The Integrated Ocean Observing System, the Global Ocean Observing System, and the Global Earth Observation 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 Oceans, and of the National Oceanographic Partnership Program's Interagency Working Group, 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 and territorial sea[3], Great Lakes, and semi-enclosed bodies of water and tidal wetlands connected to the coastal ocean.

The IOOS is the U.S. contribution to the Global Ocean Observing System (GOOS) and the Global Earth Observation System of Systems (GEOSS). GOOS, an initiative of the Intergovernmental Oceanographic Commission, is being designed and implemented to meet the requirements of international agreements and conventions to which the U.S. is a signatory. 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 July 31, 2003, when the U.S. hosted the Earth Observation Summit. Thirty nations agreed to a declaration affirming the need to support the following:

- 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 (to be completed for the ministerial conference hosted by the European Union in early 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.

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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>

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 Appendix C describes the conceptual design of the IOOS. The conceptual design is based on recommendations by groups of experts that culminated in the NORLC Report to Congress in 2002.[4]

The First Annual IOOS Implementation Conference[5]

Ocean.US completed a preliminary *Annual IOOS Development Plan* for the initial IOOS in early August 2004. Because the plan must reflect both federal and shared regional priorities, the First Annual IOOS Implementation Conference was designed to provide a forum for the leaders of nascent Regional Associations (RAs) of coastal ocean observing systems to work directly with participating federal agencies to provide guidance for completing the *First Annual IOOS Development Plan.* By consensus, conferees made the following recommendations:

- Continue to implement and strengthen current plans for the global ocean component of the IOOS;
- Implement immediately the plan for developing the DMAC subsystem of the IOOS;
- Establish and adequately fund RAs and the National Federation of Regional Associations; and
- Implement selected coastal ocean data assimilation experiments as pilot projects to 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 the national backbone recommended in the preliminary *IOOS Development Plan* and integrate these into an interoperable system; and
- Sustain the current investment in coastal ocean observing systems.

However, given the large number of options and limited time, a consensus was not achieved on a focused set of priorities for the observing subsystem of the coastal component of the IOOS. A set of high pay-off activities was recommended that, if undertaken, would enable the effective development of a fully integrated system.

Participants further identified important aspects of IOOS development that should be addressed by groups of experts before the recommendations for developing the observing subsystem in Part III of the *First Annual IOOS Development Plan* can be implemented. Of particular importance are the development of DMAC for system integration and the creation of an education network. These issues will be addressed at the Second Annual IOOS Implementation Conference, to be held in May 2005.

This document, the *First Annual IOOS Development Plan*, incorporates the consensus recommendations of the conferees. Recommendations received during a one-month public comment period (15 October through 15 November 2004) announced in the *Federal Register* were used to complete the Plan; it was submitted to the Ocean.US Executive Committee in December 2004 for approval and transmission to the NORLC. This Plan, which will be revised and updated annually following each Annual IOOS Implementation Conference, 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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[4] "An Integrated and Sustained Ocean Observing System (IOOS) for the United States: Design and Implementation" <http://www.ocean.us/documents/docs/FINAL-ImpPlan-NORLC.pdf>

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

Goals

The Integrated Ocean Observing System (IOOS) efficiently links observations to modeling 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.

The *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.

Subsystems

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, natural hazards, and human activities on oceans and coasts.

(1) The **coastal component** is designed to detect, assess, and predict the effects of weather, climate, natural hazards, 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 ecosystem health and living resources.

(2) The **global ocean component**, the U.S. contribution to the Global Ocean Observing System (GOOS), 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.

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. The integrated system (1) efficiently links the data and

information requirements of many user groups to data acquisition, processing, and modeling; (2) provides multi-disciplinary data and information from *in situ* and remote sensing; (3) fosters synergy between research and the development of operational capabilities; (4) transcends institutional boundaries; and (5) improves public understanding of the oceans and changes occurring in them, through sustained communications and education programs. The IOOS makes more effective use of the collective resources of the U.S. and leverages them to establish a fully integrated system that addresses all seven societal goals.

