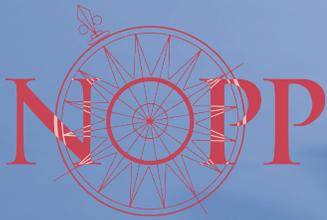


IOOS DEVELOPMENT PLAN ADDENDUM
ARLINGTON, VIRGINIA
2006



National
Oceanographic
Partnership
Program

FIRST INTEGRATED OCEAN OBSERVING SYSTEM (IOOS) DEVELOPMENT PLAN ADDENDUM



The National Office for
Integrated and Sustained Ocean Observations
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PREFACE

Over a dozen federal agencies or departments currently have environmental observing programs which include ocean and coastal measurements tailored to fulfill their specific missions and goals. Each of these agencies and departments includes within its budget requests for funding the sustaining of the operations of these important mission-specific observing programs into the future.

The President's Commission on Ocean Policy and the Administration's *Ocean Action Plan* recognize the importance of integrating much of the data and information generated across these programs and agencies to more effectively and efficiently address social, economic and political issues. Recent events such as Hurricane Katrina and the Indian Ocean tsunami underscore the immediate and growing need for a more integrated approach. To this end, the federal government had the foresight to call for the creation of an Integrated and sustained Ocean and coasts Observing System (IOOS) that will enable data streams generated by each agency, department and program to be used for multiple purposes depending on data and information requirements of decision makers from both public and private sectors – in effect, a value added process of “multiple use.” As data integration moves forward, gaps in observing system capabilities, from measurements to data management and modeling, will be identified and addressed. This is the most cost-effective way to make better use of existing infrastructure, avoid unnecessary duplication, and improve the quality and timeliness of data collection, analysis and dissemination.

Such an innovative “information assembly” approach requires a system of systems* that cross-cuts agencies, departments and programs, an approach that can be implemented only through new approaches to financing. Clearly, each agency must sustain long term support for those assets needed to achieve its missions and goals. What is new is the need to finance integration to build a “system of systems” that makes the most effective use of existing assets and new technologies as they come on line. This requires new federal investments in information technology (IT) infrastructure that enables integration of data streams from existing and new assets. This *IOOS Development Plan Addendum* describes a new approach to data management, communications and modeling that links global, national and regional elements and can be used to nowcast and forecast the combined local effects of larger scale changes occurring in the oceans and on land. Needed are effective mechanisms to finance planning, architectural design studies and the coordination necessary to make diverse data streams interoperable and networked.

* The IOOS is a “system of systems” in that it efficiently links applications to multi-disciplinary, multi-scale observational systems (operated by many different groups) via data management and modeling systems (also operated by different groups) to satisfy local, regional and national needs.

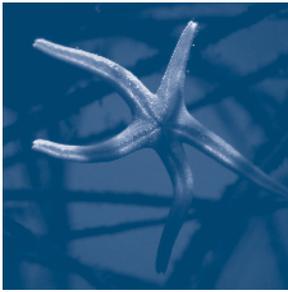


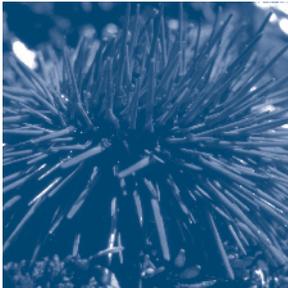
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Executive Summary

Background

The U.S. Integrated Ocean Observing System (IOOS) is being established to routinely, reliably and continuously acquire and disseminate data and information on past, present, and future states of the oceans, the nation's coastal waters and Great Lakes. The IOOS consists of two interdependent components: (1) a *global ocean component* concerned primarily with large scale global climate change and maritime operations; and (2) a *coastal component* concerned primarily with improving homeland security and the impacts of climate change, natural hazards (extreme weather, tsunamis) and human activities on coastal maritime operations, public health, ecosystems and living marine resources (where "coastal" refers to the nation's Exclusive Economic Zone [EEZ], Territorial Waters, Great Lakes, and estuaries). The coastal component can further be broken down into a National Backbone (NB) and Regional Coastal Ocean Observing Systems (RCOOSs). The global ocean component and the NB are the suite of observing subsystem elements that monitor core variables in the nation's EEZ and Great Lakes, make *in situ* measurements at a network of sentinel stations, transmit data on core variables to a national data assembly center, and link larger scale changes occurring in the ocean and on land to changes occurring in coastal waters locally and regionally. RCOOSs increase the resolution of observations and the number of variables measured based on data and information requirements of user groups in each region.

IOOS implementation is guided by *IOOS Development Plan* updates, which are "living" documents prepared as needed by Ocean.US. Through international collaboration, plans for the observing subsystem of the global ocean-climate component are in place, and implementation has begun. In contrast, the coastal component of the IOOS is in the early stages of design and implementation. Thus, *The First U.S. Integrated Ocean Observing System (IOOS) Development Plan*^A (referred to as the *First IOOS Development Plan*) summarized plans for the global component of the IOOS, identified programs for incorporation in the initial NB, recommended the formation of Regional Associations (RAs) to oversee implementation of RCOOSs, and provided road maps for implementing the Data Management and Communications (DMAC) subsystem for the IOOS and for linking ocean education and training to IOOS development.

The *First IOOS Development Plan* was based on recommendations from national workshops conducted by Ocean.US during 2002-2004.[†] Since completion

of the first development plan in 2004 following the First IOOS Implementation Conference,^A the Second IOOS Implementation Conference was held and five important reports were released by various bodies: (1) *An Ocean Blueprint for the 21st Century*, (2) the President's *Ocean Action Plan*, (3) *Framing the Grand Challenges: A Vision for Federal Disaster Reduction*, (4) the *Strategic Plan for the U.S. Integrated Earth Observation System (IEOS)*, and (5) the *Ocean.US Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive*. This *IOOS Development Plan Addendum*, focuses the first plan based on recommendations from the Conference and these reports for the following purposes:

- Revise the *First IOOS Development Plan* in response to the Ocean Action Plan (**Part I**).
- Prioritize recommendations in the *First IOOS Development Plan* by focusing on a data management-driven plan for integrating existing observing subsystem assets needed for improved prediction and mitigation of coastal inundation and by recommending priorities for improving the skill of model predictions; initiate phased implementation of the DMAC and Education plans (**Part II**).
- Improve the observing subsystem recommended in Part II through research and the incorporation of additional existing assets, continue phased implementation of the DMAC and Education Plans, and recommend the way forward for developing operational models needed to address all seven societal goals (**Part III**).

Recommendations in Parts II and III reflect results of the Second IOOS Implementation Conference and recommendations in the *Data Management and Communications Plan*, *An Ocean Blueprint for the 21st Century* and *Framing the Grand Challenges: A Vision for Federal Disaster Reduction*.

Implementation of an interoperable DMAC subsystem is critical, not only to coordinated development of IOOS, IEOS, the Global Ocean Observing System (GOOS) and Global Earth Observation System of Systems (GEOSS), but also for identifying those programs that will benefit from incorporation into the integrated system and/or contribute to the capacity of the integrated system to support the provision of new and improved products. Thus, **the DMAC subsystem is the highest priority, and its implementation will guide IOOS development over the next three years by integrating data from existing observing subsystem assets and in out years (three to ten years) as enhancements come on line**. Phased implementation will occur within the framework of the Federal Enterprise Architecture.

^A Although the 1st IOOS Development Plan was not published until 2006, the plan was completed in December 2004 and approved by the Ocean.US Executive Committee in January 2005. <http://www.ocean.us/documents/docs/IOOSDevPlan_low-res.pdf>

[†] *Building Consensus: Toward an Integrated and Sustained Ocean Observing System*, Ocean.US Report No. 1; *An Integrated and Sustained Ocean Observing System for the United States: Design and Implementation*, Ocean.US Report No. 2; *Regional Ocean Observing Systems, an Ocean.US Summit*, Ocean.US Report No. 3; *Proceedings of the National IOOS Education Workshop*, Ocean.US Report No. 4; *Proceedings of the Regional Organization Workshop*, Ocean.US Report No.5; *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive*, Ocean.US Report No. 6; *Proceedings of the First Annual IOOS Development Workshop*, Ocean.US Report No. 8. <www.ocean.us/oceanus_publications>

Summary of Recommendations

The following summarizes recommendations made in Parts I, II and III. The responsible organizations, given in parentheses at the end of each recommendation, are based on Part I, Table 3 in the *First IOOS Development Plan*. As articulated in the Federal Response to the Second IOOS Implementation Workshop, “participating agencies may focus [their resources] on selective priorities and actions.” That is, endorsement of a recommendation does not imply a funding commitment. Thus, it is understood that all references to funding by the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI) partners are (1) not recommendations to each and every agency and (2) are contingent on the availability of resources.

Part I: Implementing an Integrated System

Systems Engineering Recommendations

- Complete the IOOS Enterprise Architecture, i.e., continue and scale up the systems engineering analysis initiated in FY 2005 and development of the IOOS Conceptual Design initiated in FY 2006. (*Consultants and participating federal agencies*)

Planning and Management Recommendations

- Given that the *First IOOS Development Plan* and its updates are living documents, periodic updates should be completed as needed. (*Ocean.US*)
- Complete *IOOS Development Plan* updates early enough in the planning and budgeting cycles of participating federal agencies to help guide their budget requests. (*Ocean.US-Interagency Working Group on Ocean Observations [IWGOO]*)
- Develop sustainable funding and personnel arrangements for Ocean.US that allow the office to focus more on strategic planning and coordinated implementation of the IOOS than on funding and staffing. (*IWGOO*)
- Maintain the Ocean.US Office as an Interagency Office outside any single federal agency and replace the Ocean.US Executive Committee (EXCOM) with the IWGOO to perform its functions. (*IWGOO*)

Regional Development Recommendations

Establishing Regional Coastal Ocean Observing Systems (RCOOSs) is critical to the development of an IOOS that is locally relevant and nationally coordinated for the good of the American public as a whole. Within the broad construct of a national IOOS, Regional Associations (RAs) work with stakeholders in their respective regions to determine regional management and policy needs for information on oceans and coasts, translate these needs into regional

observing system requirements, and build RCOOSs based on these requirements. It is in the regions that new and improved products and services will be tested; it will be the outcome of the regional use of these initial products and services that will provide the feedback system developers need in order to improve the system from observations to products and services. Thus, RAs, as the developers and operators of RCOOSs: (1) integrate existing subregional observing systems and enhance them to help build the National Backbone and build RCOOSs that meet specific regional needs for decision support tools and address issues of national concern that are manifested at the regional level; (2) function as testbeds for research and development and for product development; (3) foster close collaboration with regional organizations of federal agencies to ensure that both federal and non-federal stakeholder needs are being served by each RCOOS in the most efficient and effective manner; and (4) fully engage key constituencies in defining the data and information needed to be collected at the regional level that is then used to guide RCOOS development. To these ends, the following actions are recommended:

- In collaboration with federal agencies, prepare policies and procedures for qualifying and certifying, and implement them once approved by the IWGOO. (*Ocean.US*)
- Facilitate the involvement of regional organizations of participating federal agencies in RAs and in the development of RCOOSs. (*RAs, Ocean.US*)
- Work with federal agencies to diversify agency support for regional development as appropriate to agency missions and goals. (*Ocean.US-IWGOO*)
- Continue to foster coordination among RAs and local-regional-national coordination and collaboration through the formal establishment of the National Federation of Regional Associations (NFRA). (*RAs, Ocean.US*)
- Increase support for NFRA activities that improve federal-regional collaboration for IOOS development and coordination of RA-RCOOS development nationally. (*Ocean.US, IWGOO*)

International Activities Recommendations

- To enable coordinated development of the IOOS as the U.S. contribution to the oceans and coastal component of GEOSS, appoint the Director of Ocean.US to the U.S. Delegations to the Intergovernmental Oceanographic Commission (IOC) and Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). (Joint Subcommittee on Ocean Science and Technology [JSOST])
- Initiate a process for coordinating the development of the coastal module of GOOS with Canada, Mexico and countries of the Caribbean, including the establishment of a GOOS Regional Alliance for North America. (*Ocean.US, JSOST, Department of State*)

Performance Measures Recommendations

- Continue to competitively fund analyses of estimated socio-economic benefits that may accrue from investment in the IOOS to justify funding. *(NOAA)*
- Determine which socio-economic variables should be measured as part of the IOOS, and help set priorities for IOOS development. *(JSOST)*
- Develop and apply performance metrics for IOOS operations and user satisfaction. *(Ocean.US)*

Part II: Integrating Existing Elements

Observing Subsystem: Global Component Recommendations

- Continue to implement the global component according to existing schedules and time-lines. *(NOAA and other participating federal agencies)*

Observing Subsystem: National (Coastal) Backbone Recommendations

- Building on current activities, specify observing subsystem requirements for integrated *in situ* measurements and remote sensing of core variables needed for more accurate nowcasts and forecasts of impacts of coastal inundation on coastal communities, ecosystems and resources. *(Ocean.US-IWGOO)*
- Incorporate coastal marine and estuarine elements of the National Water Quality Monitoring Network into the next *IOOS Development Plan* update, and work with the National Coastal Assessment Program to develop IOOS capabilities to provide data and information needed for national coastal assessment reports. *(Ocean.US-IWGOO)*
- Based on recommendations from the recent IOOS workshop on waterborne pathogens, formulate plans for enhancing IOOS to improve the accuracy of risk assessments and the timeliness of public health risk forecasts. Incorporate these into the next *IOOS Development Plan* update. *(Ocean.US)*

Data Management and Communications Subsystem Recommendations

- Support the activities of community-based Data Management and Communication (DMAC) Expert Teams and Working Groups in key technical areas to formulate guidelines for standards, protocols, and best practices. *(IWGOO)*
- Support the activities of DMAC Community Engagement Caucuses to enhance outreach to and feedback from key IOOS/DMAC constituencies. *(IWGOO)*

- Implement the activities recommended for development of the initial DMAC framework to support existing and emerging observing systems (the framework will evolve based on the work of the teams and working groups). *(Implementation Oversight Working Group [IOWG])*
- Continue support for the DMAC Steering Team to oversee identification and adoption of interoperability-enabling standards, protocols and best practices. *(IWGOO)*
- Continue support for the DMAC IOWG to guide the integrated interagency review, funding and implementation of DMAC standards within participating federal agencies. *(IWGOO)*

Modeling and Analysis Subsystem Recommendations

- Establish the Modeling and Analysis Steering Team (MAST) that has as its first priority the creation and support of a multi-hazard Community Modeling Network (CMN) that will work to improve and validate existing models for ensemble forecasts of coastal inundation, develop new models for mapping susceptibility (risk) and predicting impacts on coastal communities, ecosystems and resources. *(Ocean.US)*

Education Recommendations

- Establish an IOOS Education and Public Awareness network-of-networks. *(Ocean.US)*
- Ensure that IOOS Education is consistent with the national ocean education objectives and plans as articulated by the Interagency Working Group on Ocean Education (IWG-Ocean Ed). *(Ocean.US)*
- Use education network-of-networks to develop understanding among IOOS developers regarding the needs of the education and public awareness community and user satisfaction criteria, especially for data and information. *(Ocean.US)*
- Carry out education and public awareness planning efforts that: (1) provide baseline information for performance measures; (2) identify most effective practices through pilot projects; and (3) establish a coordinated and highly effective network-of-networks. *(Ocean.US)*
- Develop a mechanism for creating learning materials that: (1) address regional themes and messages within the context of national IOOS societal goals and messages and ocean literacy essential principles and fundamental concepts; (2) target specific audiences; and (3) are easily modified for use in other IOOS regions. *(Ocean.US)*

Part III: Improving the IOOS Through Enhancements and Research

Enhancing the Observing Subsystem: Global Component Recommendations

- Maintain continuity and spatial resolution of space-based remote sensing missions for surface vector winds, sea surface height and ocean color for operational applications. (NASA, Navy, NOAA)
- Coordinate maintenance of and enhancements to open ocean National Data Buoy Center (NDBC) mooring networks (including the Deep-ocean Assessment and Reporting of Tsunamis [DART] buoy network and the Tropical Atmosphere Ocean (TAO) array) and implementation of ocean time series stations to maximize multi-use of platforms and minimize ship-time costs associated with deployment and maintenance of moorings and sensors. (NOAA)
- Coordinate ship-based surveys of hydrography and biogeochemistry with Argo float deployments. (NOAA)

Enhancing the Observing Subsystem: Coastal Component Recommendations

- Optimize the tide gauge network to increase density of real-time measurements of water level in high risk areas. (NOAA, USGS)
- Increase stream gauge (continuous, real-time telemetry) coverage in the coastal zone, including near the heads and mouths of rivers for more accurate and timely estimates of freshwater water runoff and associated inputs of sediments, nutrients and pollutants on seasonal scales and during post-storm runoff. (USGS)
- Using both *in situ* measurements and remote sensing (e.g., rain gauges, Doppler radar, Tropical Rainfall Measuring Mission [TRMM], Global Precipitation Measurement [GPM] Mission), increase the density of rainfall measurements, atmospheric moisture profiles and soil moisture content. (NOAA, USGS, NASA)
- Establish a consistent, national standard vertical datum to which all vertical measurements (e.g., water level, coastal bathymetry and topography) can be referenced. (NOAA, USGS, USACE)
- Develop robust methods for blending measurements from remote and *in situ* observations. (NOAA, NASA, Navy, NSF)
- Develop algorithms for extracting higher-resolution surface wind fields from existing satellite scatterometers and future passive polarimetry, especially in close proximity to the shoreline; add QuikSCAT capability to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) if WindSat does not meet operational requirements. (NASA, Navy, NOAA)
- Explore the use of delayed-Doppler and Global Positioning Systems (GPS) altimetry to improve near shore (< 10 km) sea surface height measurements, and improve models for accurately removing tidal signals. (NOAA, USGS, USACE)

- Continue to develop, validate and implement Synthetic Aperture Radar (SAR) algorithms for surface vector winds, wave height and direction, buoyant surface plumes and slicks. (NASA, Navy, NOAA)
- Develop SAR Along-track Interferometry (ATI) and Doppler measurements for high resolution measurement of surface currents in near shore (< 10 km) waters. (NASA, Navy, NOAA)
- Deploy hyperspectral sensors (spectral bands ≤ 5 nm over a broad spectral range) to more accurately quantify phytoplankton pigment concentrations in optically complex coastal waters. (NASA, Navy, NOAA)
- Develop robust methods for integrating measurements of ocean color from different satellite platforms and sensors (e.g., Ocean Color and Temperature Scanner, SeaWiFS, Moderate Resolution Imaging Spectroradiometer [MODIS], Medium Resolution Imaging Spectrometer, Ocean Color Monitor) to create blended chlorophyll products that address data dropout due to clouds and tidal aliasing. This will require robust inter-sensor calibration and, for non-concurrent observations, vicarious calibration to enable long time-series observations. (NASA, Navy, NOAA)
- Increase real-time, time-space resolution of wind fields over water, surface current fields, directional wave fields, and sea surface temperature distribution in the Exclusive Economic Zone by integrating remote sensing and *in situ* measurements. (RAs)
- Implement repeat (one to five years) and timely post-inundation surveys of near shore coastal bathymetry-topography (including shoreline position), benthic habitats (e.g., coral reefs, submerged aquatic vegetation), and land-use/cover (e.g., tidal wetlands, forests, grassland, impervious man-made surfaces, agriculture), especially in high risk areas. (NOAA, USGS, USACE)
- Prior to and following flooding events, map buoyant coastal plumes and slicks, sea surface temperature, salinity, suspended sediments and chlorophyll-a (i.e., adaptive sampling). (NOAA, NASA)

Data Telemetry Recommendations

- Develop and implement on-demand, real-time, two-way communications (satellite and line-of-site radio technologies) to meet the command and control requirements of ocean observing systems. (Navy, NOAA)
- Develop and implement telecommunications technologies with sufficient bandwidth, and establish standards and protocols to meet the requirements for real-time transmission and dissemination of oceanographic observations for multiple applications. (Navy, NOAA)
- Implement the World Meteorological Organization (WMO) Information System (WIS) to meet the requirements of (1) routine collection and automated dissemination of observed data and products; (2) timely delivery of data and products; and (3) *ad hoc* requests for data and products. (Navy, NOAA)



Data Management and Communications Subsystem Recommendations

- Initiate system planning, design, implementation, maintenance, refreshment, and modernization activities to establish a fully functional DMAC. (*IOWG*)
- Federal and RA programs should adopt a target investment goal of at least ten percent of the resources currently applied to existing and planned observing systems for implementing and sustaining their DMAC components. (*Federal agencies*)

Modeling and Analysis Subsystem Recommendations

- Establish and support a Modeling and Analysis Steering Team (MAST) charged with: (1) identifying families of models for which Community Modeling Networks (CMNs) are needed and building a national framework to enable model development; and (2) creating a CMN for coastal inundation modeling that is tasked with (a) fostering communications among data providers and users of storm surge information, and (b) developing the next generation of coastal inundation models. (*Ocean.US, IWGOO*)

Education and Public Awareness Recommendations

- Create and fund an education coordinating office; endow it with roles and responsibilities consistent with community recommendations.
- Extend the reach of the education network-of-networks by sustaining and maturing the network created as part of Phase I of the IOOS Education Plan as described in the *First IOOS Development Plan* and by supporting activities that engage networks of frontline classroom and informal educators (i.e., Global Learning and Observations to Benefit the Environment, American Meteorological Society and EPA-National Estuarine Program networks are the priority).
- Create nationally coordinated and regionally relevant learning materials that incorporate effective practices gained from the pilot projects in Phase II of the IOOS Education Plan and that target workforce needs, K-16, community education and public awareness, and under-represented groups in the ocean workforce.
- Implement project-and-program level near-term and long-term assessment for IOOS education and public awareness utilizing the effective practices identified in pilot projects carried out as part of Phase II of the IOOS Education Plan.



Part I: Implementing an Integrated System

1. Introduction

As discussed in the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan*¹, the IOOS efficiently links observations to applications through integrated data management and modeling (Figure I.1). The observing subsystem is a multi-scale system that incorporates two interdependent components, a global ocean component with an emphasis on ocean-basin scale observations² and a coastal component that focuses on the Nation's Exclusive Economic Zone (EEZ), Territorial Waters, Great Lakes and estuaries.

The global ocean component and the National Backbone (NB) are the suites of operational **observing subsystem elements** that support the following functions:

- Monitor core variables¹ in the nation's EEZ and Great Lakes using both remote sensing and *in situ* measurements;
- Make *in situ* measurements at a network of sentinel sites using federally approved methods;
- Transmit Data Management and Communications (DMAC)-compliant data on core variables to national data assembly centers continuously, routinely and reliably (real-time or delayed mode as needed); and
- Link larger scale changes occurring in the ocean and on land to changes occurring within coastal regions.

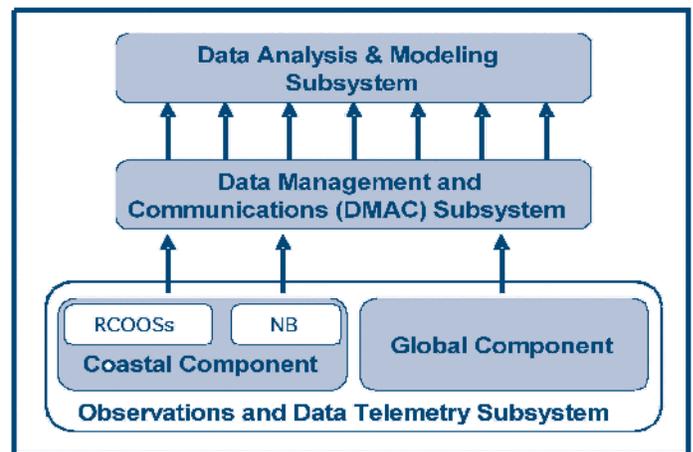


Figure I.1. The IOOS is a multiscale system of systems consisting of three efficiently linked subsystems: (1) observations and data telemetry; (2) data management and communications; and (3) data analysis and modeling. The observing subsystem consists of global and coastal components with the latter broken down into a National Backbone (NB) for the Nation's EEZ and Regional Coastal Ocean Observing Systems (RCOOSs) to address regional and local needs. The integrating engines are the DMAC and modeling subsystems. The NB provides data and information required by federal agencies and most, if not all, Regional Associations. RCOOSs contribute to the NB and are tailored to the data and information needs of each region.

¹ The *First U.S. Integrated Ocean Observing System (IOOS) Development Plan* <http://www.ocean.us/documents/docs/IOOSPlan_6-20-05_lowres.pdf>; See also: 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>; *An Integrated and Sustained Ocean Observing System for the United States: Design and Implementation* <<http://www.ocean.us/documents/docs/FINAL-ImpPlan-NORLC.pdf>>

² *Global Physical Ocean Observations for GOOS/GCOS: An Action Plan for Existing Bodies and Mechanisms* <http://ioc.unesco.org/goos/docs/GOOS_066_act_pl.htm>

1.1 Integrated Ocean Observing System (IOOS) Development Plan Updates

IOOS Development Plan updates formulated by Ocean.US focus on: (1) federal implementation of the global ocean-climate component, the National (Coastal) Backbone (NB) and the subsystems for DMAC and modeling and analysis; and on (2) procedures for establishing Regional Associations (RAs) and for coordinated and sustained development of Regional Coastal Ocean Observing Systems (RCOOSs) nationwide.

The *First IOOS Development Plan* consists of three parts. Part I recommended a governance mechanism for the design and coordinated implementation of the IOOS by federal agencies and RAs; Part II recommended elements for the initial observing subsystem, preliminary plans for the DMAC subsystem, and initial plans for an IOOS education initiative; and Part III recommended enhancements and pilot projects for improving IOOS capabilities recommended in Part II.¹ The overall emphasis of the first plan was on more rapid detection of changes in ocean states relevant to the seven IOOS societal goals as measured by core variables.

Since the final draft of the first plan was completed in 2004, the President's *Ocean Action Plan* (OAP)³ was released; the *Strategic Plan for the U.S. Integrated Earth Observation System (IEOS)* was completed⁴; Ocean.US conducted the Second IOOS Implementation Conference (3-4 May 2005)⁵ and federal agencies have responded to recommendations from the conference (Appendix A); and *Framing the Grand Challenges: A Vision for Federal Disaster Reduction*⁶ was released by the National Science and Technology Council. This *IOOS Development Plan* update revises Part I based on the OAP and federal responses to it. Parts II and III respond to recommendations from the second implementation conference and the *Grand Challenges* report. To improve multi-hazard forecasting and mitigation capabilities, Part II presents a DMAC-driven plan for integrating existing observing subsystem assets of the global component and the National Backbone; Part III recommends steps that should be taken to improve these capabilities. Implementing the governance mechanisms set forth in Part I provides the means to implement Parts II and III.

1.2 IOOS and Earth Observations

In 2002, the World Summit on Sustainable Development highlighted the urgent need for integrated observations for assessing the state of the Earth,⁷ and over thirty countries signed a declaration at the First Earth Observation Summit⁸ in Washington, D.C. in 2003, affirming their support for the following:

- Improved coordination of strategies and systems for observations of the Earth 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 full and open exchange of observations recorded from *in situ*, aircraft, and satellite networks with minimum time delay and minimum cost, recognizing relevant international instruments and national policies and legislation; and
- Preparation of a 10-year Implementation Plan, building on existing systems and initiatives.

Achieving these goals depends on coordinated, international implementation of the global ocean (Global Ocean Observing System [GOOS])⁹, climate (Global Climate Observing System [GCOS])¹⁰ and terrestrial (Global Terrestrial Observing System [GTOS])¹¹ observing systems as contributions to the Global Earth Observation System of Systems (GEOSS).¹² The Integrated Earth Observing System (IEOS) is the U.S. contribution to GEOSS; IOOS is the marine-estuarine-Great Lakes component of the IEOS, as well as the U.S. contribution to GOOS (Figure I.2). As such, the IOOS is a key contribution toward attaining the benefits of IEOS, GOOS and GEOSS (Table I.1).

Since the First Earth Observation Summit in 2003, summits have been held in 2004 and most recently in 2005, when 54 countries and over 40 international organizations established the Group on Earth Observations (GEO), endorsed the 10-Year Implementation Plan for GEOSS, and affirmed their intention to provide the support necessary to execute the Implementation Plan.¹²

³ U.S. *Ocean Action Plan* <<http://ocean.ceq.gov/actionplan.pdf>>

⁴ *The Strategic Plan for the U.S. Integrated Earth Observation System (IEOS)* <<http://www.epa.gov/ord/articles/2005/geoss.html>>

⁵ *Proceedings of the Second IOOS Implementation Conference: Multi-Hazard Forecasting* <http://www.ocean.us/documents/docs/2ndIOOS_Final_lowres.pdf>

⁶ *Framing the Grand Challenges: A Vision for Federal Disaster Reduction* <<http://www.sdr.gov/SDRGrandChallengesforDisasterReduction.pdf>>

⁷ World Summit on Sustainable Development, Johannesburg 2002 <<http://www.johannesburgsummit.org/>>

⁸ First Earth Observation Summit, Washington, DC 2003 <<http://www.earthobservationsummit.gov/declaration.html>>

⁹ The Integrated Strategic Design Plan for the Coastal Ocean Observations Module of the Global Ocean Observing System <http://ioc.unesco.org/goos/docs/GOOS_125_COOP_Plan_en.pdf>

¹⁰ Global Climate Observing System <<http://www.wmo.ch/web/gc/gcoshome.html>>

¹¹ Global Terrestrial Observing System <<http://www.fao.org/gtos/>>

¹² Global Earth Observation System of Systems <<http://www.noaa.gov/eos.html>>

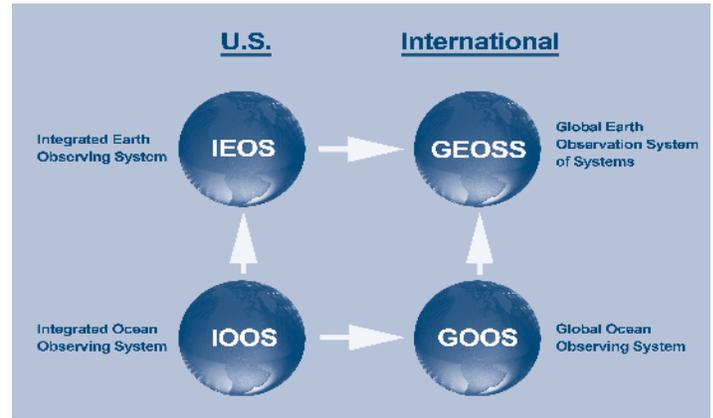


Figure I.2. Relationships among the IOOS, U.S. IEOS and the international observing systems, GOOS and GEOSS. The IOOS is the ocean and coasts component of the IEOS and the U.S. contribution to GOOS and the GEOSS.

