude of the problem and improve the accuracy of field estimates and model predictions.

There is also an overarching need for the provision of high quality, space-based observations of coastal waters. The need to sustain space-based observations (e.g., Polar Operational Environmental Satellites [POES], Geostationary Operational Environmental Satellites [GOES], NPOESS, and GOES-R) and to enhance them to increase time, space, and spectral resolution is especially acute in coastal environments, which are characterized by higher frequency variability and stronger spatial gradients than is typical of the open ocean (e.g., Box 4). In this context, much of the data used to provide operational products comes from research satellites, creating the constant potential of gaps in satellite observations. Thus, a critical enhancement to the National Backbone is for these data to be collected by operational satellites to ensure continuity in the respective data streams.

Box 4: Goes-r Hyperspectral Environmental Suite (HES) Coastal Water Imager

The ability to observe coastal waters from space would provide products needed to meet many of the goals and sub-goals of IOOS. The 2002 Ocean.US workshop and the recent First Annual Implementation Conference identified remote sensing of coastal waters as a critical part of the IOOS. The planned Coastal Water (CW) imager on the new series of GOES-R satellites will go a long way to meet the needs of a multitude of users. The requirements of the imager are being refined now. Initial requirements are for a spatial resolution of at least 300 m at nadir (at the equator directly underneath the satellite). Spectral resolution will allow measurement of ocean color and chlorophyll, in-water optical properties, and atmospheric correction data.

The key advantage of the CW imager is the repeat coverage it allows: the minimum requirement is every three hours, with selected sites hourly, with a goal of every hour over all U.S. coastal waters (including Hawaii but not Alaska). A second advantage of the imager is the ability to take images when the scene is cloud-free. For example off the east coast it often clouds up in the afternoon so morning images are best. On the west coast the opposite is often the case: morning clouds burn off in the afternoon. The CW will be able to selectively take images when scenes are cloud-free. Finally the imager can ‘stare’ at a location for seconds or minutes if needed to detect regions of low reflectance.

In the next year, the requirements of the GOES-R CW will be finalized. During that time the utility of this technology for the IOOS mission should be assessed.

3.2.1 Fields of sea surface winds, surface atmospheric pressure, and waves

Near Surface Meteorological Variables

1) *In situ* Observations

Increase the spatial resolution of meteorological measurements over the water by increasing the weather buoy network of fixed platforms in the Exclusive Economic Zone (EEZ) and Great Lakes from 175 to approximately 350, based on quantitative assessments of requirements for improved forecasts of the weather in the coastal zone, homeland security, and of the state of coastal marine systems (e.g., Box 5). Support infrastructure maintenance (e.g., maintain buoy servicing arrangements) to ensure unbroken streams of data and information and to develop a database of sufficient duration and spatial resolution to optimize both spatial resolution and location of fixed platforms based on costs and benefits.

In addition, equip all National Water Level Observation Network (NWLON) stations with meteorological packages (air temperature, humidity, wind velocity, atmospheric pressure) within the next ten years (a rate of about 30 tide gauges per year).

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2) Remote Sensing

Surface wind fields (speed and direction) are collected routinely by space-based platforms such as QuikSCAT and WindSat (data not yet publicly released) over 90% of the globe, on a daily basis, with about 25 km resolution. Other platforms, such as the Special Sensor Microwave/Imager (SSM/I) and Tropical Rainfall Measuring Mission Microwave Imager (TMI) collect global wind speed only. Future missions include the Advanced Scatterometer (ASCAT) on Envisat, the Visible Infrared Imager Radiometer Suite (VIIRS) on the NPOESS Preparatory Project and NPOESS, and the Conicalscanning Microwave Imager/Sounder (CMIS) on NPOESS. Enhancements recommended include SAR on NPOESS, temporal continuity of surface wind measurements from space on operational satellites, redundant missions to protect against failure and enhance global coverage capabilities, and product development and validation.

Surface Waves

1) *In situ* Observations

Increase the number of stations measuring directional waves in the weather buoy network (NOAA) by upgrading all buoys capable of measuring directional waves and adding 45 directional wave gauges to the U.S. Army Corps of Engineers (USACE) Coastal Field Data Collection Program (Box 5).

2) Remote Sensing

Surface waves are typically measured by TOPEX/Poseidon, Jason-1, and Ocean Surface Topography Mission (OSTM) only in the open ocean. Continued development of the altimeters to provide wave data in the coastal ocean is recommended, as is the incorporation of these sensors on operational satellites.

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Box 5: Critical Geophysical Data For Safe And Efficient Maritime Operations

NDBC operates over 170 weather buoys and fixed stations in U.S. coastal waters. The data collected are important for weather, surface current and wave forecasts, as well as to the development of climatologies. Data from near-shore stations, when integrated with additional data from NWLON (water level), PORTS® (winds, water level, air and sea surface temperature, salinity, currents) and USACE wave gauges, are especially important for addressing the goals of safe and efficient maritime operations, managing public health risks and mitigating the effects of coastal erosion and flooding. One important objective is to determine coastal boundaries and convert all sea level measurements to a common metric.

Many of the NDBC stations have been reporting hourly meteorological and oceanographic (surface wave and temperature) data for over 25 years. Originally planned as a "picket line" of offshore buoys, the network was never completed. The 2002 Ocean.US workshop©ˆ recommended a total of 350 stations and emphasized that equipping these platforms with additional oceanographic sensors would not only be costeffective (shared use), it would increase the value of the data collected by measuring meteorological and oceanographic variables synoptically in time and space. Thus, increasing the density of near-shore meteorological and physical oceanographic observations is among the highest priorities for IOOS in its early stages of development.

3.2.2 Water Level

1) *In situ* Observations

Increase the number of sites where water level measurements are made from 175 to approximately 300. Selectively enhance NWLON stations by incorporating sensors for temperature, salinity, and current velocity. Make all the stations real-time reporting (every six minutes), and geo-reference all gauges. Establish new sites based on quantitative assessments of requirements for improved predictions of water depth, tidal currents, and secular sea level change (number and location of gauges). Upgrade all gauges to provide real-time data telemetry. Incorporate additional tide gauges operated by other agencies (e.g., U.S. Geological Survey [USGS], Port Authorities) and programs as appropriate. Supplement NWLON with water level measurements made in an expanded network of Physical Oceanographic Real-Time System (PORTS®) serving additional harbors and entrances (Boxes 5 and 6).

Install 16 NOS/NWLON tsunami-reporting sea level monitoring stations (ten in the Pacific, six in the Caribbean). Coordinating with enhancements of the global tide gauge network (Section 3.2.1), upgrade 38 existing sea level monitoring stations to tsunami reporting status. Augment the present, six first-generation Deep-ocean Assessment and Reporting of Tsunami (DART) buoys, located only in the Pacific basin (Part II, Figure 1b), with

32, second-generation DART buoys located in the Pacific, Atlantic, and Caribbean basins. Procure 20 broadband seismometers in Alaska and Hawaii to enhance the seismic monitoring and information network for local hazard warnings.

2) Remote Sensing

Four altimeter missions are flying at this time: TOPEX/Poseidon, Jason-1, Envisat, and Geosat Follow-on. By 2008, it is possible that the only altimeter flying will be Jason-2. Multiple missions on operational satellites are recommended to provide adequate resolution. Wide swath altimetry with at least a ten km resolution and 200 km swath is recommended for wave measurements.

Box 6: Improving The Safety And Efficiency Of Marine Operations And Homeland Security

The Physical Oceanographic Real-Time System (PORTS®) is a program of the National Ocean Service (NOS) that supports safe and cost-efficient navigation by providing shipmasters and pilots with accurate real-time information required to avoid groundings and collisions. This localized version of an integrated coastal ocean observing system can significantly reduce marine accidents and improve the ability of cargo to move efficiently through the nation's congested seaports. PORTS® includes centralized data acquisition and dissemination systems that provide real-time water levels, currents, and other oceanographic and meteorological data from bays and harbors to the maritime user community in a variety of user friendly formats, including telephone voice response and Internet. NOS also develops and implements numerical circulation models that are typically coupled with PORTS® (not always) that can provide nowcasts and forecasts. Telephone voice access to accurate real-time water level information allows U.S. port authorities and maritime shippers to make sound decisions regarding loading of tonnage (based on available bottom clearance), maximizing loads, and limiting passage times, without compromising safety. PORTS® has the potential to save the maritime insurance industry from multi-million dollar claims resulting from shipping accidents.

PORTS® is also important for environmental protection, since marine accidents can lead to hazardous material spills that can destroy a bay's ecosystem and the tourism, fishing, and other industries that depend on it. The human, environmental, and economic consequences of marine accidents can be staggering, as demonstrated by the 35 deaths caused by the May 1980 ramming of the Sunshine Skyway Bridge in Tampa Bay (which led to the first PORTS® installation), and the estimated $3 billion cost of the EXXON Valdez accident in 1989.

PORTS® is currently operating in twelve locations around the U.S. Implementing PORTS® in all of the nation's harbors and ports is critical to the success of IOOS for addressing the seven societal goals, particularly in improving the safety and efficiency of maritime operations and homeland security.

3.2.3 Surface and interior fields of currents, temperature, salinity, nutrients, chlorophyll, dissolved oxygen, and pCO_2

1) *In situ* Observations

Increase the number of harbors and entrances served by PORTS® and the frequency of current surveys. For tidal current predictions, annually survey 35 high priority sites to update tidal current predictions and increase the number of surveys of the next highest priority stations. Map up to three regions per year using high frequency (HF) radar to fill gaps in the update cycle. Add 25 sites per year with Acoustic Doppler Current Profiler ([ADCP], side-looking and bottom mounted) to obtain real-time currents in support of navigation requirements. Initiate a national current mapping system of 150 sites by integrating data streams from the 30 HF radar sites currently in operation.

Selectively enhance the weather buoy network by increasing the data acquisition, data telemetry, and power capacities of buoys, and by incorporating oceanographic sensors for determining vertical profiles of current velocity, temperature, and salinity. As technology becomes more robust, add sensors for dissolved inorganic nitrogen, chlorophyll, pCO_2, and dissolved oxygen (section 6.2).

Increase the density of stream gauging stations in the National Streamflow Information Program (NSIP) by adding 200 stations to coastal watersheds. Expand the National Stream Quality Accounting Network (NASQAN) from 32 to 60 stations with new stations located in the coastal watersheds to better characterize the quantity and quality of contaminant flux from major rivers into coastal waters. Add side-looking ADCPs at seven NASQAN stations in or near the tidal zone to estimate velocity vectors.

Enhance data acquisition from ecosystem-related surveys. *In situ* oceanographic data are recorded routinely during the roughly 4000 days of at-sea operations of NOAA's LMR and ecosystem surveys. For example, over a one-year period in 2002-2003, routine fishery surveys conducted by NOAA Fisheries' Northeast Fisheries Science Center yielded about 1,900 conductivity-temperature-depth (CTD) casts in the Gulf of Maine and mid-Atlantic. Temperature, salinity, chlorophyll, and oxygen data recorded during the Southeast Area Monitoring and Assessment Program (SEAMAP) Summer Groundfish Survey are also being used to map the Gulf of Mexico "dead zone" in near real-time. To meet existing legal mandates, NOAA will have to roughly double the number of sea days for LMR surveys, providing a substantial increase in the amount of water column data produced.

2) Remote Sensing

SST measurements are made operationally from a number of polar and geostationary satellites. These data are readily available and are of sustained high quality when they are blended with precise *in situ* data. Near term needs are to ensure that new capabilities for SST measurements from research satellites and *in situ* measurements (e.g., shipboard radiometers) are integrated into the system. The GODAE High Resolution Sea Surface Temperature Pilot Project is an established mechanism to meet this need.

Remote sensing of sea surface salinity is an important capability that should also be developed. Establishing operational satellites for the provision of these data should be a high priority after suitable space capability is developed and operational utility demonstrated. *In situ* salinity data are being collected in a research mode, and provision of operational data is desirable.

3.2.4 Heat, water, and carbon fluxes across the air-water interface

1) *In situ* Observations

There is a need to enhance and/or develop observation systems that provide operational data needed to improve estimates of heat, water, and carbon fluxes across the air-sea interface. Data used for the analysis of heat and water fluxes are currently collected from NWLON and coastal moorings, including weather buoy network of the National Data Buoy Center (NDBC). The spatial resolution of these networks should be increased, and additional or improved sensors installed on the stations to provide data to accurately analyze these fluxes. These systems are recommended particularly for the calibration and validation of the remotely sensed data.

2) Remote Sensing

Heat and water fluxes are routinely measured and/or inferred through the use of spacebased SST and surface wind observations. Wind speed and direction from scatterometers, ocean color (chlorophyll-*a*), and SST are being used together to estimate carbon dioxide fluxes on both global and basin scales. Recommended are product development and validation, enhanced (higher spatial, temporal, and spectral resolution) ocean color measurements, improved algorithms, and more comprehensive geographic coverage. Continued ocean color measurements, meeting at least the SeaWiFS specifications for spectral and spatial resolution and product quality, are recommended.

3.2.5 Sea ice distribution and volume

1) *In situ* Observations

Sea ice distribution is currently remotely sensed (below and section 3.1.1). There is a need for improved validation and calibration, as well as to develop *in situ* techniques for operational measurements of ice volume.

2) Remote Sensing

POES is used operationally by the Joint Sea Ice Center to measure sea ice extent, and data are made available through a number of national and regional outlets. These data could to be integrated to improve the accuracy of sea ice nowcasts. Mission continuity from operational satellites is an important requirement.

3.2.6 Inputs of freshwater, sediments, nutrients, and contaminants from land-based sources

1) *In situ* Observations

Improve estimates of river borne transports of fresh water, sediments, nutrients, and contaminants from land to coastal waters by adding 200 stream gauging stations in coastal drainage basins to the NSIP; accelerating the construction and operation of 50 of these sites to monitor water stage and flow into estuaries and bays; adding side-looking ADCPs at seven NASQAN stations in or near the tidal zone to estimate current velocity; and by expanding the NASQAN from 32 to 60 stations in coastal drainage basins.

2) Remote Sensing

Except for sediment measurements, these constituents are usually inferred rather than measured directly. Qualitative information on sediment distribution can be obtained directly from ocean color measurements. Sea surface measurements indicating surface fresh water outflow from major rivers can be obtained from SAR. Data integration is the primary need, and mission continuity from operational satellites is an important requirement.

3.2.7 Spatial extent and condition of benthic habitats

1) *In situ* Observations

Improve spatial and temporal resolution of benthic habitat surveys, including coral reefs and other benthic habitats, near-shore bathymetry and coastal topography, and bathymetry of the EEZ (hydrographic surveys) using advanced space-based, aircraft, and shipboard techniques.

2) Remote Sensing

While satellites can provide few reliable measurements of submerged habitat, they can provide information on the spatial extent of exposed habitat and coral reefs with moderate resolution. Remote sensing of coastal waters from aircraft, however, provides greatly increased resolution of features and more cost effective surveys. Many of the airborne remote sensing techniques that can be used in the observation and monitoring of LMRs can also be used in certain benthic mapping. Systems such as light detection and ranging (LIDAR), SAR, and hyperspectral imaging will improve spatial and temporal resolution of benthic habitat surveys, including coral reefs and sea grass beds, near-shore bathymetry and coastal topography, and shoreline mapping. Benthic habitat mapping is discussed in more detail in sections 6.2.1 and 6.2.2.

3.2.8 Living Marine Resources and Ecosystems

1) *In situ* Observations

LMR and ecosystem data are collected by several observing programs extending over and beyond the U.S. EEZ. These can be categorized broadly as either fishery-dependent or fishery-independent. Fishery-dependent data are gathered by programs that directly involve commercial or recreational fisheries, including the fishery observer program (observers on fishing vessels), the collection of fish catch statistics, and surveys of recreational fishers. Fishery-independent data are gathered through sampling programs that are separate from and independent of commercial or recreational fisheries. These include fish trawl surveys using NOAA or charter vessels, marine mammal surveys, and ecosystem surveys.

The LMR and ecosystem data obtained under current observing programs are sufficient to assess stock status for only about 25% of the over 900 fish stocks for which NOAA has management responsibility. Increases in the number of days of ship time would provide much greater spatial and temporal resolution of both LMR and the associated physical data, such as *in situ* water column data. Other LMR observing programs could also benefit from increases of similar magnitude.