Implementing and sustaining the global component and the national backbone are federal responsibilities in terms of both funding and implementation. Establishing the **national backbone** achieves economies of scale by measuring, managing, and analyzing a set of core variables needed by all or most regions. The national backbone also makes ecosystem-based management possible by (1) extending global scale remote sensing into the coastal environment, and (2) establishing a network of sentinel stations. Both capabilities are needed for early detection of the effects of basin scale events such as El Niño, and of the effects of inputs from coastal drainage basins.

Regional Associations (RAs) represent the interests of groups that use, depend on, manage, monitor, and study marine systems. 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 regional coastal ocean observing systems (RCOOSs) that conform to IOOS design principles (Part I). With predominantly federal funding, RAs oversee the development of RCOOSs that contribute to and enhance the national backbone by increasing the time-space resolution of observations and the number of variables measured and analyzed; these activities are based on priorities for data and information determined by user groups in their respective regions.

From Research to an Operational IOOS

The initial system recommended in this *First Annual IOOS Development Plan* is an important first step toward the phased development of the IOOS. 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 mission-driven research, pilot, and pre-operational projects (Part I). Transition from pilot project testing and evaluation to pre-operational status is a major step, and it is the joint responsibility of both research and operational communities. Final decisions concerning this transition must be made by the agency or body that will fund the new operational capability.

Developing the IOOS

The focus of this *IOOS Development Plan* is on continued implementation of the global component, establishment of RAs and RCOOSs, and implementation of the initial national backbone with an emphasis on DMAC. The Plan is presented in three parts: (I) Structure and Governance, (II) Integrating Existing Assets, and (III) Improving the Initial IOOS through Enhancements and Research. The Plan provides a framework and guidelines for the development of RAs and RCOOSs, but it does not prescribe the 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 assets should be used to build RCOOSs. These decisions are the responsibilities of the RAs. Federal funding of RAs is contingent upon the ability of regional groups to formulate governance and business plans that adhere to Ocean.US specifications, as well as the ability to achieve the goals and objectives articulated therein.

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; describes the roles of RAs and a National Federation of Regional Associations in the development of the coastal component; and begins the process of establishing performance metrics.

Under the oversight of the National Ocean Research Leadership Council, Ocean.US prepares and annually updates the integrated development plan (*Annual IOOS Development Plan*). Participating government agencies and RAs implement those elements of the IOOS that are mutually beneficial and consistent with their missions, goals, and priorities. The entire process is orchestrated through a four-year planning cycle that is synchronized with the planning and budgeting cycles of federal agencies. Recognizing the need for IOOS activities to be integrated, Ocean.US prepares a multi-agency budget cross-cut based on information and guidelines provided by participating federal agencies.

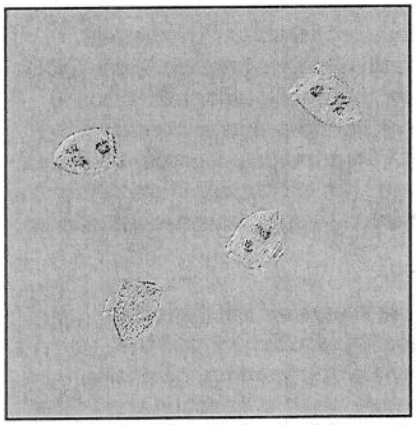
Part II: Fiscal Years 2005-2006 - Integrating Existing Assets recommends the establishment of an initial IOOS that (1) integrates existing operational observing subsystem assets of federal agencies through the development of the DMAC subsystem, (2) enables the development of RAs, and (3) begins the process of engaging groups that use, depend on, manage, and study oceans and coasts in the development of the IOOS.