Table I.1. Relative importance of monitoring and analyzing IOOS core variables (Earth observations) to realizing IEOS benefit areas (H – high, M – medium, Blank – weak or no relationship). Rankings of winds, salinity, water level (sea surface height/topography), currents, and chlorophyll (ocean color) are adapted from the *Strategic Plan for the U.S. Integrated Earth Observation System (2005)*^a with the following exceptions (*): (1) the impact of sea surface temperature (SST) on agriculture (rated M rather than H), freshwater resources (rated weak rather than M), and energy resources (rated weak rather than H) because the measurement is limited to SST; (2) the impact of currents on disasters (rated M rather than weak because of the effects of currents on coastal flooding) and human health (rated M rather than weak because of the effects of currents on exposure to waterborne pathogens in coastal waters and the Great Lakes); (3) the impact of salinity on water (rated M rather than weak) because of the impact of salt water intrusion on ground water and on upstream extent of salt water in river-estuarine systems in coastal states; (4) the effects of wind on ecology (rated H rather than M) because of the importance of turbulence and circulation to the ecology of organisms that live in over 70% of the Earth’s surface; and (5) the effects of ocean color on climate (rated M rather than weak) because of the role of phytoplankton productivity in the global carbon cycle.

IOOS Earth Observations	IEOS Societal Benefit Areas ^a								
	(1) Weather	(2) Disasters	(3) Oceans	(4) Climate	(5) Agriculture	(6) Health	(7) Ecology	(8) Water	(9) Energy
Sea surface winds	H	H	H	H	H	H	H*		M
River runoff		H	H	H	H	H	H	H	H
Sea surface temperature	H	H	H	H	M*	H	H		
Salinity			H	H			H	M*	
Sea/water level	H	H	H	H		M	H	M	
Waves		H	H			M	H		
Currents	M	M*	H	H		M	H		
Nutrients			H			M	H		
Dissolved oxygen			H				H		
Waterborne pathogens			H			H	M	M	
Ocean color			H	M*		H	H		
Habitat ^b /bathymetry		M	H				H		
Plankton ^c			H			M	H		
Living marine resources ^d			H			M	H		

^aNine societal benefits will be addressed by the U.S. Integrated Earth Observation 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 degradation; (6) understand effects of environmental factors on human health and well-being; (7) develop the capacity to make ecological forecasts; (8) protect and monitor water resources; and (9) monitor and manage energy resources. ^b Extent and condition of coral reefs, seagrass beds, kelp beds and tidal marshes. ^c Abundance and species composition. ^d Fish stock assessments, distribution and abundance of protected species.

2. IOOS Design and Implementation

2.1 Phased IOOS Development

2.1.1 Systems Engineering

The IOOS is a complex, user-driven, multidisciplinary, multi-scale, distributed “system of systems” with many characteristics that make system development a candidate for a formal systems engineering approach.¹³ These characteristics include (1) a geographically distributed infrastructure and communities of data providers and users; (2) requirements for interoperability across scales from local ecosystems to the global ocean (e.g., internationally and nationally accepted standards and protocols for metadata and data discovery, browsing, transport and archival); (3) the need to dynamically serve virtual products with geographic information layers; (4) demand for continuous data analysis and modeling; and (5) a diversity of organizational, management and funding structures involving government agencies, academia and private sectors. These characteristics and the need to improve over time by harmonizing “top down” (federal) and “bottom up” (regional) call for an iterative, stepwise process of design, implementation, operation and improvement that can best be achieved through systems engineering. The systems engineering process must be continued throughout the evolution of IOOS.

The Office of Management and Budget (OMB) requires federal agencies to implement a Federal Enterprise Architecture (FEA)¹³ as a business-based framework to enable the Federal Government to become more results-driven and market-oriented. The FEA consists of a set of interrelated “reference models” designed to facilitate cross-agency analysis and to help identify potentially redundant investments, gaps and opportunities for collaboration within and across agencies. OMB requires that all federal entities show compliance with the FEA.

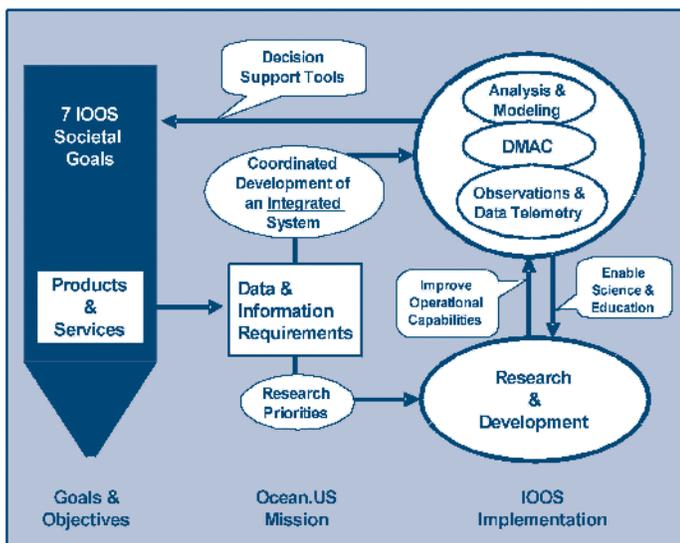


Figure I.3. Schematic for the development a user-driven system that provides data and information required to achieve the seven societal goals of the IOOS. Using data and information requirements for products and services, the mission of Ocean.US (the federal interagency office for integrated and sustained ocean observations) is to prepare scientifically sound design and IOOS development plan updates that are implemented by federal agencies, Regional Associations, and other responsible groups.

Each of the federal sponsors of IOOS is required to promulgate its own Enterprise Architecture (EA). Likewise, the Ocean.US Enterprise embraces the FEA and is employing a structured systems engineering approach to develop an EA for IOOS. The IOOS EA will explicitly describe and document both the current and the desired relationships among the IOOS stakeholders (data providers and users, federal agencies and Regional Associations, etc.) and all elements of the IOOS infrastructure. The EA is intended to serve as a tool that clearly articulates the interrelationships among all the elements in this complex “system of systems.” It will articulate stakeholder roles and responsibilities and serve as a roadmap to aid all participants in their understanding of the functionality of all the different elements that make up the IOOS (Figure I.3).

Studies developing a conceptual design for IOOS are ongoing at this time. Final results and recommendations will be released in August 2006. Next steps will be for Ocean.US to work with the federal agencies to develop one integrated Concept of Operations¹⁴ and an EA and to coordinate its phased implementation by federal agencies and RAs.

¹³ Office of Management and Budget (OMB) Circular A-130, Management of Federal Information Resources. 8 February 1996 <<http://www.whitehouse.gov/omb/circular/a130/a130trans4.html>>

¹⁴ Vorthman, R., Linn, J Klein., Managing IOOS Regional Association Development with Today’s Systems Engineering Approach, MTS-IEEE Oceans’06 Conf Proc., September 18-21, Boston, MA 2006 <<http://www.incose.org/>>



2.1.2 Research to Operations and the Evolution of an Integrated System

To enable synergy between advances in science and technology and the development of operational capabilities, the IOOS encompasses a continuum of mutually dependent research to operational activities (Box I.1), where “operational” is used to indicate the routine, sustained and timely provision of data and data-products of known quality to user groups. In terms of developing an integrated system that addresses all seven IOOS societal goals, operational capabilities are most developed for the goals of natural hazards and marine services and least developed for the goals of ecosystem-based, adaptive management for public health, environmental protection and resource management. Thus, strong Earth and ocean science research programs continue to be critical to increasing our understanding of Earth systems and expanding IOOS operational capabilities in this context.

Enabling timely positive feedbacks (synergy) between advances in science and improving IOOS capabilities requires a managed process that selectively uses new technologies (e.g., *in situ* biological sensors and platforms, high resolution of satellite-based remote sensing of ocean color) and scientific knowledge (e.g., numerical models of ecosystems, algorithms for translating ocean color into phytoplankton biomass) to enhance and supplement all three subsystems of the IOOS (Figure I.4). Using new technologies (e.g., sensors) and knowledge (e.g., models) developed through research to improve operational capabilities is a big step and is inherently difficult. In addition to cooperation and good will on the part of the research and operational communities involved, it will require ongoing guidance from both data-providers and users and advanced planning and budgeting for transitioning research capabilities to an operational mode.

BOX I.1. Example of the Relationship Between Research-Driven and Mission-Driven Programs

The research-driven Ocean Research Interactive Observatory Networks/Ocean Observatories Initiative (ORION-OOI) and the mission-driven IOOS are part of a broader national and international effort to establish a global ocean observing system, both for conducting basic research and for operational oceanographic needs.

ORION-OOI will provide key enabling research for IOOS, fundamental advances in observatory platforms and sensor technology and a basic understanding of ocean processes that will enable IOOS to meet its long-term operational goals.

IOOS will provide a larger framework of societal issues, observations and background data necessary for interpreting and setting context for the process-oriented experiments of ORION-OOI.

Steps for selectively incorporating new knowledge and technology into an operational mode and for promoting synergy between research and operational oceanography are described in the *First IOOS Development Plan*.¹ The next step is for Ocean.US to work with its federal partners to formulate and implement policies and procedures that enable this process as conceptualized in Figure I.4.

Policies and procedures for migrating new technologies and knowledge into an operational mode should consider the two dimensions of involving both data providers and users in IOOS development (Figure I.5). Integrating data streams from research projects and sustained operational sensors to serve “blended” products operationally will become especially important as long term time series observations become priorities for advancing the Earth sciences. Thus, procedures will be needed to establish standards and protocols for intercalibration and validation required to blend data from different measurement systems (remote and *in situ*). Two research programs,

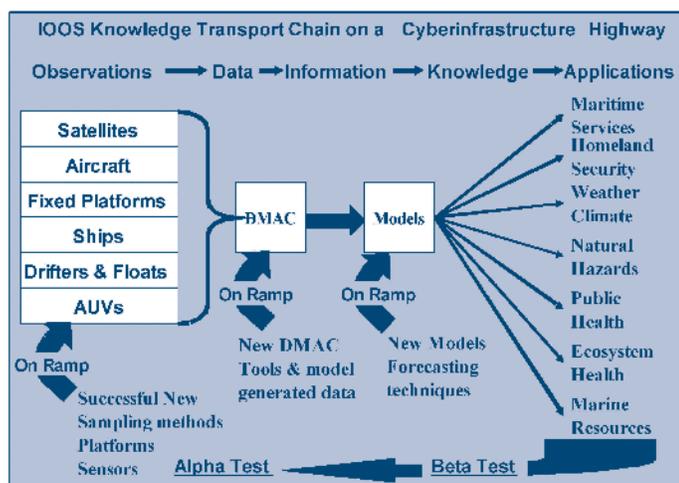


Figure I.4. “On Ramp” model for improving IOOS capabilities over time, with Alpha testing of technology (performance-based metrics) before moving into the On Ramp; Beta feedback on user satisfaction with the data and information generated by the IOOS (societal performance metrics). This demonstrates the necessity of both a research as well as an operational component for IOOS.

the Sensor Intercomparison for Marine Biological and Interdisciplinary Ocean Studies (SIMBIOS)¹⁵ project completed in 2001 and the Global Ocean Data Assimilation Experiment (GODAE) high-resolution sea surface temperature (GHRSSST)¹⁶ pilot project currently ongoing provide prototypes for the effort that will be needed to integrate data from different sensors. Both studies illustrate the non-trivial technical difficulties of combining data from different measurement systems (SIMBIOS: ocean color from an array of satellite-based sensors; GHRSSST: sea surface temperature [SST] from satellites and *in situ* measurements) for routine provision of accurate, more highly resolved sea surface chlorophyll-a (SIMBIOS) and SST time series (GHRSSST) products. These, and programs like them, will be needed to sustain and improve IOOS capabilities to serve the data and information needed to address all seven IOOS societal goals.

2.2 A Funding Model for IOOS Development

A funding model is needed for coordinated implementation, operation and improvement of the global and coastal components over time. With the first phase of systems engineering studies nearing completion (August 2006), a next step is for Ocean.US to work with federal agencies and Regional Associations (RAs) to develop a funding model that reflects both the need for long-term stability for regional, national and global operations and the reality that requirements for IOOS data and information differ regionally. Such a model must consider the following:

- The need for sustained funding for both global and coastal components;
- The National Backbone (NB) includes elements of the observing subsystem only. The Data Management and Communications (DMAC) and modeling subsystems cannot (and should not) be “stove piped” specifically to any given observing subsystem element or exclusively to the global ocean component, the NB or to Regional Coastal Ocean Observing Systems (RCOOSs);
- The importance of developing RCOOSs by RAs that ensure the system as a whole is locally relevant;
- The importance of enabling synergy between research and the development of operational capabilities;
- The importance of capacity building, training, education and public outreach;
- Although federal agencies are responsible for establishing the NB and will be its primary source of support, there are and will be important exceptions that should be encouraged, e.g., the USGS National Stream Quality Accounting Network (NASQAN) and the NOAA Physical Oceanographic Real-Time System (PORTS®)
- Elements of the NB may be operated by federal agencies, RAs, state agencies, industries, or other bodies that are certified and conform to national standards and protocols; and



		Supply	
		Research	Operational
Use	Research	<ul style="list-style-type: none"> • Aquarius (SSS) (Planned) 	<ul style="list-style-type: none"> • Global High –Res SST
	Operational	<ul style="list-style-type: none"> • OSTM (SSH) • QuikSCAT (Wind) • SeaWiFS, MODIS (SS Chl) 	<ul style="list-style-type: none"> • AVHRR (SST) • Jason-3 (planned) • VIIRS (planned)

Figure I.5. An illustration using, as an example, satellite-based remote sensing, of the two dimensions of operational capability: data supply (measurements and data telemetry) and use (provision of products and services). On the supply side, Advanced Very High Resolution Radiometer is an operational sensor for measuring sea surface temperature (SST). The data streams used to routinely produce maps of SST are sustained, continuous and guaranteed – the “use” dimension. AVHRR data, along with data on SST from other remote and *in situ* sensors, are being used in an experimental mode GODAE High Resolution Sea Surface Temperature to improve the resolution and, therefore, the usefulness of SST maps. The development of a sensor for measuring sea surface salinity (SSS) from space is a research priority. Altimetry (Ocean Surface Topography Mission, OSTM) is used to estimate changes in sea surface height (SSH) and to detect and predict trends in sea level that may be related to global warming. Although these are research missions that have a finite life time with data provided on an “as able” basis, maps of SSH are provided in an operational mode. QuikSCAT (scatterometer for estimating ocean surface vector winds) and sensors for measuring ocean color and estimating sea surface chlorophyll-a concentrations (SeaWiFS, MODIS and Aqua) also fall into this category. Jason 3 and Visible Infrared Imager/Radiometer Suite (VIIRS) are planned to be operational missions for SSH and ocean color, respectively.

¹⁵ SIMBIOS <<http://www.ioceg.org/reports/simbios/simbios.html>>

¹⁶ GHRSSST <<http://ghrsst-pp.metoffice.com/documents/GHRSSST-PP-Strategy-v1.5.pdf>>

- The distinctions between global and coastal and between regional and national will begin to blur as the system becomes fully integrated.

2.3 Engaging Stakeholders

Most of the early planning of IOOS has been done by scientists from federal agencies, universities and research institutions.^{1,5} If the IOOS is to develop as a “user-driven” system, the community of IOOS stakeholders from both public and private sectors must grow to encompass all seven IOOS societal goals. An effective way to address this challenge is to engage existing and potential stakeholders in the design, implementation, operation and improvement of the IOOS early in its development. The objectives of growing the user base and diversity of applications will be achieved through two convergent and inter-related approaches that Ocean.US is pursuing simultaneously:

- (1) A *national approach* that focuses on coordinated development of the global ocean component and the National Backbone (NB) 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 the private sector, nongovernmental organizations, state agencies, regional organizations of federal agencies, tribes and academia in the design and implementation of Regional Coastal Ocean Observing Systems (RCOOSs).

2.3.1 Mechanisms of Engagement

One approach Ocean.US is using to help engage users and transform potential stakeholders into users, is to use “success stories” that demonstrate the effectiveness of integration and timely access to or delivery of data and information (Appendix B). In addition, Ocean.US is building awareness through the following:

- Working with potential stakeholders from government agencies and with organizations outside government, including national officers and executive directors of professional and industry organizations;
- Presentations and special sessions at industry meetings and other professional conferences;
- Forums, such as Industry Days, where potential stakeholders are given briefings and encouraged to participate in IOOS planning and implementation; and
- News releases, especially in industry-related publications.

Once awareness, interest and engagement are established, transforming a user into a fully engaged stakeholder requires mechanisms that foster substantial and influential ongoing participation. These include the following:

- Stakeholder participation in Regional Associations (RA) and sharing RA experiences of successful stakeholder involvement;
- Engaging stakeholder councils and alliances in IOOS development (e.g., Gulf of Mexico Alliance, The Great Lakes Interagency Task Force);
- Formal advisory committees such as those established by the Ocean Research and Resources Advisory Panel (ORRAP) (e.g., Industry sub-panel, Education sub-panel, etc.);
- Participation of stakeholders in IOOS-related committees established by the Interagency Committee on Ocean Sciences and Resource Management Integration (ICOSRMI), its subcommittees (Joint Subcommittee on Ocean Science and Technology [JSOST] and the Subcommittee on Integrated Management of Ocean Resources [SIMOR]) and Ocean.US (e.g., DMAC Steering Team); and
- Pilot and demonstration projects that address problems and issues of interest to participating stakeholders (e.g., NOAA-Navy interoperability demonstration project).

2.3.2 Involving the Commercial Sector

There are three categories of potential business engagement with IOOS: (1) contribution to the design and implementation of IOOS infrastructure; (2) production and sale of value-added products using IOOS data; and (3) use of IOOS data and information for internal purposes. The first category is more likely to realize near-term profits associated with formation of the IOOS and its early expansion. The second and third categories have the potential to revolutionize industry sectors and thereby realize sustained long-term profits. Businesses in all three classes have been and will continue to be targeted via the mechanisms outlined in section 2.3.1.

2.4 IOOS Governance Under the Ocean Action Plan

The Oceans Act passed by Congress in 2000 established the U.S. Commission on Ocean Policy, and pursuant to its legislative mandate, the Commission released its report on 20 September 2004.¹⁷ The report and the Administration’s response, the *U.S. Ocean Action Plan* (17 December 2004)³, call for a governance structure (Figure I.6) that enhances and strengthens the current structure established by the National Oceanographic Partnership Program (NOPP) legislation. This new governance structure requires revision of the management structure recommended in the *First IOOS Development Plan*.

¹⁷ Report of the Commission on Ocean Policy, *An Ocean Blueprint for the 21st Century*. <<http://www.oceancommission.gov/>>

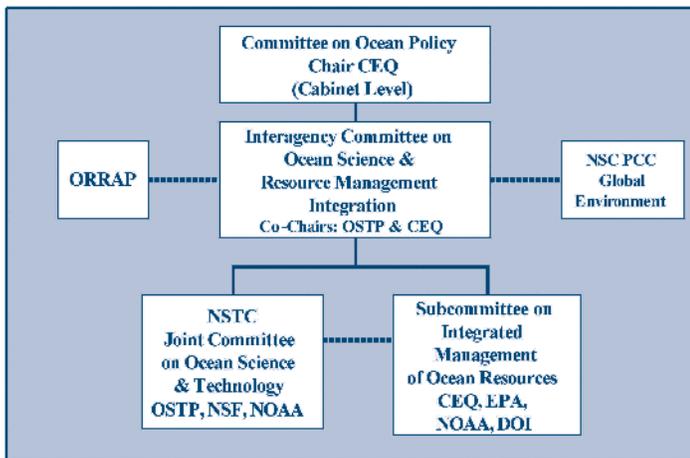


Figure I.6. Coordinated ocean governance structure called for in the Administration’s *Ocean Action Plan* (OAP). The new elements of the OAP governance structure are the Committee on Ocean Policy (COP) and the Subcommittee on Integrated Management of Ocean Resources (SIMOR). The COP was created by Executive Order as a Cabinet-level committee to “coordinate the activities of the Executive Branch departments and agencies regarding ocean-related matters in an integrated and effective manner to advance the environmental and economic interests of present and future generations of Americans.” The Chair of the Council on Environmental Quality (CEQ) also Chairs the COP, which includes the Secretaries of State, Defense, Interior, Agriculture, Health and Human Services, Commerce, Labor, Transportation, Energy, and Homeland Security; the Attorney General; the Administrators of EPA and NASA; the Directors of National Intelligence, NSF, Office of Management and Budget and Office of Science and Technology Policy; Chairman of the Joint Chiefs of Staff; Assistants to the President for National Security Affairs, Homeland Security, Domestic Policy and Economic Policy; an employee of the U.S. designated by the Vice President; and such other officers and employees of the U.S. that the COP chairman may designate as needed. Under the oversight of the COP, the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI) will incorporate the National Ocean Research Leadership Council current mandate within its broader mandate to include ocean resource management. The Joint Subcommittee on Ocean Science and Technology (JSOST) is a direct descendent of the Joint Subcommittee on Oceans (JSO) of the National Science and Technology Council (NSTC). Commensurate with its expanded functions, the ICOSRMI will have two advisory bodies: the Ocean Research and Resources Advisory Panel (ORRAP) and the National Security Council (NSC) Policy Coordinating Committee on the Global Environment. The functions of these groups are described in the OAP.³

It is anticipated that the governance structure called for in the OAP (Figure I.6) will be implemented without new legislation. Under current legislation, the governing body for NOPP, the National Ocean Research Leadership Council (NORLC), created the Ocean.US Office in 2000 to design the IOOS and plan its coordinated implementation. An Executive Committee (EXCOM) was also established to provide policy guidance, approve development plans and ensure sustained federal support of Ocean.US.¹ Subsequent to the establishment of the Ocean.US-EXCOM Enterprise, the NORLC identified four strategic goals: (1) achieve and sustain an integrated ocean observing system; (2) promote lifelong ocean education; (3) modernize ocean infrastructure and enhance technology development; and (4) foster interagency partnerships to increase and apply scientific knowledge. Ocean.US is responsible for goal 1 and is contributing to goal 2.

IOOS Development Plan updates prepared by Ocean.US provide guidance to participating federal agencies and Regional Associations for the preparation of IOOS funding budget requests. Based on this plan and guidance from federal agencies and the National Federation of Regional Associations (NFRA), Ocean.US facilitates a coordinated interagency set of budget requests from federal agencies for the Office of Management and Budget (OMB) and Congress. With the formation of the ICOSRMI and its subcommittees (JSOST and SIMOR), a new oversight mechanism for Ocean.US is needed. Therefore, Ocean.US makes the following recommendations:

- Maintain Ocean.US outside of any single federal agency, dissolve the EXCOM and task the JSOST Interagency Working Group on Ocean Observations (IWGOO) to continue to perform EXCOM functions (Figure I.7);
- Implement the four year Ocean.US planning cycle described in the First IOOS Development Plan; and
- Develop sustainable funding and personnel arrangements for Ocean.US that allow the office to focus more on strategic planning and coordinated implementation of the IOOS than on funding and staffing.

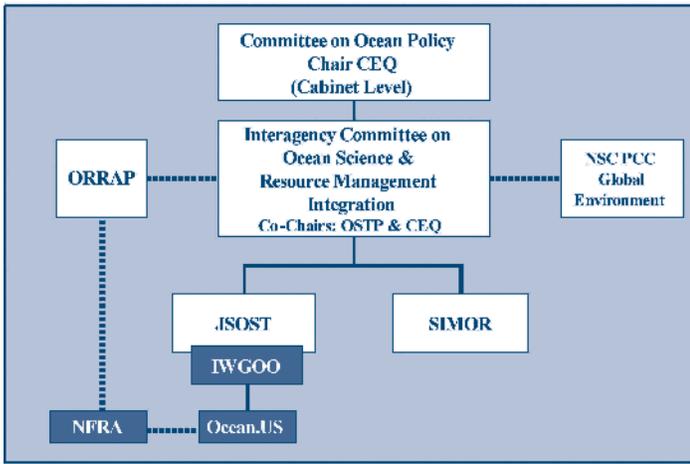


Figure I.7. Recommended linkage between Ocean.US and the JSOST in the governance structure called for in the *Ocean Action Plan*. Solid lines indicate governance oversight linkages; dashed lines indicate communications, coordination or advisory linkages. The Interagency Working Group on Ocean Observations (IWGOO) of the JSOST will take on current functions of the EXCOM. The National Federation of Regional Associations (NFRA) represents regional interests to the federal government and provides a mechanism to coordinate the development of RAs and RCOOSs nationwide, promote capacity building among regions, and enable information exchange among federal agencies and Regional Associations.

2.5 Regional Development

Impacts of natural hazards, global climate change and human activities are greatest in the coastal zone. At the same time, the susceptibility of the coastal zone to these forces differs significantly among regions as does the nature and magnitude of their impacts. Thus, Regional Coastal Ocean Observing Systems (RCOOSs) are especially important for linking user needs to IOOS development on both global and local scales. Based on requirements of user groups for data and information in the respective regions, Regional Associations oversee the development of RCOOSs that contribute to the National Backbone (NB) and enhance it by increasing the time-space resolution of observations and the number of variables measured. Design principles for the IOOS are given in the *First IOOS Development Plan*.¹

During FY 2004 and 2005, regional groups were competitively funded to develop organizations intended to qualify as IOOS RAs eligible to compete for sustained funding (Figure I.8). Ocean.US recommends continued federal support for RAs that foster engagement of user



Figure I.8. Eleven regional groups have been funded to develop Regional Associations (RAs) that will oversee the design, implementation, operation and improvement of Regional Coastal Ocean Observing Systems (RCOOSs). A National Federation of Regional Associations (NFRA) has been created to coordinate RCOOS development for interoperability, to facilitate information exchange among RAs, to inform federal agencies of common needs, and to collaborate with federal agencies to help guide the development of the IOOS as a whole.

groups from public and private sectors in IOOS development, engagement of regional organizations of participating federal agencies, and the integration of sub-regional observing systems to build RCOOSs; and for a National Federation of Regional Associations (NFRA) that enables coordination among RAs and results-driven collaboration among RAs and government agencies (local, state and federal). The next step is for Ocean.US to collaborate with the federal agencies to formulate policies and procedures for certifying responsible RAs that meet their legal requirements.

3. International Activities and Partnerships

As the national focal point for integrating ocean observing activities, Ocean.US collaborates with participating federal agencies and RAs to ensure coordinated development of and interoperability among the IOOS, the Global Ocean Observing System (GOOS) and the Global Earth Observation System of Systems (GEOSS).

3.1 IOOS and GOOS

The Intergovernmental Committee for GOOS (I-GOOS) was established by the Intergovernmental Oceanographic Commission (IOC) Executive Council in 1992 to oversee the design and implementation of GOOS and to secure funding for implementation (Figure I.9).¹⁸ The GOOS Scientific Steering Committee (GSSC) provides scientific and technical guidance to the I-GOOS for the design and implementation of GOOS as a whole, and the Oceans Observations Panel for Climate (OOPC) provides technical and scientific guidance to the GSSC. Coordination of U.S. IOOS and GOOS development is effected through the IOC Assembly and directly through the I-GOOS and the GSSC. In regard to the latter, the Director of Ocean.US serves as the U.S. point of contact and as a U.S. representative to I-GOOS. Although the current Director of Ocean.US is a Vice Chair of I-GOOS, Ocean.US is not officially represented on the U.S. Delegation to the IOC.

The Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) is an intergovernmental body of experts that provides the mechanism for coordination, regulation and management of international operational oceanographic and marine meteorological activities (Figure I.9). The Commission is organized around four Program Areas: Observations, Data Management, Products and Services, and Capacity Building. Within each Program Area, specific activities are undertaken by Expert Teams, Task Teams and Panels. Overall guidance and oversight of JCOMM is provided by a Management Committee, chaired by the Co-Presidents of JCOMM. This Committee also includes the four Program Area



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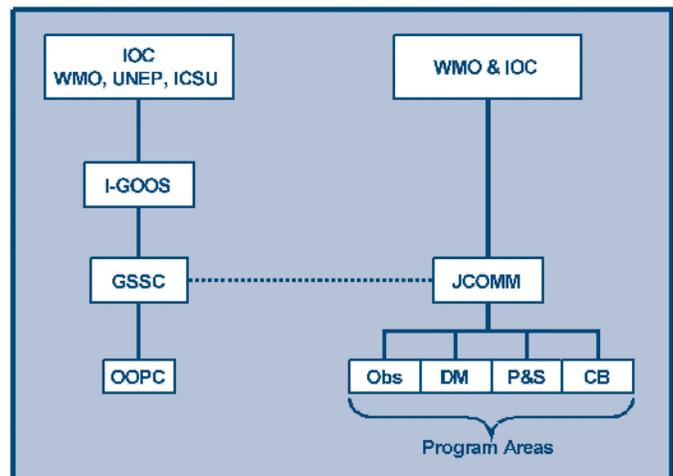
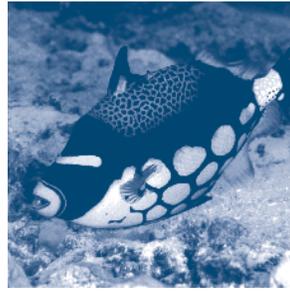
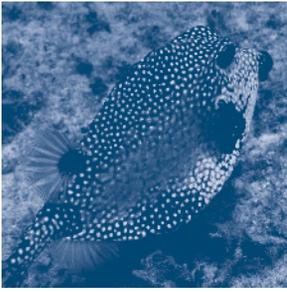


Figure I.9. Governance structure of GOOS. The Intergovernmental Oceanographic Commission (IOC), the World Meteorological Organization (WMO), the United Nations Environmental Programme (UNEP), and the International Council for Science (ICSU) are the sponsors of the Intergovernmental Committee for GOOS (I-GOOS) and its subsidiary bodies. JCOMM and its program areas for observations (Obs), data management (DM), products and services (P&S) and capacity building (CB) are sponsored by WMO and IOC. Solid lines indicate institutionalized reporting and/or advisory linkages. The dotted line indicates informal exchanges of information, guidance and recommendations that are not institutionalized.