2) Remote Sensing

Some of the recommendations expressed above can be addressed with current methods and technologies, but many of the required improvements can be accomplished only by developing and adopting new and enhanced technologies. Several emerging technologies hold great promise for advancing the LMR and ecosystem survey capabilities through more comprehensive and rapid surveys that can provide data in near real-time. These include LIDAR, laser line scanning, multibeam acoustics, multifrequency acoustics, broadband acoustics, DNA characterization, video observation and image processing systems, high-resolution imaging sonar systems, and systems for monitoring and managing fishing gear performance. Broader use and deployment of acoustic instruments should be high priorities for research and development. To date, acoustic technology has afforded characterization of only a single species at a time. Recently developed techniques for measuring total target strengths and remotely identifying marine animals *in situ* have proven the utility of wide bandwidth characterization and model validation of fish and large zooplankton. These techniques could be employed extensively through pilot projects. Acoustic technology will increase ship-time efficiency, as multiple species may be surveyed simultaneously while also surveying greater areas. These systems will provide fundamentally new types of data, which will require new hardware and software for data management and communications.

Distributions of phytoplankton biomass as chlorophyll-*a* can be estimated operationally, in Case 1 coastal waters, from measurements of ocean color, and concentrations of some LMRs can be inferred from proxies based on these estimates and estimates of SST fields. High priority should be placed on the development of algorithms for Case 2 waters and for continuity in satellite missions with sensors that at least meet SeaWiFS specifications for spectral and spatial resolution. Visible and infrared imaging spectrometer data should be added to NPOESS to provide additional data on LMRs.

3.3 Coordinated Development of the Global and Coastal Components

Critical to meeting the societal goals of the IOOS is the ability of the global component to provide data and information necessary for the high-resolution products developed by the coastal component of the IOOS. For example, (1) nowcasts and forecasts of sea level and coastal currents require oceanic boundary conditions, and (2) warnings of high-impact weather events require detailed knowledge of ocean-atmosphere interactions. The global component can meet these requirements in several ways, including the (1) provision of direct observations of sufficient temporal and spatial resolution and accuracy; (2) provision of model derived boundary conditions for coastal models; and (3) ability to host nested littoral or estuarine models with even higher resolution into the global models. Development of a coastal ocean data assimilation pilot project similar to GODAE, in collaboration with GODAE scientists, is needed to define the requirements of the coastal component for products from the global component (Box 7 and section 6.2).

Box 7: High Priority Pilot Project: Coupling Shelf And Deep Ocean Models

Participants in the First Annual IOOS Implementation Conference[2] recommended that high priority be given to regional pilot projects that quantify improvements in the skill of coastal physical and biogeochemical models through the use of open boundary conditions generated by deep ocean forecast systems, such as those being developed by GODAE. It will be advantageous to conduct pilot projects in contrasting regions (e.g. narrow versus wide shelves, eastern versus western boundaries of ocean basins). It will also be important to supplement shelf modeling with an active shelf observation program to initialize models and evaluate the accuracy of the forecasts.

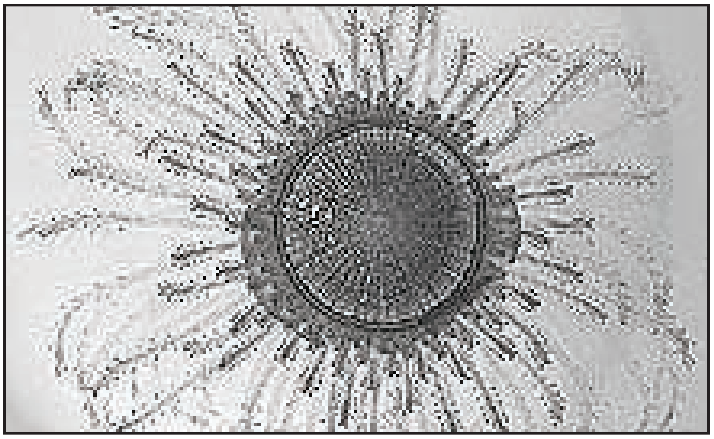
The GODAE Common should be extended to include coastal modeling. Questions to be addressed include the following:

- How much do shelf modelers really gain in forecast skill by including offshore boundary conditions from the present generation of deep ocean models, and what can be expected over the next five years?
- What are the priority data sets needed to improve forecast skill in the coastal ocean and Great Lakes?
- Can Observing System Simulation Experiments (OSSEs) be used to optimize sampling schemes?
- What metrics should be used to assess forecast skill on the shelf for physical and nonphysical variables? The same group could also build on the idea of the GODAE Common and promote the development of community modeling and assimilation software for coupled models.

Products should include extended forecasts (e.g. lead times of tens of days) of conditions on the continental shelves and standardized measures of forecast skill for physical and selected biogeochemical variables.

3.4 Data Telemetry

There are many challenges to efficiently transmit the broad diversity of data types (geophysical, chemical, biological) and data volumes from *in situ* and remote sensing platforms and sensors to data assembly centers. Platforms such as drifting buoys with simple sensor systems (e.g., SST and basic meteorology) may transmit a few bytes of data daily or even less frequently. Gliders may transmit tens of kilobytes in bursts while at the surface, and some moored buoy systems can now transmit Megabits per second (including streaming video in real time). Some sensing systems deployed in the field can be reprogrammed remotely, some with two-way communications that enable continuous adaptive control. There are phenomena critical to IOOS that will require continuous realtime monitoring and reporting (e.g., surface currents, harmful algal blooms [HABs], beach contamination) while other variables may require data to be reported at monthly or at less frequent intervals (e.g., spatial extent and condition of coral reefs; distribution and abundance of large, long-lived fish populations). As but one example, ecosystem-based management of



fisheries may require real-time, and near real-time data on ecosystem states (e.g., temperature and chlorophyll fields) and delayed mode data on fish stocks (e.g., monthly, seasonal, or annual, depending on the species), where "delayed" refers to the time lag between real-time changes in fish stocks and the detection of such changes.

Observing system platforms have a wide variety of options for transmitting data. Those deployed within line-of-sight (LOS) of shore or of other platforms that can relay the signal can benefit from any one of a number commercial and affordable LOS telemetry technologies (Very High Frequency [VHF], Medium Frequency [MF], Digital Switched Calling (DSC), point-to-point and point-to-multipoint microwave or even cellular telephone networks in some near coastal instances). Emerging "WiMax" technology (the 802.16 protocol with higher power and longer range than the 802.11x that currently enables WiFi hotspots for wireless internet connections at coffee shops) holds particular promise for broadband telemetry of near-shore coastal measurements. Coastal platforms farther off shore (typically beyond 25 km) or those over-the-horizon (OTH) sites that comprise the global component of IOOS can still reliably report at varying data throughput rates (up to Mbps) and frequency intervals (up to continuous streaming realtime) through HF and HF-DSC links, or a variety of deployed and operational communication satellite constellations. Some of these communications satellites are government owned and operated, while commercial providers lease bandwidth on others in a variety of frequency bands (commercial Ku-, C-, L-Band transponders are all currently in use for telemetry of oceanographic data, and the emergence and increasing adoption of Ka-Band portends to further increase data throughput rates. Sensors deployed beneath the sea surface can also report data and be remotely controlled from shore through a variety of methods, chief among them electrical/optical cables either ending at shore or terminated at a surface telemetry buoy, acoustic data modems transmitting to a surface vessel or float, or releasable data packages, which ascend to the surface to telemeter data ashore or to be retrieved by vessels. Once transmitted ashore, IOOS data is ported into the National Backbone that is designed to take maximum advantage of our nation's existing and robust telecommunications infrastructure and the industries that support it.

A summary of existing telemetry technologies for coastal ocean observing systems can be found in the report of a workshop held by the Alliance for Coastal Technologies (ACT).[7] The workshop also addressed the shortcomings of these systems for the purpose of facilitating future technological advancements. Key recommendations from the workshop for the development of the data telemetry infrastructure for the IOOS are to:

(1) Identify and adapt existing infrastructure to meet the missions of the IOOS;
(2) Develop simple and robust technologies that can be implemented immediately by users, and continue to develop technologies as new telecommunications systems are developed and deployed;
(3) Develop standards and protocols for telemetry technologies used within the IOOS in order to facilitate dissemination of the data for research and operational purposes;
(4) Implement technical support programs for telecommunications systems utilized within the IOOS; and
(5) Procure cost-effective telecommunications services.

Working with federal agencies, Ocean.US, has established an *ad hoc* Group of Experts to develop advanced data telemetry techniques using Low Earth Orbiting (LEO) satellite systems. Ocean.US will establish additional Groups of Experts, including representatives from ACT, federal agencies, and RAs, as necessary to respond to these recommendations for other telemetry systems (Medium-Earth Orbiting and Geosynchronous Satellite Systems; LOS; OTH, etc.).

3.5 Primary Data Assembly and Quality Control

IOOS measurements are highly heterogeneous, ranging from biological surveys (e.g., fish stock assessments), serial and underway oceanographic cruise measurements, laboratory analyses, remote sensing, and automated data from *in situ* sensors that include multiparameter time series, profiles, swath maps, grid surveys, and others. Getting these data from the sensor to data assembly centers involves a wide range of data telemetry, ranging from cellular telecommunications, established networks such as the Global Telecommunication System (GTS), and more *ad hoc* procedures.

IOOS Primary Data Assembly and Quality Control (PDAQC) defines the interface between the IOOS observing subsystem and the IOOS DMAC subsystem. While some forms of PDAQC are employed at virtually all points along the “sensor-to-user” pathway, the IOOS PDAQC is the entry point beyond which all data must be “IOOS compliant.” This certification, or labeling, is required for all data served by the IOOS.

The character of IOOS PDAQC varies greatly depending on the data type and requirements for timely data delivery. The data assembly process may involve digitizing hand-written log sheets, automated conversion of voltages to physical units, or calculations of anomalies based on comparisons with nearest-neighbor measurements or climatologies. Through this process the myriad original individual measurements are assembled into “data sets” that may be referenced and queried as a whole. This process is well recognized in the management of distributed observation systems such as the assembly and quality control of marine weather buoy data (NOAA, NDBC), and of Earth ocean observing satellite data (NASA’s Physical Oceanography Distributed Active Archive Center, or PODAAC).

The scale of IOOS PDAQC operations will likely vary, depending on the number of contributing observing activities, individual data volumes and coverage type (spatial, temporal, or both). Some activities may be conducted as a part of a data management strategy for a particular measurement type, in conjunction with the data assimilation process serving forecast modeling and state estimation (e.g., the U.S. GODAE Server that operates in close association with the Navy’s Fleet Numerical Meteorological and Oceanography Center), or regionally. The IOOS PDAQC responsibilities will be shared between the IOOS DMAC subsystem and the RAs. At this time, the process of implementing DMAC must ensure that appropriate procedures and standards of scientific quality control (QC) are identified so that data QC flags can be appended to the observational data prior to those data being published within the IOOS framework. Standards and procedures for quality control will be developed cooperatively by the relevant marine science, user, and data management communities.

IOOS data managers have the responsibility to ensure that all IOOS data streams undergo primary data assembly and IOOS-compliant quality control processing prior to making them available. It is the goal of IOOS to foster the growth of “intelligent” sensors and instruments that can perform much of the data assembly and quality control functions at the instrument subsystem level, and thereby reduce the additional processing and associated time delays at the subsequent data assembly points.

[7] “A Workshop of Developers, Deliverers, and Users of Technologies for Monitoring Coastal Environments: Data Telemetry Technologies for Coastal Ocean Observations” <http://www.actonline.ws/Download/Telemetry_Report.pdf>

4. Data Management and Communications

Central to the success of IOOS is a DMAC infrastructure that seamlessly joins together the components of IOOS with observing systems of partner organizations and relevant systems in disciplines outside of the marine environmental sciences. It is recommended that the DMAC subsystem be implemented in a phased manner, beginning with the identification, evaluation, selection, and adoption of system-level interoperability standards and protocols. Developmental work will be initiated to address gaps identified between the existing, accepted community standards, and the requirements of IOOS data user, provider, and stakeholder communities. These Phase 1 tasks (FY 05-06) to establish an initial, minimally functioning DMAC interoperability framework of shared standards and protocols are described in Part II. They provide a foundation for the longer-term Phase 2 (FY 07 and beyond) activities discussed in this section. A more detailed discussion of all activities can be found in the DMAC Plan.[6]

The DMAC Plan calls for deployment of the full DMAC subsystem over a five-year period (FY 07-11), once the foundation has been built during Phase 1. Activities during the initial five-year period include system planning, design, implementation, maintenance, refreshment, and modernization. Activities during the subsequent five years (FY 12-16) include largely system refreshment, maintenance, and modernization. Training, outreach, and capacity-building activities are also high priorities for DMAC, especially in the regions. Ocean.US will work closely with participating federal agencies throughout the IOOS Planning Cycle described in Part I of the *Development Plan* to ensure that sufficient funds are available for DMAC implementation.

Priority activities for Phase 2 fall into the following categories:

(1) **Interoperability framework** (initiated during Phase 1): core standards, protocols, and software tools;
(2) **Interoperability infrastructure:** hardware, system software, networking capacity, archival center expansion, and systems integration labor; and
(3) **Design and demonstration:** pilot projects to usher in and test the new technologies, and integrate data across sectors, disciplines, geographic areas, and organizations.

Table 4 summarizes the activities recommended in the DMAC Plan for FY 07, grouped into the above three categories. In addition, suggested priority levels are provided. Table 5 presents a selected list of consensus recommendations for agency-specific DMAC tasks in FY 07, resulting from the First Annual IOOS Implementation Conference[2]. Most of the recommendations listed in Table 5 fall under the category of design and demonstration and are consistent with IOOS and DMAC plans. These activities should be considered for implementation in FY 07, guided by the suggested priority levels in Table 4 for the **design and demonstration** category. Detailed descriptions of DMAC activities beyond FY 07 can be found in the DMAC Plan. These activities represent new efforts above and beyond the existing relevant programs already funded by the federal agencies and RAs. They involve specific DMAC services, hardware, software, and infrastructure that will achieve the IOOS goals of data and metadata integration, and interoperability among existing and future observing system components.

It is recommended that a target investment goal be adopted for the DMAC components of federal and RA programs that is approximately ten percent of the funding applied to existing and planned observing systems. The ten percent estimate is based on various national assessments of the true cost of observational data management over the life cycle of such programs. The annual investment will vary greatly, depending upon the level of maturity of the existing DMAC systems, as well as the degree to which they comply and are compatible with the emerging DMAC interoperability standards.

© Courtesy NASA/JPL-Caltech

Table 4. Summary of prioritized DMAC activities recommended for implementation in FY 07 as recommended in the DMAC Plan (priority 1- highest, priority 3 - lower). Priorities are given within each major category (interoperability framework [IF], interoperability infrastructure [II], and design and demonstration [DD]). Multiple IOOS/DMAC functions with the same priority level must be developed in a balanced way.[a]

Priority	DMAC Functions	Activities[a]
IF-1	Metadata and Data Discovery	- Determine metadata content and format standards - Develop tools and procedures to support metadata providers - Discovery: Select/develop and maintain catalog and search capability - Discovery: Design discovery Portal - Discovery: Design and implement data location service
IF- 2	Data Archive and Access	- Current archive & access assessment - Determine dataset priorities for all IOOS data disciplines - Determine IOOS dataset categorization - Recruit centers for IOOS Archive System and form partnerships - Develop archive critical metadata - Define IOOS archive and access data policy - Establish IOOS data stream developers guidelines - Develop Archive System data discovery interfaces - Receive and provide more data in real time - Broaden base for user services - Establish procedures to document the archive System Metrics - Procedure to resolve data retention issues - Write plan for archive & access security
IF-2	Data Transport	- Develop comprehensive IOOS data model(s) - Deliver time critical (real-time) data to Data Assembly and Operation Modeling - Develop DMAC middleware - Make data available using IOOS middleware solution - Develop metrics and implement performance monitoring - Implement middleware security - Provide guaranteed geo-temporally-referenced browser for all IOOS data - Aggregation of unstructured data (e.g., vector, point, sequence, profile) - OPeNDAP-GIS client and GIS-OPeNDAP server
II-2	Communication Infrastructure	- Includes communications hardware at ~10 sites that contribute to essential DMAC infrastructure (i.e., archive centers and primary data assembly centers) - Communications lease for entire infrastructure
II-3	Servers at Centers	- Servers at ~ 10 sites, including hardware and software, and hardware maintenance after year of installation.
II-1	Engineering Integration	- Coordinate and manage the total hardware, software, and infrastructure definition, design, procurement, installation, integration, and maintenance. - Oversee Capacity Building, the effort in providing labor and services to data providers to enable them to reach and maintain the level at which they can participate.
DD-2	Data Discovery	*Design and Demostration Pilot Projects (see DMAC Plan)*
DD-2	Access/Infrastructure	
DD-2	Data Transport	
DD-2	Archive	
DD-2	Information Assurance	
DD-2	Innovative Architectures	

[a] Note that some of these activities may be initiated in FY 05-06, and most are multi-year.