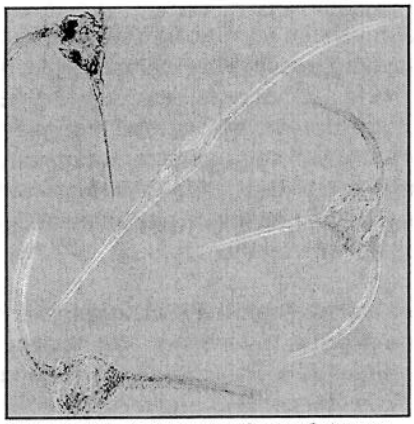
The initial IOOS is a first step in developing a fully integrated system that addresses all seven goals. Together, programs recommended for the initial system provide data and information needed to improve the nation's capabilities to engage in ecosystem-based management, assess current states of oceans and coasts, and to more rapidly detect and predict changes in them. The initial focus is on integrating programs that document changes in:

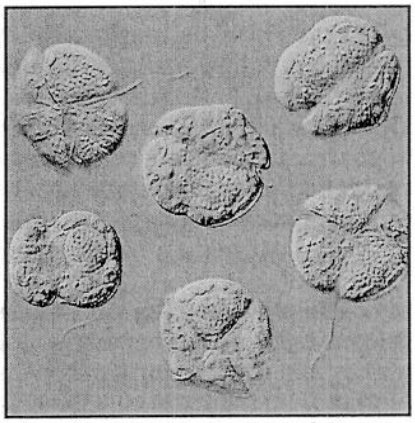
- Water level (from tides and coastal flooding due to tsunamis and storm surges to sea level rise);
- Ocean storage and global transport of carbon, heat, and fresh water;
- Air-sea exchange of heat and freshwater;
- Extent and condition of pelagic and benthic environments;
- Abundance and distribution of living marine resources (including protected species); and
- Freshwater flows and associated fluxes of sediments, nutrients, and contaminants from coastal drainage basins into coastal waters.

Federal agencies are responsible for implementing the global component and the national backbone of the coastal component. Specific agencies are designated as the lead, co-lead, or a partner for administration, DMAC, research, operations, education, and assessment.

Part III: Improving the IOOS Through Enhancements and Research recommends enhancements and priority pilot projects needed to improve the initial IOOS in the longer term (decadal time scale). Recommended improvements 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; physical-biogeochemical-trophic interaction). In this context, high priority is placed on the following:







Executive

- Sustaining satellite-based observations and increasing time, space, and spectral resolution for coastal applications;
- Increasing the spatial and temporal resolution of near-surface meteorological observations in coastal waters;
- Increasing the number of harbors and estuaries equipped with Physical Oceanographic Real-Time Systems (PORTS®) and increase the number and sensing capabilities of the tide gauge network (National Water Level Observation Network, or NWLON);
- Increasing the spatial and temporal resolution estimates of surface waves and current fields in coastal waters (including enhancements to the Deep-ocean Assessment and Reporting of Tsunamis [DART] mooring network in the Pacific and its expansion into the Caribbean and Atlantic basins);
- Routinely providing maps of shoreline position and bathymetry-topography across the land-sea interface (from 30m below to 30m above mean low water);
- Routinely providing maps of the distribution and condition of benthic habitats that support living marine resources; and
- Developing the capability to routinely provide estimates of the distributions of temperature, salinity, dissolved inorganic nutrients, dissolved oxygen, chlorophyll-*a*, zooplankton, and fish populations in near-real time.

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. ***Over the next two to three years, the IOOS must transition into a system that engages a broader spectrum of data providers and users in the development of an IOOS that meets the collective needs of groups that use, depend on, manage, and study oceans and coasts.*** 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 *First Annual 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 all user groups in their respective regions and are responsible for the design, implementation, operation, and improvement of RCOOSs.

As the IOOS develops, it will become a valuable teaching tool, and the need for a skilled workforce to develop and sustain the IOOS will grow. Thus, Ocean.US is working with participating federal agencies and nascent RAs to (1) develop and sustain a network of educators that use data and information from the IOOS and other sources to achieve their objectives, and (2) create the workforce needed to operate and improve the initial IOOS over time.

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]

(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]

Note that throughout this document, the term "coastal" refers to the nation's Exclusive Economic Zone (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.

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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>