¹⁸ <<http://ioc.unesco.org/goos/>>; <http://ioc.unesco.org/goos/igoos_tr.htm>; <<http://ioc.unesco.org/jcomm/>>; <<http://ioc.unesco.org/goos/oopc/>>.



Coordinators; one representative each from GOOS, the Global Climate Observing System (GCOS) and the International Oceanographic Data and Information Exchange; and a small number of selected experts. Ocean.US is not represented on JCOMM or its subsidiary bodies.

The JCOMM has established an Expert Team on Data Management Practices (ETDMP), and there are opportunities for “internationalizing” DMAC through cooperation with ETDMP.¹⁹ Examples of such opportunities include collaborating on the establishment of metadata standards (ISO 19115), development of a semantic data model, development of data transport tools and a data archive plan, and implementation of joint pilot projects. These and other collaborations will be enabled by cross-membership with the DMAC Steering Team and JCOMM Data Management Program Area (DMPA). Clearly, such cooperation between DMAC and the JCOMM DMPA will benefit both groups. As a step in this direction, a member of the Ocean.US DMAC Steering Team has been elected as Chair of the JCOMM DMPA. He also leads the DMAC Steering Team International Community Engagement Caucus to facilitate outreach to, and feedback from, the international community.

It is recommended that the Director of Ocean.US serve on the U.S. Delegations to the IOC Assembly and to JCOMM, and that ETDMP appoint a representative to serve on the DMAC Steering Team.

3.2 IOOS, IEOS and GEOSS

The U.S. Group on Earth Observations (USGEO), which oversees the design and implementation of the Integrated Earth Observation System (IEOS, the U.S. contribution to the Global Earth Observation System of Systems [GEOSS]), was established by the National Science and Technology Council (NSTC) in March 2005 as a standing subcommittee of its Committee on Environment and Natural Resources (CENR). Although designated as the National Office for Integrated and Sustained Ocean Observations, Ocean.US is not represented on the USGEO.

Ocean.US staff are involved in several phases of the intergovernmental Group on Earth Observations (GEO) process as follows:

- As the Vice Chair of the I-GOOS (a member of GEO), the current Director of Ocean.US represents I-GOOS at the GEO Plenary and serves on the GEO Architecture and Data Committee and the User Interface Committee;
- The current Deputy Director for Research represents the Partnership for Observations of the Global Ocean (POGO, a member of GEO) at the GEO Plenary;
- The current Deputy Director for DMAC is working with the World Meteorological Organization (WMO) Intergovernmental Working Group overseeing the development of the “Future WMO Information System” for GEOSS.

For national continuity and international coordination, it is recommended that the Director of Ocean.US be appointed to the USGEO.

3.3 GOOS Regional Alliances

GOOS is being implemented by nations and by GOOS Regional Alliances (GRAs, coalitions of nations, national ministries, and/or non-governmental organizations) that have been formed worldwide (Figure I.10). In this regard, the development of the IOOS should be more closely coordinated with similar efforts by other countries, including Canada, Mexico and Caribbean nations. Actions should include initiating joint planning and implementation activities and the establishment of North America as a GRA.



Figure I.10. GOOS Regional Alliances are forming to establish the global ocean and coastal modules of GOOS worldwide. The list of contributing countries and descriptions of GRAs can be found at <<http://ioc.unesco.org/goos/key3.htm#reg>>.

¹⁹ Report of the First Session of the JCOMM/IODE Expert Team on Data Management Practices (ETDMP), Flanders Marine Institute, Oostende, Belgium, September 2003.



4. Performance Measures

Developing and implementing the IOOS successfully requires a systematic and rigorous process for annual performance evaluations of IOOS capabilities, in terms of both the flow of data from measurements to models and the provision of data and information at rates and in forms specified by the users. Performance measures for the initial IOOS will be based on existing performance measures being developed by the federal agencies in compliance with the Government Performance and Results Act of 1993 and will focus on measures of integration in four categories (Figure I.11) established for the IEOS.

An example of integration at the agency level occurs within NOAA, where programs established to meet the climate mission are also components of the weather and water missions. In this case, improving temperature and precipitation forecasts by integrating data from multiple sensors contributes to achieving both missions. Performance measures and metrics for the global component of the IOOS are relatively well-defined, having been under development for over a decade, driven in part by the requirements of international conventions.²⁰ These measures will continue to evolve as requirements are refined in response to increased understanding of the geophysical system. Performance measures and metrics in use by participating federal agencies for IOOS-related activities, such as those being developed and implemented by NOAA²¹, will be evaluated and used as appropriate. Ultimately, performance measures and metrics will be needed for the IOOS as a whole to assess the effectiveness of integration across the four integration levels (Figure I.11) on both regional and national scales.

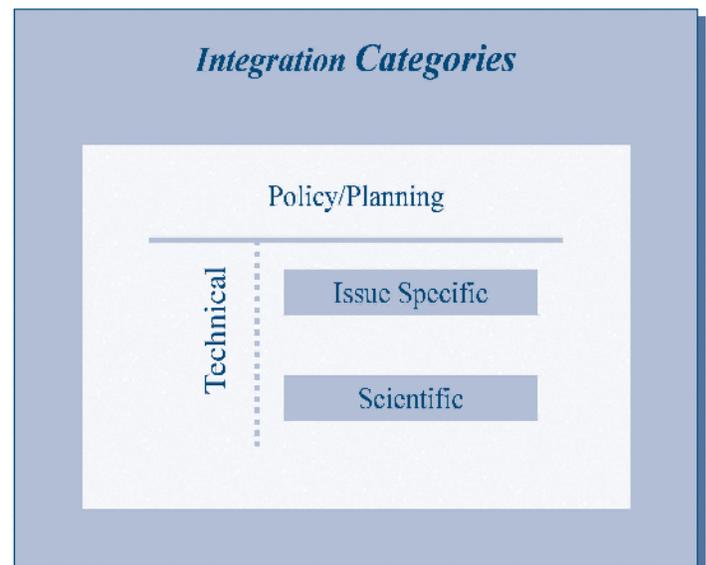


Figure I.11. Levels of observing system integration. **Policy/Planning** integration focuses on the realization of the seven IOOS societal goals; integration at the **issue level** brings data, research and modeling (i.e., understanding) together in developing decision support tools and products, including products for education and training purposes; **scientific integration** brings together all of the scientific tools required to develop understanding (e.g., access to and assimilation of data from multiple platforms and sensors for model simulations and predictions, optimize sampling schemes involving both *in situ* measurements and remote sensing using model simulations); **technical integration** is the establishment of the enabling technologies (e.g., communications, platforms, data management).

²⁰ United Nations Framework Convention on Climate Change <<http://unfccc.int/2860.php>>

²¹ <http://www.oco.noaa.gov/docs/programplan_04_05.doc>



Part II: Integrating Existing Elements

1. Introduction

A major immediate objective for coordinated development of the global and coastal components of the Integrated Ocean Observing System (IOOS) is to demonstrate the benefits of integration in terms of the cost-effective production of new or improved products (proof of concept). Achieving this objective requires prioritized, phased integration of observing subsystem elements that will lead to early successes. To these ends, the first programs to be integrated should meet the following criteria:

- Address changes in the state of marine systems that have major socio-economic consequences;
- Result in new or improved products and/or services through integration within the next year or two; and
- Provide data and information needed to address two or more of the seven societal goals of the IOOS.

Developing IOOS capabilities for predicting, managing and mitigating the effects of tropical storms, tsunamis and extra-tropical storms meets these criteria. In addition to improving the timeliness and accuracy of predictions of coastal inundation caused by these events, the data and information provided by the IOOS will help address the goals of improving homeland security, reducing public health risks, protecting and restoring healthy ecosystems, and sustaining and restoring living marine resources. Improved predictions of changes in water level related to global climate change will also lead to more accurate predictions of the impacts of coastal inundation. Thus, the Second Annual IOOS Implementation Conference (3-4 May 2005) focused on requirements for developing an integrated, multi-hazard warning system that will provide data and information needed to improve nowcasts and forecasts of the time-space extent of coastal inundation and its impacts on coastal communities, ecosystems and living marine resources.¹ Results from the workshop and the National Science and Technology Council's *Grand Challenges for Disaster Reduction* (Box II.1)² are the foundations of the recommendations made herein.

¹ Second IOOS Implementation Conference, <http://www.ocean.us/documents/docs/2ndIOOS_FINAL_lowres.pdf>

² Natural Disaster Reduction, A Plan for the Nation <<http://www.usgs.gov/sndr/report/>>; "Framing the Grand Challenges: A Vision for Federal Disaster Reduction" <<http://www.sdr.gov/SDRGrandChallengesforDisasterReduction.pdf>>

Box II.1: Six Grand Challenges for Disaster Reduction^a

1—Provide hazard and disaster information where and when it is needed: To identify and anticipate natural hazards, a mechanism for real-time data collection and analysis must be readily available to and usable by scientists, emergency managers, first responders, citizens, and policy makers. Developing and improving observation tools is essential to provide pertinent, comprehensive, and timely information for planning and response.

2—Understand the natural processes that produce hazards: To improve forecasting and predictions, scientists and engineers must continue to pursue basic research on the natural processes that produce hazards and understand how, when and where natural processes become hazardous. New data must be collected and incorporated into advanced and validated models that support an improved understanding of underlying natural system processes and enhance assessment of the impacts.

3—Develop hazard mitigation strategies and technologies: To prevent or reduce damage from natural hazards, scientists must invent—and communities must implement—affordable and effective hazard mitigation strategies, including land-use planning and zoning laws that recognize the risks of natural hazards. In addition, technologies such as disaster-resilient design and materials and smart structures that respond to changing conditions must be used for development in hazardous areas.

4—Recognize and reduce vulnerability of interdependent critical infrastructure: Protecting critical infrastructure systems, or lifelines, is essential to developing disaster-resilient communities. To be successful, scientists and communities must identify and address the interdependencies of these lifelines at a systems level (e.g., communications, electricity, financial, gas, sewage, transportation, and water). Using integrated models of interdependent systems, additional vulnerabilities can be identified and then addressed. Protecting critical infrastructure provides a solid foundation from which the community can respond to hazards rapidly and effectively.

5—Assess disaster resilience using standard methods: Federal agencies must work with universities, local governments, and the private sector to identify effective standards and metrics for assessing disaster resilience. With consistent factors and regularly updated metrics, communities will be able to maintain report cards that accurately assess the community's level of disaster resilience. This, in turn, will support comparability among communities and provide a context for action to further reduce vulnerability. Validated models, standards, and metrics are needed for estimating cumulative losses, projecting the impact of changes in technology and policies, and monitoring the overall estimated economic loss avoidance of planned actions.

6—Promote risk-wise behavior: Develop and apply principles of economics and human behavior to enhance communications, trust, and understanding within the community to promote “risk-wise” behavior. To be effective, hazard information (e.g., forecasts and warnings) must be communicated to a population that understands and trusts the messages. The at-risk population must then respond appropriately to the information. Changes must occur at both the policy level and in the societal perception of risk so that adoption and adaptation keep pace with advances in science and technology. A sustained emphasis on risk mitigation and public-private partnerships is essential throughout all aspects and at all levels of the community. Within this integrated planning context, improved coordination of sustained Federal science and technology investment to address the Grand Challenges for Disaster Reduction will enhance disaster resilience and national safety.

^a Framing the Grand Challenges: A Vision for Federal Disaster Reduction <www.sdr.gov/SDRGrandChallengesforDisasterReduction.pdf>

Part II of the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan*³ recommends

(1) federal programs for the initial observing subsystem; (2) implementing the Data Management and Communications (DMAC) plan; (3) establishing Regional Associations (RAs) to engage stakeholders and manage the development of Regional Coastal Ocean Observing Systems (RCOOSs); and (4) establishing education networks that will link science education, training and public outreach to IOOS development. Part II of this *IOOS Development Plan* update focuses the broad recommendations of the first plan by targeting priorities for integrating multi-hazard observing capabilities (from observations to modeling) through phased implementation of the DMAC subsystem. The latter will guide integration of:

- Selected elements of the initial National Backbone (NB) for improving forecasts of coastal inundation and its impacts on coastal communities, ecosystems and natural resources;
- The NB with RCOOSs; and
- The global and coastal components of the IOOS.

In the context of the first plan, the recommendations herein provide a roadmap for developing the modeling and analysis subsystem, regional development, setting research priorities, linking education and IOOS development, and addressing the public health goals of IOOS. Implementation of the roadmap will provide data and information on coastal inundation needed by three categories of user groups: (1) real-time responders (Federal Emergency Management Agency [FEMA] and other emergency managers, fire and police departments; local and state officials, U.S. Coast Guard, etc.); (2) near-term, post event re-builders (environmental protection agencies, insurance companies, transportation and public works managers, construction contractors, residents, etc.); and (3) longer-term planners, decision makers, researchers and educators (coastal zone managers, FEMA, floodplain managers, land-use planners, local and state officials, natural resource managers, Non-governmental Organizations (NGOs), politicians, re-insurance companies, Sea Grant extension agents, academics, etc.). Real-time responders need timely forecasts with known uncertainty of where and when (spatial and temporal extent) an inundation event is likely to occur; post event re-builders need timely forecasts of where and when the event will end so they can begin re-building as soon after the event as possible; and longer-term planners need to know the spatial distribution of susceptibility to coastal inundation (risk) and how susceptibility changes due to changes in shoreline position, sea level, near-shore bathymetry and topography, hardening of the shoreline, land-cover and -use in the coastal zone. These data and information needs are used to help guide recommendations herein.

2. The Observing Subsystem

Numerical modeling has developed rapidly in scope (from hydrodynamics to ecology) and resolution (from one-dimensional, 10^2 elements to three-dimensional, 10^8 elements) during the last forty years as understanding of marine systems and computing power have increased. Unfortunately, observational and data management capabilities have not kept pace. Severe under-sampling of oceanic and coastal systems (in terms of temporal and spatial resolution as well as the ecological complexity of the marine environment) and the time needed to obtain data of known quality from different sources currently constrain the improvement of existing operational models.⁴ These problems are especially acute and challenging in dynamic coastal systems subject to cross-boundary forcings associated with basin scale changes, inputs from land-based sources, atmospheric deposition and human uses (Figure II.1).⁵ Increasing the temporal and spatial resolution of key core variables will lead to more accurate and timely predictions of the impacts of coastal inundation and more effective mitigation of these impacts.

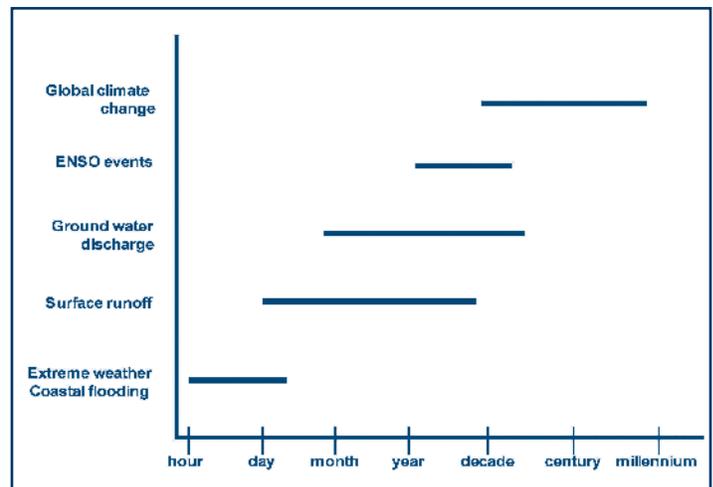


Figure II.1. Time scales of major external forcings of coastal marine and estuarine systems. Given the range of time-space scales that must be captured, both remote (satellite, aircraft, land-based) and *in situ* sensing are needed.

³ The *First U.S. Integrated Ocean Observing System (IOOS) Development Plan* <<http://www.ocean.us/ioosplan.jsp>>.

⁴ Prandle, D., H. Los, T. Pohlmann, Y-H. de Roeck, and T. Stipa (eds.) 2005. Modeling in coastal and shelf seas – European challenges. European Marine Board Position Paper 7, 28 p.

⁵ Gardner, R., Kemp, W.M., Petersen, J. and Kennedy, V. (eds.), 2001. *Scaling relations in experimental ecology*. Columbia University Press, New York, ; Malone, T.C., Knap, T. and Fogarty, M., 2005. Overview of science requirements. In *The Sea: The Global Coastal Ocean: Multiscale Interdisciplinary Processes*, 13, Robinson, A.R. and Brink, K. (Eds). Harvard University Press, Boston. 1033 pp.; Botsford, L.W., Castilla, J.C. and Peterson, C.H., 1997. The management of fisheries and marine ecosystems. *Science*, 277: 509-515.

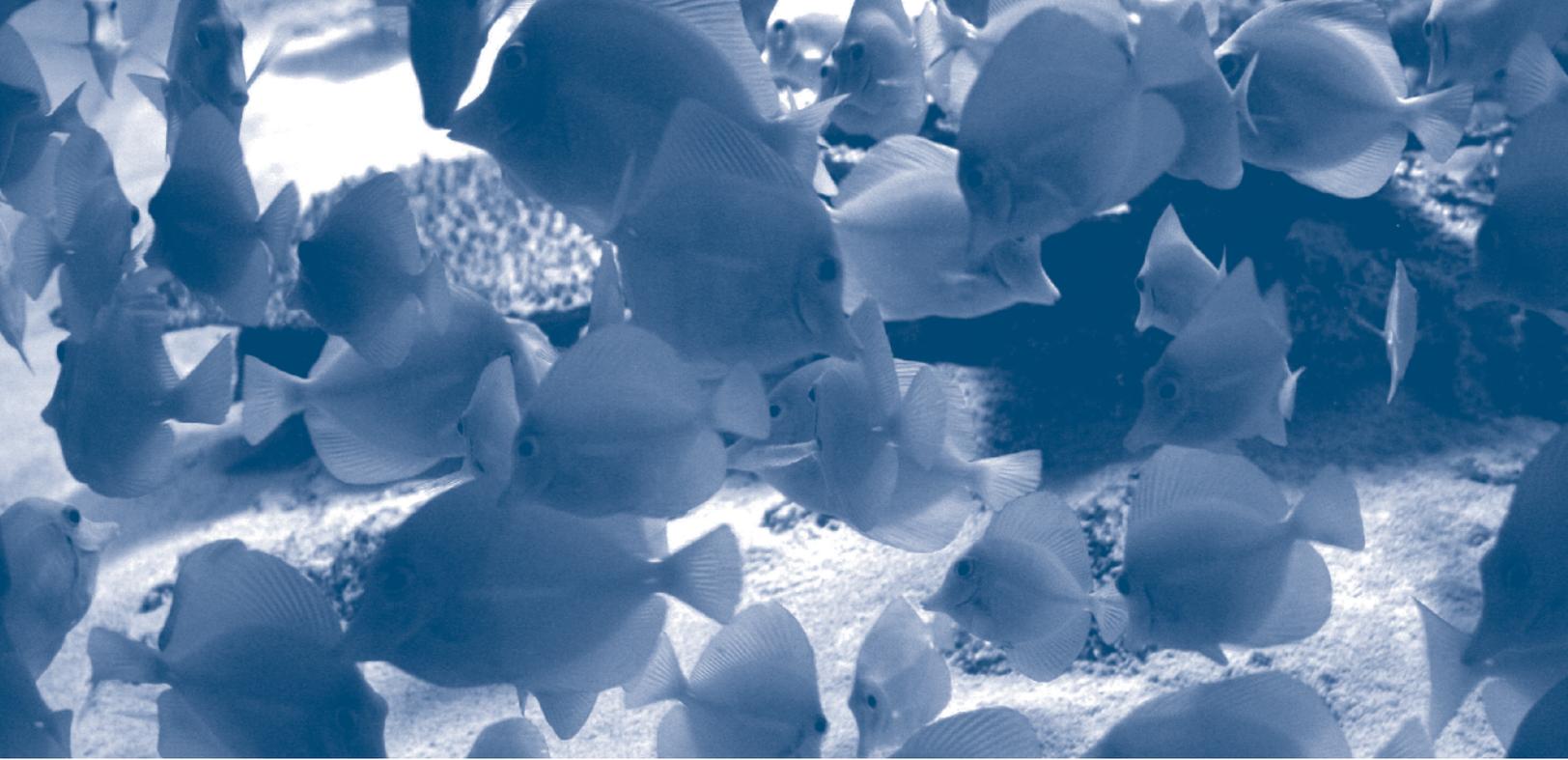
The recently completed report of the Integrated Global Observing Strategy's (IGOS) Coastal Theme Team⁶ specifies observing subsystem requirements for core variables in coastal systems (Table II.1) that can be achieved only through integrated, coordinated development of the National Backbone and RCOOSs and the combined use of remote (satellites, aircraft and land-based) and *in situ* (ships, moorings, drifters, autonomous underwater vehicles) sensing. Spatial dimensions of pattern are best captured with remote sensing, especially

in environments that exhibit episodic and high frequency temporal variability (e.g., the atmosphere, upper ocean and coastal waters). Remote sensing is also useful for capturing low frequency variability (basin scale warming of the upper ocean and sea level rise). With some important exceptions (coral reefs and sea grass beds in clear, shallow waters), temporal variations in coastal marine and estuarine systems, surface runoff, and subsurface pelagic and benthic habitats are best captured by *in situ* observations.

Table II.1. Coastal observing subsystem requirements for geophysical and biogeochemical variables and for mapping coastal features and habitats (HR – Horizontal Resolution, OC – Observing Cycle [frequency], AV – Availability, ACC – Accuracy, MIN – minimum requirement). Modified from the IGOS Coastal Theme Report.⁶

	PARAMETER	HR	HR MIN	OC	OC MIN	AV	AV MIN	ACC	ACC MIN
GEOPHYSICAL	Sea surface Temperature	100 m	1 km	3 h	6 h	1 h	3 h	0.2° C	0.5° C
	Wind speed and direction	300 m	10 km	1 h	6 h	1 h	3 h	1 m/s 10°	2 m/s 20°
	Sea surface height	1 km	15 km	1d	10 d	1 h	3 h	4 cm	6 cm
	Surface wave height-direction	1 km	10 km	3 h	1 d	1 h	3 h	0.2 m 5°	0.2 m 10°
	Salinity	1 km	25 km	24 h	7 d	1 h	3 h	0.1 psu	0.3 psu
	Currents	300 m	5 km	1 h	24 h	1 h	3 h	3 cm/s	10 cm/s
	Streamflow	1 km	10 km	1 h	24 h	1 h	3 h	10%	30%
	Precipitation	1 km	15 km	1 h	8 h	1 h	3 h	0.5 mm/h	2 mm/h
BIOGEOCHEMICAL	Phytoplankton pigments	100 m	500 m	1.5 h	3 h	1 h	3 h	20%	30%
	Total suspended matter	100 m	500 m	1.5 h	3 h	1 h	3 h	30%	40%
	Optical properties (includes PAR)	100 m	500 m	1.5 h	3 h	1 h	3 h	10%	20%
	Dissolved inorganic nutrients (N, P, Si)	10 km	100 km	1 d	1 mo	1 d	7 d	10%	30%
	O ₂ pCO ₂	10 km	100 km	1 d	1 mo	1 d	7 d	10%	30%
MAPPING	Bathymetry	30 m	50 m	2 d	24 d	4 h	1 d	1.1 m (depth)	1 m (depth)
	Shoreline position	1 m	5 m	15 d	3 mo	1 d	7 d	1 m	5 m
	Surface slicks & plumes	25 m	50 m	3 h	2 d	1 h	3 h	50 m	100 m
	Habitat maps (intertidal wetlands)	5 m	20 m	15 d	3 mo	1 d	7 d	--	--
	Habitat maps (coral reefs, sea grass beds)	1 m	5 m	15 d	3 mo	1 d	7 d	2 m	10 m

⁶ 2005. IGOS Coastal Theme Report <<http://www.eohandbook.com/gosp/Coastal.html>>



As documented in the Coastal Theme Report, current and planned satellite missions of the international community for the period 2005 – 2018 are most effective for the open ocean, where continuity of observations (surface vector winds, sea surface temperature, sea surface height, sea surface roughness, and ocean color) is the primary challenge.⁶ **For most coastal marine and estuarine systems within about 100 km of the coastline, existing satellite missions are inadequate not only in terms of continuity, but also in terms of knowledge (e.g., algorithms for calculating phytoplankton pigment concentrations in turbid coastal waters) and resolution (time, space and spectral).** These challenges are addressed in Part III.

2.1 The First U.S. IOOS Development Plan System Concept

As a point of departure, brief summaries of recommendations in the *First IOOS Development Plan* are given here (Tables II.2 and II.3).³ The recommendations given in subsequent sections are not meant to replace those of the first plan. Rather, they focus them on coastal inundation, a major forcing that cross-cuts the seven IOOS societal goals.

2.1.1 Global Component

Continued implementation of the global ocean component of the IOOS must remain a high priority. Data and

information provided by global observations of the ocean are needed to improve the safety and efficiency of maritime operations, forecasts of natural hazards, and predictions of climate change. High priorities are to document 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. The required data-products needed to achieve these goals are given in the *Implementation Plan for the Global Ocean Observing System for Climate*.⁷

Progress on establishing the global component continues at a consistent pace, with over 50% of the *in situ* system now in place (Table II.2).⁸ As *in situ* networks are needed to fully characterize the three-dimensional structure of the ocean, full deployment of the Argo float array is a high priority. The number of subsurface ocean profiles of temperature and salinity has increased dramatically over the last two years, due in large part due to the growth of the Argo array of profiling floats (Figure II.2), with 1,928 floats reporting in June 2005 out of the required 3,000 needed for global 3° resolution coverage (to be achieved by 2007). In some parts of the world ocean, Argo floats have now contributed more vertical profiles of temperature and salinity to the historical record than all other previous measurements combined. Critical satellite missions (research and operational) supporting the provision of products and services by government agencies and other organizations in the U.S. are summarized in Table II.3.

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 OODSP, 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 UNFCCC. <<http://www.wmo.ch/web/goos/gooshome.html>>

⁸ <http://www.ocean.us/documents/docs/US%20GOOS%20NAT%20REP_Final.pdf>

Table II.2. Implementation status of the core *in situ* elements of the observing subsystem for IOOS (number of operational sensors or platforms that are or are expected to be operational in any given year).

<i>In Situ</i> Observing Element		United States				International
		2003	2004	2005 plans	2006+ plans	GOOS Goal
DBCP ^a	Surface drifting buoys	751	820	900	900	1250
	with barometer	32	32	300	300	600
	Sea ice buoys (IABP ^b , IPAB ^c)	17	25	28	31	
	Global tropical moored buoy network	55	55	69	71	119
	Coastal moorings	83	88	94	95	
Ocean SITES	Global reference mooring network (GRMN)	5	5	5	5	29
	Total time series sites including GRMN	8	8	8	9	58
GLOSS ^d	Stations committed to GLOSS	42	24	24	24	290
	GLOSS real-time reporting stations	34	19	29	41	170
	GLOSS geolocated stations	14	8	10	12	170
SOT ^f	High-density XBT ^e lines occupied	11	11	12	17	64
	Frequently-repeated XBT lines occupied	4	4	5	6	25
	Number of XBTs deployed	9444	11248	13000	14000	23000
	VOS AWS ^g ships	30	30	30	30	
	VOS Clim ships	12	12	24	36	200
	ASAP ^h ships	30	30	30	30	
	ASAP sondes deployed	30	30	30	30	
IOCCP ⁱ	Carbon survey (lines completed since 2001)	2	4	6	7	31
	VOS Carbon	8	8	9	10	
Argo floats, operational		474	810	1150	1500	3000
Sustained and repeated ship hydrography lines		30	30	30	30	
Data Centers		4	4	4	4	

^aData Buoy Cooperation Panel, ^bInternational Arctic Buoy Program, ^cInternational Program for Antarctic Buoys, ^dGlobal Sea Level Observing System, ^eExpendable Bathythermograph, ^fShip Observations Team, ^gVolunteer Observing Ship Automated Weather System, ^hAutomated Shipboard Aerological Programme, ⁱInternational Ocean Carbon Coordination Project

Table II.3. Current and planned satellite-based earth observing capabilities (research and operational) that are observing core variables and supporting the provision of products and services by U.S. Government agencies and organizations (AVHRR – Advanced Very High Resolution Radiometer, GOES – Geostationary Operational Environmental Satellite, GFO- GEOSAT Follow-On, MODIS – Moderate Resolution Imaging Spectroradiometer, TRMM – Tropical Rainfall Measuring Mission, TMI – TRMM Microwave Imager, SeaWiFS – Sea-viewing Wide Field-of-view Sensor, HES – Hyper-spectral Environmental Suite, ABI – Advanced Baseline Imager, CMIS – Conical image: rain rate scanning Microwave Imager/Sounder, OSTM – Ocean Surface Topography Mission, AMSR – Advanced Microwave Scanning Radiometer, SSM/I - Special Sensor Microwave/Imager, DMSP – Defense Meteorological Satellite Program, SAR – Synthetic Aperture Radar).