Table 5. Summary of DMAC related working group recommendations from the First Annual IOOS Implementation Conference: DMAC Plan Implementation Areas, related Conference recommendations, and potential agencies affected.[a]

DMAC Implementation Plan Needs Area	Representative Breakout Group Priority Recommendations	Potential Affected Agencies
Inventory of current programs	• Inventory NOAA & EPA coastal & estuarine data sets, especially bottom, habitat and ecosystemrelated, and by extension each IOOS core variable observing effort.	• All Agencies
Data discovery	• Assure agency data inventories are" registered" and accessible through IOOS portal	• All Agencies
End-to-end integration	• Enable stream gauge observations integration • Enable wave observations integration • Interconnect HF radar & fixed sensor wind & wave data	• USGS & NOAA • ACOE, NOAA & Navy • NOAA, USCG & Navy
Metadata development	• Develop Lagrangian metadata for AUV's • Develop imagery metadata & characterization to enable fusion and assimilation • Integrate species-level information (e.g., genetics, habitat, life history, etc.)	• NSF & Navy • NASA, NOAA, USGS & Navy • NSF, NOAA, & EPA
Semantic data model(s) development	• Semantic data model to enable imagery fusion w/models • Fusion of spatial & tabular nutrient data fields	• NASA, NOAA, Navy & USGS • EPA & NOAA
Data transport	• Develop mechanisms for providing satellite data • Interconnect HF radar & fixed sensor marine wind data	• NASA, NOAA & USGS • USCG, NOAA , ACOE & Navy
Data archival	• Develop climatologies of oxygen, chlorophyll, nutrients and pCO_2 observational data	• EPA, NOAA & ACOE
QA/QC	• Enable integration of stream gauge data into national network across all observing elements	• USGS and NOAA

[a] Due to time constraints, projected costs and timeframes for these activities (most of which fall into the Design and development category) could not be developed during the Conference. However, these activities are consistent with recommendations of the DMAC Plan, which provided cost estimates and priority levels for design and development activities, along with the other activities recommended for FY 07 in Table 4.

5. The Modeling and Analysis Subsystem

The objectives of modeling in the IOOS are to (1) improve, develop, test, and validate operational models (Box 8); (2) produce accurate estimates of current states of marine systems (e.g., estimates of the distributions of core variables); (3) develop data assimilating techniques to initialize and update models for more accurate forecasts of state changes; and (4) optimize the observing subsystem (e.g., observing system simulation experiments [OSSEs]). Clearly, improving IOOS operational capabilities will require strong and ongoing interactions between the development of the observing and modeling capabilities of the IOOS. This section describes the role of models in IOOS development, provides a preliminary assessment of the current state of marine modeling and data assimilation, identifies gaps in modeling capabilities, and recommends priorities for developing operational modeling capabilities.

Box 8: Characteristics of Operational Models

Operational models (1) provide outputs at rates and in forms specified by decision makers and other user groups; (2) are well documented (detailed descriptions of underlying concepts, equations, simplifying assumptions, inputs, and outputs are available); (3) incorporate uncertainty into models for more useful, probabilistic predictions; (4) quantify differences between model predictions and observations; and (5) are operated by responsible organizations that ensure the quality and continuity of model predictions.

5.1 Overview of Marine Modeling

Models include simple statistical relationships (e.g. rules of thumb, dose-response relationships, multiple and multivariate regression models), more sophisticated statistical constructs (e.g. state space models such as Geographic Information Systems [GIS], virtual population analyses, observation network performance analysis), dynamical models based on first principles (e.g. storm surge models, numerical ecosystem models in both Lagrangian and Eulerian frames of reference), or coupled models of the biological and non-biological components of the marine ecosystem (e.g. coupled atmosphere-oceanwave-sediment-biogeochemistry and ecosystem models) (Table 6).

Table 6. Summary of current marine modeling capabilities.

MODEL	Typical Capabilities
Sea Ice	Short-term and seasonal forecasts of ice properties and ice motion
Single Species	Reconstruction of past and present abundance levels, forecasts of abundance under different management strategies
Storm Surge	Warnings of coastal flooding with lead-time of hours to days
Surface Waves	Forecasts of wave conditions with lead times of hours to days
Tsunamis	Forecasts of tsunami arrival with lead times of minutes to hours
Water Clarity	Standardized water clarity calculations and analysis of remotely sensed images
Ecotoxicology	Predictions of the fate and effects of anthropogenic chemicals with limited application as routine ecotoxicological tool in natural ecosystems
Fecal Pollution	Evaluation of whether beaches/shellfish harvesting areas and shellfish meet local/regional/international health guidelines and standards. Help to establish optimum combination of waste treatment level, length and depth of outfall sewers, and the number of multiple discharge manifold pipes at end of outfalls
Water Quality	Cornerstones for large-scale expenditures aimed at mitigating the effects of anthropogenic nutrient inputs
Coastal Currents and Hydrography	Hindcasts, nowcasts, and forecasts of coastal currents and temperature and salinity fields
Shoreline Change	Predictions of shoreline and nearshore evolution in response to external forcing
Aquaculture	Information required to help manage aquaculture operations and regulate their environmental impacts
Multiple Species	Time-varying patterns of predation mortality, optimal (sustainable levels of harvest, evaluation of harvesting strategies for multi-species assemblages
Ecosystem	Indicators of ecosystem status, evaluation of impacts of harvesting strategies on non-exploited species, evaluation of impacts on global change on exploited and non-exploited resources
Health Risk/Dose-Response	Estimates of increased incidence of gastroenteritis and respiratory infections caused by bathing in contaminated water, and infectious diseases from consuming raw shellfish harvested in feces-contaminated waters

Modeling and the making of observations are complementary and intrinsically linked activities. Data assimilation, here referred to as the blending of time-dependent dynamical models and observations, is a critical linkage. Data assimilation is used to update a model's state, parameters, and forcing in a manner that is consistent with the observations. Data assimilation is not restricted to physical models, but is being used to increase the capacity to use data more effectively in marine biology in areas such as nutrient-phytoplankton-zooplankton modeling.

The main value of models is in the estimation of quantities that are not, and often cannot be, observed directly. Models are used to estimate the past (hindcasts), present (nowcasts), and future states (forecasts) of the coastal ocean and its living resources.

(1) **Hindcasts** are used to help estimate values based on limited observational data of, for example, changes in the abundance of commercially important fish stocks, and to help identify and understand the frequency and magnitude of HABs, trends in the loss of coral reefs, and the spatial and temporal extent of bottom water oxygen depletion. Hindcasts are also used extensively on a routine basis to determine the mean, second, and higher moments of marine physical variability fundamental to environmental science and engineering design (climatologies).

(2) **Nowcasts** are used to assess the current status of exploited fish stocks and to ensure safe navigation in shallow water. They can also be used to guide adaptive sampling of marine ecosystems based on real-time estimates of current conditions.

(3) **Forecasting** the future state of marine systems with known uncertainty is arguably the most challenging objective of modeling. Models are now used routinely to forecast storm surges and wave spectra with a lead-time of hours to days. Models have been used for decades in fisheries management to forecast the abundance of commercially important fish stocks with lead times of years. Models are now also being used to generate climate change scenarios to help understand potential linkages between natural variability and anthropogenic forcing. Yet, for each of these forecasts, quantifying the errors associated with them remains a challenge.

Observation, modeling, and scientific inquiry are mutually dependent activities (Figure 2). IOOS users stand to benefit from attention to all of these components. A failure in one area will adversely affect the overall success of IOOS.

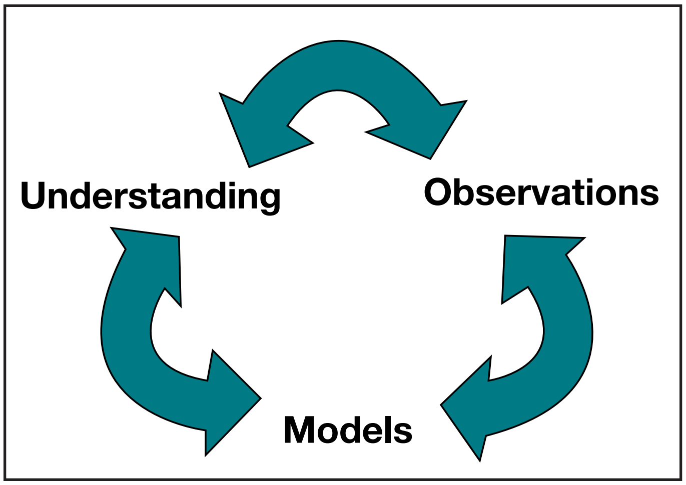


Figure 2. Models play a critical role in helping to develop effective observation strategies and in improving our understanding and prediction of the ocean's global and coastal environment.

5.2 The State of Marine Modeling

Meeting the diverse modeling challenges inherent in IOOS will require major advances in modeling capabilities (Figure 3).[8] The global and coastal components must not only each be addressed, but also as importantly, the interfaces between the two. Effective use of observations will be facilitated by establishing interlocked modeling networks that enable both large-scale and small-scale issues to be addressed.

Models are being used to address a wide range of ocean and coastal issues at varying levels of maturity and understanding. Global and coastal models differ in spatial and temporal scale resolutions, but the observational support and developmental challenges associated with each class are fundamentally similar (e.g., coastal and global ocean circulation models). A key difference between global and coastal-scale models is in their use. Many coastal models that will be useful to IOOS focus on estimating site-specific phenomena such as water depth, storm surge flooding, circulation in estuarine and coastal upwelling systems, water quality, and sustainable fish catches. The time frames for such models depend on the time scales upon which the phenomena being modeled vary and on the time scales of management actions. For example, hydrodynamic models used for nowcasting and forecasting water depths and currents in ports, or storm surge flooding caused by tropical storms, run in real-time and may be updated hourly, 24 hours per day, seven days per week (24/7). Many models for assessing fish stocks run on an annual basis, while models relevant to fisheries that are regulated on the basis of total allowable catch may run on time scales of days to weeks. Supporting such a diverse array of models will involve assimilating a

[8] The Integrated Strategic Design Plan for the Coastal Ocean Observations Module of the Global Ocean Observing System, GOOS Report No. 125. IOC Information Documents Series No. 1183. UNESCO, pp. 69-87. <http://ioc.unesco.org/goos/COOP-3/COOP-DESIGN-TCs.htm>

diversity of data streams over a broad range of temporal and spatial scales. Research on ecosystem structure and function and on how physical and oceanographic factors affect ecosystems and populations of managed species is a very active scientific field. As information continues to accumulate, modeling requirements will rapidly evolve.

A great deal of work has been completed or is under way by the academic community, the private sector, and federal and state agencies. Given the large population of marine models, it would be impossible to provide an exhaustive discussion within this document. The intent, therefore, is not to provide a comprehensive review, but rather an indication of the scope of the models and their capabilities, their current developmental or operational status, and predictive capabilities.

For the purposes of IOOS, "operational" is not defined exclusively in terms of the provision of real-time data 24/7. Rather, a model that is classified as operational is defined as having the following characteristics:

(1) Clear and complete documentation describing the underlying concepts (equations, where appropriate), simplifying assumptions, inputs and model outputs;
(2) Quantitative descriptions of model-observational data misfits based on rigorous retrospective analysis and validation using appropriate data (e.g., data rich periods when specific processes can be identified, isolated, and tested);
(3) Model outputs (e.g., hindcasts, nowcasts, forecasts) are provided at rates and in forms required by user groups;
(4) An institution or organization has taken responsibility for routine and timely model runs and for the quality and continuity of its products; and
(5) A clearly identified and sustained funding pipeline is in place.

Qualitative estimates based on the community's assessment for each model area's inherent complexity and predictive skills are also provided.[9] A review of the current status of modeling indicates that the modeling of the physical aspects of the ocean's environment (sea ice, storm surge, surface waves, surface currents, tsunamis, water clarity) is more advanced than that for detecting and predicting changes in phenomena that require measurements of biological and chemical variables (e.g., HABs, invasive species, ecosystem-based management of water quality, and fisheries). This review underscores the importance of relevant research in the development of both improved sensor technologies (leading to improved observations) and models of ecosystem dynamics.

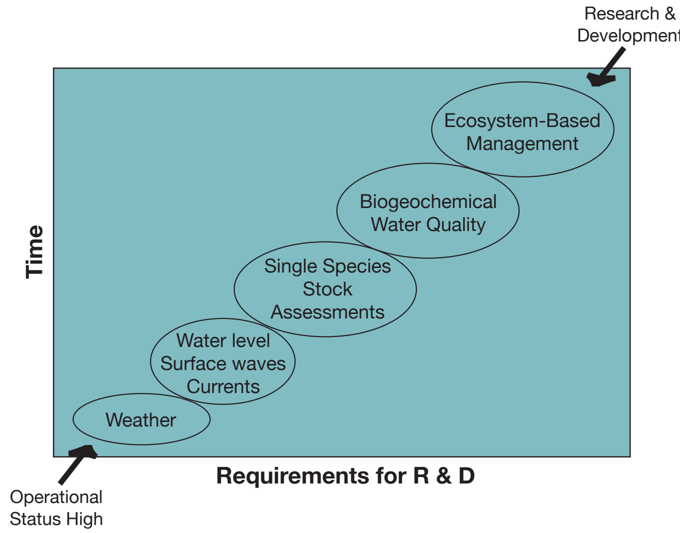


Figure 3. Operational status of current (2004) models needed to address the seven societal goals of the IOOS.

5.3 Data Assimilation

Data assimilation is a numerical procedure for combining observations and dynamical models. Data assimilation has long been an essential and routine component of weather forecasting, where it is used to continuously reinitialize forecast models based on differences between previous forecasts and newly available data. Similar practices are also being employed using hindcasts and nowcasts. Data assimilation schemes can also be used to assess the value (and uncertainties) of observations made at arbitrary locations and times, as well as to improve the design of observing systems. Data assimilation schemes are most advanced for atmospheric models, although the data assimilative physical oceanographic models are closing the gap.[10] Data assimilation has not been developed for the purposes of ecosystem-based management of water quality and living resources. However, this situation is expected to change with increasing computing power, the development of research observatories (e.g., NSF's ORION/Ocean Observatories Initiative [OOI]) and the development of the IOOS. The development of data assimilating models of ecosystem dynamics into coastal ecosystem models will present a number of technical challenges, including:

(1) The need to begin addressing the problem of under-sampling by increasing the resolution of chemical and biological measurements, and to increase the volume of real-time data telemetry for data assimilation;

(2) The strong non-linearity, high dimensionality and need for coupling multiple modeling components into ecosystem-level models;

[9] Robinson, A.R., 1999. Forecasting and simulating coastal ocean processes and variabilities with the Harvard ocean prediction system. Coastal Ocean Prediction, AGU Coastal and Estuarine Studies, 56pp. <http://people.deas.harvard.edu/~robinson/PAPERS/mooers.html>

[10] Robinson, A.R. and Lermusiaux, P.F., 2002. Data assimilation for modeling and predicting coupled physical-biological interactions in the sea. Vol. 12 In: A. R. Robinson, J.J. McCarthy and B.J. Rothschild (eds.): The Sea. Biological-Physical Interactions in the Sea. New York: John Wiley & Sons. <http://people.deas.harvard.edu/~robinson/PAPERS/The_Sea_Ch12.pdf>

(3) The long memory of some components of the coastal ecosystem (e.g. coastal eutrophication can continue to be a problem long after nutrient inputs have been reduced because benthic sediments can store large quantities of nutrients that are released over extended periods), making initial conditions estimation difficult; and

(4) Rapid variability in both space and time, requiring high-resolution models.

These are major challenges that can be addressed only through coordinated development of research initiatives that focus on long-term, high resolution time-series observations to advance our understanding of the dynamics of marine systems and the development of an IOOS that takes advantage of these data streams for operational purposes.

In summary, data assimilation helps bring together models and data in order to increase the predictability of marine ecosystems, help design better observing systems, and control the quality of data;, it is, therefore, of central importance to IOOS. If IOOS is to realize its full potential, modeling and data assimilation must be integrated, from the beginning, into the observing systems design, operation, and ongoing evaluation.

5.4 Summary and Recommendations

Models will play a critical role in the development of the IOOS and in the generation of products. A review of the current status of data assimilation and modeling for marine services and natural hazards, LMRs, public health, and ecosystem health shows that the state of modeling for marine services and natural hazards is well advanced relative to those services available for detecting and predicting change in phenomena that require measurements of biological and chemical variables.[8] This review underscores the importance of research, not only for the development of improved sensor technologies for biological and chemical variables and predictive models of ecosystem dynamics, but also for increasing the time-space resolution of measurements and more effective linking of observations to models through data assimilation. Thus, significant investments in the ocean sciences are recommended to establish long-term, time-series observations and the development of data assimilating dynamical models of ocean ecosystems.

Although the above overview of models is not comprehensive, it is possible to draw the following conclusions:

(1) A large number of models are being used to address a wide range of coastal issues. This situation presents both opportunities and challenges for implementation of the IOOS. The models have been developed to solve real problems, so the links between modelers and users are being made, and much useful infrastructure is already in place.

(2) The range of models and their data requirements makes the design of an integrated observing system a complex task, arguably a challenge far greater than that faced in the design and implementation of the atmospheric analog, the World Weather Watch, that now provides the observations, data assimilation, and forecasts of weather worldwide.

(3) An operational capability for many of the non-physical models is generally viewed by the community to be at least five years away, and data assimilation has yet to have a significant impact in this area. Therefore, it is important to design an observing system that provides sufficient data to develop and validate non-physical models (e.g., water quality, population and ecosystem dynamics) and provides sufficient data inputs for models to predict changes in biological and chemical states of marine systems with skill. This need underscores the importance of research programs, such as NSF's ORION/OOI initiative, to improve operational capabilities of the IOOS;

(4) The development of predictive, coupled models (e.g. shelf and deep-ocean, shelf and atmosphere, water properties and HABs, among others) is essential. Accurate atmospheric forecasts (especially coastal winds) are needed for improving and developing predictive models of ocean circulation, biogeochemistry, populations, and ecosystems. This is challenging especially in the coastal zone, with its rugged orography and strong land-sea contrasts of temperature, humidity, and surface roughness. Consequently, continued development of high resolution atmospheric models will be critical to the successful development of the coastal observing system component of the IOOS.

(5) Data assimilation will play an increasingly important role in the design and operation of the observing system and in the generation of products for users. However, data assimilation poses a number of problems that are acute particularly in the coastal zone, including: (a) the high space-time variability of the coastal and near-shore physical environment (e.g. tides, river outflows); (b) the multidisciplinary aspects of ecosystem models; (c) the need for high resolution, real-time observations of chemical and biological variables; and (d) developing observing, modeling, and assimilation strategies to deal with highly episodic and extreme events.

(6) Community models have proven to be very useful in oceanography. Examples include, but are not limited to, the Princeton Ocean Model (used widely for shelf problems over the last decade) and the Parallel Ocean Programme, developed by the Los Alamos National Laboratory and used for deep ocean studies). Broad communities of scientists use such models for fundamental research and the generation of useful products, such as operational forecasts of surface currents and sea level. A similar community-based approach, possibly through a Community Modeling Network, could accelerate the development of models for biogeochemical problems, and for coupling multiple models within or across regions.

(7) A sustained and systematic evaluation of the modeling and assimilation component of the IOOS is essential. The first type of evaluation is an internal evaluation of model skill based on well-defined and nationally accepted metrics. The second type of evaluation is external and will provide a measure of the usefulness of model products. This external evaluation will necessarily involve the users and may be more qualitative than the internal evaluation, at least initially. This external evaluation will be facilitated by the development of user-oriented model products, software interfaces, and visualization tools that allow users to explore model output and performance.

The recommendations above reflect the intrinsic importance that modeling has to the IOOS, and it is recommended that a focused working group of experts be convened to explore these issues in depth and to address the pathway(s) ahead for developing data assimilation techniques and improved coupled physical, biogeochemical, and ecosystem models in a systematic and managed fashion.

6. Research and Development

6.1 IOOS Research Priorities

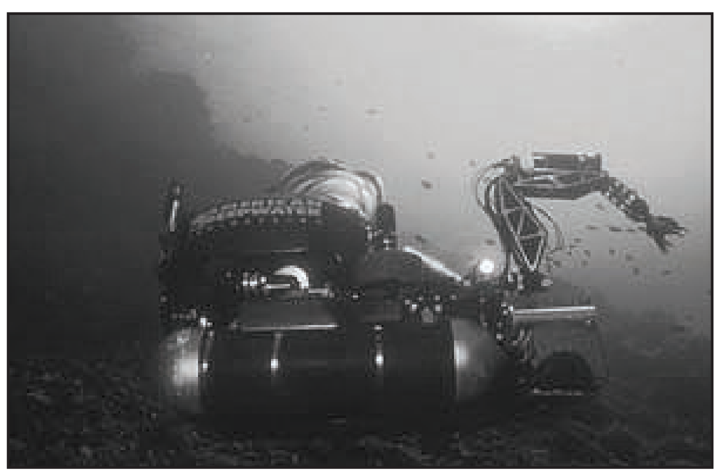
Advances in fundamental scientific knowledge of ocean processes are necessary to achieve the goals of the IOOS. New technology and scientific knowledge are required to enable IOOS user requirements to be met, to improve IOOS products and their interpretation, to develop new applications to serve existing requirements, and to provide new products for user requirements not currently anticipated. Thus, engaging researchers and research agencies in the IOOS is critical to the evolution of the observing system, ultimately leading to broader use of IOOS information, more sophisticated products, and increased user satisfaction. Research to improve and extend IOOS will come from both directed and undirected (curiosity-driven) research projects.

Priority areas for investment in ocean sciences to improve IOOS include efforts to (1) develop new sensors and associated algorithms, especially for measuring chemical and biological variables in near real-time; (2) develop new ocean access technologies (power supply, transmitting large data volumes); (3) increase capabilities for observing extreme environments (e.g., hydrothermal vents, methane hydrates, sea ice, the deep sea); (4) increase the resolution of time-series observations for testing the parameterization of processes unresolved by current numerical models; (5) achieve higher spatial resolution (moored arrays or arrays deployed around cabled observatories) than will be realized by the IOOS to capture the full spectrum of variability and change in the oceans; and (6) develop ecosystem models that will be needed to implement ecosystem-based management of public and ecosystem health risks and LMRs.[11]

Research priorities for improving operational capabilities of the IOOS were identified at the Ocean.US 2002 workshop[1] as follows:

- Network of HF radar nodes for coastal current mapping nationwide;
- Gliders for water column profiling;
- Increase in temporal, spatial and spectral resolution of satellite based remote sensors for measurements of surface currents, waves, salinity, and phytoplankton biomass and pigment composition;
- *In situ* sensors for real-time measurements and data transmission of key biological and chemical variables; and
- Coupled physical-ecosystem models to enable ecosystem-based management.

As discussed in Part II, the National Oceanographic Partnership Program (NOPP) provides an important means for supporting science and technology development for IOOS. The NOPP process provides an opportunity for multiple federal agencies to support private and public sector partnerships for implementing research that will lead to advances in knowledge and technologies to improve IOOS capabilities.



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[11] NRC. 2003. Enabling Ocean Research in the 21st Century: Implementation of a Network of Ocean Observatories. National Academy Press, Washington, D.C., 220 pp. <http://www.nap.edu/books/0309089905/html/>

Box 9: An Example of Agency Led, IOOS Relevant Research

The Ocean Research Interactive Observatory Network (ORION) Program and its infrastructure component, the Ocean Observatories Initiative (OOI) of the NSF, will provide important advances in knowledge and technologies that will enable the development of IOOS operational capabilities.[a] As emphasized in the National Research Council (NRC) report "Enabling Ocean Research in the 21st Century: Implementation of a Network of Ocean Observatories"[b] and in the report of the U.S. Commission on Ocean Policy, significant synergies will develop between the IOOS and ORION/OOI. ORION is being designed to meet ocean science needs for long-term, *in situ* measurements of biological, chemical, geological, and physical variables over a broad range of time scales. The NSF-funded observatories will be used to examine the processes that drive atmospheric, ocean, and terrestrial systems, and they will serve as incubators for new technologies to monitor these processes. In reality, basic research and technology development from the NSF observatories and the information generated by the IOOS are interdependent, with each program supplying ingredients essential to the other.

To ensure that the best available science and technology are continuously integrated into the national IOOS, close coordination and cooperation between IOOS and the observatories programs will be necessary to capitalize on these benefits. NSF recently established the ORION Project Office, and one of its tasks will be to coordinate with an appropriate NOAA entity to develop plans for transferring new technologies to an operational mode in the IOOS and with Ocean.US. Through NSF's competitive grant process, ORION/OOI is likely a direct source of support for IOOS infrastructure and operations. First, NSF anticipates that many, if not all, scientific institutions that successfully compete for NSF grants for coastal observatories will also be or become members of the IOOS RAs. These same institutions are also likely participants in the regional ocean information programs (as described in the U.S. Commission on Ocean Policy report), which will be focused regionally on research, outreach and education, and ecosystem assessment. Second, the ORION Project Office is working with NOAA's Office of Climate Observations (OCO) on joint plans for open ocean observing platforms. OCO, with its focus on observations related to global climate, and ORION, with a broader focus that includes global climate, both require sustained observations from open ocean platforms. OCO's need for Ocean Reference Stations and ORION's need for open ocean buoys and other research platforms are the basis for this developing partnership.

[a] http://www.coreocean.org/Dev2Go.web?Anchor=orion_home_page&rnd=19169

[b] http://books.nap.edu/allpricing.phtml?record_id=10775

6.2 Pilot Projects

Pilot projects are recommended to develop the operational capabilities of the IOOS that were identified at the Ocean.US 2002 workshop.[1] These projects focus on systems that provide higher quality products and on developing improved techniques and instruments. Current operational capabilities of the global and coastal components of IOOS (Part II, Tables 3 and 4, respectively) vary considerably. To date, IOOS implementation has focused more on goals (e.g., safe and efficient marine operations, natural hazard mitigation, climate prediction) that require geophysical data (winds, SST, currents, waves, water level, etc.) than on the goals (managing public health risks, healthy ecosystems, sustainable resources) that require data on chemical (dissolved oxygen, nutrients, contaminants, toxins) and biological (pathogens, harmful algae, plankton species, etc.) variables. Developing an IOOS that provides the data and information needed to achieve all seven societal goals will require additional planning, research, and efficient use of new technologies and knowledge to improve operational capabilities of the IOOS (e.g., Box 10).

Box 10: Regional Pilot Projects

Regional and sub-regional coastal ocean observing systems provide important incubators for pilot projects, and funding regional pilot projects and implementing such projects was identified as a high priority by participants in the First Annual IOOS Implementation Conference.[2] It was also recommended that, given the diversity of needs and capabilities across regions, results from ongoing NOPP-funded socio-economic analyses (that are specific to regions and economic sectors) be used to guide selection and design. Pilot projects are an important mechanism to achieve and showcase early successes, to entrain private sector data users and data product suppliers, to build regional and national constituencies using the NFRA infrastructure, and to function as test beds for the development of new technologies needed to build operational capacity. A good example is "Surface Circulation Radar Mapping in Alaska Coastal Waters", a NOPP project funded by MMS and NOAA.

Pilot projects are a critical first step in this process. They "repeatedly test (over a range of conditions) techniques and approaches that show promise as potential elements of the operational system."[12] This process reveals weaknesses and provides opportunities to address them and gain community acceptance of new techniques (from measurements to models). Pilot projects may target specific elements of the IOOS (i.e., sensors, platforms, models) or be "product-driven" (improve an existing product or produce a new product).

[12] Nowlin, Worth D. and T. Malone, 2003. Research and GOOS, Marine Technology Society Ocean Observing Systems, Vol 37, No 3. <http://www.mtsociety.org>

Priorities identified by participants in the Ocean.US 2002 workshop[1] and the First Annual IOOS Implementation Conference[2] are used here to guide the identification of pilot projects intended to enhance the initial IOOS, especially for goals related to public health, ecosystem health, and living resources. Additional pilot projects may be identified as IOOS planning and implementation proceed, especially for ecosystemrelated products and technologies.

6.2.1 Product-Driven Pilot Projects

The pilot projects listed below are intended to develop the operational aspects of the IOOS, as outlined in the Ocean. US 2002 workshop, by providing systems that generate better products, thus increasing the capability and utility of IOOS.

• Global Ocean Data Assimilation Experiment (GODAE)

The vision behind GODAE is that societal and economic benefits of ocean research and observations cannot be realized without implementing a global system of observations, data telemetry, data assimilation, and modeling that will deliver regular, comprehensive information on the state of the oceans for the maximum benefit of society. GODAE will make ocean monitoring and prediction a routine activity in a manner similar to weather forecasting today.

The U.S. component of the GODAE project involves a team of academic and government researchers to improve assimilative physical oceanographic models (circulation, SST fields) as part of the international GODAE Project. New products coming from GODAE will include analyses for initializing and testing seasonal to interannual climate forecasts and globally consistent four-dimensional re-analyses of temperature, salinity, and current fields. GODAE is designed to demonstrate the power of integrating satellite and *in situ* observations working in real time. Funding for the U.S. GODAE began in 1997 and runs through 2008. Involvement of operational agencies (Navy and NOAA) increased in 2003, when the operational demonstration phase of GODAE began.

• Surface Current Mapping

Surface currents are a highly ranked core variable. Surface current maps of coastal systems can be improved by establishing high frequency (HF) radar networks and integrating data streams from space-based sensors (altimetry, scatterometry, Advanced Very High Resolution Radiometer [AVHRR], ocean color), *in situ* sensors (ADCPs), and HF radar. In addition to improved surface current maps for ship routing, more effective search and rescue, and more accurate predictions of coastal erosion and flooding, more accurate estimates of current fields are critical to achieving the goals of ecosystem-based management of human health risks, environmental protection, and fisheries management. Thus, the regular release of surface current maps and access to the data used to derive them are important for achieving the seven societal goals of the IOOS. Potential pilot projects for coastal systems were identified by a group of experts during a Surface Current Mapping Initiative workshop in September 2003. Projects include merging data from different systems, demonstration of data assimilation, products beyond surface currents (wave and wind), antennae systems, and integration of data from diverse HF radar systems. Interested agencies include NOAA, U.S. Coast Guard (USCG), Minerals Management Service (MMS), Navy, and USACE.

• Coastal erosion, sediment transport and shoreline position

Combining aircraft- and satellite-based LIDAR technology with hyperspectral technologies promises to provide new mapping products of great use to hydrographers, coastal engineers and resource managers, scientists, and decision makers. Pilot projects can address integration issues, including sampling specifications, geometries, development of visualization and interpretation techniques, and physics-based aspects related to fusing physical and environmental measurements for characterizing the coastal zone. Final products should include maps of land cover and benthic habits across the land-sea interface, habitat condition and change, characterization of bottom characteristics, and time-series visualizations of coastal erosion and sediment transport patterns. These data products are essential to development of robust models of vulnerability and change in coastal environments.

The USGS, NASA, USACE, Navy, and NOAA are currently collaborating to document shoreline impacts of extreme weather and long-term changes in shoreline position and geomorphology across the land-sea interface. This partnership is designed to ensure that the “best available system” is applied in a coordinated effort to provide time-sensitive assessments of storm and hurricane impacts. Systems currently available include:

(1) NASA’s Airborne Topographic Mapper (ATM) - The ATM provides an effective tool to survey beach topography along hundreds of kilometers in a single day, with data densities that cannot be achieved by traditional methods.