Core Variable	NASA	NOAA	DOD	Foreign
Sea Surface Temperature	MODIS on Aqua TMI on TRMM	AVHRR on GOES-Imager ABI on GOES-R ^a	WindSat	
Ocean Color	MODIS on Aqua SeaWiFS ^b	HES on GOES-R ^a		
Sea Surface Height	Altimeters on Jason-1, OSTM ^{a,c}		GFO	
Surface Vector Winds	Sea Winds on QuikScat		WindSat	
Sea Ice	Sea Winds on QuikScat AMSR-E on Aqua		SSM/I on DMSP	SAR on RadarSat-1 ^d

^aPlanned Missions

^bCommercial provider, Orbital Sciences Corporation

^cFrance (CNES) is international partner

^dOperated by Canada (Instrument and satellite have the same name)

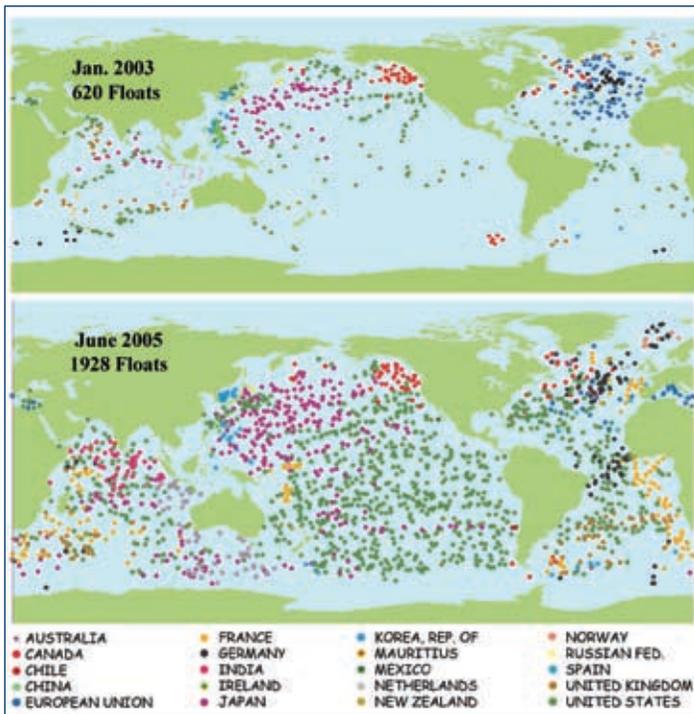


Figure II.2. Progress made in the Argo profiling float network over two years. Argo floats measure temperature and salinity from the surface to 1,000 - 2000 m depth every 10 days depending on the instrument and water mass characteristics. The Argo network is now 64% complete, and the goal is to seed the ocean with 3,000 floats by 2007, yielding a 3° global resolution of sub-surface temperature and salinity. Colors denote the country responsible for the float.

2.1.2 National Backbone of the Coastal Component

The National Backbone (NB) of the IOOS is the suite of operational **observing subsystem elements** that support the following functions:

- Monitor core variables³ in the nation's Exclusive Economic Zone (EEZ) and Great Lakes using both remote sensing and *in situ* measurements;
- Make *in situ* measurements at a network of sentinel sites using federally approved methods;
- Transmit DMAC-compliant data on core variables to national data assembly centers continuously, routinely and reliably (real-time or delayed mode as needed); and
- Link larger scale changes occurring in the ocean and on land to changes occurring within the regions.

Recommendations for the initial observing subsystem of the NB in the *First IOOS Development Plan* focus on using existing assets to improve estimates of changes in the state of marine systems as measured by the core variables.

2.2 Implementing a Coastal Inundation Warning System

Given the socio-economic benefits of improving predictions of coastal inundation as the means for managing and mitigating impacts on coastal communities, ecosystems and resources², the initial IOOS must focus on both short term variability (e.g., tidal scale) and long term trends (e.g., global ocean storage of heat and freshwater) by providing the following information:

- Frequency and time-space extent of coastal inundation (caused by tropical storms, tsunamis and extra-tropical storms);
- Extent and condition of near-shore coastal habitats that affect susceptibility to coastal inundation, species diversity and the capacity of coastal ecosystems to support living resources (intertidal habitats including salt marshes and mangrove forests; subtidal habitats including sea grass beds, kelp beds, coral reefs, and oyster reefs); and
- Impacts of coastal inundation on these habitats, water quality, living marine resources and coastal erosion (shoreline position, nearshore bathymetry-topography).

Rapid detection and timely prediction of trends in these environmental conditions require sustained observations and analyses over a broad range of scales (Figure II.1).^{3,6} Coastal flooding caused by tropical cyclones, extratropical storms and tsunamis is a common concern for coastal populations on episodic time scales. On longer time scales (e.g., decadal), the potential for sea level rise associated with subsidence and/or global warming is also a significant concern that may exacerbate episodic events in the long term. Coastal erosion and deposition processes that affect shoreline morphology and sediment distribution interact with these phenomena to accelerate or reduce their impacts. As a first priority, core variables for which distributions should be estimated in real-time with tidal scale resolution include the following:

- Sea surface vector wind, current and directional wave fields;
- River and stream flows and associated fluxes of sediments, nutrients and contaminants into coastal waters;
- Sea surface height and water levels; and
- Sea surface fields of temperature, salinity and chlorophyll-a.

Table II.4 highlights those variables that should be observed for coastal inundation based on recommendations from participating federal agencies and participants in the Second Annual IOOS Implementation Conference.¹

Table II.4. *In situ* pre-operational and operational programs that monitor core variables (from the *First IOOS Development Plan* with additions based on recommendations from EXCOM agencies following the completion of the first plan). Core variables that should be measured for integrated improved multi-hazard warnings are highlighted.

Core Variable	NOAA	Navy	USACE	USGS	EPA
Sea surface winds	C-MAN ^a , NWLON ^b NDBC ^c , PORTS ^{®d} , NERRS ^e	Integrated buoy program			
Stream flow				Stream gauging NSIP ^f NASQAN ^g	
Temperature	NDBC, CoastWatch, C-MAN NWLON, PORTS [®] , LMR-ES ^h , NERRS	Integrated buoy program			
Salinity	LMR-ES, PORTS [®] , NERRS, NDBC, C-MAN	Integrated buoy program			
Coastal Sea Level-Topography	NWLON, PORTS [®] , DART			NSIP GSN ⁱ	
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 NCAP ^j				NCAP
Water Quality/ Pollution	BEACH Program ^k NCAP			BEACH Program NAWQA ^l	BEACH Program NMDMP ^m NCAP NCAP
Chlorophyll	LMR-ES, NERRS, NCAP				NCAP
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 Shoreline Mapping	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 NCAP				NCAP

^aCoastal-Marine Automated Network; ^bNational Water Level Observation Network; ^cNational Data Buoy Center (moored meteorological sensors, DART mooring systems); ^dPhysical Oceanographic Real-Time System; ^eNational Estuarine Research Reserve System; ^fNational Streamflow Information Program; ^gNational Stream Quality Accounting Network; ^hLiving Marine Resources-Ecosystems Survey; ⁱGlobal Seismographic Network; ^jNational Coastal Assessment Program is a collaborative effort among EPA, NOAA and state agencies, ^kThe Beaches Monitoring and Notification Program is a collaborative effort among EPA and the states to monitor the quality of the water at U.S. beaches to help protect beach goers from waterborne pathogens; ^lNational Water Quality Assessment Program, ^mNational Marine Debris Monitoring Program; ⁿPopulation statistics = sex, weight, length, and stomach contents of fish species.



The efficacy of current predictive models of coastal inundation (section 4) will be improved by increasing the volume of data on these core variables (from *in situ* and remote sensing for both the coastal and the global ocean components) that can be accessed in near-real time (section 3). As recommended in the *First IOOS Development Plan* and summarized in Table II.4, the immediate priority over the next five years is to achieve the following:

- The National Data Buoy Center (NOAA/NDBC) should increase the number of stations for meteorological observations to 350 and increase the number of stations measuring directional waves and vertical current velocity profiles;
- The Center for Operational Oceanographic Products and Services (NOAA/CO-OPS) should increase the number of National Water Level Observation Network (NWLON) stations to 300 and upgrade them to provide real-time data telemetry;
- USGS should increase the number of National Streamflow Information Program (NSIP) and National Stream Quality Accounting Network (NASQAN) stations to 200 and 60, respectively; and
- CO-OPS (The National Current Observation Program) should update the Nation's tide tables more frequently by surveying 35 high priority stations per year to sustain and improve the accuracy of water level predictions.

The following are also recommended with actual numbers to be determined:

- Equip more NWLON stations with meteorological and oceanographic (temperature, salinity, current velocity) sensors;
- Increase the number of ports and estuaries served by Physical Oceanographic Real-Time System (PORTS[®]) and add side-looking and bottom mounted Acoustic Doppler Current Profilers (ADCPs);
- Measure selected contaminants at more NASQAN stations;
- Equip NASQAN stations located in intertidal waters with side looking ADCPs;
- Increase the number of Coastal Field Data Collection Programs measuring directional waves;

- Increase the number and spatial resolution of National Current Observation surveys; and
- Increase the spatial and temporal resolution of all hydrographic surveys and coastal mapping.

In addition to the provision of real-time, tidally resolved observations, predicting, managing and mitigating the impacts of coastal inundation require maps of susceptibility to coastal inundation that are updated periodically (one to ten year intervals depending on coastal geomorphology).² Such maps must take into consideration changes in shoreline position and near-shore bathymetry-topography across the land-sea interface as well as changes in the extent and condition of near-shore (e.g., < 50 m in depth and < 100 m in height above mean water level) benthic habitats (e.g., coral reefs, seagrass beds, kelp beds, tidal marshes and mangrove stands, rocky intertidal). Observing subsystem requirements for both variables and maps are given in Table II.1.

Models that integrate all of these data to predict impacts of coastal inundation based on both the magnitude of the event and changes in susceptibility over time do not exist at this time. Likewise, models for predicting the impacts of coastal inundation (run up) and the subsequent runoff events on public health risks (e.g., exposure to waterborne pathogens), coastal ecosystems (e.g., habitat loss, harmful algal blooms, oxygen depletion) and living marine resources (impacts on recruitment, essential habitats and catch per unit effort; mass mortalities) are in the formative stages of research and development at best. Thus, research needed to develop models that provide these predictions in support of decision making must be a high priority (section 4).

First steps in developing a multi-hazard capability for the National Backbone focus on the related issues of technical development and the need to “promote risk-wise behavior” (Box II.1):

- The technical priority is to specify observing subsystem requirements for core variables highlighted in Table II.4 and begin integrating existing data streams to improve maps of vulnerability and model predictions. The two primary integrating tools are DMAC (section 3) and modeling (section 4), and high priority must be given to taking these initiatives forward in concert. Initially, the rate of DMAC implementation will drive this process, but ultimately the requirements of models for environmental data must drive enhancements in the observing and DMAC subsystems based on data and information requirements specified by the users.
- Communicating information on hazards (early warnings, susceptibility) to coastal communities that understand and will respond appropriately to the message is addressed in section 6.

2.3 Ecosystem and Public Health Goals

Coastal flooding and subsequent runoff caused by tropical storms, tsunamis and extra-tropical storms impact ecosystem health and public health in a variety of ways, including increases in exposure risk to waterborne pathogens and chemical pollutants, marine debris, coastal erosion and habitat loss, and excessive nutrient loading leading to harmful algal blooms and oxygen depletion (dead zones). These realities underscore the importance of designing and implementing the National Water Quality Monitoring Network as a key element of the IOOS and the development of public health requirements for the IOOS.

2.3.1 National Coastal Assessment Program and National Water Quality Monitoring Network

Two related federal efforts will contribute to and benefit from IOOS development as described above:

- The National Coastal Assessment Program (NCAP, a partnership among EPA, NOAA and State agencies)⁹ prepares coastal assessments every two to three years; and
- A National Water Quality Monitoring Network (NMN)¹⁰ that is currently being planned, as recommended by the U.S. Commission on Ocean Policy.¹¹

Implementing recommendations in section 2.2 will benefit both NCAP and the NMN by improving estimates of land-based inputs of water, sediments, nutrients and contaminants and the distribution and fate of these materials once they enter marine and estuarine systems. With respect to the NMN, the Advisory Committee on Water Information (ACWI) was tasked by the Council on Environmental Quality (CEQ) and the National Science and Technology Council (NSTC) to provide advice and recommendations for the design of the NMN that integrates watershed, coastal waters and ocean monitoring based on common criteria and standards. To these ends, a NMN Design Working Group was established by the National Water Quality Monitoring Council (of the ACWI) to design the NMN. As recommended in the *First IOOS Development Plan*³, the National Backbone will measure, manage and analyze a set of core variables that include those required for the NMN (extent and condition of habitats, concentrations of nutrients, suspended sediments, chlorophyll, dissolved

oxygen, harmful algae and waterborne pathogens) and used by the NCAP. The NMN will contribute to assessments prepared by the NCAP and will contribute to and benefit from IOOS development. Once the design plan for the NMN has been completed, it will be used by Ocean.US to help guide coordinated implementation of the water quality elements of the coastal IOOS.

2.3.2 Waterborne Pathogens

Noting the variety and frequency of health threats from infectious and toxic marine organisms, recent reports call for improved data collection and the use of new technologies.¹² The economic benefits of more accurate assessments and timely predictions of exposure risks to waterborne pathogens are substantial. A recent study of nine economic sectors concludes that increases in revenues from beach recreation could bring annual benefits of \$94M to California and \$50M to Florida alone due to fewer lost beach days and less human exposure to waterborne pathogens.¹³ However, observing system requirements for reducing public health risks were not addressed in the *First IOOS Development Plan*³. High priorities are more accurate assessments and timely predictions of exposure risks to waterborne pathogens, especially following extreme rainfall and coastal flooding events.

Consistent with recommendations by the U.S. Commission on Ocean Policy¹¹, there is an immediate need for an interdisciplinary analysis of observing subsystem and modeling requirements to address the public health goal. To these ends, Ocean.US collaborated with federal agencies (EPA, NOAA, NSF, NASA, CDC and USGS) to conduct a workshop in January 2006 that provided a forum for public health officials (decision makers from state and federal agencies – the users) and technical experts on public health, coastal oceanography, and marine ecology to meet and reach consensus on priorities for developing an IOOS that will provide data and information needed to achieve two goals: (1) reduce public health risks of exposure to waterborne pathogens and to toxic harmful algal blooms; and (2) reduce the number of beach- and shellfish-closure days due to unacceptably high risks. Public health issues such as seafood contamination by microbial pathogens and anthropogenic chemicals and beneficial uses of ocean resources (e.g., in medically useful products) will be addressed at future workshops. Workshop participants worked to develop

⁹ <<http://www.epa.gov/emap/nca/html/about.html>>; <http://www.epa.gov/ged/crc_dw.htm>

¹⁰ National Monitoring Network (NMN) <<http://acwi.gov/monitoring/network/index.html>>

¹¹ *An Ocean Blueprint for the 21st Century*, Report of the Commission on Ocean Policy. <<http://www.oceancommission.gov/>>

¹² National Research Council. 1999. From Monsoons to Microbes: Understanding the Ocean's Role in Human Health. Washington, D.C., National Academy Press, 132 pp.; *Oceanography* 19(2). Special Issue: The Oceans and Human Health. June 2006

¹³ Hauke L. Kite-Powell, H.L., C.S. Colgan, and others. 2005. Estimating the Economic Benefits of Regional Ocean Observing Systems. Woods Hole Oceanogr. Inst. Tech. Rept., WHOI2005-03 <http://www.ocean.us/documents/docs/Ocean.US_Rpt_No._10_WHOI-2005-03.pdf>

recommendations for the following: (1) science and technology requirements for improving *in situ* and remote sensing of key variables (concentrations and distributions of pathogens and harmful algal blooms along with key environmental parameters); (2) science and technical requirements for improving assessments and predictions; and (3) an action plan that recommends the way forward, including concepts for pilot projects that target integrated approaches to improving assessments and predictions.

The report of this workshop is in preparation, and its recommendations will be used to improve IOOS operational capabilities to provide data and information needed to reduce public health risks associated with exposure to waterborne pathogens and algal toxins and to increase the cost-effectiveness of beach and shellfish bed closures. The report will also be useful to the recently established Joint Subcommittee on Ocean Science and Technology's (JSOST) Working Group on Human Health, Harmful Algal Blooms and Hypoxia (oxygen depletion). Workshop recommendations relevant to coastal inundation are as follows:

- Make more nearshore measurements and increase the accuracy and timeliness of estimates of the concentration and distribution of waterborne pathogens, toxic algae, and their toxins;
- Implement national standards and protocols for measurements, data management and communications, and modeling;
- Make environmental observations (e.g., vector winds, temperature, salinity, waves and currents) on time scales relevant to the population dynamics of waterborne pathogens and harmful algae;
- Improve our capability to assess risk of exposure to water-borne pathogens and toxins that cause illness by connecting environmental and epidemiological databases;
- Specify chemical, physical and biological data requirements for predicting the development of harmful algal blooms and their trajectories;
- Develop and validate coupled physical-pathogen transport models for nowcasting risks and forecasting changes in risk with known accuracy;
- Develop and improve nearshore circulation models that link land-based inputs and nearshore processes with better offshore boundary conditions;
- Provide the data and information needed to quantify relationships between changes in land use and land-based inputs to coastal waters and changes in public health risks; and
- Develop methods for real-time, *in situ* detection measurements of microbial indicators or pathogens for more accurate and timely warnings and advisories for closing and opening beaches and shellfish beds.



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Effectively assessing and reducing public health risks requires a new paradigm of interagency cooperation as well as cooperation among federal, state and local levels of government. The workshop has initiated a process that is intended to promote greater coordination among federal and state agencies responsible for protecting public health through the EPA Beaches Environmental Assessment and Coastal Health (BEACH) Program, the NOAA Oceans and Human Health Initiative, the Centers for Disease Control, USGS and other federal and state programs.

The development of the IOOS for public health purposes will be closely coordinated with programs in other nations. Coordination with Canada, Mexico, the Wider Caribbean Region and Pacific Island countries will take place concurrently with those countries who are partners with the U.S. in developing Global Earth Observation System of Systems (GEOSS).

2.3.3 Marine Debris

The U.S. Commission on Ocean Policy recognized that marine debris is unsightly and poses a serious threat to everything with which it comes into contact.¹¹ Marine debris can be life-threatening to marine organisms and humans and can wreak havoc on ecosystems, coastal communities and the fishing industry. Combining inventories of the types and locations of marine debris with data on winds, waves, water levels and currents into transport models provides information on the sources of marine debris and can help forecast the ultimate destination of floating debris. Locating the sources of marine debris will help reduce the amount of debris polluting our estuaries, shores and ports. Understanding the trajectory of the debris will allow for its interception and removal. Worldwide, marine debris is recognized as a hazard by coastal residents. Over 6.2 million volunteers from 127 countries and all 50 U.S. States have participated in the International Coastal Cleanup over the last twenty years.¹⁴

¹⁴ International Coastal Cleanup <<http://www.coastalcleanup.org>>

Hurricane Katrina provides a recent example of the problems posed by marine debris. An estimated 1.15 million cubic yards of waste, including automobiles, large appliances, railroad cars, and even whole houses, are in Mississippi waters. The Federal Emergency Management Agency (FEMA) recently gave the U.S. Coast Guard two major marine debris removal mission assignments:

- A \$230 million project to remove debris from waterways extending south from Interstate 10 to one-half mile into the Gulf of Mexico from the Mississippi shoreline at mean high tide; and
- A \$1 million project to remove debris in waterways north of Interstate 10.

The USCG will accomplish these missions through contracts now being awarded. Until the debris is removed, boating and swimming remain hazardous activities.¹⁵

2.4 Primary Data Assembly Centers

Measurements are an important element of the observing subsystem, but they are only the first step in an end-to-end system. Once data are communicated to a data collection point, the next step is data assembly and quality control of the data streams. Primary Data Assembly Centers (DACs) process raw measurements from observing subsystem elements and make them available to the Data Management and Communications (DMAC) infrastructure. The DMAC subsystem works with DACs to ensure that data entering the DMAC subsystem are properly documented and formatted for use by the IOOS community. DACs transform raw measurements that arrive in a variety of proprietary and manufacturer-specific formats into common data transport standards adopted by IOOS DMAC, such as the Open-source Project for a Network Data Access Protocol (OPeNDAP).¹⁶ They also implement quality management systems, consistent with the standards established by the International Standards Organization (ISO) at all steps along the data flow – from data provider accreditation to statistical process control at the DAC, to solicitation and assessment of data customer feedback for continuous process improvement.

The data assembly process may involve converting voltages to physical units, or calculating anomalies based on comparisons with nearest-neighbor measurements or stored climatologies. Through this process the original individual measurements are assembled into “data sets” that may be referenced and queried as a whole by the Primary DACs, Regional Associations (RAs), universities or the public.

Primary DACs will control the quality of observations based on their functional area of expertise, e.g., the quality of *in situ* marine observations (e.g., ocean currents), ecosystem-habitat assessments (e.g., fish stocks and water quality), remotely-sensed marine observations (sea surface temperatures) or remotely-sensed coastal observations (surface currents). This process is already well recognized in the management of distributed observation systems. It is used in the assembly and quality control of *in-situ* marine atmospheric and oceanographic observations at the NOAA’s National Data Buoy Center (NDBC); *in-situ* port and harbor observations at NOAA’s Center for Operational Oceanographic Products and Services; and the Earth Observing System ocean data at NASA’s Physical Oceanography Distributed Active Archive Center. A “success story” highlighting NDBC’s successful integration of non-federal, real-time marine weather observations is included in Appendix B.

The *in situ* marine observations Primary DAC, located at the NDBC, serves IOOS DMAC in five capacities:

- Obtaining marine weather and ocean observations from NDBC platforms, NOAA observatories, RCOOSs, commercial platforms and university marine networks;
- Ensuring the quality of these observations in a timeframe consistent with needs of forecasters, mariners, modelers, archive centers and their federal, state and local agencies;
- Disseminating the data to diverse user communities, federal, state and local agencies via multiple transmission pathways;
- Taking a leadership role in developing and setting IOOS standards and protocols through workshops and meetings; and
- Coordinating with IOOS personnel to effectively and efficiently interoperate between diverse organizations (both public and private) to validate users’ requirements.

Other Primary DACs may or may not function with exactly the same five capacities. However, the overall goal of the Primary DACs will be the same (i.e., to ensure that observations entering the DMAC subsystem are properly documented and formatted for use by the IOOS community).

The IOOS Primary DAC 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, while others may operate in conjunction with the data assimilation process serving forecast modeling and state estimation (the U.S. Global Ocean Data Assimilation Experiment [GODAE] Server).

¹⁵ <<http://www.fema.gov/news/newsrelease.fema?id=27418>>

¹⁶ <<http://www.opendap.org>>

At this time, the process of implementing DMAC must ensure that appropriate procedures and standards of scientific quality control are identified so that data quality control 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.

3. Data Management and Communications Subsystem

Since IOOS is the ocean and coasts component of the U.S. Integrated Earth Observation System (IEOS)¹⁷, the strategy for designing and implementing the IOOS Data Management and Communications (DMAC) subsystem is being closely coordinated with IEOS design and implementation. Coordination is also occurring with related activities in the federal agencies and regional, national and international Earth observing systems (e.g., Global Earth Observation System of Systems [GEOSS], Joint Commission for Oceanography and Marine Meteorology [JCOMM], Future WMO Information System [FWIS], and the Ocean Research Interactive Observatory Networks [ORION]).

The IOOS DMAC subsystem is being planned, developed, maintained and enhanced in a systematic, coordinated, cost-effective, interoperable manner with support from professional systems engineering services (Part I, section 2.1.1). It provides a coherent framework for integrating existing and emerging U.S. coastal and ocean observation systems into a seamless, interoperable data-sharing network. DMAC-enabled integration increases access and use of observational data resources, expands the quantity and kinds of data readily available, and increases overall efficiency of the nation's coastal and ocean observation programs.

The key to achieving interoperability lies in the flexible and expandable approach for reaching agreement on the use of common standards across all IOOS components proposed in the IOOS DMAC Plan (*Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems*).¹⁸ The DMAC Plan, which received extensive formal technical and public review, discusses DMAC implementation principles, outlines a process for identifying and adopting common standards (including protocols, formats, interfaces and other technical best practices), recommends activities for establishing the initial DMAC subsystem, and provides guidance to IOOS data providers. The recommended standards process emphasizes the use of existing standards whenever possible; the evolution of existing

standards to meet IOOS needs when existing standards fall short; and only if necessary, the development of new IOOS-specific standards. This approach strongly leverages ongoing and emerging community standards development efforts (e.g., Web and Grid services) and best operating practices.

Implementing the DMAC strategy, while challenging, lies within the scope of present and emerging information technologies. The greater challenge is a cultural one of gaining cooperation, commitment and coordination among the diverse user communities in the IOOS network and their observation programs.

3.1 Progress in Implementing DMAC Recommendations in the First U.S. IOOS Development Plan

The *First IOOS Development Plan* recommends a strategy for the initial build-out of the IOOS that links selected existing, sustained observing subsystems assets through an integrated DMAC framework.³ The plan's recommendations for the DMAC subsystem were examined by the DMAC Steering Team at its first meeting in April 2005 and presented for additional review to the participants in the Second IOOS Implementation Conference in May 2005. Conferees endorsed the recommendations and also updated the short-term guidance to IOOS data providers on standards (as originally presented in the March 2005 DMAC Plan, and extended by the DMAC Steering Team in April 2005). However, conferees expressed both concern and a sense of urgency that, despite the strong consensus recommendations from the First IOOS Implementation Conference to implement the DMAC Plan's proposed actions, there continues to be a rapidly expanding disparity between the increasing federal investments in existing/emerging observing systems and the lack of complementary investments in the interoperability-enabling DMAC standards process. This disparity perpetuates the historical incompatibilities among coastal and global ocean observing systems and their associated data management and data access infrastructures. The lack of integrated access to these data presents a huge impediment to development of a multi-hazard forecasting and mitigation system, a major focus of the Second IOOS Implementation Conference.

Significant resource constraints have limited progress in implementing the preceding DMAC recommendations. Implementation status and remaining unresolved issues are summarized in the following sections.

¹⁷ Strategic Plan for the U.S. Integrated Earth Observing System <http://iwgeo.ssc.nasa.gov/docs/EOCStrategic_Plan.pdf>

¹⁸ Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems <http://dmac.ocean.us/dacse/imp_plan.jsp>



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3.1.1 Seating a National DMAC Steering Team

Ocean.US established the recommended DMAC Steering Team in March 2005, with membership drawn from a broad cross-section of the IOOS community, representing federal, regional/state, private, academic, public and international sectors. Ocean.US tasked the Steering Team with re-visiting the initial guidance to IOOS data providers contained in the March 2005 DMAC Plan. The Steering Team was asked to update those recommendations to reflect technical advances made in the intervening time since the plan was first drafted in 2003. Special attention was given to expanding the guidance provided to the operators of the newly funded coastal ocean observing systems. The Steering Team was further tasked with identifying gaps – areas where updated guidance could not be provided – and recommending improvements in the standards identification process. The Steering Team was guided by the following operating principles at its April 2005 meeting:

- Increase the ease and efficiency of data provider and user interactions through shared standards and protocols, thereby expanding access to IOOS data and information;
- Maximize the use of existing open community standards and activities supporting standards development – adopt, adapt and only if necessary consider development; and
- Do not interfere with existing communications pathways or processes in place between data providers and their users – focus on the interfaces between systems that present barriers to system-to-system data exchange and not on established internal processes.

3.1.2 Seating a Federal DMAC Implementation Oversight Working Group

Federal agencies already have in place their own well-established observation and data management programs, and responding in a coordinated manner to forthcoming community-based IOOS DMAC standards recommendations is a key challenge for them. The Ocean.US-EXCOM Enterprise has helped to establish an interagency DMAC Implementation Oversight Working Group (IOWG) whose members are drawn from the participating federal agencies to address this challenge.

The IOWG will provide oversight of federal implementation of recommended IOOS DMAC standards; recommend actions needed for coordinated interagency adoption of DMAC standards; identify technical and resource requirements for the development of common standards, protocols, and shared communications software – for consideration by the agencies; and serve as an information resource in DMAC inter-agency planning efforts. The IOWG held its inaugural meeting in April 2005, and in June 2005 it was tasked by the EXCOM with the review of recommendations received from the DMAC Steering Team. The activities of the DMAC IOWG are supported by the participating federal agencies.

The DMAC standards identification process outlined in the DMAC and IOOS plans faces many challenges. Availability of resources and development of effective coordination processes among the sponsoring and participating organizations have historically been difficult because responsibilities (and interests) cut across agency and program organizational and budgetary lines. In addition to these challenges, standards solutions will require in-depth examination of current observing program practices, specific mission-related requirements already in place, and technological opportunities.

To illustrate these challenges, consider the suite of ongoing operational water level monitoring programs now in place. These programs encompass a key sub-set of the IOOS core variables and provide a useful example of some of the challenges DMAC faces in standards identification. Many similar examples exist for other IOOS core variables (Table II.4). At least five federal agencies measure water level and related variables (Table II.5). While consistent in principle, the technical specifications (e.g., metadata descriptions that enable discovery and retrieval, specific data formats, levels of user accessibility, data retrieval protocols, frequency of collection of observations, spatial extent, availability on-line, etc.) vary significantly across individual programs. While each of these efforts may satisfy individual agency mission requirements, an integrated view across watersheds, regions and the nation is hindered by these cross-program incompatibilities. A successful IOOS-DMAC standards adoption process will address these differences and lead to integrated national and regional views of water level conditions and trends.

Table II.5. Summary of major operational coastal and oceanic water level observation activities across federal IOOS partners, illustrating some of the challenges (and opportunities) for achieving interoperability through IOOS-DMAC.

Parameter	USGS	NOAA	USACE	EPA	NASA	IOOS Target
Water Level Observation						
Stream/ River	Y					Y
Harbor		Y				Y
Reservoir/Lake			Y		Y	Y
Coastal/Oceanic			Y		Y	Y
Flow/ Currents	Y		Y	Y		Y
Water Table			Y			Y
Precipitation	Y					Y
Power Generation Levels			Y			Y
Winds		Y				Y
Air Temperature		Y				Y
Water Temperature		Y	Y			Y
Barometric Pressure		Y				Y
Water Quality	Y			Y		Y

3.1.3 Implementing Key DMAC Expert Teams

Several critical technical standards areas (previously identified in the DMAC Plan and at the IOOS Implementation Conferences) must be addressed early on to avoid propagating incompatibilities in existing observing systems into the emerging systems and upgrades to present systems. Since these areas are technical in nature, they are best addressed through community-based working groups with the appropriate expertise. Expert Teams (ETs) provide the connections among the IOOS community requirements, the policy-driven process for identifying standards, and the technical resources offering potential standards solutions. Close coordination will be maintained with relevant community standards development activities. The formation of the following Expert Teams was endorsed by the DMAC Steering Team and IOOS Conference participants:

- **IOOS/DMAC Standards Process:** Establish community resources to facilitate collaborative identification and evaluation of existing standards and best practices, and exchange of information and lessons-learned among IOOS developers and users. The proposed tasks and required resources to support this effort were submitted to the DMAC Interagency Oversight Working Group (IOWG) in June 2005. This work is partially supported.
- **Metadata and Discovery:** Oversee the adoption/creation of metadata content and controlled vocabulary(ies) appropriate to marine data and needed to support consistent, Web-enabled data discovery and use. The proposed tasks and required resources to support this effort were submitted to the DMAC IOWG in July 2005, and funding is in place to initiate this Team's activities. The Metadata ET presented its initial recommendations at the Fall 2005 meeting of the DMAC Steering Team. This ET is supported through FY 2006.

- **Transport and Access:** Identify the suite of common transport protocols (e.g., OPeNDAP, File Transport Protocol [FTP], Hyper-Text Transfer Protocol [HTTP], etc.) to support the IOOS Web Services-based architecture. The statement of work for this team was presented to the DMAC IOWG in July 2005. This ET is presently partially supported.
- **Archive:** Engage the major existing data archive infrastructure and recommend actions supporting archive services in a distributed IOOS environment. The statement of work for this team was submitted to the DMAC IOWG in June 2005. This ET is supported through FY 2006.

Working groups (precursors to ETs) were recommended for IT Security, On-Line Browse, and Systems Engineering. A statement of work for the Systems Engineering group was submitted to the DMAC IOWG in June 2005. The Systems Engineering group is partially supported.

Finally, the area of Quality Assurance/Quality Control (QA/QC) has not yet been addressed by Ocean.US. QA/QC has historically been outside the purview of the IOOS DMAC subsystem. QA/QC is a major responsibility of IOOS observing subsystem participants, and a coordinated effort to develop common QA/QC guidelines for IOOS data and information has only recently begun. The DMAC Steering Team has therefore identified this as a major gap in IOOS planning. The DMAC Steering Team is encouraging the IOOS community, especially those involved in the collection and dissemination of near real-time observations (for example, the Quality Assurance Real Time Oceanographic Data [QARTOD] working group) to develop recommendations on how to proceed. The DMAC Steering Team will monitor these efforts and work with the federal agencies and IOOS data providers to put in place a recognized process for IOOS QA/QC.

3.1.4 Engaging the User and Data Provider Communities

Nationally coordinated DMAC activities must engage substantively with the major IOOS constituencies and partners. Of particular importance are the regions; the private sector; data management and standards development components of relevant international programs and activities; and the modeling community. DMAC Community Engagement Caucuses have been formed to facilitate an ongoing dialogue with these key communities as recommended by the DMAC Steering Team. For example, the Modeling Caucus will provide the primary means by which data requirements for models developed through Community Modeling Networks (Part III, section 5.2.2) are used to help guide DMAC development.

3.1.5 Building the Initial DMAC Framework

The *First IOOS Development Plan* recommends a two-phased approach for implementing DMAC priority actions, starting in FY 2005.³ It was anticipated that the critical, near-term Phase 1 (FY 2005-06) actions would establish a minimally functioning initial IOOS infrastructure of data management standards, protocols, and operating practices. This infrastructure would enable the initial integration framework between existing and emerging observing systems. Phase 2 (FY 07 and beyond) addressed the development of a comprehensive DMAC subsystem that meets the needs of the full range of IOOS partners. To date (July 2006), resources have become available to proceed with a very limited number of these DMAC recommendations. Thus, rather than refer to specific fiscal years, Phase 1 is now recommended for the “next two years” and Phase 2 is ramping up over the next two to five years.

3.2 Immediate (Next Two Years) Priorities for Implementing DMAC

Federal agencies that already have an extensive infrastructure of independent observing systems and associated data management practices in place are beginning to implement components of the initial IOOS as part of the National Backbone (Table II.4). Nascent Regional Associations (RAs) are rapidly organizing and beginning to deploy sub-regional Regional Coastal Ocean Observing Systems (RCOOSs) as part of the IOOS. Ocean.US and the participating federal agencies are also just beginning to implement the DMAC process and standards recommendations contained in the *First IOOS Development Plan*.³

Given current resource constraints, implementation of the DMAC subsystem is occurring at a more measured pace than originally recommended (Tables II.6, II.7 and II.8). Following recommendations from the IOOS community and federal agencies, the highest priorities for early implementation are: formalizing the community engagement and DMAC standards oversight processes, and ensuring that observations are documented in a consistent manner (metadata).



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Table II.6. Recommended DMAC activities and timelines for implementation

DMAC Activities	Functions	Sub--Teams, Groups, Caucuses	FY 2005		FY 2006				FY 2007				
			Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
DMAC Steering Team	National community-based planning, coordination, recommendations		Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update							
DMAC Expert Teams	Technical evaluation/assessment	Standards Process			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
		Metadata & Discovery			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
		Transport Archive			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
DMAC Pre-Expert Team Working Groups	Technical evaluation/assessment	IT Security			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
		Systems Engineering			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
DMAC Community Caucuses	Outreach and feedback	On-Line Browse			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
		International Modeling			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
DMAC Community Caucuses	Outreach and feedback	Regional			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
		Private Sector			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update			
Federal DMAC IOWG	Coordinated, integrated, interagency oversight, funding, implementation		Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update							
Key:			Start-up, initial planning, guidelines	Interim results, documents, guidelines	Official recommendations, documents, guidelines	Official recommendations, documents, guidelines	Sustained review and update						

A significant body of work must be accomplished by each Expert Team, Working Group and Caucus. The work of each will be prioritized so that it addresses standards and best practices for the core variables listed in Table II.4 early on, with an initial focus on the programs that measure the italicized variables required for development of a multi-hazard warning system. As an example, the major tasks that will be carried out by the Metadata and

Discovery ET are presented in Table II.7. An initial set of recommendations will be developed for each area of responsibility. The recommendations will subsequently be updated or expanded to more fully meet the identified needs based upon additional assessments and feedback from the IOOS community. These activities are being conducted within the context of related regional, national and international standards development work.

Table II.7. Example of Metadata & Discovery Expert Team milestones and timeline. (Shaded blue indicates completion of milestone; solid blue indicates continuing review and update).

Metadata Activities/Tasks	FY 2005		FY 2006				FY 2007			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Initial team meeting, work plan adopted		■								
Evaluation of existing core and profile standards for highest priority IOOS data types, and ID gaps			■							
Recommendations for interim core and profiles standards				■						
Recommendations for adaptive and/or developmental work on core or profiles, if appropriate				■						
Community testing and feedback on interim standards recommendations					■	■				
Standards adaptation and developmental work					■	■				
Recommendations issued for Official Guidelines to IOOS Data Providers for core and profile standards recommendations to IOWG							■			
Continuing review and update								■	■	■



Table II.8 (updated from the *First IOOS Development Plan*³) provides a partial summary of the specific tasks that must be addressed in parallel with the activities presented in Table II.6 to build the initial DMAC framework.

This initial framework will support existing and emerging observing systems, and will evolve based upon the recommendations of the DMAC Steering Team and its technical and outreach groups.

Table II.8. Key activities recommended for building the initial DMAC framework over the next two years (Metadata & Discovery; Data Transport & Access; Archive). This list incorporates recommendations from the DMAC Plan,¹⁸ the *First IOOS Development Plan*,³ and updates endorsed by the DMAC Steering Team and participants in the Second Annual IOOS Implementation Conference.¹

DMAC Component	RECOMMENDATIONS
Metadata & Discovery	<ul style="list-style-type: none"> • Create metadata in an XML-schema and provide style sheet • Use Federal Geographic Data Committee (FGDC) standards. If not available for data type in question, use alternative, community-accepted standard and document standard used • Data providers should identify gaps and advise DMAC Steering Team • Submit metadata to one of the National Spatial Data Infrastructure nodes • Document data dictionary used in the metadata • Guidance should be applied to both present data sources, and legacy data holdings • Develop bi-directional linkages between data discovery, data transport, and on-line browse • Conduct a test-bed effort to develop distributed search capability
Data Transport & Access	<ul style="list-style-type: none"> • Gridded data providers should install servers providing access to their data through OPeNDAP data access protocol • For complex data collections in relational data base: (i) use OPeNDAP relational data base server or (ii) use enterprise (e.g., OGC) GIS protocols • For large collections of individual files comprising single (logical) data set–use OPeNDAP servers if available for the file types in question • Data providers should participate in DMAC pilot and/or test-bed activities to develop “aggregation” capabilities that will provide more ordered view of collections • Establish consistent OPeNDAP documentation and needed extensions (i.e., non-gridded data and time-series data) • Develop resources to train data managers in use of recommended IOOS standards and best practices • Adopt, adapt, or develop marine semantic data model(s) compatible with recommended DMAC architecture • Develop interoperability among common standards: OPeNDAP, OBIS, and OGC. • DMAC-compatible interfaces should be SOAP-enabled • Gateway services (protocol conversion resources) must be accelerated to respond to many types of users (e.g., Register UDDI users) • Install Live Access Server, and examine OGC-compatible web services for additional candidates for on-line browse function
Archive	<ul style="list-style-type: none"> • Data providers should ensure that irreplaceable data are archived at a responsible entity • Federal archive centers should, for now, maintain present archive processes • Develop a framework to inventory and assess the state of marine data archive • Conduct test bed efforts to modernize access to data sets delivered in real time • Existing archive centers should structure their collections so that they are accessible and searchable under the current DMAC Plan, i.e., collections documented and registered to DMAC metadata standards • Data providers should negotiate with the federal archive centers for data management • Data Transport and Access should be closely coordinated with Archive

The DMAC process outlined herein is necessary to provide an evolving set of standards and best practices that enable incorporation of existing and future systems into the IOOS network. Based upon current estimates of funding availability, the key DMAC recommendations in Table II.6 will be completed by the middle of FY 2007. Plans are not yet in place to fund and implement the activities recommended in Table II.9.

Table II.9. Key activities recommended for building the initial DMAC framework over the next two years (IT Security & Information Assurance; Quality Assurance & Control; Additional areas). This list incorporates recommendations from the DMAC Plan, the *First IOOS Development Plan*, and updates endorsed by the DMAC Steering Team and participants in the Second Annual IOOS Implementation Conference.

IT Security and Information Assurance	<ul style="list-style-type: none"> • Assess and evaluate the differing security roles, challenges and constraints faced by data providers, service providers, and data users • Until specific IOOS data and network security guidelines are defined, IOOS users providing data (including model output) used in the production of official forecasts and/or warnings should negotiate for their use with the appropriate federal data collection/operations center responsible for those kinds of forecasts/warnings, and who have implemented certified IT security safeguards • Until specific IOOS security guidelines are produced, IOOS participants not otherwise guided by formal IT security guidelines above (e.g., forecasts and warnings) shall use prudent, community-accepted “best IT Security practices”
Quality Assurance & Control	<ul style="list-style-type: none"> • Present guidance is reaffirmed: delegate data management and QA/QC for marine buoy and mooring data to NOAA NDBC
Additional	<ul style="list-style-type: none"> • Establish DMAC Test-Beds to support standards identification and/or development

3.3 Integrating Existing Observing Subsystem Assets through DMAC

The Integrated Earth Observation System (IEOS) Strategic Plan defines four perspectives for addressing integration: policy and planning, issue and problem focused, scientific, and technical systems.¹⁷ The technical systems perspective is further subdivided into several categories, and IOOS DMAC activities fit into the Information Technology Integration category. IOOS planning documents address integration at all these levels; however, special attention has been focused on the DMAC area because major benefits will accrue to IOOS stakeholders from relatively modest investments in integration at this level. Adoption of the DMAC subsystem framework of common data and metadata standards, protocols and best practices will link all IOOS components together into a seamless network by integrating the diverse IOOS data streams across disciplines, organizations, time scales, and geographic locations.

In summary, the DMAC Steering Team is establishing community-based ETs in each key DMAC technical area to evaluate existing standards and best practices against the requirements of IOOS data users and providers, and formulate specific guidelines. The work of the ETs will be prioritized so that, early on in their schedules, they address the data types most relevant to the systems comprising the initial IOOS (Table II.4). The guidelines and recommendations developed by the ETs will be vetted by the DMAC Steering Team and Ocean.US, and then made available to the IOOS community. Since the existing federal agency data management and communications activities are at various stages of maturity in terms of meeting recommended IOOS DMAC guidelines, the timelines and costs for these organizations to become IOOS DMAC “compliant” will likely vary greatly.

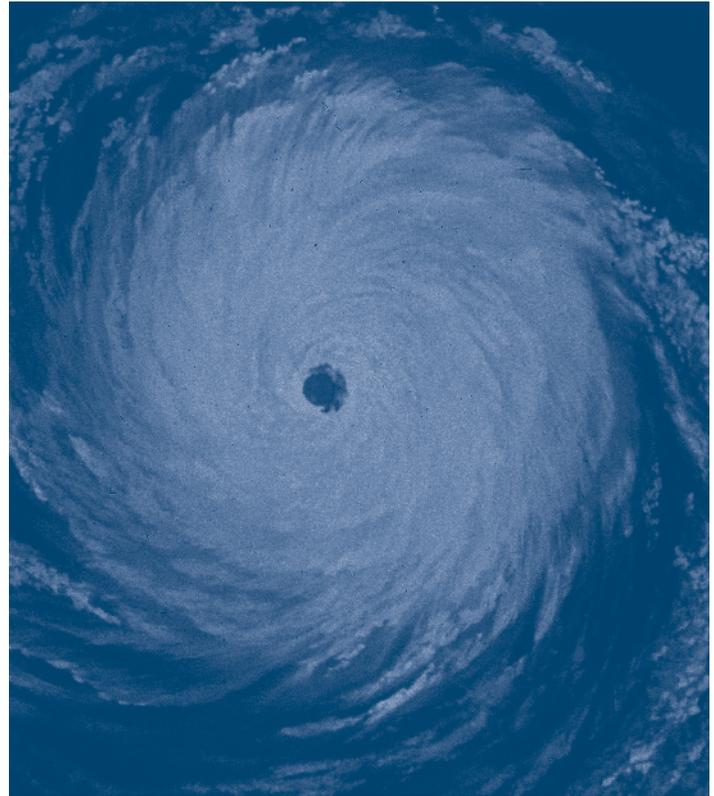
If implemented, the DMAC activities described in this section will provide an initial minimally functioning DMAC framework to support interoperability among existing and emerging observing systems. Also recommended are detailed guidelines to IOOS data providers by the end of FY 2007 for achieving full interoperability through compliance with agreed upon, community-based standards and best practices. These guidelines will provide specific target goals that will enable development of timelines (with milestones and costs) for integrating components of the initial IOOS, as well as for integrating emerging and future components.

4. Modeling and Analysis Subsystem

A road map for implementing an IOOS modeling initiative that encompasses all seven IOOS societal goals is described in Part III. Here, the focus is on global climate change and coastal inundation caused by tropical storms, extra-tropical storms and tsunamis.

4.1 Coastal Inundation Modeling

Several federal agencies and research groups are engaged in the development and application of storm surge prediction systems (Table II.10) and the models they incorporate (Table II.11). The diversity of user groups and modeling activities underscores the need for Community Modeling Networks (CMNs) (Part III, Section 5.2.2) and shows that the ingredients needed to establish them are in place. Thus, it is recommended that a CMN for coastal inundation modeling be established and tasked with: (1) fostering communications among users and providers of storm surge information; and (2) developing the next generation of coastal inundation models for improved forecasts of coastal flooding and more effective management and mitigation of impacts on coastal communities, ecosystems and resources.



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Table II.10. A sampling of federal agencies and universities engaged in the development and application of storm surge models and models currently in use (FIU – Florida International University, LSU – Louisiana State University, NCS – North Carolina State University, UCF – University of Central Florida, UD – University of Delaware, UF – University of Florida, UH – University of Hawaii, UNC – University of North Carolina, UND – University of Notre Dame).

Model	Agency - University
Advanced Circulation (ADCIRC)	FEMA, Navy, NOAA, USACE Many universities including FIU, LSU, UCF, UD, UF, UNC, UND
Coastal & Estuarine Model Environmental Prediction System (CEMEPS)	NCS
Coastal Flooding Model (CFM)	NOAA
Continuous Operational Real-Time Monitoring System (CORMS)	NOAA
FEMA Surge	FEMA
Flood-Wave (FLDWAV)	UCF
GIS-Based Simulation of Impact on Coastal Habitats	USGS
Hybrid Coordinate Ocean Model (HYCOM)	NOAA
Princeton Ocean Model (POM)	Navy NCS
Regional Ocean Model System (ROMS)	UD
Sea, Lake and Overland Surges from Hurricanes (SLOSH)	NOAA, FEMA, USACE

Table II.11. A sample of community and commercial models currently in use for simulating water levels, currents, waves, sediment transport, and drainage basin hydrology.

MARINE CIRCULATION

- Bergen Ocean Model (BOM) (<http://www.mi.uib.no/bom/>)
- Coupled Hydrodynamical Ecological Model for Regional Shelf Seas (COHERENS) (<http://www.mumm.ac.be/~patrick/mast/coherens.html>)
- Delft hydraulics model (delft3d) (<http://www.wldelft.nl/soft/d3d/intro/index.html>)
- Estuarine Coastal & Ocean Model (ECOM) (<http://woodshole.er.usgs.gov/operations/modeling/ecomsi.html>)
- Fine Resolution Antarctic Model (FRAM) (<http://www.mth.uea.ac.uk/ocean/fram.html>)
- ENSO Equatorial Pacific Model (GModel) (<http://www.knmi.nl/onderzk/cko/gmodel.html>)
- Estuarine Fluid Dynamics Code (EFDC) (<http://www.epa.gov/athens/wwqtsc/html/efdc.html>)
- Eulerian-Lagrangian Circulation Model (ELCIRC) (<http://www.ccalmr.ogi.edu/CORIE/modeling/elcirc/>)
- Finite Volume Coastal Ocean Model (FVCOM) (<http://codfish.smast.umassd.edu/FVCOM.html>)
- Hallberg Isopycnal Model (HIM) (<http://www.gfdl.noaa.gov/~rwh/him/him.html>)
- Hamburg Ocean Model (HOPE) (http://www.phys.ocean.dal.ca/~pohlman/latif_etal_ecmwf_2002.pdf)
- EPA hydrodynamics sediment contaminant model (HSCTM2D) (<http://www.epa.gov/ceampubl/swater/hsctm2d/>)
- Hybrid Coordinate Ocean Model (HYCOM) (<http://hycom.rsmas.miami.edu/>)
- Miami Ocean Model (MICOM) (<http://oceanmodeling.rsmas.miami.edu/micom/>)
- Modular Ocean Model (MOM) (http://www.gfdl.noaa.gov/~fms/pubrel/j/mom4/doc/mom4_manual.html)
- Navy Coastal Ocean Model (NCOM) (http://www7320.nrlssc.navy.mil/global_ncom/)
- Navy Layer Ocean Model (NLOM) (http://www7320.nrlssc.navy.mil/global_nlom/index.html)
- NOAA's Real-Time Ocean Forecast System (RTOFS) (<http://polar.ncep.noaa.gov/cofs/>)
- Parallel Oregon State University Model (POSUM) (<http://posum.oce.orst.edu/>)
- Ocean Circulation Advanced Modeling (OCCAM) (<http://www.soc.soton.ac.uk/jrd/occam/agora/report.html>)
- Princeton Ocean Model (POM) (<http://www.aos.princeton.edu/wwwpublic/htdocs/pom/>)
- Regional Ocean Model System (ROMS) (<http://marine.rutgers.edu/po/index.php?model=roms&page=>)
- Shallow water circulation model (QUODDY) (<http://nccoos.unc.edu/mods/quoddy/>)
- S-Coordinate Rutgers University Model (SCRUM) (<http://marine.rutgers.edu/po/models/scrum.html>)
- S-coordinate Primitive Equation Model (SPEM) (<http://marine.rutgers.edu/po/models/spem.html>)

COASTAL WAVES AND INUNDATION

- SWAN Coastal Wave Model (http://www.onr.navy.mil/sci_tech/ocean/reports/docs/cd/02/cdvandon.pdf)
(<http://www.wldelft.nl/cons/area/wds/index.html>)
- NOAA's Wave Watch III wave model (http://polar.ncep.noaa.gov/waves/main_int.html)
- Southern California Swell Model (<http://cdip.ucsd.edu/?nav=documents&sub=faq&xitem=nowcast>)
- Coastal inundation – Sea, Lake and Overland Surges from Hurricanes (SLOSH) model (<http://chps.sam.usace.army.mil/USHESdata/SLOSH/sloshgeneral.htm>)
- Coastal inundation - Advanced Circulation Model (ADCIRC) (<http://www.nd.edu/~adcirc/>)
- Wave Prediction Model (WAM) (http://w3g.gkss.de/G/gms_en.html/KSD_dev_wam.html)
- Steady State Spectral WAVE (STWAVE) (<http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=SOFTWARE:9&g=141>)

COUPLED HYDRODYNAMIC-SEDIMENT TRANSPORT

- Hydrodynamic, Sediment and Contaminant Transport Model (HSCTM2D) (<http://www.cee.odu.edu/model/hsctm2d.php>)
- Three-dimensional hydrodynamic and sediment transport model (ECOMSED) (http://www.hydroqual.com/ehst_ecomsed.html)
- SED module of Delft3D (<http://www.wldelft.nl/soft/d3d/mods/sed/index.html>)

HYDROLOGICAL INPUTS FROM LAND-BASED SOURCES

- SPARROW (<http://water.usgs.gov/nawqa/sparrow/>)

Existing prediction capabilities for estimating the time-space extent of coastal flooding (Figure II.3) need to be improved in terms of both timeliness (at least 48 hours before flooding begins) and accuracy (surge height to ± 1 foot). Areas for improvement include the following:

Modeling

- Boundary conditions for near-shore and coastal bay models;
- Coupling weather, hydrodynamic, tidal, wave and hydrological models to improve storm surge forecasts;
- Development of ensemble modeling capabilities;
- Development of surge models for extra-tropical storms;
- Inclusion of tides, waves, rainfall and river flows as model inputs; and
- More accurate and periodically updated geographical information system (GIS) maps of susceptibility and GIS-based predictions of impacts of storm surge flooding on coastal communities and habitats.

Observations

- Increase the density of measurements (water level, sea surface temperature, winds and barometric pressure over the sea surface, rainfall and river flows);
- More frequent and accurate surveys of bathymetry-topography across the land-sea interface; and
- More frequent surveys of the condition and spatial extent of coastal habitats (e.g., coral reefs, seagrass beds, mangrove forests, tidal marshes, beaches and sand dunes)

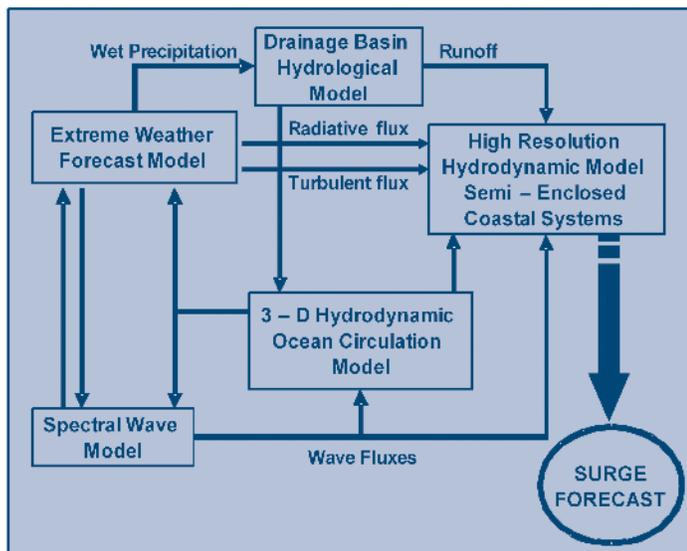


Figure II.3. Schematic for systems of atmosphere-ocean-coastal-drainage basin coupled models for surge forecasts where forecasts include both the run up (spatial and temporal extent of flooding) and impact of the subsequent runoff on coastal circulation. Such systems of coupled meteorological-wave-hydrodynamic-hydrological models must also be developed and expanded to include impacts of subsequent runoff events on coastal water quality (e.g., salinity, sediment and nutrient transports, phytoplankton blooms, oxygen depletion) and living marine resources (e.g., distribution and abundance of fish species, extent and condition of coral and oyster reefs).

4.2 Improving the Predictive Skill of Global Ocean-Climate Models

Computer models and the platforms on which they run have become increasingly complex and time-consuming. Consequently, resources are being dedicated to solving computational rather than scientific problems. The Earth System Modeling Framework (ESMF) Project is a CMN established to address the need for software infrastructure for Earth system modeling with an initial focus on the global ocean-climate system.¹⁹ ESMF is a collaboration of Earth scientists and computational experts²⁰ from major U.S. Earth modeling centers “developing a robust, flexible set of software tools to enhance ease of use, performance portability, interoperability, and reuse in climate, numerical weather prediction, and data assimilation applications.” The goal is to create a framework usable by individual researchers as well as major operational and research centers.

The first step was to create an open-source community “Ocean Modeling Environment using a generalized hybrid vertical coordinate and vertically Lagrangian solution techniques.” The project will center on code base development and best practice studies. The result will not be a single ocean model, but a collection of ocean modeling codes and algorithms from which optimal ocean models for specific applications can be constructed, along with a systematic effort to evaluate the various options and establish “best practices” for model development. A major goal is to improve the skill of modular ocean-climate models for climate forecasting. In this context, a high priority is the implementation of a series of basin-scale ocean forecast systems beginning with the Atlantic in 2006 (e.g., Box II.2). Critical challenges that must be addressed include setting standards for observations and forecasts system components (with performance metrics), obtaining and processing observations for diverse purposes (monitoring, data assimilation, community applications), and outreach to active and interested users.

¹⁹ The Earth System Modeling Framework <<http://www.esmf.ucar.edu/>>

²⁰ NOAA (Geophysical Fluid Dynamics Laboratory, National Centers for Environmental Prediction), NSF (National Center for Atmospheric Research), NASA (Goddard Global Modeling and Assimilation Office, Goddard Institute for Space Studies, Jet Propulsion Laboratory, Goddard Land Information Systems project), DoD (Naval Research Laboratory, Air Force Weather Agency, Army Engineer Research and Development Center), DOE (Los Alamos National Laboratory, Argonne National Laboratory), University of Michigan, Princeton University, Massachusetts Institute of Technology, UCLA, Center for Ocean-Land-Atmosphere Studies, Programme for Integrated Earth System Modeling (PRISM), and Common Component Architecture (CCA).



Box II.2: Observations for Improving the Skill of Model Predictions

Observing the Atlantic Meridional Overturning Circulation (MOC) is a fundamental requirement for modeling the effects of the Atlantic thermohaline circulation on rapid climate change. Current hydrographic data can provide snapshots but not a continuous time series of the MOC. Using output from two eddy-permitting numerical ocean models the feasibility of a monitoring system for the MOC in the North Atlantic has been tested.* The results suggest that a relatively simple array using moorings placed across a longitude-depth section and the zonal wind stress are able to capture most of the MOC strength and vertical structure as a function of time. Being closely related to the transport of energy to the North Atlantic, measuring the MOC would open the prospect of having continuous information about a key element of northern hemisphere climate.

* 2003. A monitoring design for the Atlantic meridional overturning circulation. *Geophysical Research Letters*, 30(7): 1413 <http://voa.soc.soton.ac.uk/rapidmoc/publications/reports/original_proposal.pdf>

The U.S. contribution to the Global Ocean Data Assimilation Experiment (GODAE) is progressing in the ESMF framework. GODAE, a coordinated international effort, is a five year project (planning began in 1997).²¹ The objectives of GODAE are to: (1) apply state-of-the-art ocean models and assimilation methods for short-range forecasts of open-ocean states, the provision of boundary conditions to improve the skill of coastal marine and estuarine models, and more accurate initial conditions for climate forecast models; and (2) provide global ocean analyses for improving understanding of the ocean, assessing the predictability of ocean variability, and assessing the design and effectiveness of a global ocean observing system.

5. Regional Development

5.1 Current Status

A National Federation of Regional Associations (NFRA) Governing Committee has been formed, elected a governing board and adopted Terms of Reference and By-Laws. Major accomplishments of the nascent Regional Associations (RAs) as of 13 December 2005 are summarized in Table II.12. Although funding for these efforts was staggered (some beginning in FY 2004 and some in FY 2005), all eleven nascent RAs have engaged stakeholders from both public and private sectors in the initial stages of RA development, have initiated or will soon begin inventories of observing system assets, and are conducting or have plans to assess needs (gap analysis). Progress of the regional groups is summarized as follows:

- Nine have established interim governing bodies and hired staff;
- Ten have hired full or part-time staff;
- Eight have established websites;
- All eleven are coordinating with adjacent regions and five with neighboring countries;
- Ten are in the process of incorporating active sub-regional observing systems, and seven are serving some data in real-time;
- Six have initiated pilot projects;
- Nine are engaged in Data Management and Communications (DMAC) activities;
- Nine have initiated education and/or outreach activities, and two are forming Education and Outreach Councils to oversee these activities;
- Six have draft governance plans in review, three have governance plans that have been approved by stakeholders, and one has been incorporated; and
- Three have draft business plans in review.