(2) The Joint Airborne LIDAR Bathymetry Technical Center of Expertise (JALBTCX) is a USACE-Navy collaboration to map this and other nation's coastal regions. JALBTCX employs the Naval Oceanographic Office's new Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system to rapidly and accurately map the coastal margin across the land-sea interface. CHARTS combines bathymetric and topographic mapping lasers with geopositioned digital aerial and hyperspectral imagery in one system capable of accurately mapping across the land-sea interface of the coastal region.

(3) The USGS and NASA are jointly developing applications of the NASA Experimental Airborne Advanced Research LIDAR (EAARL), which also provides both topographic and bathymetric mapping capabilities with geopositioned digital aerial imagery and hyperspectral scanning.

Data resulting from these systems have immediate applications for broad agency and user-group needs, including support of the USGS National Assessment of Coastal Change Hazards, which has as one objective of updating coastal map products for the nation's coastline every five years. The data resulting from the USGS-NASA surveys are provided to coastal managers by NOAA's Coastal Services Center. These data will also be useful to MMS, which has been assigned the task of developing a comprehensive marine "cadastre" that describes the legal rights and responsibilities for marine "real estate," including the seabed, water column, sea surface, and the air above (Office of Management and Budget, Circular A-16).

Enhancement of data collection platforms and analysis tools, effectively combining LIDAR, photographic, and hyperspectral data, will provide new capabilities to survey sandy beaches and coastal bluffs, coastal vegetation, shallow water bathymetry, and both benthic and terrestrial habitats. These important efforts should be developed for incorporation into the IOOS as a collaboration among USGS, USACE, NOAA, NASA, and MMS.

6.2.2 Pilot Projects that Target Elements of the IOOS

The pilot projects listed below will help develop the operational aspects of the IOOS, as outlined in the Ocean.US 2002 workshop[1], by providing better techniques andinstruments, thus increasing the capability and utility of IOOS.

- **Vertical profiling platforms and data telemetry**

The Argo program is in the process of deploying a global array of 3,000 floats that provide temperature and salinity profiles of the upper ocean (1000 m uniform parking depth with a 2000 m maximum) with data telemetry via satellites in near-real time. Together with satellite observations and other *in situ* surface observations (volunteer observing ships, ship of opportunity, drifters), the data from the Argo array are used by operational forecast centers and climate change predictions. U.S. deployments began in 2001, nearly 50% of the array was deployed by 2004, and the full array is expected to be deployed by 2006.

- **Benthic habitat mapping across the EEZ**

Depending on the underlying purpose, benthic-habitat mapping can be undertaken at a wide range of scales and can employ any of several different technologies. Combined use of acoustic and/or optical remote sensing technologies has great promise for rapid, repeat surveys of benthic habit extent and condition. However, remote sensing data must be ground-truthed with *in situ* observations and/or sampling. Because of their small scale and lack of integration, benthic habitat mapping projects, as they are currently conducted, are considered research or pilot project activities, based on IOOS criteria.

Development of these observing subsystem technologies through pilot projects will lead to operational systems. These systems will help achieve the goals of protecting and restoring healthy coastal marine ecosystems and more effectively sustaining LMRs. These pilot projects must include the following:

(1) Integration of data streams from existing technologies, including remote-sensing and *in situ* data;
(2) Improvement or adaptation of existing technologies as they become available;
(3) Tests of the ability of recently developed technologies to perform;
(4) Tests of recently developed data-management models;
(5) Tests of data collection standards as they are developed;
(6) Tests of mechanisms for incorporation of existing data, including an archive of existing Federal Geographic Data Committee (FGDC)-compliant metadata, and development of metadata for existing geospatial benthic habitat data sets that lack adequate documentation; and
(7) Testing a standard, hierarchical, habitat classification scheme, such as the method being developed by the USGS and NOAA.[13]

[13] A National Coastal/Marine Classification Standard. Christopher J. Madden et. Al., June 2003. NatureServe, Arlington, VA. NOAA Fisheries, Silver Spring, MD. NOAA Coastal Services Center, Charleston, SC. 51pp.

Ongoing efforts relevant to this potential pilot project include a joint USGS-NOAA project to define the geological basis for habitat classification and delineation, as well as NOAA's Integrated Ocean Mapping project. Partnering agencies should include NOAA and USGS.

- ***In situ* sensors for real-time measurements of key biological and chemical variables**

Sensors for bio-chemical variables are critical to IOOS but are scarcely available. They must be developed based on needs and support platform constraints.

Chlorophyll-*a*, bio-optical properties, dissolved nutrients, oxygen, and carbon dioxide were listed in the Ocean.US 2002 report as some of the most important bio-chemical variables to be incorporated into the National Backbone of the IOOS. In the case of nutrients, there are currently two types of sensors available commercially to make those measurements: an optical sensor and a wet-chemistry sensor. Neither sensor is considered to be beyond the research stage of development. The situation is similar for measurements of oxygen and carbon dioxide. All are being used in a research mode, and pilot projects are needed to repeatedly test, over a range of conditions, these techniques to reveal weaknesses, provide opportunities to address those weaknesses, and gain community acceptance. Sensor testing should take advantage of existing platforms such as NDBC buoys, observatories, and tide and stream gauge networks.

- **Living marine resource and ecosystems surveys**

Characterization and assessment of LMRs and the ecosystems upon which they depend can be improved through innovative uses of existing technologies. Numerous technologies are now entering operational status or are in the pre-operational, pilot, or research phase.

Participants in the Ocean.US 2002 workshop ranked fish abundance and species identifications (fish, zooplankton, and phytoplankton) as important biological variables. Acoustic–based surveys utilizing reflections from fish swim bladders have become operational for a few selected stocks (e.g., Gulf of Maine herring, Alaska pollock, and Pacific hake). These surveys are highly efficient and have great potential for monitoring the populations of other species with well-developed swim bladders. However, pilot projects are needed to develop this potential for other species and for surveying fish populations where fish communities contain many co-occurring species.

Other technologies are still in the research phase, and pilot projects could be developed as the relevant research progresses. One example is the Monterey Bay Aquarium Research Institute's project to identify phytoplankton species associated with HABs, utilizing a prototype *in situ* Environmental Sample Processor. In addition, the NOAA Fisheries Advanced Sampling Technology Program is working to develop and adapt LIDAR, laser line scanning, multi-beam and broadband acoustics, DNA characterization, video observations and image processing, optical plankton recorder, high-resolution imaging sonar, and systems for monitoring and managing fishing gear performance for monitoring fish populations.

- **Develop remote sensing capabilities for coastal marine systems**

Remote sensing provides unique data covering broad spatial regions at a variety of time scales. Developing operational capabilities for coastal systems in general and for the purposes of ecosystem-based management should be a high priority. Many of the key variables required by IOOS (ocean color [chlorophyll-*a*, primary productivity], SST, sea surface salinity [SSS], wind, altimetry) to obtain synoptic, repeated observations of the ocean, especially in the coastal zone, can be measured only by satellite- or aircraft-based sensors. Considerable research effort has been taking place to increase resolution, algorithm development for Case 2 coastal waters, and data delivery. Passive acoustics are also being studied as a means of monitoring certain marine mammals. It is critical that existing capabilities involving remote sensing for coastal waters be moved from research to pilot projects.

- **Autonomous Lagrangian Platforms and Sensors (ALPS)**

During the last decade, oceanography has witnessed a revolution in observing capabilities as autonomous platforms and the sensors they carry have developed rapidly.[14] Deployments of ALPS have demonstrated their potential for studying and monitoring changes in marine ecosystems and for addressing the problem of under-sampling the three dimensional space of the oceans. ALPS technologies are now ready for pilot project development to foster the use of ALPS technologies and the development of ALPS networks as a part of the IOOS infrastructure.

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

7. Education and Public Awareness

IOOS Education goals are to (1) develop and sustain a community of educators across a broad education spectrum that use IOOS information (e.g., data, careers, societal uses) to achieve their education objectives; and (2) create the workforce needed to develop and sustain the IOOS, and produce the allied information products, services and tools (Box 11). Consistent with IOOS design principles (Part I), these goals will be achieved by:

(1) Building on the best of what is already in place;
(2) Paying special attention to quality, sustainability, and scalability of efforts; and
(3) Using partnerships across federal, state and local government, academia, industry, professional societies, and non-profit organizations to implement this plan.

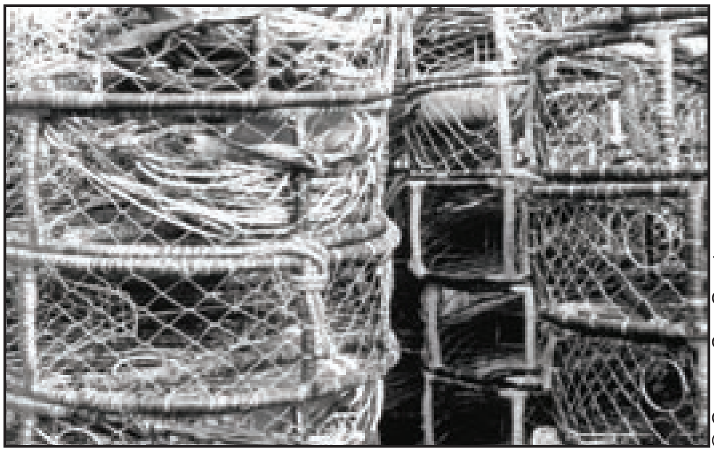
Box 11: PROMOTING LIFELONG OCEAN EDUCATION

The U.S. Commission on Ocean Policy recommends that "Congress should amend the NOPP Act to add a national ocean education office (Ocean.ED) with responsibility for strengthening ocean-related education and coordinating federal education efforts. Ocean.ED should:

- Develop a national strategy for enhancing education achievement in natural and social sciences and increasing ocean awareness, including promotion of programs that transcend the traditional mission boundaries of individual agencies;
- Develop a medium-term (five year) national plan for ocean-related K-12 and informal education, working with federal, state, and nongovernmental education entities;
- Coordinate and integrate all federal ocean-related education activities and investments; and
- Establish links among federal efforts, state and local education authorities, informal education facilities and programs, institutions of higher learning, and private-sector education initiatives, and strengthen existing partnerships.

The recommendations for education and public awareness made herein address these objectives.

Each goal will be addressed in parallel and in phases, with each phase building upon previous efforts. The first phase will assess IOOS workforce needs and establish a community of educators[15] whose work benefits from access to IOOS information (Figure 4). The second phase will focus on sustaining and expanding the community of educators by providing support services, professional development and learning resources, and working with the community to establish postsecondary curricula that address the workforce needs of the IOOS. The third phase will focus on expanding the IOOS allied workforce and postsecondary programs and credentials, and on expanding awareness of careers. The plan is based on recommendations from the Ocean.US *IOOS-COOS and Education Workshop*.[16]



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[15] Throughout, educator refers to practitioners in many disciplines and venues, including classroom teachers and education administrators in kindergarten through Grade 12; faculty members in Grades 13-18 at two and four year colleges; continuing education professionals; adult, basic-and-secondary education professionals; education and exhibit staff at natural and cultural history sites (parks, sanctuaries,reserves,seashores)andinformallearningcenters(aquariums,museums,coastallearningcenters,scienceandtechnologycenters);leadersandtrainersofyouthgrouppersonnel;scienceuppersonalel;scinece writers; and filmmakers.

[16] IOOS-COOS and Education Workshop, held March 22-24 in Charleston, SC. The report, currently in preparation, will be available on the Ocean.US website. Anticipated publication date: Winter 2004. <http://www.ocean.us>

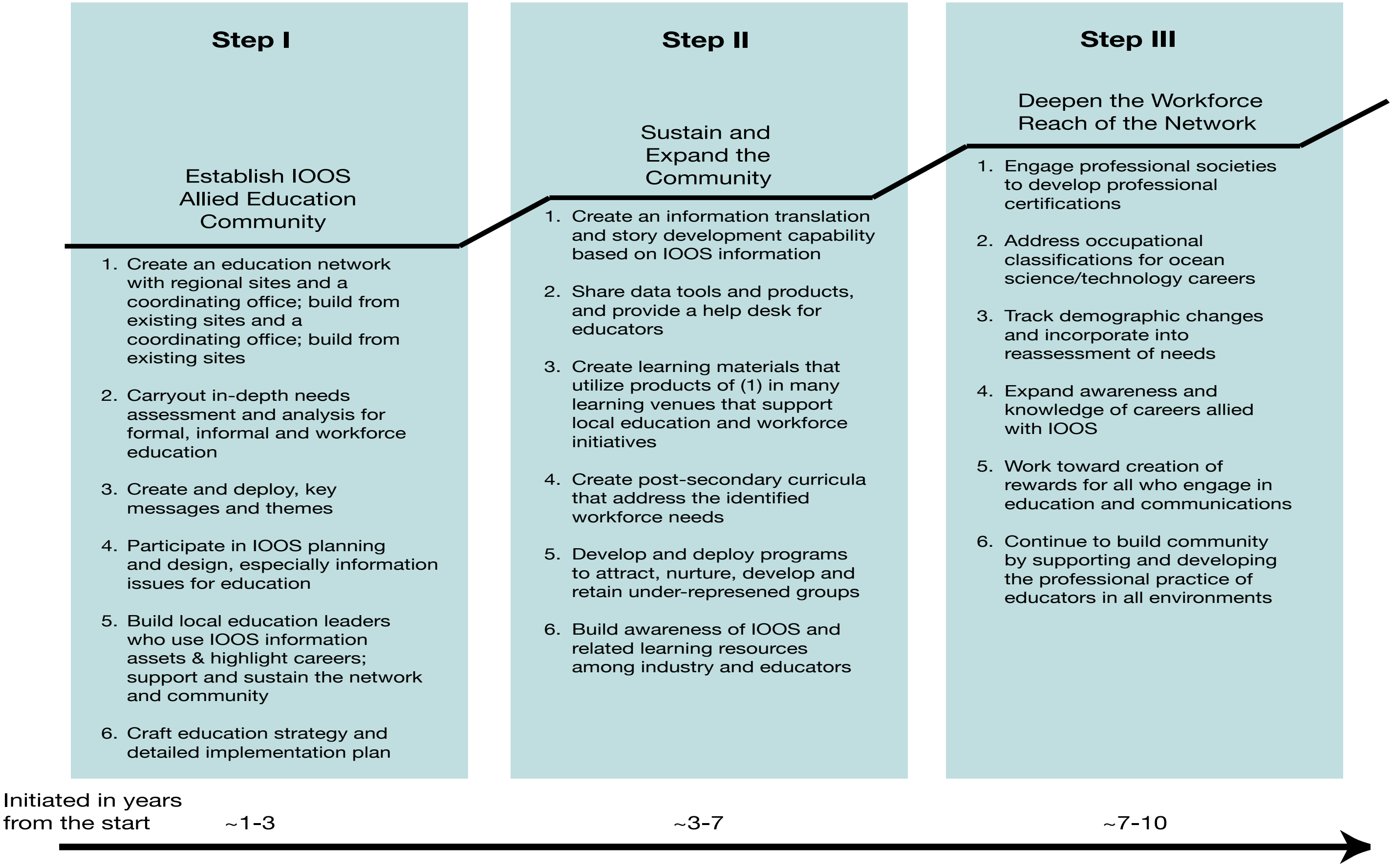

Figure 4. Functional Timeline for Development of Education Allied with IOOS.

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7.1 Establishing an Education Community that Uses IOOS Information, and Assessing Education and Workforce Needs Allied with IOOS

A community of educators who use IOOS information and influence its development will be created through the formation of a collaborative education network that is nationally coordinated. The network will be embedded within a larger geography and Earth/space system science education collaborative[17, 18]; it will tightly couple education to observing system assets and give education a reach far beyond the observing system itself (e.g., Box 12). Initial efforts will focus on establishing this community from existing education offices within nationwide education networks that have expressed interest in participation. Follow-on efforts will extend the reach of the network by embracing regional and state-based educator networks, as well as individual education programs.