²¹ <<http://hycom.rsmas.miami.edu/publications/godae/GODAE-Strategic-Plan.pdf>>



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Table II.12. Summary of regional activities as of 31 December 2005, with nascent RAs listed according to the number of years of funding received (years 1, 2, and 3). (P- part time, F- full time; GCOOS - Gulf of Mexico Coastal Ocean Observing System, SECOORA - Southeast Coastal Ocean Observing Regional Association, AOOS - Alaska Ocean Observing System, NANOOS - Northwest Association of Networked Ocean Observing Systems, CeNCOOS - Central and Northern California Ocean Observing System, GLOS - Great Lakes Observing System, SCCOOS - Southern California Coastal Ocean Observing System, MACOORA - MidAtlantic Coastal Ocean Observing Regional Association, NERA - Northeast Regional Association, PacIOOS - Pacific Integrated Ocean Observing System, CaRA - Caribbean Regional Association).

Category	Activity	GCOOS	SECOORA	AOOS	NANOOS	CeNCOOS	GLOS	SCCOOS	MACOORA	NERA	PacIOOS	CaRA
Funding	Funding Year	3	3	3	3	3	3	2	2	1	1	1
Organization	Governing Body	X	X	X	X	X	X	X	X	X		
	Website	X	X	X	X	X	X	X	X			
	Staff	P	P	F	F	F ^a	F	P	P	F		P
	Stakeholders	X	X	X	X	X	X	X	X	X	X	X
	Inventory	X	X	X	X	X ^b	X	X	X	X	X	X
	Gap analysis	X	X	X	X	X	X	X	X	X	X	X
	Regional Coordination	X	X	X	X	X	X	X	X	X	X	X
	International Coordination	X		X	X		X	X		X	X	
Infrastructure	Subregional OS	X	X	X	X	X	X	X	X	X	X	
	Real-time	X	X	X	X	X	X	X	X	X	X	
	Pilot Project		X ^c	X ^d	X ^e	X ^f		X ^g		X		
	DMAC	X ^h	X	X ⁱ	X	X	X	X		X	X	
Education	Implementation	X	X	X	X	X	X	X	X	X		
	Council	X	X				X ^j					
Governance	Plan in Review		X	X	X		X	X	X			
	Approved by Stakeholders	X				X			X			
	Incorporated								X			
Business Plan	In Preparation			X		X		X				
	In Review	X	X				X					
	Approved by Stakeholders											
TOTAL		15	15	15	14	14	15	15	12	12	8	5

^a Added two ½ time positions – Oceanographer and Product Development Lead and Outreach Specialist; ^bGeoreferenced database on ongoing ocean observing activities that allows map-based queries via a public web site; ^c Developing manuals for best data management practices (funded by SURA-SCOOP); ^d Prince William Sound Observing System (an AOOS subsystem); ^e A pilot coastal ocean observatory for the estuaries and shores of Oregon and Washington; ^f Currents demonstration project; ^g California Coastal Current Monitoring; ^h Uses the NDBC modem kit that enhances data access for modeling and product development at minimal cost; ⁱ Hired a data manager; ^j Together with SeaGrant, established the Great Lakes COSE

Each nascent RA is working to establish and manage a single Regional Coastal Ocean Observing System (RCOOS) for its region. These RCOOSs are comprised of the various subregional observing systems in the region. The RAs are in the process of identifying the viable subregional systems that should become a part of the RCOOS, integrating them, and, ultimately, enhancing them in a way that allows the RCOOS to meet the regional needs of the RA's stakeholders. A list of existing subregional systems appears in Appendix C. Of the regions, only the Caribbean has no subregional systems.

In addition to these efforts, the Ocean Action Plan calls for supporting the Great Lakes Interagency Task Force and for establishing state-federal partnerships in the Gulf

of Mexico.²² Operators of the Great Lakes Observing System (GLOS) are coordinating with the former, and the organizers of the Gulf of Mexico Coastal Ocean Observing System (GCOOS) are working with the newly formed Gulf of Mexico Alliance to coordinate these efforts with regional IOOS development.

5.2 The Coastal Observation Technology System

The development of the coastal component is being accelerated through Office of Naval Research (ONR) and NOAA Coastal Observation Technology System (COTS) projects.²³ These projects target all aspects of IOOS development from end-to-end integration of the three subsystems, to subsystem development and education (Table II.13).

Table II.13. Office of Naval Research (ONR) and NOAA Coastal Observation Technology System (COTS) projects that will benefit IOOS development in the categories indicated (COOS – End-to-End Coastal Ocean Observing System, R & D – Research and Development, DMAC – Data Management and Communications subsystem).

PROJECT	IOOS Development Category				
	Subregional COOS	R & D	DMAC	Modeling	Education & Training
Alliance for Coastal Technologies (ACT)		X			
Alaska Ocean Observing System (AOOS)	X		X		
Carolinas Coastal Ocean Observing and Prediction System (CaroCOOPS)			X	X	
Central Gulf of Mexico Ocean Observing System (CenGOOS)	X				
California Center for Integrative Coastal Ocean Research (CICORE)		X			X
Center for Integrated Marine Technologies (CIMT)		X			
Coastal Ocean Monitoring and Prediction System (COMPS)	X			X	
Coastal Ocean Observing and Analysis (COOA)		X	X	X	
Coastal Ocean Research and Monitoring Program (CORMP)	X	X	X	X	X
Gulf of Maine Ocean Observing System (GoMOOS)	X		X	X	
Joint Center for Ocean Observing Technology			X	X	
Long Island Sound Integrated Coastal Observing System (LISICOS)	X	X	X	X	X
Ocean-Atmosphere Sensor Integration System (OASIS)	X	X			
Coastal Ocean Observatory for the Estuaries and Shores of Oregon and Washington	X			X	
Southeastern Universities Research Association Coastal Ocean Observing and Prediction Program (SCOOP)			X	X	
Southern California Coastal Ocean Observing System Shelf to Shoreline Observatory	X		X	X	
Wave Current Surge Information System (WAVCIS)	X				
Integration of West Florida Coastal Observing Systems	X				

²² U.S. Ocean Action Plan <<http://ocean.ceq.gov/actionplan.pdf>>

²³ Coastal Observations Technology System <<http://www.csc.noaa.gov/cots.cots.html>>

The ONR and NOAA COTS projects have collaborated to establish an environment that enables the sharing of data, information and technologies that foster IOOS development. Partners share information on the techniques and methods they employ and work to create a seamless flow of data, information and products. Interoperability is the first overarching theme of this effort to create a model for integrated observing systems that will serve to advance the national agenda as well as address regional needs by establishing a framework for coordinating the various groups working within and across regions. The overall effort includes facilitating communications, reporting and workshops as needed, with the NOAA Coastal Services Center serving as the lead federal coordinating partner. These efforts can also serve as the first step in the transition from research to an operational sensor or system.

Several of the COTS efforts are designed to address coastal inundation. For example, the Southeastern University Research Association Coastal Ocean Observation and Prediction system is focused on environmental prediction and hazard planning; the Carolina Coastal Ocean Observation and Prediction system is being developed to predict coastal ocean processes; and the Coastal Ocean Monitoring and Prediction system for west Florida provides data for models enhancing emergency preparedness.

6. Education

As presented in the *First IOOS Development Plan* (Part III, Figure 4)³ a stepwise approach is recommended to achieve the following goals of IOOS education and public awareness:

- Develop and sustain a community of educators across a broad education spectrum that uses IOOS information (e.g., data, careers, societal uses) to achieve its education objectives; and
- Create the workforce needed to develop and sustain the IOOS and to produce allied information products, services and tools.

The following four Phase I activities are priorities for the next three years: (1) form an IOOS Education and Public Awareness Network-of-Networks; (2) participate in IOOS governance; (3) address IOOS education planning priorities; and (4) coordinate the design of learning materials. Achieving these objectives will result in tangible progress on infrastructure development and advance related Phase I objectives. This prioritization is based on guidance received from the ocean observing community at the Second IOOS Implementation Conference.¹

Listed in priority order above and below, these Phase 1 activities will be implemented in parallel. Each has a

different overall difficulty and, therefore level of effort required to build on what already exists, to scale and then sustain. The activities interact and build on each other to create a coherent, coordinated, and collaborative education framework for utilizing the unique assets of integrated ocean observing systems 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 governments; academia, industry, professional societies, and non-profit organizations to implement this plan.

Formation of a coherent and coordinated ocean observing education presence is essential to minimize confusion among the education community and promote use of ocean observing assets in education and public awareness. Fortunately, the goals, principles and priorities for IOOS and the Ocean Research Interactive Observatory Networks²⁴ education (ORION, the sister ocean observing effort whose focus is on extending fundamental understanding of oceanographic processes) offer the opportunity to unite under that banner, while their differences serve to complement each other. They are similar in that both recognize the:

- Critical role of an Education and Communications Coordinating Office;
- Importance of a coordinated approach to data management and scientific visualizations;
- Opportunity that observing systems present for new science and technology careers and a revitalization of the ocean workforce;
- Importance of nurturing students and educators from diverse audiences to successfully pursue careers allied with the ocean; and
- Advantages of a public that is aware and knowledgeable about the ocean and our dependence upon it.

They differ while complementing each other in the following areas:

- IOOS focuses on use of oceanographic understanding and information to address societal goals of national importance and ORION on discovery that advances fundamental understanding of oceanographic processes that, in turn, advances solutions to societal goals;
- IOOS focuses on operational processes, resilience and sustainability of observing systems and ORION on science research results and new technologies that enable discoveries; and
- IOOS focuses on a coordinated network-of-networks to support education and public awareness and ORION on a coordinated education network within the ORION program that is positioned to participate in a network-of-networks.

²⁴ "Ocean Research Interactive Observatory Networks (ORION) Education and Public Awareness Draft Strategic Plan." July 2006. 25pp. ORION Education and Public Awareness Committee.



6.1 Forming the IOOS Education and Public Awareness Network-of-Networks

The highest educational priority activity to be initiated immediately is the formation of a national network of educators.^{25, 26} This activity directly addresses Goal 1 of the IOOS education and public awareness plan.²⁷ A network-of-networks will be built from existing, functional, active education networks each composed of sites. A nationally coordinated effort will harmonize bottom-up and top-down approaches, thereby ensuring a nationally coordinated, locally relevant network of networks. The end result will be the transparent linkage of local sites belonging to different networks (via the Regional Associations active at the local level) and the linkage of the networks at the national level.

Initially, the network-of-networks will form by forging partnerships between four existing networks at both the national and regional levels: the Centers for Ocean Science Education Excellence (COSEE), the education and training programs of the National Estuarine Research Reserve System (NERRS) network, the education network of the National Marine Sanctuary Program (NMSP), and the education and extension network of the National Sea Grant Office (NSGO). The RAs will forge bottom-up regional partnerships, while Ocean.US will promote the top-down national partnerships between networks. In the beginning, participating networks may vary regionally, but ultimately, the network-of-networks will embrace members from all of the four education networks. This top-down and bottom-up approach will encourage multiple, coordinated activities across the education network, thereby strengthening the foundation of the network-of-networks.

As the network-of-networks forms, a plan will be developed to address the formation of the Education Network Coordinating Office responsible for day-to-day coordinated implementation of the network-of-networks and the education plan. Development of this plan is a priority of the education planning initiative described in section 6.3.

6.2 Participating in IOOS Governance

Educators will participate in the governance of the RAs through the formation of a grassroots regional education body that guides and coordinates regional education efforts, especially the regional component of the network-of-networks. At the national level, immediate priorities are to: (1) establish a mechanism to coordinate planning for education among the regions; and (2) develop a process to ensure that IOOS education is consistent with the priorities of the ocean education committee (Interagency Working Group on Ocean Education) that has formed under the auspicious of the federal Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI).

6.3 IOOS Education Planning Priorities

IOOS education planning priorities include completing the following, consistent with federal ocean education priorities:

- Prepare and periodically update an Education Action Plan based on the IOOS national education strategy;
- Determine: (a) current and future ocean science, technology and operational workforce needs, skills, and education and training sources; and (b) the extent and depth of the public's understanding of the ocean's role in its lives; use this information to identify gaps in capability and knowledge that the workforce and public awareness efforts will seek to fill;
- Prepare a plan that builds on existing capabilities, specifies implementation roles and responsibilities and resource requirements to create and sustain a National Education Coordinating Office;
- Formulate key national and related regional messages and themes that convey the goals and objectives of IOOS as part of the Integrated Earth Observation System (IOES) and Global Earth Observation System of Systems (GEOSS); use these to guide the formulation of IOOS education messages and themes that incorporate ocean literacy concepts;
- Participate in data management planning to ensure IOOS data is useful and useable by educators and enrich data managers' knowledge of educators' requirements; and
- Design and implement four pilot projects: three that determine best practices for learning materials that utilize IOOS data with a focus on 1) the design, 2) the development, and 3) and the deployment of learning materials, respectively, and a fourth pilot project that determines best practices for education assessment strategies.

²⁵ *Educators* refers to practitioners in many disciplines and venues including classroom teachers and education administrators in kindergarten through grade 12, faculty members active in grades 13-18 at two and four-year colleges, professionals of continuing education, professionals of adult-basic and adult-secondary education, and education program and exhibit staff at natural and cultural history sites (parks, sanctuaries, reserves, seashores) and informal learning centers (aquariums, museums, coastal learning centers, science and technology centers), leaders and trainers of youth group personnel, science writers, filmmakers, etc.

²⁶ An *education network* is any organized collection of educators, defined as in footnote 25, whose members are active in formal, informal or non-formal education. These members engage in a wide range of activities and possess many different titles (e.g., teacher, faculty members, youth leader, extension agent, interpreter, community liaison, instructor, continuing education specialist, media specialist, science writer, exhibit designer, etc.)

²⁷ *Promoting Lifelong Ocean Education: Using the IOOS to Shape Tomorrow's Earth Stewards and the Science and Technology Workforce*. (2004). Ocean.US Report No. 4. <http://www.ocean.us/documents/docs/Education%20Report/LoRes_Final_IOOS_Edu_Pub.pdf>

6.4 Coordinated Approach to Design of Learning Materials

The final high priority area is to develop an approach for creating learning materials (informed by the pilot projects listed in section 6.3) that effectively target specific audiences and regions within the framework of the seven IOOS societal goals. Specifically, learning materials should be conceived as suites of related materials that address regional sub-themes and sub-messages within the seven IOOS societal goals, with each element of the suite targeted to a specific audience and structured so each element is easily modified for use in other IOOS regions.

7. Socio-Economic Benefits

Coastal inundation impacts not only the nation's economy, but also the safety, health and well being of coastal populations; the health of coastal ecosystems and the sustainability of living resources (Box II.3).²⁸ Marine resources, including fish, marine mammals, sea birds, corals, seagrass beds, kelp beds, plankton communities, beaches and shoreline, oil and gas reserves, sand, salt, and sea water itself account for a significant portion of the U.S. economy in goods and services. Coastal areas alone produce 28 million jobs, millions of dollars in goods and services, and provide attractive tourist destinations for 180 million Americans every year. The health and availability of these resources affect millions of U.S. citizens, tourists and bordering nations. Coastal areas of the U.S. are among the most developed in the nation, with over half of our population residing within less than one-fifth of the land area in the contiguous United States. Coastal and ocean management is critically important to the environment, economy and public safety. Protecting and sustaining U.S. coastal and ocean resources in the face of natural disasters are essential to ensure these benefits for future generations.²⁹

In the long-term, economic growth depends not only on sustained, secure and affordable water, food and energy supplies, but also on the maintenance of healthy ecosystems and the goods and services they support. Improving IOOS capabilities for coastal inundation will also improve the effectiveness with which we are able to address the goals of homeland security, safe and efficient maritime operations, public health, ecosystem health and sustaining living marine resources (Box II.3). As shown in recent studies^{13, 29}, the capability to rapidly assess the states of marine systems and to detect and predict changes in them in a timely manner will yield significant socio-economic benefits.



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²⁸ Cheves, M., 2003. Monitoring the heartbeat of mother earth. EOM, 12 (6): 6-10; IPCC's *Special Report on Emission Scenarios*, 2000; UNEP. 1995. Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities; <<http://www.pnas.org/cgi/content/abstract/0403239101>>; <http://www.weather.com/newscenter/tropical/?from=wxcenter_news>; <<http://www.us-weathernews.com>>; <http://www.whoi.edu/redtide/notedevents/gennews/gennews_2-22-01.html>; <<http://www.gpa.unep.org/pollute/sewage.htm>>; <http://www.trans-inst.org/ind_profile.html>; <http://iwgeo.ssc.nasa.gov/docs/review/Human_Health_Technical.pdf>.

²⁹ Protect and Monitor Our Ocean Resources <http://iwgeo.ssc.nasa.gov/docs/review/Oceans_Technical.pdf>

Box II.3: Examples of Socio-Economic Benefits of an Integrated Approach to More Timely and Accurate Forecasts of Coastal Inundation and More Effective Mitigation of Impacts

More effectively predict and mitigate the effects of natural hazards: Globally, tropical cyclones and tsunamis caused damage estimated at U.S. \$300 billion during 1990-1999. Hurricane Katrina alone caused US \$80 billion in damage to the US Gulf Coast, eclipsing the previous record of US \$26.5 billion in damage caused by Hurricane Andrew in 1992. Hurricanes Katrina, Rita, Wilma, and the lesser storms combined to set a record for estimated annual damages of US \$107 billion in 2005, more than double the previous record of US \$45 billion set in 2004. Risks cannot be completely eliminated, but implementing IOOS will enable improved forecasts of coastal inundation events, changes in susceptibility to them and mitigation of their impacts on coastal populations, ecosystems and resources. This will reduce loss of life and property and help to mitigate the effects of inundation events on coastal ecosystems and living resources.

Improving operational capabilities for natural hazards will also provide data and information needed to address the remaining six societal goals.

Improve homeland security: Nearly 90% of U.S. world trade is transported through the nation's coastal port facilities (worth more than \$220 billion a year), the security of which depends on timely and accurate forecasts of surface winds and waves, littoral currents and water levels, and riverine/estuarine conditions.

Improve weather and climate predictions: For developed countries, national institutions providing weather, climate, and water services to their citizens contribute an estimated US\$20-\$40 billion each year to their national economies.

Improve the safety and efficiency of maritime operations: More accurate and timely forecasts of water depth in ports and harbors will allow ships to carry more cargo and increase the safety and profits of marine operations. More accurate and timely forecasts of surface current and wave fields will reduce time and fuel costs through more effective ship routing.

Reduce public health risks: The global burden of human disease caused by waterborne pathogens introduced by sewage inputs to coastal waters is estimated to be ~ US\$16 billion per year. The annual income from recreational activities in the world's coastal zone (~ US\$100 billion/year) is threatened by pollution from land-based sources from both point sources (e.g., increases in the discharge of partially treated waste water containing human pathogens, nutrient pollution, and toxic chemicals) and non-point sources (e.g., inputs of contaminants through surface runoff and atmospheric deposition). Harmful algal blooms (HABs) in coastal ecosystems appear to be increasing nationwide. There are more toxic HAB species, more HAB events, and more areas and fisheries affected than 25 years ago. A recent study estimated that the average annual impact of HABs nationwide is \$49 million, but individual events can cost that much. More rapid detection and timely predictions of HABs will reduce economic losses. Improved estimates of land-based inputs of waterborne nutrients, pathogens and contaminants combined with models of coastal circulation and water quality will reduce risks of human exposure, reduce the number of beach closure days and increase recreational income.

Protect and restore healthy ecosystems more effectively: Through improved models and more accurate and timely estimates of sea surface current and wave fields, the cost (economic and environmental) of oil pollution can be reduced significantly by more efficient and effective deployment of clean-up equipment. For one oil spill, the savings in mitigation expenses was estimated to be \$225,000 (Appendix C).

Sustain and restore living marine resources more effectively: Nearly 75% of fisheries are categorized as overfished or fished to the limit, and large fish stocks have fallen to ten percent or less of their numbers at the onset of commercial fishing. The associated economic losses are very large (Billions in US\$) and impossible to realistically measure. Establishment of the coastal module of IOOS is required to engage in ecosystem-based, adaptive management of fisheries and other living marine resources as the means to restore and sustain healthy stocks.

Part III: Improving the IOOS through Enhancements and Research

1. Introduction

More timely and accurate forecasts of the time-space extent of coastal inundation and more effective mitigation and management of their effects on public health, ecosystem health and the sustainability of living marine resources is the highest priority for IOOS development over the next five years. To these ends, recommendations of this plan focus on filling gaps in observing subsystem capabilities targeted to coastal inundation (Table III.1), continued implementation of Data Management and Communications (DMAC), and the development of operational models for all seven IOOS societal goals.

2. Enhancing the Observing Subsystem

Significant gaps exist between current capabilities and observing subsystem requirements detailed in action and implementation plans for the global ocean-climate component of the IOOS¹ and for the coastal modules of the Global Ocean Observing System (GOOS) and Global Terrestrial Observing System (GTOS).² Gaps fall into one or more of the following categories:

- *Sustainability* challenges focused on maintaining existing observation capabilities;
- *Resolution* challenges that target requirements for increasing time, space and spectral resolution;

- *Synoptic* challenges of measuring geophysical and biogeochemical variables at the same times and places;
- *Knowledge* challenges that require research and development; and
- *Resilience* challenges that require the hardening of sensors and systems against natural forces and vandals.

In terms of enhancing operational capabilities of the IOOS, *sustainability* challenges are concerned with both continuity of funding over time and transitioning observing subsystem capabilities from research to operational modes (Box III.1). *Resolution* challenges range from increasing the spectral and spatial resolution of ocean color observations from space to blending data from *in situ* and remote sensing for improved temporal and spatial resolution (e.g., the Global Ocean Data Assimilation Experiment's (GODAE) High Resolution Sea Surface Temperature (GHRSSST) pilot project³). *Synoptic* sampling challenges include the need for concurrent measurements of geophysical and biogeochemical variables in time-space as well as the need for multipurpose platforms for more cost-effective operations (e.g., more effective use of ship-time). *Knowledge* challenges range from advances in technology (e.g., satellite-based remote sensing of sea surface salinity) to more accurate algorithms for estimating concentrations of chlorophyll-*a* and other phytoplankton pigments in turbid coastal waters. *Resilience* challenges include not only sensors but also power systems, moorings and platforms, as well as data collection, analysis and transmission systems.

Cross-cutting all of these challenges is the issue of increased capacity and infrastructure. As more platforms

Table III.1. Enhancement priorities for the IOOS observing subsystem and the societal goals these enhancements will address, targeted to coastal inundation and an all hazards warning system (as recommended in the *First U.S. IOOS Development Plan*) (G – Global component; NB – National Backbone).

CORE VARIABLES	Societal Goal						
	Weather & Climate	Marine Operations	Natural Hazards	National Security	Public Health	Healthy Ecosystems	Sustained
Sea Surface Winds	G, NB	G, NB	G, NB	NB	NB	NB	NB
Waves	G, NB	G, NB	G, NB	NB	NB	NB	NB
Currents	G, NB	G, NB	G, NB	NB	NB	NB	NB
Coastal Sea Level – Topography	NB	NB	NB	NB	NB	NB	NB
Stream Flow		NB	NB	NB	NB	NB	NB
Chlorophyll	G, NB	G, NB	G, NB	NB	NB	NB	NB
Habitat & Bathymetry		NB	NB	NB		NB	NB

¹ 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 UNFCCC. <<http://www.wmo.ch/web/gcos/gcoshome.html>>

² 2005. IGOS Coastal Theme Report <<http://www.eohandbook.com/gosp/Coastal.html>>; COOP Implementation Strategy for the Coastal Module of GOOS <<http://unesdoc.unesco.org/images/0014/001412/141242E.pdf>>

³ Global High Resolution Sea Surface Temperature project (GHRSSST) of the Global Ocean Data Assimilation Experiment (GODAE) <<http://ghrsst-pp.metoffice.com/pages/GHRSSST-PO/>>

BOX III.1. Mechanisms for Transitioning from Research to Operations

IOOS development depends on scientific and technical research from NSF's ORION-OOI program, NASA's Earth Exploration missions, and ONR's technology investments to provide the new knowledge and technology needed to improve operational capabilities. A systematic mechanism for incorporation of improvements in measurements, technology and analysis derived from these research programs does not exist today. Such a mechanism would ensure that improvements occur continuously and come with the resilience and reliability operational organizations require for their decision-making. This systematic mechanism can be likened to ramps on the interstate highway system: on-ramps import science and technology advancements; off-ramps provide a means to sunset outdated technologies.

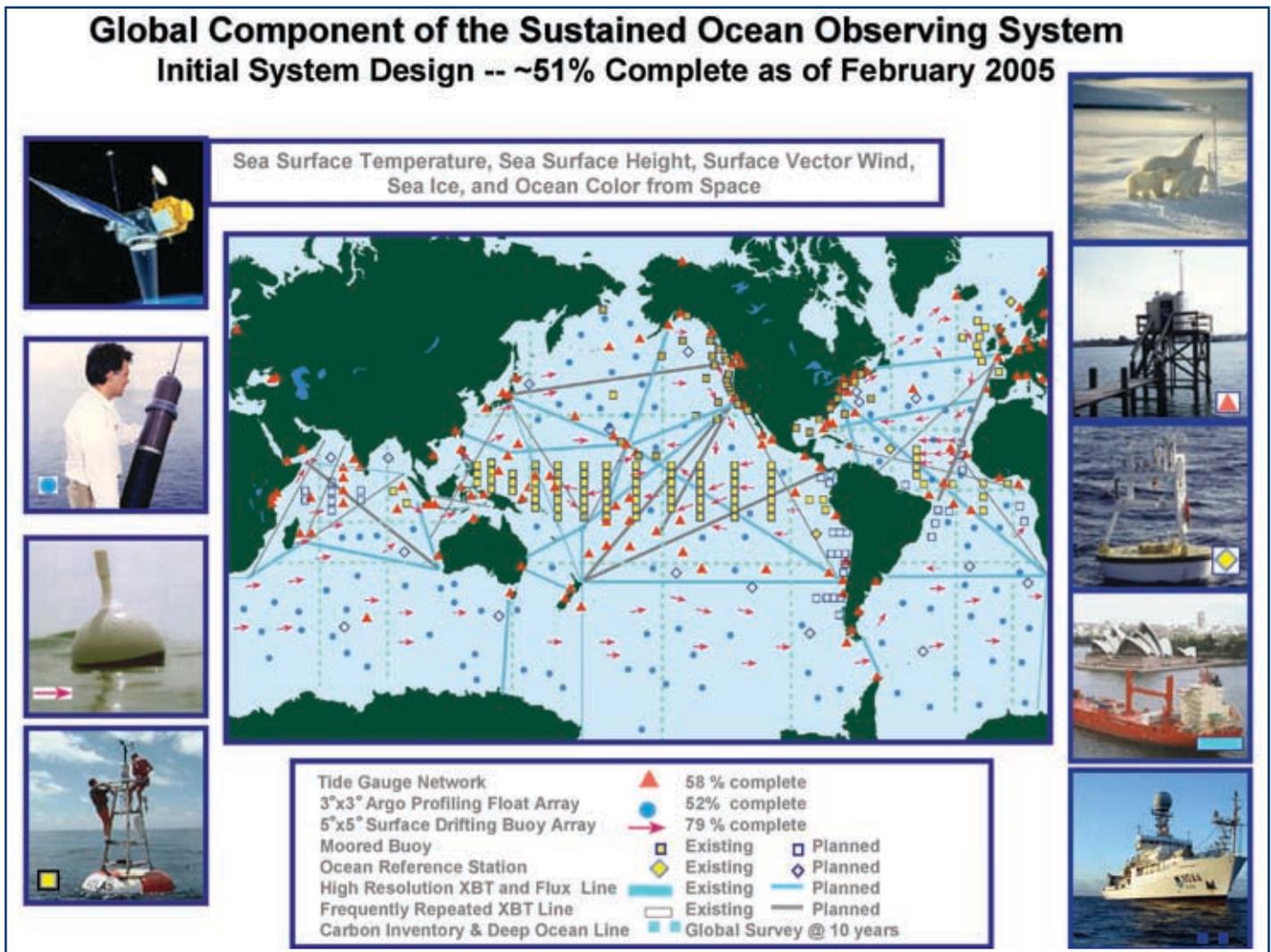
are added to the National Backbone and Regional Coastal Ocean Observing Systems (RCOOSs), for example, additional ships and technicians will be needed for installation and maintenance. As the volume of data increases, more transmission, analysis and dissemination capability will be needed. As the enhancement of IOOS is undertaken, planning for increased infrastructure and support capability must be included.

2.1 Global Ocean Component

The global component of the IOOS observing subsystem consists of sustained, high-quality satellite measurements of the ocean surface and *in situ* measurements of the upper and deep ocean (Figure III.1).

Enhancements of the global ocean component of the IOOS focus on continued implementation of the *in situ* observations and sustaining the continuity of satellite-based remote sensing.

Figure III.1. Schematic of the composite *in situ* ocean observing systems and current status of their implementation against the goals of the global ocean design plan.



2.1.1 Remote Sensing

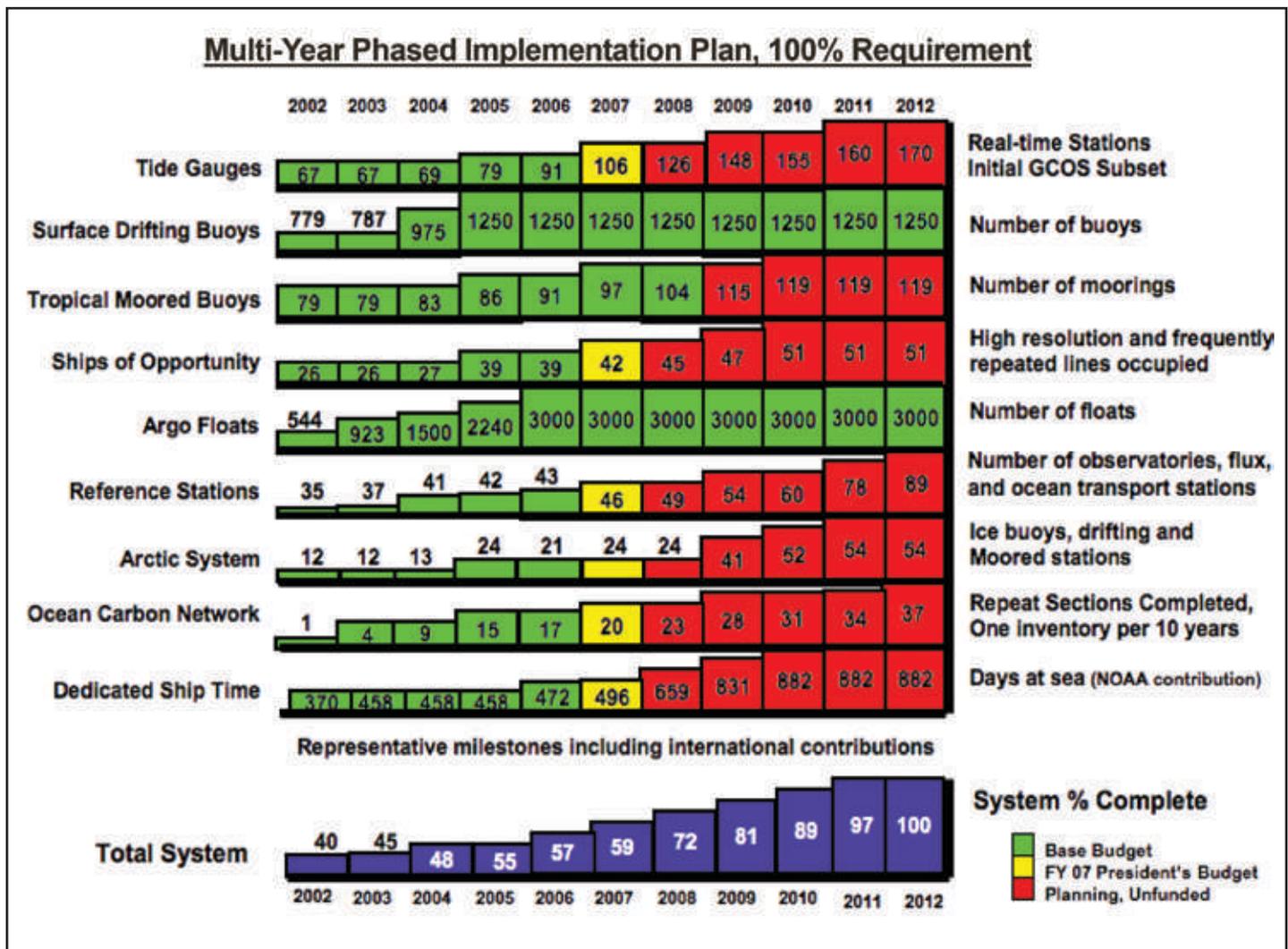
Satellite-based remote sensing of the surface ocean provides near-global coverage of sea surface temperature (infrared radiometers, microwave sensors), sea surface height (altimeters), sea surface roughness (active and passive microwave systems), and ocean color (spectrometers). A number of ocean variables is derived from these basic parameters including sea surface winds, currents, significant wave height, sea level, sea-ice extent and concentration, oil slicks and chlorophyll-a concentration. Existing, approved and planned satellite missions for mapping these parameters and variables through 2020 are well documented in the most recent Earth Observation Handbook.⁴

For the U.S., major continuity challenges include sustained delivery of high-quality products on surface vector winds (e.g., QuickSCAT, WindSat), sea surface height (timely implementation of the Ocean Surface Topography Mission [OSTM], Jason-3), and ocean color (access to SeaWiFS data, intercomparability among different sensors, and demonstration that the Visible Infrared Imager/Radiometer Suite [VIIRS] meets operational requirements). The challenges of resolution, synoptic sampling and knowledge are greatest for the coastal component.

2.1.2 In Situ Sensing

As summarized in Part II, substantial progress has been made in a number of the system components, including completion of the design goal of an array of 1,250 global drifter buoys and implementation of 60% of the Argo sub-surface profiling buoy network. Incremental progress is being made towards implementing each of the other main elements of the *in situ* ocean observing system (Figure III.2).

Figure III.2. The last five years of progress and plans for the next five years of *in situ* observations for the global component of the sustained ocean observing system. The design plan calls for completion of the initial ocean climate observing system by 2010.



⁴ Committee on Earth Observations (CEOS). 2005. Earth Observation Handbook. <<http://www.eohandbook.com>>

With the planned enhancements to the tsunami warning system⁵, there is a unique opportunity to enhance open ocean observations and address the challenges of “synoptic” sampling through multiple use of platforms. The U.S. tsunami warning system includes a Deep-ocean Assessment and Reporting of Tsunamis (DART) mooring in the tropical South Pacific near a Tropical Atmosphere-Ocean (TAO) mooring. This mooring has been serviced as a routine augmentation to the normal TAO maintenance cruises. The improved tsunami detection and warning system includes several moorings that are at or near TAO moorings or planned Ocean Time Series stations (Figure III.3). Multiple-use moorings should be employed at sites where TAO, Ocean Time Series and/or Tsunami Warning System sites coincide. Where sites are not coincident but in the region, cruises servicing TAO, Ocean Time Series or Tsunami Warning System moorings in the vicinity of these sites should service them as well.

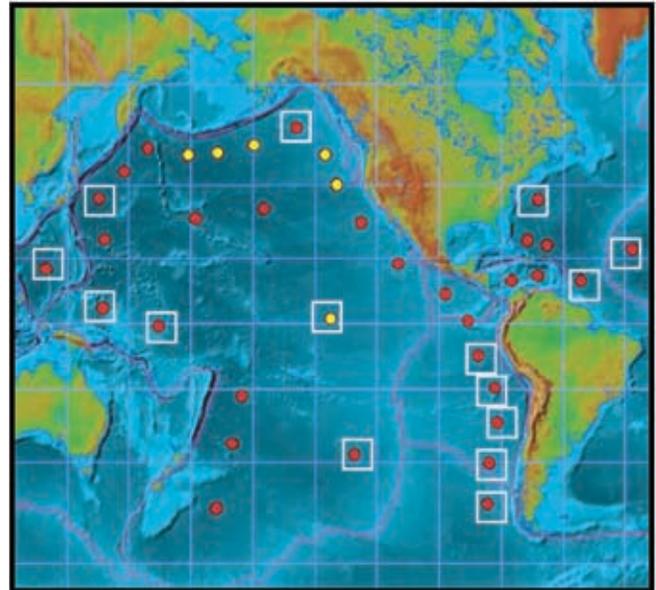


Figure III.3. Locations (white boxes) where multiple-use moorings and/or common logistical support activities for the U.S. IOOS and tsunami detection and warning system may be implemented. Yellow dots represent the locations of the current DART array. Red dots represent estimated DART system locations for the National Tsunami Hazard Mitigation Program.

A second high priority is to integrate hydrographic surveys with Argo float deployments. The Argo program deploys instruments from dedicated aircraft, small chartered vessels, hydrographic survey vessels from a number of nations, research vessels and Volunteer Observing Ships (VOS) during routine transits. Most Argo floats are deployed from VOS and small chartered vessels which also deploy drifting buoys and expendable bathythermographs (XBTs) during their cruises. However, VOS and small chartered vessels do not conduct coincident hydrographic observations. More accurate calibration of Argo float and surface drifter sensors will be achieved by employing survey and research vessels to conduct conductivity-temperature-depth (CTD) hydrographic surveys to deploy Argo floats and surface drifters.

2.2 National (Coastal) Backbone

2.2.1 In Situ Measurements and Land- and Aircraft-Based Remote Sensing

The first two challenges identified in *Grand Challenges for Disaster Reduction*⁶, produced by the National Science and Technology Council (NSTC), are to “Provide hazard and disaster information where and when it is needed” and “Understand the natural processes that produce hazards.” With these challenges in mind, the Second IOOS Implementation Conference⁷ focused on coastal inundation caused by tsunamis, tropical storms and extra-tropical storms in order to provide recommendations that would address these challenges. Recommendations from the conference emphasized a combination of *in situ* observations and land- and aircraft-based remote sensing of: (1) geophysical variables (sea surface meteorological



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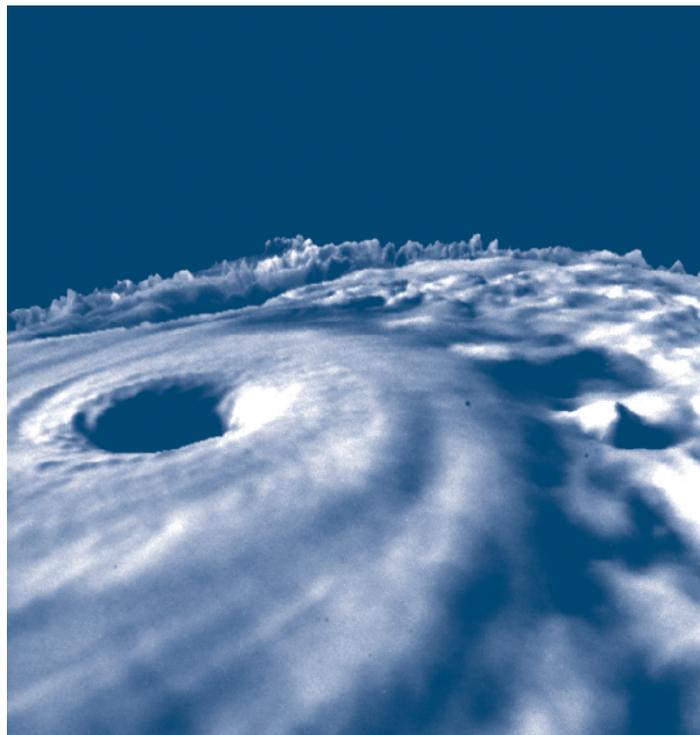
⁵ Tsunamis: Monitoring, Detection and Early Warning Systems: <<http://www.pmel.noaa.gov/tsunami-hazard/hazard3.pdf>>, <<http://www.usembassy.it/pdf/other/RL32739.pdf>>, <<http://www.ostp.gov/html/TsunamiFactSheet.pdf>>

⁶ Grand Challenges for Disaster Reduction <<http://www.sdr.gov/SDRGrandChallengesforDisasterReduction.pdf>>

⁷ Proceedings of the Second IOOS Implementation Conference <http://www.ocean.us/documents/docs/2ndIOOS_FINAL_lowres.pdf>

variables, surface waves, water level, surface and interior current fields, distributions of temperature and salinity, surface runoff and wet deposition); (2) biogeochemical variables (distributions of nutrients, chlorophyll, dissolved oxygen and partial pressure of carbon dioxide); and (3) mapping (bathy-topographic and shoreline position and habitats that buffer coastal communities against flooding). Likewise, the *First U.S. IOOS Development Plan*⁸ focused on programmatic recommendations. This section focuses on gaps between observing subsystem requirements (Table III.1) and current capabilities with an emphasis on satellite-based remote sensing and the challenges that must be addressed to fill them.²

More specific recommendations for improving the observing subsystem are given in the following sections. Of these, some are already in the *First IOOS Development Plan*, one is from experience, and some stem from the Second IOOS Implementation Conference (as indicated by **NEW**.) Initially, proven technologies will be used to improve operational capabilities of the observing subsystem to address these recommendations (Table III.2).



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Table III.2. Existing observing subsystem assets that should be integrated and enhanced to serve and/or improve products and services needed to manage and mitigate the impacts of coastal inundation (SCAT - scatterometer, SAR - synthetic aperture radar, DART - Deep-ocean Assessment and Reporting of Tsunamis; HF - High Frequency; ADCP - Acoustic Doppler Current Profilers; IR - Infrared; VIS - Visual; AVIRIS - Airborne Visible/Infrared Imaging Spectrometer).

PRODUCTS & SERVICES	IMPORTANT FIELDS, FEATURES, & PROCESSES	OBSERVING SUBSYSTEM ASSETS
Forecasts of time-space extent of coastal flooding	Surface winds & atmospheric pressure	Moored anemometers, SCAT, SAR
	Surface wave height & direction	DART buoys, wave measuring buoys, SAR, altimeters, HF Radar
	Surface currents	ADCP, HF Radar, Drifters, SCAT, Altimeters
	Sea surface temperature	Field sensors, IR imagers, Passive microwave imagers,
	Sea/water level, sea surface height	Tide gauges, altimeters
	Surface water runoff	Stream gauges
	Wet precipitation	Rain gauges, Doppler radar, Radiometers
	Near shore bathy-topographic; shoreline position	Sonar, Lidar, VIS imagery, IR imagers, SAR
	Near shore benthic habitats	Surveys, Lidar, AVIRIS
	Land-use, -cover	VIS/IR imagery, Surveys
Maps of Risks & Impacts	Water-borne inputs of sediments, nutrients, and pollutants	Stream gauges, bio-optical field sensors, <i>in situ</i> sensors, laboratory analysis
	Surface plumes, slicks	SAR, SCAT
	Sea surface salinity	<i>In situ</i> conductivity, Microwave radiometers
	Sea surface chlorophyll	Bio-optical field sensors, Ocean color imagery

⁸ The First U.S. Integrated Ocean Observing System (IOOS) Development Plan <<http://www.ocean.us/foosplan.jsp>>

Forecasting the time-space extent of coastal flooding

- Reduce the lag time between events in the ocean and their detection, and increase time-space resolution of observations as related to surface vector wind fields over water, surface current fields, directional wave fields and sea surface temperature distribution (Exclusive Economic Zone). Included should be increasing the number of real-time, bottom pressure and upper ocean oceanographic measurements (ocean basin scale) by deploying additional DART buoys in the Pacific Ocean and expanding the array for all coasts (Figure III.3). **NEW**
- Optimize the tide gauge network to increase density of real-time measurements of water level in high risk areas.
- Increase stream gauge (continuous, real-time telemetry) coverage in the coastal zone, including near the heads and mouths of rivers for more accurate estimates of surface water runoff.
- Using both *in situ* measurements and remote sensing (e.g., rain gauges, Doppler radar, Tropical Rainfall Measuring Mission [TRMM], Global Precipitation Measurement [GPM] Mission), increase the density of rainfall measurements, atmospheric moisture profiles and soil moisture content. **NEW**
- Establish a consistent, national standard vertical datum to which all vertical measurements (e.g., water level, coastal bathymetry and topography) can be referenced. **NEW**
- Develop capability for long-term monitoring of river flows and lake levels from space. **NEW**
- Improve the resilience of sensors, systems and platforms to increase their survivability during extreme events and their resistance to vandalism. **NEW**

Susceptibility to flooding

- Repeat measurements (one to five years) of near shore coastal bathymetry-topography (including shoreline position), benthic habitats (e.g., coral reefs, sea grass beds, kelp beds), and land-use/cover (e.g., tidal wetlands, forests, grassland, impervious man-made surfaces, agriculture), especially in high risk areas.
- Establish a consistent, national standard vertical datum to which all vertical measurements (e.g., water level, coastal bathymetry and topography) can be referenced. **NEW**



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Impacts on habitats, water quality and erosion

- Increase stream gauge coverage for more accurate and timely estimates of inputs of freshwater, sediments, nutrients and pollutants on seasonal scales and during post-storm runoff.
- Repeat measurements (one to five years) and timely post-inundation updates of near shore coastal bathymetry-topography (including shoreline position), benthic habitats (e.g., coral reefs, sea grass beds, kelp beds), and land-use/cover (e.g., tidal wetlands, forests, grassland, impervious man-made surfaces, agriculture), especially in high risk areas.
- Prior to and following flooding events, map intertidal wetlands, submerged aquatic vegetation, buoyant coastal plumes and slicks, sea surface temperature, salinity, suspended sediments and chlorophyll-a (adaptive sampling).

Requirements for biogeochemical measurements are not fully addressed by existing and planned observing subsystem capabilities, especially in coastal waters and the Great Lakes.² An important step toward addressing these gaps will be implementation of the design plan for the National Water Quality Monitoring Network (Box III.2).

BOX III.2: The National Water Quality Monitoring Network (NMN)

In its report (*An Ocean Blueprint for the 21st Century*), the U.S. Commission on Ocean Policy called for "...a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of the ocean and coastal resources." Specific recommendations include the following:

- **Recommendation 15-1:** The National Oceanic and Atmospheric Administration, U.S. Geological Survey, and U.S. Environmental Protection Agency, working with states and other appropriate entities, should develop a national monitoring network that coordinates and expands existing efforts, including monitoring of atmospheric deposition. The network should be built on a federally funded backbone of critical stations and measurements to assess long-term trends and conditions, with additional stations or measurements as needed to address regional characteristics or problems.
- **Recommendation 15-2:** The National Oceanic and Atmospheric Administration should ensure that the national monitoring network includes adequate coverage in both coastal areas and the upland areas that affect them, and that the network is linked to the Integrated Ocean Observing System, to be incorporated eventually into a comprehensive Earth observing system.

In response to these recommendations and directed by the President's *Ocean Action Plan*, the Council on Environmental Quality (CEQ) asked the President's Advisory Committee on Water Information (ACWI) to develop the NMN. The ACWI accepted the charge and delegated the work to the National Water Quality Monitoring Council (NWQMC). A Steering Committee of ten members was created by the NWQMC to oversee the efforts of four work groups (Design, Inventory, Methods and Data Comparability, and Data Assembly and Access). Ocean.US actively participates on the Design Work Group. The organizations represented on the Steering Committee are:

- Alabama Department of Environmental Management
- American Society of Limnology and Oceanography
- Ohio River Valley Water Sanitation Commission
- National Association of State Conservation Agencies
- National Oceanographic and Atmospheric Administration
- New Hampshire Department of Environmental Services
- Tennessee Valley Authority
- U.S. Environmental Protection Agency (Co-chair)
- U.S. Geological Survey (Co-chair)

The Committee began work in February 2005 on five objectives:

- Define status and trends of key water quality parameters and conditions nationwide.
- Provide data to assess whether goals, standards and resource management objectives are being met.
- Provide data to identify and prioritize existing and emerging problems to help guide implementation of more intensive monitoring in support of preventive actions and remediation.
- Provide data to support and define coastal oceanographic and hydrologic research, including influences of freshwater flows.
- Provide quality-assured data for use in the preparation of ecosystem assessments and educational materials.

The NMN is to be a nationally coordinated design that builds on existing networks and is closely linked to IOOS development. An objective is to enable coordination among federal agencies and Regional Associations to ensure that the NMN and the IOOS are closely linked and coordinated to improve operational capabilities for monitoring and improving water quality. As a first step, regional NMN boundaries will coincide with boundaries of the eleven IOOS regions. The final report of the Design Work Group is due in May 2006.

Implementation of the NWN in collaboration with the IOOS will improve significantly the Nation's capability to rapidly detect, predict and mitigate the impacts of coastal inundation on coastal marine and estuarine water quality. This includes the impacts of flooding and subsequent runoff on human exposure to waterborne pathogens, as well as impact of nutrient and contaminant loading on coastal ecosystems and living marine resources.

2.2.2 Satellite Capabilities and Gaps

Sustainability

Sustainability of observations is a major concern for both coastal and global ocean components in that there are no guarantees that measurements of key core variables will be sustained without breaks in the record. While maintaining current operational satellite observing capabilities, there is an immediate need to use existing and proposed research satellites and sensors to improve operational capabilities. Prime candidates are research satellites currently being used to provide products and services (Figure I.5). These include altimetry (Jason, GEOSAT Follow-on [GFO]), European Remote Sensing ([ERS] and Envisat series), sea surface winds (WINDSAT), synthetic aperture radar (RadarSat, ERS and Envisat series), scatterometry (QuikSCAT, MetOp and National Polar Orbiting Environmental Satellite System [NPOESS]) and ocean color (Terra-Aqua, NPOESS, Geostationary Operational Environmental Satellite [GOES]-R mission). Implementation of the NPOESS mission is of particular concern, especially the reduction in the number of satellites, elimination of important sensors, and the delay in launching the first satellite. Critical concerns include the loss of the Altimeter on NPOESS and the dependence on European Meteorological Operational Satellites for sea surface winds until a replacement sensor is developed for the Conical Scanning Microwave Imager/Sounder.

Resolution

Observing subsystem requirements for the coastal component (Table II.1) call for much higher temporal, spatial and spectral resolution than is available now or planned. Although this is especially true for salinity, surface winds, waves, sea surface height and ocean color (all of which are currently dependent on research missions), space-based remote sensing of sea surface temperature (operational for decades) also requires improved resolution to address coastal needs. Opportunities for increasing spatial resolution include wide-swath altimetry for ocean surface topography; Synthetic Aperture Radar (SAR) processing of scatterometer measurements for ocean vector winds; and lightweight large-aperture mirrors. Temporal resolution can be improved by pursuing alternatives of low Earth orbits (LEO) orbits, including medium Earth orbits (MEO) for vector winds and geostationary Earth orbits (GEO) for ocean color.



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For observations that depend on visible and infrared (IR) bands, cloud cover often causes gaps in both spatial and temporal coverage, an effect that is exacerbated by large pixel sizes. Improved methods are needed to fill gaps and remove contamination from aerosols and clouds. Land contamination is a particular challenge for sea-viewing satellite measurements. Data lost in pixels adjacent to land must be minimized, and mixed land-sea pixels across intertidal boundaries should be a priority.

Synoptic Sampling

For the purposes of predicting and mitigating the impacts of coastal inundation, synoptic and high spatial resolution maps are needed on hourly time scales for key features and processes (Table III.2). Although achieving these levels of time-space resolution continuously is not practical, integrated use of remote sensing, *in situ* measurements and adaptive sampling provide an effective solution. In its most effective application, “adaptive sampling” involves the integrated use of *in situ* measurements and satellite remote sensing to increase the resolution of observations in targeted areas and times based on timely detection of environmental conditions likely to cause a coastal inundation event or lead to changes in susceptibility (Box III.3).

Box III.3. Spatially Synoptic Mapping and Adaptive Sampling

(1) Mapping coastal inundation risk

Maps of the risk of coastal inundation should be updated regularly and following coastal inundation events. Such maps should be based on probabilities of being impacted by storm surges, tsunamis and excessive rainfall as well as maps of coastal bathymetry, topography, benthic and intertidal habitats, and land-use/cover. Changes in risk occur due to coastal erosion, habitat loss and modification, coastal development and changes in water level, all of which should be monitored in both sustained (continuous or repeated at regular intervals) and episodic (adaptive sampling) modes. Major challenges to providing accurate maps of risk are the adoption of a national standard vertical datum as a common reference for mapping across the land-sea interface; repeated and timely updates of such maps; and the integrated use of data from multiples sensors including tide and stream gauges, altimeters, Lidar, visual/infrared imagery, and field surveys.

(2) Mapping environmental impacts of coastal inundation

Estimates of sea surface concentrations of phytoplankton pigments (e.g., chlorophyll-*a*, an index of phytoplankton biomass), colored dissolved organic matter (CDOM), and particulate matter (turbidity) can be extracted from ocean-leaving radiance spectra (ocean color). SAR provides high resolution (< 100 m) observations of sea surface roughness that can be used to monitor surface plumes from point source and river discharges into coastal waters. Such inputs increase in the wake of coastal flooding events and are not only sources of waterborne pathogens and nutrients that may fuel harmful algal blooms, but also create discontinuities where pathogens and harmful algae are often concentrated. Thus, the combined use of ocean color and backscatter returns from SAR may be used to guide adaptive sampling and blended with *in situ* observations to produce maps and exposure risks.

The combined use of satellite observations of ocean color and sea surface temperature (SST) has been used operationally to locate fish stocks. Synoptic maps of surface chlorophyll-*a* concentration and SST pre- and post-flooding events could be used to improve assessments of the impacts of flooding events on fish stocks.

(3) Mapping Socio-Economic Impacts

Environmental impacts must be translated into socio-economic risks by linking environmental forecast models to decision support models tailored to mitigate specific risks in impacted areas. The major challenge is to inventory decision support models (tools) currently in use and being developed for each of the seven societal goals and ensure that they can assimilate the environmental data and information.

Knowledge

Knowledge challenges for integration of data from different platforms and sensors include the development of methods for: (1) evaluating and correcting for measurement bias or uncertainty (from instruments, algorithms and sampling) associated with disparate data sources or types; (2) assimilating large volumes of data from satellite observations and, increasingly, from continuous *in situ* measurements; (3) accounting for uneven distribution of *in situ* measurements within and among regions; (4) extracting information on the distribution of core variables from satellite measurements of basic parameters; and (5) assessing interdisciplinary relationships among geophysical and biogeochemical fields and features. The recently approved Aquarius mission for estimating sea surface salinity fields will contribute to addressing challenges 3, 4 and 5.⁹

Resilience

Extreme events and vandalism affect sensors, systems and platforms. Considerable progress has been made in hardening sensors and systems and making platforms less vulnerable, but events such as Hurricane Katrina show that more must be done. With each event, information about the mechanism of the failure is gathered, and improvements are made. This is and must always be a continuing process.

There are needs that cross-cut these challenges. First, there are needs for improved calibration and validation. Satellite-based sensors require calibration prior to deployment and continued calibration during their use. *In situ* measurements are critical for both instrument calibration and validation of estimated quantities derived from satellite observations. Obtaining sufficient and

⁹ NASA's Aquarius Mission for estimating sea surface salinity <http://science.hq.nasa.gov/missions/satellite_59.htm>

representative *in situ* measurements to adequately assess and improve the accuracy of these estimates requires enhancements to existing *in situ* observing subsystem elements as recommended in section 2.2.1 and in Part III of the *First U.S. IOOS Development Plan*.⁸

The second set of cross-cutting needs is for increased capacity and infrastructure. There must be enough ships to deploy and service platforms at sea. Satellite data transmission capacity must be sufficient for data throughput. Data assembly and analysis facilities must have the ability to receive, quality control, analyze and disseminate the data produced by the systems. Finally, there must be enough trained people to make the systems work. The need for increased capacity and infrastructure is included in the recommendations in section 2.2.1.

2.2.3 Enhancements of Satellite Observations Needed to Fill Gaps

Geophysical measurements

- Sea surface temperature (SST) – Develop robust methods for blending SST measurements for different satellite platforms (LEO and GEO) and measurement techniques (infrared and microwave). The GODAE high-resolution sea surface temperature (GHRSSST) pilot project is an important effort that should be expanded to include coastal ecosystems and used to increase operational capabilities of the IOOS.
- Surface vector winds – Develop algorithms for extracting higher-resolution information from existing satellite scatterometers and future passive polarimetry, especially in close proximity to the shoreline; assess National Polar-orbiting Environmental Satellite System (NPOESS) capability to meet ocean vector wind data requirements, especially with having to depend on European satellite data until a new microwave imager/sounder is developed and put on NPOESS.
- Sea surface height (SSH) – Ensure continuity of the Jason series and the transition to a long-term data record for sea level; explore the use of delayed-Doppler and GPS altimetry to improve near shore (< 10 km) SSH measurements, and improve models for accurately removing tidal signals.
- Sea surface roughness – Continue to develop, validate and implement Synthetic Aperture Radar (SAR) algorithms for surface vector winds and wave height and direction; understand the differences and advantages to be gained through the use of different kinds of SAR measurements including C-band vs. L-band, multi-polarimetric and interferometric.
- Sea surface currents – Develop SAR Along-track Interferometry (ATI) and Doppler measurements, for high resolution measurement of surface currents in near shore (< 10 km) waters.
- Develop and validate remote sensing techniques for sea surface salinity.



Biogeochemical measurements

Satellite-based measurements of ocean color (i.e., the detection of phytoplankton pigments that are indicators of phytoplankton biomass and floristic composition) provide the only basin-to-global scale observations of the ecology and productivity of the upper ocean. Improving measurements of ocean color for coastal applications in general, and for optically complex coastal waters in particular, requires the following enhancements:²

- Expand ocean color observations to include GEO satellites to more accurately capture the scales of variability that characterize phytoplankton dynamics in coastal ecosystems and to minimize the effects of cloud cover and tidal aliasing; and
- Deploy hyperspectral (spectral bands ≤ 5 nm over a broad spectral range) sensors to more accurately quantify phytoplankton pigment concentrations in optically complex coastal waters. Required are sensors with coverage into the UV range (350-400 nm); a high signal/noise ratio; development of new, more accurate algorithms; improved characterization of aerosols for atmospheric corrections; adequate calibration and validation; and techniques for assimilating large volumes of data.

2.3 Regional Priorities

Regional priorities for the National Backbone (Table III.3) can be summarized as follows:

- Increase the number of data buoys and ship-surveys to improve time-space measurements of core variables;
- Increase the number of harbors and ports equipped with the Physical Oceanographic Real-Time System (PORTS[®]);
- Provide higher resolution estimates of directional wave fields, sea surface current fields; and
- Increase the frequency and spatial coverage of bathymetric-topographic mapping.

These recommendations are consistent with and underscore the importance of the initial focus on coastal inundation.