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[17] Example education networks and efforts: NSF-NOAA-Navy/ONR Centers for Ocean Science Education Excellence (COSEE); NOAA Office of Education and Sustainable Development; NOAA Sea Grant; NOAA National Marine Sanctuary Program (NMSP); NOAA National Estuarine Research Reserves System (NERRS); NSF Digital Library for Earth System Education (DLESE); NASA Earth Explorers network; Geography networks–an alliance exists for each state, e.g., Kansas Geography Alliance; Space science network–NASA's Space Science Education and Public Outreach (E/PO) Support Network; Individual projects: EPA–Chesapeake Bay Program Education; NASA–Earth System Science Education Alliance; U.S. Navy–Neptune's Web at Commander, Naval Meteorological and Oceanography Command; NOAA–Office of Ocean Exploration, NOAA Teacher at Sea; NSF–Ocean Research Interactive Observatory Networks (ORION) education; USGS–regional professional training programs; and National Marine Educators Association–regional chapters.

[18] Ocean, coastal and aquatic sciences are a fundamental component of Earth system science (hydrosphere, geosphere, biosphere, atmosphere, and cryosphere)

Box 12: Making the Most of *Teachable Moments*

Within days of the 26 December 2004 Southeast Asia Indian Ocean Tsunami, educators and education organizations were capturing a *teachable moment.* Educators were using the event to introduce and deepen the knowledge and understanding of tsunamis - their causes, warning signs, and physical processes - by students, other educators, and adults. Websites all across the country were enriched with images, graphs, visualizations, and stories, and tsunami education "clearinghouse" sites were created. These sites offer resources of use to educators and are often contributed by educators from diverse arenas (classroom teachers, popular publications, educational television, museums, etc.).

<http://science.nsta.org/nstaexpress/nstaexpress_2004_01_10_tsunami.htm>

With the development of IOOS and the IOOS education community, best practice tsunami learning resources will exist, will be known, and will be used extensively within the Earth and space science education network in which the IOOS education network will be embedded. When a tsunami occurs, these resources will be rapidly updated with the latest images and visuals from the information translation and story development capability. For those learning materials that access *live* data, the tsunami data will be automatically available because it abides by the IOOS data management standards, guidelines, and protocols for these learning materials. In this way, these data will be immediately available to the students, teachers, informal educators, and the public who use these learning materials.

A national coordinating office will be established from existing education networks or programs. The office will foster collaboration across the network, provide a focal point for interaction with IOOS at the national level, and help guide the development of the IOOS-affiliated education network. In this capacity, the coordinating office will facilitate a broad-based audience needs assessment and analysis of formal and informal education audiences, with a focus on use of IOOS information assets. These findings will inform and guide the efforts outlined below. Once the IOOS education network is assembled, efforts will focus on building educatorleaders within the network who are experts in Earth/ocean system and technology[19] concepts. These educator-leaders will serve as expert resources for the broader collaborative Earth/geography/space system education network, helping to build capacity to use IOOS information assets (e.g., *in situ* and remote sensing, data streams, static data sets, visuals, career information), and to create and use IOOS-related learning resources. Thus, a community of educator-leaders will be established as a user of IOOS information, a resource for professional development of educators in their disciplines and local communities, and as catalysts for infusion of ocean/Earth system science into their discipline and community's education improvement initiatives at all levels. Many education and professional networks will ultimately participate in this network.[20]

In the workforce and postsecondary education areas, in addition to the community building efforts mentioned above, the primary effort in this initial phase is an in-depth needs assessment and analysis. The results of this study will guide future workforce and postsecondary efforts, and will enable a systematic and organized approach to planning and development efforts to ensure that they are coordinated and coherent. Articulation with formal, primary-and-secondary education, especially in mathematics and technology, is critical for technology, information technology, and engineering based careers. The workforce efforts will strive to match the supply of appropriately skilled professionals with the needs of the ocean observing community (*in situ* and satellite based observations, and information technology products, services, and tools).

In this initial phase, network members, guided by the national coordinating office, will develop a strategy and an implementation plan that focuses on establishing and achieving a set of measurable goals and objectives using strategic methodologies that embody IOOS design principles. The plan will prioritize and sequence the development of specific learning materials[21] and programs within and between the three traditional education areas.[22] This methodical approach makes possible a coordinated and coherent plan for creating and launching education products, and it supports local communities and the local education leadership in their education improvement initiatives.

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[19] Technology education implies a very broad range of subject matter that encompasses engineering (e.g., civil, electrical, electronic, hardware and software systems, acoustics, optical, etc.) and many related careers (e.g., computer science, information science, information systems, information analysis, materials science, etc.).

[20] All of those listed in Footnote 17 and the following: NASA's and NSF's Global Learning to Benefit the Environment (GLOBE); American Meteorological Society's DataStreme programs and Maury Project program; state Geography Alliances; National Association for Interpretation; Association of Science-Technology Centers, American Zoo & Aquarium Association, and National Marine Educators Association; NASA's Earth System Science Education for the 21st Century (ESSE-21), American Society of Civil Engineers—Coasts, Oceans, Ports, and Rivers Institute (COPRI), Institute for Electrical and Electronic Engineers (IEEE) Continuing Education Programs, IEEE Computer Society Education and Certification Programs, Association for Computing Machinery (ACM) Education Programs, and Marine Advanced Technology Education (MATE) Center.

[21] Learning materials/products, training materials/products, and learning resources — general terms for a wide array of *items* used for learning. These *items* range from individual graphs or animations with little or no associated contextual information, to 10,000 to 20,000 sq ft of museum floor space that contains an exhibit, to a robust website, to an entire curriculum that includes lessons, data sets and classroom ready experiments and tools that are deployed throughout an entire school district. Learning materials/products and training materials/products usually refer to materials that are ready for use by their intended audience, while learning resources usually refer to the individual pieces that are used to construct the final, audience-ready materials.

[22] The traditional education areas are formal primary, secondary, and adult-basic-and-secondary education; informal, self-directed learning; and workforce and postsecondary education.

7.2 Sustaining and Expanding the Community via Support Services, Professional Development, and Learning Resources

A prototype information translation and story development capability will be established as a community support service. Initially, this service will be modeled after that used by NASA. This effort will extend the NASA model by developing a streamlined methodology to identify and translate IOOS information into engaging stories and visuals for use by both education and communications professionals. This effort will also develop an effective process for education professionals to identify and acquire these materials. It is likely that this capability will be a joint IOOS and ORION venture since the ORION education community has recommended the formation of a similar capability.[23]

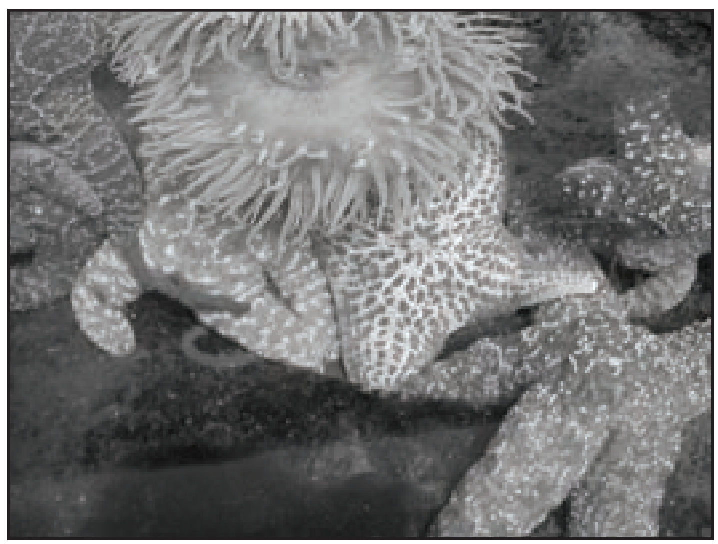
A clearinghouse for sharing of these story translations and visualizations, data, learning materials, and education tools will be established along with a helpdesk for assistance in accessing and using them. The Digital Library for Earth Systems Education (DLESE), an education community resource that provides a clearinghouse for educational resources and a variety of educational services, has committed to being a partner for these efforts and to help provide access to community data, tools, and learning products.

Initial formal and informal education efforts will address the gaps identified through audience needs assessment and analysis. Existing learning materials and programs will first be enhanced, followed by the development of new materials and programs where there are gaps in ocean/ Earth system and technology concepts, and where IOOS information makes a unique contribution. Materials produced through the information translation and story development capability will serve as a major source of content for these enhancements and additions.

At the postsecondary level, curricula will be developed and deployed that are aligned with the documented workforce needs. Industry innovators and professional organizations, representing current and future employers, will be encouraged to help shape the curricula within the documented needs. Members of the community and organizations will be key to developing and deploying these curricula materials.[24] During creation and enhancement of all learning materials, at all learning levels, and in all learning environments, special attention will be given to developing materials and programs that will attract, nurture, develop, and retain populations underrepresented in the science and technology workforce and in ocean careers specifically.

7.3 Expanding the Workforce and Postsecondary Community, and Developing Awareness of Careers

At this phase, education efforts will expand the workforce and postsecondary education area. Specifically, professional societies will be engaged to sponsor and develop, with others, professional certification programs for specific career areas[25] and to offer short courses in these areas. Once the demand for this workforce is established, efforts will be made with the U.S. Department of Labor to strive to develop and adopt occupational classifications that align with the developing ocean science and technology career fields. These changes will permit, for the first time, routine tracking of careers allied with ocean science and technology at the national level.[26] Demographic changes in the country will be tracked, and learning materials and programs will be adjusted, as needed, to address these changes in demography. Efforts to develop the awareness and knowledge of careers associated with IOOS will be improved and expanded, as will efforts that build community, support and develop the professional practice of educators, and infuse new content into learning programs and materials.



[23] Ocean Research Interactive Observatory Networks (ORION) Workshop, Jan 2004. San Juan, Puerto Rico. Report in preparation. Anticipated publication date, Fall 2004. <http://www.geoprose.com/draft_orion_rpt/>

[24] NASA's Earth System Science Education for the 21st Century (ESSE-21), American Society of Civil Engineers—Coasts, Oceans, Ports, and Rivers Institute (COPRI), Institute for Electrical and Electronic Engineers (IEEE) Continuing Education Programs, IEEE Computer Society Education and Certification Programs, Association for Computing Machinery (ACM) Education Programs, and Marine Advanced Technology Education (MATE) Center.

[25] Including for example: The Oceanography Society (TOS), Marine Technology Society (MTS), American Meteorological Society (AMS), Institute for Electrical and Electronic Engineers (IEEE), Association of Computing Machinery (ACM), America Society of Civil Engineers (ASCE), Marine Advanced Technology Education (MATE), all are active in this area and have a vested interest in certification programs

[26] Our current ability to project workforce needs (size, location, skills, supply, salary, etc.) for ocean science and technology careers is extremely limited because there are no occupational classifications for these careers and, therefore, they are not tracked in the national labor statistics.

Appendices

Appendix A

Historical Development of an Integrated Approach to Ocean Observations

International

1989
- Intergovernmental Oceanographic Commission (IOC) passes resolution to establish a Global Ocean Observing System (GOOS)

1991
- Under aegis of the IOC, the World Meteorological Organization (WMO), the United Nations Environment Programme, International Council for Science, GOOS Support Office and Development Plan begins
- Initial GOOS envisioned to consist of five modules regarding climate, marine services, pollution, living resources, and coastal zone management

1992
- United Nations Conference on Environment and Development (Earth Summit) endorses GOOS in its "Agenda 21"

1995
- Initial Strategic Plan completed for the climate module of GOOS

1997
- GOOS Steering Committee forms
- Marine services and climate requirements combine into one global module of GOOS

1998
- GOOS Prospectus published with strategic guidance, foundation, and framework articulated

1999
- First International Conference on the Global Climate Observing System (GCOS); Unified operational and long-term research needs; consensus on requirements for global module

2000
- Publication of Ocean Theme (document of the Integrated Global Observing Strategy partnership) defining ocean requirements for satellite observations and setting rolling review process
- Initial design plans completed for pollution, marine resources, and coastal modules of GOOS
- Three modules of GOOS (Health of the Oceans, Living Marine Resources, Coastal Zone Management) combined into one Coastal Module (Coastal Ocean Observations Panel)

2001
- Initial meeting of the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology; signals formal beginning of operational global oceanography

2002
- Strategic Design Plan completed by the Coastal Ocean Observations Panel for combined coastal module
- First Forum of GOOS Regional Alliances

2003
- Earth Observation Summit affirms the need for timely, quality, long-term, global information as a basis for sound decision-making; planning initiated for the Global Earth Observation System of Systems (GEOSS)

2004
- "Earth EKG," the second Earth Observation Summit, adopts framework for a ten-year implementation plan for the GEOSS

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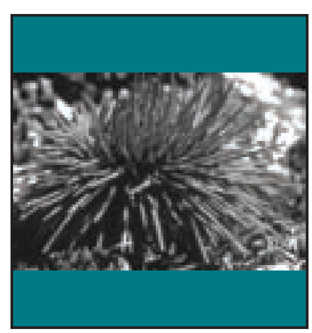

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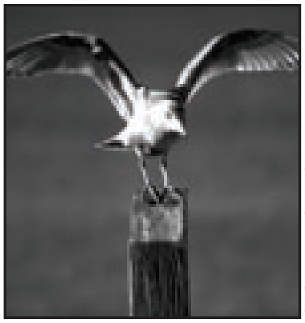
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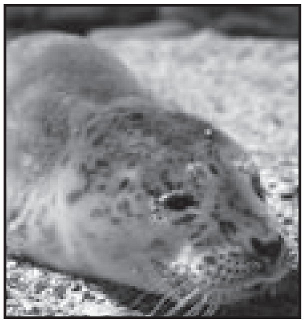
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National

1990
- First national meeting to consider the concept of a U.S. GOOS

1991
- Economic benefits studies of improved climate predictions begin

1992
- First U.S. GOOS Workshop and Report, “First Steps Toward a U.S. GOOS”

1993
- Interagency working group for U.S. GOOS forms

1995-1996
- National Oceanic and Atmospheric Administration’s Office of Global Programs begins preparation of an implementation plan for the U.S. contribution to the GOOS climate module

1997
- National Oceanographic Partnership Program (NOPP) is established by law

1998
- U.S. GOOS Steering Committee established; initiates assessment of users and products needed by U.S. regional coastal observing systems

1999
- First planning documents for U.S. GOOS by NOPP issued at the request of Congress (“Toward a U.S. Plan for an Integrated, Sustained Ocean Observing System” and “An Integrated Ocean Observing System: A Strategy for Implementing the First Steps of a U.S. Plan”)
- Workshop to begin the design of the coastal component of the U.S. GOOS (“An Ocean Observing System for U.S. Coastal Waters: First Steps”)

2000
- Ocean.US Office established; planning begins for development of a sustained and integrated ocean observing system for the U.S.

2001
- NOAA Ten-year Implementation Plan for Building a Sustained Ocean Observing System for Climate completed and reviewed

2002
- Ocean.US national workshop on U.S. Integrated Ocean Observing System (IOOS). Consensus reached on (1) vision for the system, (2) core elements to be federally supported, (3) need for an improved data and information management system, and (4) need for additional economic benefits studies
- “An Integrated and Sustained Ocean Observing System (IOOS) For the United States: Design and Implementation,” with an estimated first-year budget, submitted to Congress via NOPP and the Office of Science and Technology Policy
- Proceedings of the Ocean.US workshop published (“Building Consensus: Toward an Integrated and Sustained Ocean Observing System”)
- Planning for an integrated Data Management and Communications Subsystem initiated

2003
- Ocean.US Regional Summit develops recommendations for the structure and function of Regional Associations (RAs) to design, implement, and develop regional coastal ocean observing systems as part of the U.S. IOOS
- Resolution signed to establish a National Federation of Regional Associations (NFRA).

2004
- Ocean.US Regional Organizational Workshop develops recommendations for criteria for certifying regional groups as RAs and initiates a process to form the NFRA
- U.S. Commission on Ocean Policy Report recommends the establishment of the IOOS, with Ocean.US as the Integrated Planning Office.

Appendix B

Definitions

Coastal Ocean – For the purposes of the Integrated Ocean Observing System (IOOS), the coastal ocean encompasses (a) the region from head of tide to the seaward boundary of the U.S. Exclusive Economic Zone (EEZ), and (b) the Great Lakes.

Data Providers – Individuals or organizations that monitor the environment and supply the data required by user groups for applied or research purposes. This includes both research and operational communities from academia, private enterprise, government agencies, and non-governmental organizations (NGOs).

Data Users (User Groups) – Government agencies (local, state, and federal), private enterprise, the public at large, NGOs, and the science and education communities that use, benefit from, manage, or study ocean and coastal systems. User groups specify requirements for data and data-products and evaluate the IOOS performance.

Exclusive Economic Zone (EEZ) – An area beyond and adjacent to the territorial sea, subject to the legal regime established in Part V of the United Nations Convention on the Law of the Sea. This area shall not extend beyond 200 nautical miles from mean low water of the coastline from which the breadth of the territorial sea is measured. Within this zone, the coastal state has sovereign rights for the purposes of exploring and exploiting, conserving and managing natural resources, and other activities such as the production of energy from water, currents, and winds.

Global Earth Observation System of Systems (GEOSS) — The world-wide system of atmospheric, oceanic, and terrestrial observing systems integrated so as to monitor continuously the state of the Earth, to increase understanding of dynamic Earth processes, to enhance prediction of the Earth system, and to further implement environmental treaty obligations.

Global (Open) Ocean – The marine environment seaward of the shelf break front, including the deep basins of the world's oceans, where the influences of land-based processes are small compared to those of coastal waters. Boundaries between the open and coastal oceans are not fixed and will vary depending on the phenomena of interest (e.g., surface wave spectra, straddling fish stocks such as salmon and tuna, coastal eutrophication, and levels of enteric bacteria); one size does not fit all.

Integrated Global Observing Strategy (IGOS) – An international strategic planning process for the coordinated development of the Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). The IGOS is a collaboration involving United Nations Agencies (United Nations Educational, Scientific and Cultural Organization [UNESCO] and its Intergovernmental Oceanographic Commission [IOC], United Nations Environmental Program [UNEP], World Meteorological Organization [WMO], and Food and Agricultural Organization [FAO]), the Committee on Earth Observation Satellites (CEOS), integrated research programs on global change within the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP), the International Council for Science (ICSU), and the International Group of Funding Agencies for Global Change Research (IGFA).

Integrated Ocean Observing System (IOOS) – A system of systems that provides data and information on the state of the oceans from the global scale of ocean basins to local scales of coastal ecosystems. The IOOS consists of two closely linked components, a global ocean component and a coastal component. The latter includes both a national backbone for the nation's EEZ and Great Lakes, as well as regional coastal ocean observing systems (RCOOSs). Each component efficiently links three subsystems: (1) the observing subsystem (measurement and transmission of data); (2) the data management and communications subsystem ([DMAC],organizing, cataloging and disseminating data and information); and (3) the data analysis and modeling subsystem (translating data into products in response to user needs and requirements). The integrated system includes research and development projects (research, pilot, and pre-operational projects) upon which the development of the operational elements of the system depends.

Integrated System – As system that (1) efficiently links environmental observations, data management and communications, and data analysis and modeling (to form an "end-to-end" system); (2) provides rapid access to multi-disciplinary data from many sources; (3) serves data and information required to achieve multiple goals that historically have been the domain of separate agencies, offices, or programs; and (4) involves cross-cutting partnerships among federal and state agencies, the private sector, and academic institutions.

Lead Agency – Agency with primary responsibility for funding implementation, operation, evaluation, and improvement of designated elements of the IOOS, for interagency coordination, and for developing interagency collaboration as needed.

National Federation of Regional Associations (NFRA) – A nationally coordinated union of Regional Associations (RAs) formed to promote federal support for RCOOSs in U.S. coastal waters, to establish geographic boundaries as needed, to promote collaboration among regions (where boundaries overlap, to enable effective transfer of technologies and knowledge), to influence the development of the national backbone and global component of the IOOS, and to adopt and implement national standards and protocols for measurements and the transmission and management of data.

National Backbone – As part of the coastal component of the IOOS, the national backbone (a) consists of the three subsystems (observing and data telemetry, DMAC, data analysis and modeling) for observing and processing the core variables; (b) establishes reference and sentinel stations in the nation's EEZ and Great Lakes; and (c) adopts and implements national standards and protocols for measurements, data telemetry, DMAC, and modeling. Federal agencies are responsible for funding the backbone and for operating it in collaboration with RAs.

Operational – An activity in which the provision of data streams and data products of known quality is routine, guaranteed, and sustained (in perpetuity or until no longer needed) at rates and in forms specified by user groups.

Participating Agency – An agency that contributes to, takes part in, or partners with other agencies and organizations in funding, implementing, operating, and/or improving elements of the IOOS.

Phenomena of Interest – A broad spectrum of marine properties and processes that influence the Earth's climate, the safety and efficiency of maritime operations, the impact of natural hazards, national and homeland security, public health risks, the health of marine ecosystems, and the sustainability of living marine resources. These phenomena include surface waves and currents; sea level; coastal flooding and erosion; presence of human pathogens and chemical contamination; habitat modification and loss of biodiversity; harmful algal blooms and invasions of non-native species; mass mortalities of fish, mammals, and birds; declines in marine fisheries; and aquaculture practices. More rapid detection and timely predictions of changes in or the occurrence of these phenomena are required to achieve the seven goals of the IOOS.

Region – Regions are coastal areas where the IOOS is enhanced to address local priorities for data and information on marine and estuarine systems. RCOOSs are being established for the Great Lakes; the Gulfs of Alaska, Maine, and Mexico; the Southern California, Middle Atlantic and South Atlantic Bights; Central and Northern California; the Pacific Northwest; Hawaii; and the Caribbean. Boundaries between regions are fixed for the purposes of funding and accountability. However, it is recognized that many of the phenomena of interest will require transboundary observations that will require collaboration and coordination among Regional Associations.

Regional Association (RA) – A partnership or consortium responsible for the establishing, operating, and improving RCOOSs. RAs consists of representatives of stakeholder groups that (a) use, depend on, manage, or study oceans and coasts (including state and federal agencies, industries, NGOs, tribes and academia) and (b) specify data requirements and products. Stakeholders include both the users of IOOS data and IOOS data providers responsible for the design, implementation, operation, and improvement of a regional observing system. In many cases, the same groups will function as both data providers and users. There will be one RA for each RCOOS.

Regional Coastal Ocean Observing System (RCOOS) – A network of observations, DMAC, and data analysis and modeling that links the needs of users to observations of coastal marine and estuarine environments and the Great Lakes on regional scales. Establishing, operating, and improving RCOOSs are administered and managed by RAs. This role includes oversight and evaluation mechanisms to ensure the continued and routine flow of data and information, and the evolution of a system to meet the needs of user groups and respond to new technologies and understanding. RCOOSs are designed to contribute to and benefit from the national backbone by producing and disseminating ocean data and products that benefit the nation and user groups within the respective regions.

Regional Group - A team of stakeholders in a coastal region of the U.S., funded to develop an organization that meets the requirements for being certified as an RA.

Appendix C

Conceptual Design of the IOOS

Goals and Objectives

The IOOS is designed to provide the data and information required to address seven societal goals:

(1) Improve predictions of climate change and weather and their effects on coastal communities and the nation;
(2) Improve the safety and efficiency of maritime operations;
(3) More effectively mitigate the effects of natural hazards;
(4) Improve national and homeland security;
(5) Reduce public health risks;
(6) More effectively protect and restore healthy coastal ecosystems; and
(7) Enable the sustained use of ocean and coastal resources.

Addressing these goals depends on the capacity to rapidly determine current states of marine and estuarine systems, and to provide timely assessments and predictions of changes in these systems. This capacity requires observations and estimates (usually model calculations) of marine properties and processes, of interactions among coastal marine and estuarine ecosystems, and of exchanges across the land-sea boundary, the air-sea interface, and the boundary between shelf and deep-sea waters. Thus, the design of IOOS must consider the complex nature of marine systems and the propagation of change and variability across scales. The latter requires a hierarchy of observations, from global to local scales. To achieve this hierarchy, the IOOS consists of two closely related components: (1) a global ocean component, and (2) a coastal component. The latter is further broken down into a national backbone for the U.S. Exclusive Economic Zone (EEZ), Great Lakes, and regional coastal ocean observing systems (RCOOSs). The national backbone links changes that propagate across global and regional scales, provides observations and analyses required by all or most of the regions, establishes a sparse network of reference and sentinel stations (early detection of basin scale effects and the effects of land-based inputs), and implements national standards and protocols for measurements, data management and communications (DMAC) and modeling. RCOOSs contribute to the national backbone and enhance it based on stakeholder priorities in their respective regions.

Linking Observations to Applications

Achieving the objectives articulated above depends on the establishment of a system that routinely and continuously provides required data and information in forms and at rates specified by the users. Such an operational system must efficiently link (1) observations and data telemetry, (2) DMAC, and (3) data analysis and modeling. These three aspects are referred to as IOOS subsystems.

The observing (measurement, monitoring) subsystem consists of the infrastructure of platforms, sensors, sampling devices, and measurement techniques needed to measure variables on the time and space scales needed to detect and predict changes in coastal and open ocean environments. The DMAC subsystem (protocols and standards for quality assurance and control, data dissemination and exchange, archival, user access, provision of data in real-time and delayed mode) is the primary means of data integration that links observations to data analysis and applications. Modeling (including data assimilation), the primary means of synthesis and analysis, includes geographic information systems, statistical calculations, algorithms, risk analyses, and numerical analyses.

A major goal of the IOOS is to reduce the time required to acquire, process, and analyze data of known quality, and to tune the delivery rates of these data and information to the time scales required for environmental decision making. The DMAC subsystem will be developed for both real-time and delayed mode data, and it will allow users to rapidly exploit multiple data sets from many diverse sources. A hierarchy of local, regional, and national organizations will provide data, information, and access, as required by user groups.

Observations and modeling are mutually dependent processes, and the development of the fully integrated system will require an ongoing synergy between observations, advances in technology, and the formulation of predictive models. Models will play critical roles in the implementation, operation, and development of the observing system. They are important tools used to estimate quantities that are not observed directly with known certainty (i.e., predict past [hindcasts], present [nowcasts], and future [forecasts] states of coastal marine and estuarine systems and the errors associated with such predictions). A review of the current status of data analysis and modeling for marine services and natural hazards, living marine resources, public health, and ecosystem health shows the advanced state of modeling for marine services and natural hazards relative to those available for detecting and predicting changes in phenomena that require measurements of biological and chemical variables. This review underscores the importance of research for the development of both improved sensor technologies and models of ecosystem dynamics.

Appendix D

Resolution to Establish a National Federation of Regional Associations of Regional Coastal Ocean Observing Systems

Whereas the Congress and the National Ocean Research Leadership Council (NORLC) made the implementation of an integrated ocean and coastal observing system a high priority; and

Whereas the Congress has directed that a plan include the development of "integrated regional systems" as vital components of a national system; and

Whereas in the coming decade, a national, integrated ocean observing system (IOOS) will become operational, and information from this system will serve national needs for the following:

1. Detecting and forecasting oceanic components of climate variability;
2. Facilitating safe and efficient maritime operations;
3. Ensuring national security;
4. Managing resources for sustainable use;
5. Preserving and restoring healthy marine ecosystems;
6. Mitigating natural hazards;
7. Ensuring public health; and

Whereas the NORLC has asked the Ocean.US Office as the National Office for an Integrated and Sustained Ocean Observing System to draft an implementation plan for an IOOS that calls for a federation of regional coastal ocean observing systems (RCOOSs) with sustained funding; and

Whereas a significant number of observing efforts already exist in the coastal waters of the nation's ports, harbors, estuaries, continental shelf, and exclusive economic zone (EEZ), and these systems can add greatly to the goal of an IOOS; and

Whereas these systems that are in various stages of development from nascent to well established, in general, are not "integrated" in that frequently, they do not serve the multiple users or purposes called for by the NORLC, share standards and protocols, or address different spatial and temporal scales; and

Whereas it is in the vital interest of these regions to organize themselves in order to have a voice in the development of the rules and procedures that will govern a National Federation of Regional Associations (NFRA) of RCOOSs; and

Whereas it is in the vital interest of these systems to be prepared to effectively utilize funds that may be appropriated in the future as part of a national ocean observing system; and

Whereas these systems need continual evaluation and improvement to incorporate new methodology, technology, and requirements; and

Whereas it is appropriate to begin discussion of the responsibilities and benefits of establishing regional observing systems and participation in the NFRA,

Now, therefore, the undersigned parties resolve as follows: the undersigned Signatories hereby resolve to work together toward the establishment of an NFRA of RCOOSs to develop regional governance structures and foster national coordination; to work toward common data management standards; and to openly share data, metadata and related information

A. Purpose

a. To explore the cooperative steps necessary, within the respective region of each, to establish RAs that collectively will comprise an NFRA.
b. To collaborate with Ocean.US to establish an NFRA.

B. Definitions

a. The Coastal Ocean encompasses the region from head of tide to the seaward boundary of the U.S. EEZ, including the Great Lakes.
b. A Regional Coastal Ocean Observing System is a system designed to produce and disseminate ocean observations and related products deemed necessary to the users in a common manner and according to sound scientific practice. The system links the needs of users to measurements of the coastal oceans and the Great Lakes on a regional or sub-regional basis. Such a system requires a managed, interactive flow of data and information among three subsystems: (1) the observing subsystem (measurement and transmission of data); (2) the data management and communications subsystem (organizing, cataloging, and disseminating data and information); and (3) the data analysis and modeling subsystem (translating data into products in response to user needs and requirements). The RCOOS consists of the infrastructure and expertise required for each of these subsystems. It also includes oversight, evaluation, and evolution mechanisms that ensure the continued and routine flow of data and information, the evolution of a system that adapts to the needs of the user groups and to the development of new technologies and understanding.
c. A Regional Association is a partnership of information producers and users allied to manage coastal ocean observing systems within its region to the benefit of stakeholders and the public.
d. A National Federation of Regional Associations is the organization representing a nationally coordinated network of RAs.

C. Signatory Qualifications

The Signatories to this Resolution are strongly committed to the establishment of a sustained coastal observing system in the United States that includes regional observing systems.

D. Implementation

The Signatories resolve to:
1. Collaborate to establish the NFRA, foster national coordination, and build capacity nationally;
2. Develop governance structures for RCOOSs (RAs);
3. Participate in the formulation of national standards and protocols for data management and communications;
4. Advocate free and open sharing of data, metadata, and related information consistent with Ocean.US recommendations; and
5. Foster improved public awareness, involvement, and education.

E. Reservation of Authority

Nothing herein shall be construed in any way as limiting the authority of individual Signatories in carrying out their respective responsibilities.

Reference
Ocean.US. 2002: An Integrated and Sustained Ocean Observing System (IOOS) for the United States: Design and Implementation. Ocean.US, Arlington, VA, 21 pp.


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Appendix E

Resolution to Coordinate the Development of Regional Coastal Ocean Observing Systems as an Integral Part of the Integrated Ocean Observing System

Whereas the Congress and the National Ocean Research Leadership Council (NORLC) have made development of a sustained Integrated Ocean Observing Systems (IOOS) a high priority; and

Whereas the Congress has directed that the IOOS include the development of "integrated regional systems" as vital components of a national system; and

Whereas the NORLC has charged the Ocean.US Office to draft and annually update an implementation plan for an IOOS; and

Whereas user requirements for data and information on coastal marine and estuarine systems differ from region to region; and

Whereas it is in the vital interests of the nation for regional coastal ocean observing systems (RCOOSs) to develop in response to user requirements in a consistent and orderly manner in order to ensure efficient and timely access to data and information nationwide and satisfy the far-ranging user needs across the IOOS; and

Whereas the IOOS is a national effort requiring partnerships of federal and non-federal institutions and joint funding, and recognizing that the Ocean.US Office is an expression of the IOOS at the federal level, it is essential that regional interests be represented by an independent, non-federal body;

Therefore, the undersigned Signatories hereby resolve to work together to establish Regional Associations (RAs) that meet a specified set of common criteria and a National Federation of Regional Associations (NFRA) to represent RAs at the federal level and coordinate the nationwide development of RCOOSs that conform to IOOS design principles.

A. Purpose

1. To collaborate with Ocean.US in the formulation of criteria and procedures for certifying regional groups as RAs that are eligible for funding to design, implement, operate, and improve sustained RCOOSs as a part of the IOOS.
2. To recommend procedures and a timeline with milestones for the establishment of the NFRA.
3. To recommend the format and content of the annual reports by regional groups that are to be submitted to Ocean.US in May of each year.

B. Definitions

1. RAs design, operate, and improve RCOOSs. RAs:
    - Represent the interests of those that use, depend on, study, and manage coastal environments and their resources in a region;
    - Are legal entities that provide for a fiscal agent with final responsibility for acceptance and expenditure of funds according to the rules of grantors of the funds, insurability, and the ability to enter into enforceable contracts;
    - Are partnerships or consortia of data providers and users from state and federal agencies, private industry, non-governmental institutions, and academia;
    - Provide the means by which these bodies and the public at large benefit from and contribute to the development and sustained operation of an integrated ocean observing system for the open ocean and the nation's estuaries, Great Lakes, and U.S. Exclusive Economic Zone (EEZ); and
    - Ensure continued and routine flow of data and information and the evolution of RCOOSs that adapt to the needs of the user groups and the timely incorporation of new technologies and understanding based on these needs.

2. RCOOSs are designed, implemented, operated, and improved by RAs to provide data, information, and products on marine and estuarine systems deemed necessary to the users in a common manner and according to sound scientific practice. RCOOSs link the needs of users to measurements through a managed, interactive flow of data and information among three subsystems:

- Observations;
- Data management and communications (DMAC); and
- Data analysis and modeling.

RCOOSs consist of the infrastructure and expertise required for each of these subsystems.

3. The NFRA represents the interests of RAs and their members at the federal level and fosters the development of RCOOSs that conform to IOOS design principles.

4. The Interim Organizing Committee is an *ad hoc* committee established to:
    - Draft Terms of Reference, a Charter, and By-Laws of the NFRA;
    - Recommend categories of and requirements for membership in the NFRA;
    - Work with the Ocean Research Advisory Panel to recommend a process for certifying RAs and other important topics as they arise;
    - Implement procedures for the establishment of the NFRA; and
    - Function as an interim NFRA until a formal body has been established.

C. Signatory Qualifications

Workshop participants have extensive knowledge and experience in coastal ocean observing activities and use and depend on, manage, or study coastal marine and estuarine systems. Participants were drawn from the private sector, state, and federal agencies, non-governmental organizations, and academia. The Signatories to this Resolution are committed to the establishment of a national network of RAs and the NFRA as an integral part of IOOS.

D. Implementation

The Signatories resolve to:

- Collaborate to establish and participate in RAs, the NFRA, and an interim Organizing Committee that foster national coordination and build capacity nationally;
- Develop governance structures for RAs and the NFRA;
- Develop products that serve regional as well as multi-regional and national needs;
- Participate in the formulation and implementation of national standards and protocols for quality assurance/quality control and effective data management;
- Contribute to the design and implementation of an integrated DMAC subsystem that provides rapid, free, and open access to non-commercial and non-proprietary data, metadata, and related information; and
- Foster improved public awareness, involvement and education.

E. Reservation of Authority

Nothing herein shall be construed in any way as limiting the authority of individual Signatories in carrying out their respective responsibilities.

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Appendix F

Development of Regional Coastal Ocean Observing Systems as an Integral Part of the Integrated Ocean Observing System

1. Functions of Regional Associations

Regional coastal ocean observing systems (RCOOSs) are designed, implemented, operated, and improved by Regional Associations (RAs) to provide data, information, and products on marine and estuarine systems deemed necessary by user groups (stakeholders) in the region. An RA is a partnership or consortium of data providers and users[a] from both private and public sectors that use, depend on, study, and manage coastal environments and their resources in a region.[b] RAs oversee and manage the sustained operation of integrated[c] RCOOSs that provide data and information required to achieve one or more of the seven societal goals; establish geographic boundaries as described in section; obtain and disperse funds required to operate and improve regional observing systems; and ensure the timely provision of quality controlled data and information in forms specified by user groups. To qualify as an RA, regional groups must formulate governance and business plans that meet Ocean.US criteria and are approved by the National Ocean Research Leadership Council (NORLC).

There will be a fixed number of RCOOSs governed by an equal number of RAs (approximately ten nationwide), with one RA for each RCOOS. Within each RCOOS, there will be several observing system elements (including subregional observing systems), and it is the responsibility of the RA to ensure that (1) the RCOOS develops as an integrated system (not just a collection of elements), and (2) each observing system element is represented in the planning and operation of the RCOOS.

2. Functions of the National Federation of Regional Associations (NFRA)

The NFRA will coordinate the development of RAs; contribute to the formulation of national standards and protocols for the observing, data management and communications (DMAC), and data analysis and modeling subsystems; and represent RAs in the formulation of IOOS planning documents at the federal level (including but not limited to the *Annual IOOS Development Plan*). A charter, terms of reference and by-laws for the NFRA are currently being formulated by an interim Organizing Committee which will also perform the functions of the NFRA until such body is established.

The NFRA will include representatives from all RAs and will perform the following functions:

- Promote funding for and the establishment of sustainable RAs and sustainable RCOOSs nationwide;
- Enable effective communications between federal agencies and RAs;
- Work with RAs to establish geographic boundaries as needed;
- Provide a forum to promote regional and international collaboration among regions (e.g., to enable effective transfer of technologies and knowledge);
- Guide the development of a national backbone that meets regional needs;
- Work with federal agencies to develop national standards and protocols for measurements and DMAC; and
- Promote implementation of national standards and protocols.

3. Development of Regional Associations and Creation of the NFRA

During FY 04, regional groups were competitively funded to develop organizations intended to qualify as IOOS RAs. Under the guidance of Ocean.US, regional groups agreed to meet certain criteria for certification and have formed an interim NFRA Organizing Committee that will perform the functions previously described and formulate terms of reference, a charter, and bylaws for the NFRA. Once certified RAs are in place, the NFRA will be formally established.

The establishment of sustainable RAs requires (1) that operations be credible and accountable, (2) the establishment of a diverse base of user groups that depends on IOOS data and information to achieve their missions and goals, (3) development and maintenance of diverse revenue streams, (4) development and implementation of performance metrics, (5) involvement of both data providers and users in assessments of performance and improvements of the IOOS, and (6) the use of IOOS data and information for science education and outreach for a more informed public. To ensure that these requirements are met, regional groups must be formally certified to become an official RA. To be certified, regional groups must formulate governance and business plans for a regional body that are endorsed by regional stakeholders, are approved by the Ocean.US Executive Committee (EXCOM), and can deliver an integrated and sustained system that will provide data and information on oceans and coasts required by user groups in the region by incorporating, enhancing, and supplementing existing infrastructure and expertise in the region. The governance of an RA must be designed to perform the following functions:

- Engage in legally binding agreements and assume the fiscal authority to receive and disperse funds;
- Ensure accountability for such agreements and revenue streams;
- Add and remove members to ensure that the interests of a diversity of data providers and user groups in the region are represented and actively participate in the RA;
- Establish a governing board to oversee the development and operation of a the RA and an RCOOS that functions in accordance with IOOS principles;[d]
- Establish a panel to advise the governing board on issues concerning user needs and applications of IOOS data and information; and
- Develop education and public outreach programs to ensure effective use of IOOS data and information for science education and public outreach.

The business plan must clearly articulate the following:

- Goals and objectives based on regional priorities and consistent with the seven societal goals of the IOOS;
- Benefits of and procedures for product development and marketing that are related explicitly to goals and objectives;
- Plans for obtaining, sustaining, and diversifying revenues for system design, implementation, operation, and improvement, including the process by which the regional body will engage in the Ocean.US planning cycle;
- Plans for operationally and efficiently linking the three subsystems of the IOOS to the provision of data and information specified by user groups in the region;
- Procedures for establishing research priorities and for transitioning observing system elements from research to the operational system; and
- Procedures for assessing system performance in terms of operational continuity and user satisfaction.

It is expected that roughly two years will be needed to become eligible for certification as an RA through the formulation of stakeholder-endorsed governance and business plans. Ocean.US will oversee the certification process and recommend groups to be certified to the EXCOM for approval on behalf of the NORLC. The certification of all RAs will be reviewed at five-year intervals, and it will be renewed based on the previously described criteria, as well as progress toward meeting regional goals and objectives established by stakeholders in the region.

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4. Regional Boundaries and Collaboration

Regional boundaries will be both fixed and flexible as follows:

- For purposes of administration, funding, and accountability, fixed geographic boundaries between regions will be needed[b];
- For purposes of detection and prediction, boundaries will vary depending on the space scale of the phenomena of interest, and they will often transcend fixed geographic boundaries.

Clearly, RAs must collaborate with each other and adjacent countries (e.g., Canada, Mexico, and countries of the Caribbean) to address those problems that transcend fixed geographic boundaries. For example, the goal of developing ecosystem-based, adaptive management practices for fisheries management (and for environmental protection) requires a regional approach such as the Large Marine Ecosystems program. This will be important especially in research and pilot project stages where a particular species can be targeted and used to specify requirements for spatial boundaries, variables to measure, and the time-space resolution of estimated fields. Such an approach also provides an important mechanism for fisheries managers (in this example) to partner with RAs via fishery management councils and fisheries research laboratories.

5. Funding

The long-term sustainability of RAs is critical to the success of the IOOS. This sustainability will require creativity and flexibility as this new enterprise becomes established. Successful development depends on the establishment of a diversity of funding streams from both public and private sectors, and Ocean.US is working with federal agencies to establish support mechanisms. Once funded, RAs must be nurtured to success, and the mechanism(s) and criteria for RA certification must be met as one requirement for sustained funding.

Appendix G

Resolution to Establish a National Education Network Associated with the Integrated and Sustained Ocean Observing System to Improve Ocean and Coastal Science Education

Whereas the Congress and the National Ocean Research Leadership Council (NORLC) have made development of the Integrated Ocean Observing System (IOOS) a high priority; and

Whereas the Congress has directed that the IOOS include the development of an "integrated regional system" (i.e., National Federation of Regional Associations [NFRA]) as a vital component of a national system; and

Whereas the Congressionally-established National Oceanographic Partnership Program (NOPP) has been directed to establish an effective National Strategy to strengthen science education and communication in the United States through improved knowledge of the ocean and the coasts; and

Whereas the NOPP partners have been directed to establish a partnership between federal agencies, academia, industry, and the private sector to improve ocean literacy, outreach, and science education; and

Whereas the NOPP partners have been directed to ensure that effective use of the ocean and coastal data obtained by the IOOS be used to improve ocean literary and strengthen science and technology education; and

Whereas Earth system including ocean and aquatic science education networks already exist at the local, state, and national level, these networks can add greatly to the goal of a national education network associated with the IOOS; and

Whereas it is in the vital interests of the nation that the IOOS infrastructure be viewed as a valuable resource for ocean and coastal science and technology education;

Therefore, the undersigned Signatories hereby resolve to work together to establish a national education network that will further the national objectives in science and technology education using the IOOS infrastructure and the Earth system themes associated with the ocean, coasts, and inland seas.

A. Purpose

Collaborate with Ocean.US to initiate a national education network integral to IOOS.

B. Signatory Qualifications

Workshop participants have extensive knowledge and experience in ocean observatories and science education
efforts. Participants were drawn from state and federal agencies, non-governmental organizations, and academia.
The Signatories to this Resolution are committed to the establishment of a national education network to support the
IOOS.

C. Implementation

The Signatories resolve to:

- Collaborate to form an education network to further the national objectives in science and technology education using the ocean and IOOS infrastructure as the uniting elements;
- Participate in the development of education recommendations and strategies to be incorporated into the planning of the IOOS; and
- Advocate participation of IOOS members in science and technology education.

D. Reservation of Authority

Nothing herein shall be construed in any way as limiting the authority of individual Signatories in carrying out their respective responsibilities or committing the home institution of individual Signatories to any action.

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Appendix H

Acronyms

ACT............. Alliance for Coastal Technologies
ADCP.......... Acoustic Doppler Current Profiler
ALPS........... Autonomous Lagrangian Platforms and Sensors
ATM .... Airborne Topographic Mapper
CHARTS ..... Compact Hydrographic Airborne Rapid Total Survey
C-MAN……... Coastal Marine Automated Network
CSC……… . Coastal Services Center
CTD .... Conductivity-temperature-depth
DART .... Deep-ocean Assessment and Reporting of Tsunamis
DMAC…….. Data Management and Communications
DMAC-SC... Data Management and Communications-Steering Committee
DSC .... Digital Switched Calling
EEZ............. Exclusive Economic Zone
ENSO……. . El Niño-Southern Oscillation
EPA……… .. Environmental Protection Agency
EXCOM....... Executive Committee
FGDC……. . Federal Geographic Data Committee
FOFC .... Federal Oceanographic Facilities Committee
FY…………. Fiscal Year
GCMD .... Global Change Master Directory
GCOS……. . Global Climate Observing System
GEOSS…… Global Earth Observation System of Systems
GIS………... Geographic Information System
GODAE….. . Global Ocean Data Assimilation Experiment
GOES.......... Geostationary Operational Environmental Satellite
GOOS .... Global Ocean Observing System
GPS .... Global Positioning System
GTS……….. Global Telecommunication System
HAB .... Harmful Algal Bloom
HF .... High Frequency
ICSU……... International Council for Science
IGOS........... Integrated Global Observing Strategy
IOC……… .. Intergovernmental Oceanographic Commission
IODE……. .. International Oceanographic Data and Information Exchange
IOOS........... Integrated Ocean Observing System
IOWG.......... Implementation Oversight Working Group
IT................. Information Technology
JALBTCX .... Joint Airborne LIDAR Bathymetry Technical Center of Expertise
JCOMM…. . Joint Technical Commission for Oceanography and Marine Meteorology
LIDAR .... Light Detection and Ranging
LMR............ Living Marine Resources
LOS……….. Line-of-Sight
MMS………. Minerals Management Service
MODIS….. . Moderate Resolution Imaging Spectroradiometer
NASA……… National Aeronautics and Space Administration
NASQAN…. National Stream Quality Accounting Network
NCDDC…… National Coastal Data Development Center
NDBC…… .. National Data Buoy Center
NERRS……. National Estuarine Research Reserves System
NESDIS…. . National Environmental Satellite, Data and Information Service
NFRA .... National Federation of Regional Associations
NGO .... Non-Governmental Organization

NMFS……. .. National Marine Fisheries Service
NOAA.......... National Oceanic and Atmospheric Administration
NOPP.......... National Oceanographic Partnership Program
NORLC .... National Ocean Research Leadership Council
NOS .... National Ocean Service
NPDES........ National Pollutant Discharge Elimination System
NPOESS ..... National Polar-orbiting Operational Environmental Satellite System
NRC............ National Research Council
NSF……….. National Science Foundation
NSIP……... . National Streamflow Information Program
NWLON…... National Water Level Observation Network
OBIS………. Ocean Biogeographic Information System
OMB……… .. Office of Management and Budget
ONR……..... Office of Naval Research
OOI .... Ocean Observatories Initiative
OPeNDAP.. . Open Source Project for a Network Data Access Protocol
ORAP.......... Ocean Research Advisory Panel
ORION……. Ocean Research Interactive Observatory Networks
OSSE……... Observing System Stimulation Experiments
OSTM…….. . Ocean Surface Topography Mission
OSTP……... Office of Science and Technology Policy
OTH .... Over-the-horizon
PDAQC .... Primary Data Assembly and Quality Control
POES……... Polar Operational Environmental Satellite
PORTS®…… Physical Oceanographic Real-Time System
QC…… .... Quality Control
RA............... Regional Association
RCOOS…… . Regional Coastal Ocean Observing System
SAR .... Synthetic Aperture Radar
SOOP .... Ships-of-Opportunity
SSH .... Sea surface height
SST............. Sea surface temperature
UN………..... United Nations
UNEP……... UN Environmental Programme
UNESCO…. UN Educational, Scientific and Cultural Organization
USACE…… United States Army Corps of Engineers
USCG…….. United States Coast Guard
USGS…….. United States Geological Survey
WHOI……… Woods Hole Oceanographic Institute
WMO……… . World Meteorological Organization