REGIONAL PRIORITIES	SE Atlantic	G-Mexico	Great Lakes	Alaska	NW Pacific	Central Cal	Mid-Atlantic	S. California	Northeast ^a	Caribbean	Pacific Islands	TOTAL
Data Buoys: Expand network^b	X	X	X	X	X	X	X	X	X	X	X	11
• Directional waves	X	X	X	X	X	X		X			X	8
• Current profiles		X		X			X	X			X	5
• Temperature				X	X	X		X			X	5
• Salinity				X	X	X		X			X	5
• Bio-chemical measurements			X	X	X	X					X	5
• Solar radiation				X	X	X		X				4
• Visibility		X		X	X							3
Remote Sensing	X	X	X	X	X	X	X	X	X	X	X	11
• Land-based												
o LR HF Radar	X	X	X	X	X	X	X	X	X	X		10
• Airborne												
o LIDAR	X	X	X	X	X	X		X		X	X	9
o Hyperspectral imaging			X		X	X						3
o Aerial photography					X	X		X				3
• Satellite-borne												
o Data continuity	X	X	X	X		X	X			X		7
o Temperature			X	X		X						3
o Ocean Color			X	X		X						3
Integrating Models	X	X	X	X	X	X		X	X	X	X	10
• Circulation	X	X	X	X		X		X				6
• Waves, surge, water level	X			X	X			X				4
• Sediment transport, erosion, shoreline position			X	X	X	X						4
PORTS/NWLON: Expand network^c		X	X	X	X	X		X	X	X	X	9
• Water level		X	X	X	X	X		X	X	X	X	9
• Chemical, biological			X			X					X	3
Ship Surveys^d	X	X	X	X	X	X		X			X	8
• Bathymetry	X				X	X		X			X	5
• Ecosystem health, benthic habitat	X	X	X	X	X	X		X				7
• Fisheries	X			X	X							3
Stream Gauging^e		X	X	X	X	X		X	X		X	8
• Water quality		X	X	X	X			X			X	6
• Sediments			X	X	X						X	4
C-MAN Stations^b		X	X	X		X				X	X	6
• Water quality			X			X					X	3
VOS	X			X	X		X					4

Table III.3. Highest priorities for the observing subsystem of the National Coastal Backbone that are common to three or more regions. Totals in the right column give an indication of priorities on a national scale. (^aReport not received [GoMOOS priorities only], ^bIncrease the number of sites [increase spatial resolution] and augment meteorological sensors [physical, biological and chemical], ^cIncrease the number of ports and harbors equipped with PORTS[®] and augment meteorological and physical oceanographic sensors with biological and chemical sensors, ^dIncrease frequency and spatial resolution of ship-based observations for more accurate bathymetry and assessments of ecosystem health and living marine resources – which has obvious implications in terms of UNOLS and NOAA fleet renewal, ^eIncrease the number of gauged streams and rivers for more accurate estimates of freshwater flows from land to ocean and associated fluxes of nutrients, sediments and contaminants.)

3. Data Telemetry

The *First IOOS Development Plan* provided a description of the challenges IOOS faces in terms of transmitting sensor data and also provided a thorough survey of the techniques and technologies to do so from both coastal and global platforms with both wireless and “hard-wired” solutions.⁸ Here, the focus is on current and projected geographical and bandwidth requirements and on emerging technologies that may be brought to bear. As for the oceanographic fleet and other supporting infrastructure, the data telemetry systems upon which IOOS, IEOS, GOOS and GEOSS depend need to be upgraded and expanded. The following are addressed: (1) data telemetry from sensor to the terrestrial network; (2) bandwidth of the terrestrial network; and (3) emerging technologies of the sensors themselves that will impact requirements for the overall telemetry architecture.

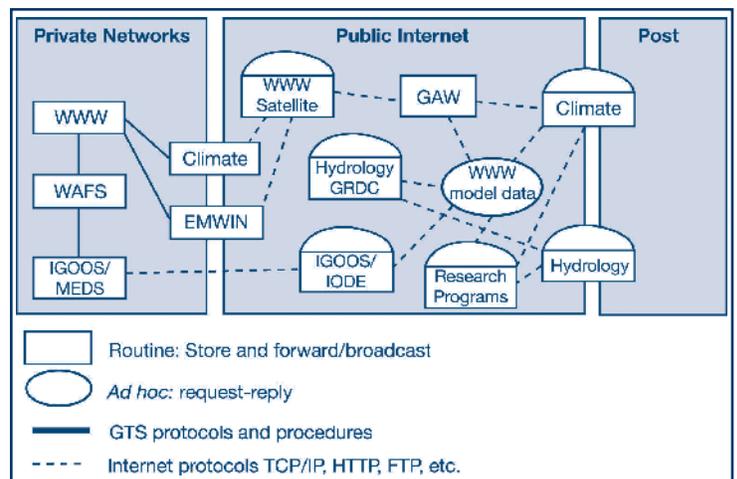
3.1 The Global Telecommunications System

For global communications, the Global Telecommunications System (GTS) is the operational network upon which the World Meteorological Organization (WMO) relies for the provision of real-time high-priority data (Figure III.4). It is a well tested system that has operated for decades according to well-defined procedures. However, it suffers from a number of inherent deficiencies that prevent it from meeting the diverse observational requirements of the IOOS, especially for the diversity and volume of data expected to be served as part of the coastal component.¹⁰ These deficiencies include the following:

- The GTS provides for only limited utilization of the Internet for operational store and forward applications;
- It provides only limited connectivity between applications developed to serve the needs of different users; and
- The GTS causes the integration of disparate data sets to be technically challenging. The lack of agreed standards hampers application of multidisciplinary (e.g. meteorological, hydrological and oceanographic) data.

The failure of GTS to support data telemetry requirements for the increasing diversity and volume of data being generated has given rise to a plethora of information systems that have been developed to meet the specific requirements of individual programs. The multiplicity of these disparate systems has resulted in incompatibilities, inefficiencies, duplication of effort and higher overall costs. Continuing to develop systems in this uncoordinated manner exacerbates these problems and further isolates activities from each other, making it more difficult to share data and information in a timely fashion.

Figure III.4. Current architecture of the GTS.



To address these limitations, the WMO is adopting a coordinated global infrastructure, the WMO Information System (WIS). It is envisioned that WIS will be used for collecting and sharing data and information for all WMO and related international programs. The WIS would provide a common roadmap to guide the orderly evolution of these systems into an integrated telemetry “system of systems” that efficiently meets all of the international environmental information requirements. Such an integrated approach stands to meet the requirements of: (1) routine collection and automated dissemination of observed data and products (the “push”); (2) timely delivery of data and products (appropriate to requirements); and (3) *ad hoc* requests for data and products (the “pull”).

With the rapid evolution of information systems technology, upgrades to existing infrastructure should utilize industry standards for protocols, hardware and software¹¹ to both reduce costs and allow exploitation of the ubiquitous Internet and web services. To be sustainable, expanded systems must be modular, scalable, and able to adjust to changing requirements and allow dissemination of products from diverse data sources. Just as is the case with IOOS, chief among the issues to be addressed with WIS is providing security for both the data and the network.

3.2 Sensor to Data Assembly Centers

Many IOOS sensors will best be served by radio frequency (RF) telemetry via satellite. Existing data telemetry infrastructure is reaching its capacity and is slated for expansion and upgrade. Currently, NOAA operates two types of environmental satellites, the Polar Operational Environmental Satellite (POES) and GOES (located over the equator). Both carry transponders to relay environmental data from sensor to data assembly centers.

¹⁰ Vision for the Future WMO Information System, 1 October 2002 <www.wmo.org>

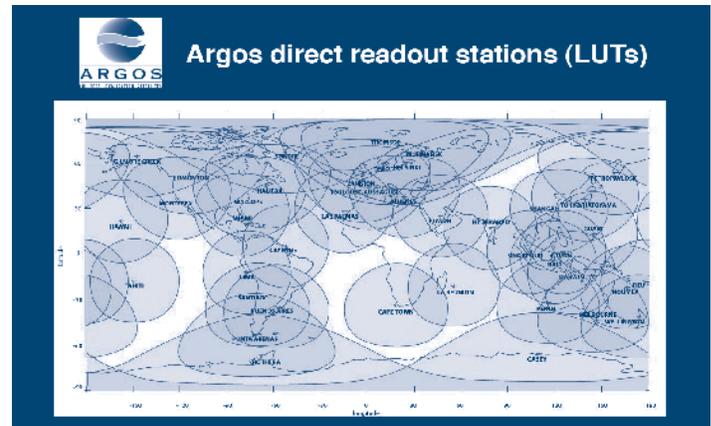
¹¹ E.J. Feinler, O.J. Jacobsen, M.K. Stahl, C.A. Ward, eds. *DDN Protocol Handbook*. DDN Network Information Center, SRI International, 1985.

The number of environmental data collection platforms serviced by POES in 2004 was about 12,000. This number is expected to grow to nearly 100,000 by 2020. Similarly, the number of data collection systems serviced by GOES in 2004 was about 40,000 and is expected to grow to nearly 160,000 by 2020.¹² In the coming years, NOAA will also operate the NPOESS series of satellites to replace the POES series. These will also carry transponders to provide data telemetry. The data telemetry capability of NPOESS will play a major role in IOOS.

A number of NASA satellites also provides the capability to access local data by direct downlink telemetry. NASA Direct Broadcast enables local use of Moderate Resolution Imaging Spectroradiometer (MODIS) SST and ocean color in particular.

The Argos Data Collection System (DCS) currently provides the data telemetry for POES. Data collection platforms throughout the world, both fixed and mobile, transmit signals containing environmental observation information that are received by POES satellite transponders when passing over these platforms (Figure III.5). The data received from the platforms for the entire orbit are stored onboard the satellite, then down-linked to NOAA's National Environmental, Satellite and Data Information Service (NESDIS) stations, which deliver the data to the NOAA Satellite Operations Facility. Data are then transmitted to Service Argos in Largo, Maryland. The current Argos system operates in receive-mode only. The GOES DCS is limited to geostationary coverage areas. The GOES DCS relays data from earth-based platforms within the GOES coverage area/footprint; i.e., GOES East (75° East) and GOES West (135° West). The transponder on the GOES satellite receives data from the platforms, then relays it to the Command and Data Acquisition (CDA) station at Wallops Island, Virginia. The GOES DCS includes an interrogation capability with the ability to relay commands from the Wallops CDA station to platforms. NPOESS development delays will mean that the first satellite will not launch until 2013. NPOESS will continue the DCS capabilities and present an opportunity to perform a technology refresh both on the space platform (receiver/transmitter and relay capability) and associated ground terminal users. At full operational capability, the NPOESS system will have two operational satellites populating two orbital planes. Once operational, NPOESS environmental data records should be available at the NOAA server within 28.3 minutes from observation, 95% of the time.

Figure III.5. ARGOS Direct Readout Stations (Local User Terminals [LUTs]).



With the launch of NPOESS, consideration can be given to substantially increase the capability of the DCS subsystem in several aspects: expanded frequency coverage (401–401.7 megahertz), larger message size (up to 25 megabytes) and data rates up to 32 kilobits per second. The means and methods by which the DCS subsystem is currently operated thus warrants revisiting. NOAA is currently evaluating other alternatives to Service Argos, including a number of commercial satellite service providers. The attendant choice will have a substantial impact on IOOS.

The most widely used satellite data relay system for scientific research remains Argos.³ However, communication is presently only one-way, at 400 baud, with practicable data rates of the order of 1 kilobyte per day. Transmissions in this mode are unacknowledged by the system and therefore have to incorporate redundancy if data transfer is to be assured. While not continuous, Argos is one of the few systems that offers true global coverage. Data collection platforms that utilize the Argos system for meteorological and oceanographic purposes include drifting buoys, ice buoys, moored buoys, sub-surface floats, ships, containers, balloons, Automatic Weather Stations (AWSs) and pelagic animals with tags.

¹² Relay of Environmental Data from NOAA Data Collection System Platforms (DCPs) to the Users, Request for Information (RFI) Sol. No. NESDIS-DCS-HLK, Jan 24, 2005.

A workshop of experts convened by Ocean.US and sponsored by Office of Naval Research (ONR)¹³ concluded that the Iridium Satellite System is the only provider of truly global, truly mobile satellite voice and data solutions with complete coverage of the Earth (including ocean, airways and Polar regions). It is a LEO satellite network that provides a two-way, near-real time data communications capability.¹⁴ There are four components to the network: (1) a constellation of 66 satellites and 13 spares; (2) three terrestrial gateways (or downlink sites); (3) a Satellite Network Operations Center (SNOC); and (4) Iridium Subscriber Units (ISU). Inter-satellite link, or ISL, is the network architecture employed by Iridium (versus bent-pipe employed by Globalstar and Orbcomm). A unique feature of the Iridium ISL capability is that the satellites can talk not only to ISU and gateways, but also to each other, forming a network aloft. Iridium ISL also allows ISUs to talk to each other without referencing to ground stations, thereby reducing signal latency that can adversely affect time-sensitive protocols such as the Transmission Control Protocol/Internet Protocol (TCP/IP).

Iridium provides enhanced system reliability and capacity and eliminates the need for multiple regional gateways, reducing associated costs and eliminating a potential regional “single point of failure.” In addition, ISL allows the capability of global coverage without signal latency in either voice or data mode. With 66 operational satellites and 13 spares orbiting in a constellation of six polar planes, each satellite is cross-linked to four other satellites: two satellites in the same orbital plane and two in an adjacent plane. The result is a greater data throughput capacity than Argos without the associated latency. With the Argos system, data is often stored on tape for later downlink with latency timeframes as previously addressed. Iridium covers areas not serviced by other commercial LEO satellites (Globalstar or Orbcomm) or geostationary (Inmarsat) systems. In addition, as Iridium satellites orbit at 780 km above earth, considerably less power is required to relay data as compared to the GEO Inmarsat system, positioned 33,600 km above the earth. For these reasons, Iridium appears to be the best commercial solution currently available to answer many of the needs of IOOS data telemetry.



4. Data Management and Communications Subsystem

A Data Management and Communications (DMAC) infrastructure that seamlessly joins together the components of IOOS partner organizations with relevant systems in disciplines outside of the marine environmental sciences is central to the success of IOOS. Part II of this plan recommends a process to develop the DMAC subsystem, identifies high priority near-term activities and presents timelines for their implementation. When implemented, this DMAC framework will support the identification of IOOS DMAC standards and protocols required to enable interoperability across the IOOS. This framework must be in place to support the expansion and improvement of IOOS over the timeframe FY 2008-12. Without this framework, present incompatibilities among existing observing systems arising from the lack of shared standards will be propagated into the future.

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 early tasks (FY 2006-07), described in Part II, are targeted to establish an initial minimally functioning DMAC interoperability framework of shared standards and protocols. They provide a foundation for the longer-term Phase 2 (FY 2008 and beyond) activities discussed in this section. A more detailed discussion of all activities can be found in the DMAC Plan.¹⁵

¹³ Technical Workshop on Applications of Iridium Telecommunications to Oceanographic and Polar Research, Univ. of Washington APL, 19-21 May 2004 <http://www.ocean.us/system/files/Iridium_TechWork_0.pdf>

¹⁴ Iridium was developed by Motorola® and is now owned and operated by Iridium Satellite LLC (ISLLC).

¹⁵ Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems <http://dmac.ocean.us/dacsc/imp_plan.jsp>



The DMAC Plan, endorsed by the DMAC Steering Team and participants in the 2004 and 2005 IOOS Implementation Conferences, calls for deployment of the full DMAC subsystem over a five-year period (FY 2007-11) once the foundation has been built during Phase 1. This time period has been adjusted to FY 08-12 to reflect the investments made to date. Activities during the initial five-year period include system planning, design, implementation, maintenance, refreshment and modernization. Activities during the subsequent five years (FY 2013-17) 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 *First IOOS Development Plan* to ensure that sufficient funds are available for DMAC implementation.

Following the approach taken in the DMAC Plan, priority activities for Phase 2 are organized into the following categories:

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

Table III.4 summarizes activities recommended by the DMAC Plan for the first five-year effort (updated here to begin in FY 2008), grouped into the above three categories. In addition, suggested priority levels are provided. Table III.5 presents a selected list of consensus recommendations for agency-specific DMAC tasks in FY 2007, resulting from the First and Second IOOS Implementation Conferences.^{7,16} Most of the recommendations listed in Table III.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 2008, guided by the suggested priority levels in Table III.4 for the design and demonstration category. Detailed descriptions of DMAC activities beyond FY 2008 can be found in the DMAC Plan.¹⁵ These activities represent new efforts above and beyond the existing relevant programs already funded by the federal agencies and Regional Associations (RAs). They involve specific DMAC services, hardware, software and infrastructure that will achieve the IOOS goals of data and metadata integration and interoperability between existing and future observing system components.

¹⁶ Proceedings of the First Integrated Ocean Observing System Implementation Conference. <http://www.ocean.us/documents/docs/Final_IOOSProceed_lowres.pdf>

Table III.4. Summary of prioritized DMAC activities recommended for implementation in FY 2008 as described in the DMAC Plan). Priorities (1 - highest, 3 - lower) are given within each major category (interoperability framework [IF], interoperability infrastructure [II], design and demonstration, [DD]). Multiple IOOS/DMAC functions with the same priority level must be developed in a balanced way. Some activities may be initiated in FY 2005-06, and most are multi-year.

Priority	DMAC Functions	Activities
1	Integrated Planning, Oversight, Coordination	- DMAC Steering Team, DMAC Expert Teams and Working groups, Community Engagement Caucuses
IF-1	Metadata & 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, Design and implement data location service
IF- 2	Data Archive & 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 - Deploy IOOS DMAC gateways to handle format conversions automatically - Develop metrics and implement performance monitoring - Implement middleware security - Provide guaranteed geo-temporally-referenced browser for all IOOS data - Aggregation of unstructured GIS 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	Systems 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	<i>Design and Demonstration Pilot Projects (see DMAC Plan)</i>
DD-2	Access/Infrastructure	
DD-2	Data Transport	
DD-2	Archive	
DD-2	Information Assurance	
DD-2	Innovative Architectures	

Ocean.US recommends that a target investment goal of at least ten percent of the resources currently applied to existing and planned observing systems be adopted by federal and RA programs for implementing and sustaining their IOOS DMAC components. 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 may vary significantly, 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.

Table III.5. Summary of ranked DMAC-related consensus recommendations and associated responsible agencies from the First and Second IOOS Implementation Conferences.^a

DMAC Implementation Plan Needs Area	Consensus Recommendations	Potential Affected Agencies
DMAC Standards Process	<ul style="list-style-type: none"> Fully implement DMAC Standards identification process (Expert Teams & Caucuses) as recommended by DMAC Steering Team and in DMAC Plan Continue IOOS systems engineering analysis to ensure interoperability among the federal backbone, Regional Associations, U.S. IEOS, GOOS, and GEOSS components Establish IOOS DMAC test-beds to assess standards 	<ul style="list-style-type: none"> All Agencies
Inventory of current programs	<ul style="list-style-type: none"> Inventory NOAA & EPA coastal & estuarine data sets, and by extension each IOOS core variable observing effort 	<ul style="list-style-type: none"> All Agencies
Data discovery	<ul style="list-style-type: none"> Assure agency data inventories are “registered” and accessible using IOOS DMAC metadata recommendations 	<ul style="list-style-type: none"> All Agencies
End-to-end integration	<ul style="list-style-type: none"> Enable stream gauge observations integration Enable wave observations integration Interconnect HF radar & fixed sensor wind & wave data 	<ul style="list-style-type: none"> USGS & NOAA USACE, NOAA & Navy NOAA, USCG & Navy
Metadata development	<ul style="list-style-type: none"> Develop Lagrangian metadata for AUVs Develop imagery metadata & characterization to enable fusion and assimilation Integrate species-level information (e.g., genetics, habitat, life history, etc.) 	<ul style="list-style-type: none"> NSF & Navy NASA, NOAA, USGS & Navy NSF, NOAA, & EPA
Semantic data model(s) development	<ul style="list-style-type: none"> Semantic data model to enable imagery fusion with models Fusion of spatial & tabular nutrient data fields 	<ul style="list-style-type: none"> NASA, NOAA, Navy & USGS EPA & NOAA
Data transport	<ul style="list-style-type: none"> Develop mechanisms for providing satellite data Interconnect HF radar & fixed sensor marine wind data 	<ul style="list-style-type: none"> NASA, NOAA & USGS USCG, NOAA, USACE & Navy
Data archival	<ul style="list-style-type: none"> Develop climatologies of oxygen, chlorophyll, nutrients and pCO₂ observational data 	<ul style="list-style-type: none"> EPA, NOAA & USACE
QA/QC	<ul style="list-style-type: none"> Enable integration of stream gauge data into national network across all observing elements 	<ul style="list-style-type: none"> 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.

5. Modeling and Analysis Subsystem

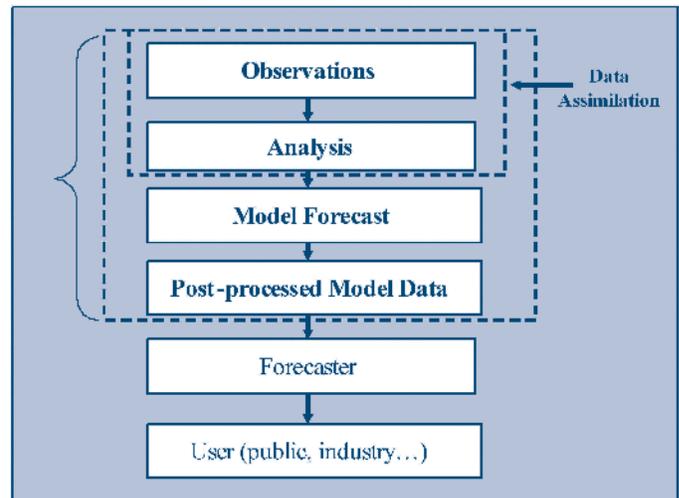
Fundamental to developing the IOOS subsystem for modeling and analysis is to promote existing modeling activities and supplement them as needed to address the seven IOOS societal goals. This section presents an implementation strategy for enabling the research needed to improve operational modeling capabilities in support of all seven societal goals of the IOOS.

5.1 Functions of the IOOS Modeling and Analysis Subsystem

Apart from serving quality controlled data, most IOOS applications (products and services) will be supported by models of various kinds, including numerical and empirical (statistical) models. Important functions of models are to produce more comprehensive (e.g., more accurate and complete space-time coverage, more variables estimated, and analyses and forecasts) estimates of the states of marine systems (than can be gained by observations alone) and associated errors (product uncertainty or confidence assessment products) and to guide the development of an optimal mix of *in situ* and remote measurements (e.g., Observing System Simulation Experiments) needed to quantify and improve predictive skill. For the purposes of the IOOS, “operational” models are tools for the provision of products or services that routinely enable informed and timely decisions.¹⁷ The operational readiness of models ranges from high for numerical weather prediction to low or nonexistent for ecosystem-based, adaptive management of water quality and living marine resources.

Environmental prediction systems for nowcasting and forecasting current and future states generally rely on historical statistics or data assimilation techniques (Figure III.6). Thus, coordinated development of the observing and modeling and analysis subsystems of the IOOS is critical for developing, testing and validating models (assessing the skill of model predictions) and for initializing and updating model runs for more accurate predictions, including comprehensive and integrated spatial representations of past (hindcasts), present (nowcasts or analyses) and future (forecasts) states of marine and estuarine systems.

Figure III.6. Environmental prediction systems link models to observations through data assimilation. See the Hybrid Coordinate Ocean Model (HYCOM) Consortium for Data Assimilative Modeling (http://hycom.rsmas.miami.edu/regional_sim.html).



Provision needs to be made for two general types of prediction systems:

- Strategic modeling (e.g., continually operating systems such as the Regional Ocean Forecast System of the National Centers for Environmental Prediction (NCEP)¹⁸ and the Navy Coastal Ocean Model (NCOM) of the Naval Oceanographic Office (NAVOCEANO¹⁹); and
- Tactical modeling (e.g., event-driven, rapidly deployable, limited-duration systems such as those used for search and rescue by USCG; for storm surge forecasts by NOAA [a collaboration between the Coastal Survey Development Laboratory and the Center for Operational Oceanographic Products and Services²⁰]; and for oil spill trajectory forecasts by the NOAA Office of Response and Restoration).

The latter often depends on the provision of routine data from strategic models. Ideally, tactical systems, with their smaller domains, are coupled to the strategic systems, with their larger domains. Such predictions serve many purposes, including the following:

- Facilitating maritime weather forecasting, ship routing, search and rescue; safe and efficient marine operations (Outer Continental Shelf oil and gas recovery, sand

¹⁷ To be operational, a model must meet the following criteria: (1) provides reliable predictions (hind-, now- or fore-cast) used by decision makers responsible for one or more of the seven societal goals; (2) provides such predictions in forms and at rates approved by the users (on a schedule or on demand); (3) model operations, including quality control, has a sponsor and is institutionalized; and (4) model performance (e.g., skill of model predictions) has been verified to meet standards agreed to by both operators and users. Although not an independent body strictly speaking, the Navy's Administrative Model Oversight Panel comes close to meeting these criteria.

¹⁸ <<http://polar.ncep.noaa.gov/cofs/>>

¹⁹ <http://www7320.nrlssc.navy.mil/global_ncom/>

²⁰ <<http://tidesandcurrents.noaa.gov/csdl.html>>

and gravel dredging, waste disposal, etc.); safe marine recreation (swimming, boating, fishing, etc.);

- Improving national defense by enabling operational safety and providing force multipliers over the opposition through improved environmental prediction;
- Managing and mitigating the effects of natural and human-induced hazards (e.g., coastal inundation caused by tropical storms and tsunamis; chemical and oil spills) on socio-economic systems, ecosystems and natural resources;
- Improving predictions of climate change on local to global scales;
- Assessing the condition and function of marine ecosystems (e.g., by conducting habitat assessments) and the living marine resources they support (e.g., by conducting stock assessments);
- Supporting ecosystem-based management of public health risks, water quality, natural habitats and natural resources; and
- Enabling advances in science and technology that increase our understanding of oceanic and coastal systems through detailed model-observation comparisons.

Regardless of whether models are used strategically or tactically, three phases of operational modeling must be considered: pre-prognosis, prognosis and post-prognosis. The first and last phases have the same elements for the dynamical and statistical approaches; the second phase has different elements for each approach.

- (1) Pre-Prognosis (numerical and empirical modeling) includes both quality control (e.g., ensuring compatibility between different observations of the same variable such as surface temperature from profiling floats, expendable bathythermograph (XBTs), moorings and space-based remote sensing) and translation of raw data into forms suitable for ingestion.
- (2a) Prognosis (numerical models only) includes estimates of uncertainty, data assimilation, optimal initialization of the numerical model and numerical predictions.
- (2b) Prognosis (empirical models only) includes an appropriate statistical scheme for predictions with estimates of uncertainty.
- (3) Post-prognosis (numerical and empirical modeling) consists of the generation and transmission of standard products from model output to users (often via GTS); short-term (circa 30 days) and long-term archival of subsets of model input and output data; quantitative assessments of the accuracy of predictions (hindcasts, nowcasts or forecasts) using performance metrics; and assessments that are used

to ensure that evolving user needs are satisfied.

5.2 Implementing the IOOS Modeling Initiative

Following the DMAC process, a Modeling and Analysis Steering Team (MAST) will be created as a technical body to provide scientifically sound advice for improving and developing operational modeling capabilities in support of IOOS goals. As described below, the MAST will engage existing Community Modeling Networks (CMNs) and create new ones as needed to improve and develop operational models as decision support tools for policy and decision makers responsible for one or more of the seven societal goals. This effort will build on and leverage existing modeling efforts. New CMNs will be phased in over time based on user needs and modeling capabilities.

As in the DMAC process, the MAST functions as an advisory body and an implementation oversight working group (MA-IOWG) will be needed to assess the skill of model predictions (validate performance) and to implement the federal contribution to the modeling and analysis IOOS subsystem. This committee will consist of representatives from federal agencies only, since its members will be involved in the planning and budget cycles of their respective agencies.

5.2.1 MAST Statement of Work

The MAST will work with Ocean.US to establish an action plan (timetables, milestones, budgets) for achieving the objectives given below. Ocean.US and the MAST will work with participating federal agencies to secure the required funding based on the availability of resources.

With due consideration for the seven IOOS societal goals, current modeling activities relevant to achieving these goals (both nationally and internationally), and the work of the DMAC Modeling Caucus, the objectives of MAST are as follows:

- (1) Periodically review and update modeling sections of the IOOS development plan; conduct periodic assessments of how implementation is proceeding; and use the assessments to remedy problems.
- (2) Identify existing modeling groups relevant to IOOS model development,²¹ identify points of contact, and establish working relationships with them to coordinate activities, achieve common goals, and leverage funding.
- (3) Characterize existing operational¹⁷ modeling requirements²² and promote activities to improve the

²¹ Existing CMNs, groups within federal agencies, within RAs, international groups, programs such as The Global Atmospheric Research Program (THORPEX); the Earth System Modeling Framework (ESMF); and the PARTnership for Advancing Interdisciplinary Global Modeling (PARADIGM).

²² "Modeling requirements" apply to individual models as well as to systems of linked or coupled models as appropriate to the task.

skill of their predictions as needed to address the societal goals;

- (4) Envision future operational modeling capabilities (broken down by time horizon and by national and regional scales) and promote the expansion of operational modeling capabilities to address them, especially for the goals of public health, ecosystem health and living marine resources.
- (5) With due consideration of the IOOS societal goals and existing modeling activities that are relevant to the development of operational modeling capabilities for the IOOS:
 - Determine the scope of each CMN needed to address model development for all of the seven societal goals and oversee their activities;
 - Prepare Terms of Reference for each CMN;
 - Through a phased, stepwise process, establish CMNs and associated CMN Coordinating Committees (CCCs) as described below;
 - Finalize Terms of Reference for CCCs using recommendations from a Task Team as a starting point for discussion; and
 - Work with CCCs to develop and update inventories of operational modeling capabilities and activities that satisfy their data and information needs.
- (6) Recommend to Ocean.US and the federal agencies it represents procedures (including assessing the skill of model predictions and funding mechanisms) for transitioning existing modeling capabilities from research to an operational mode based on user requirements for products and services.
- (7) For those areas for which operational modeling capabilities are weak or non-existent, recommend priorities for research and development to fill these gaps.
- (8) Initiate activities including implementation of large observational-numerical modeling experiments such as GODAE that will promote close linkage between modeling and observations, and, in this context, between research and operational communities.
- (9) Coordinate with the DMAC Modeling Caucus to clarify roles, minimize duplication of efforts, and collaborate to make the most effective use of time and resources.
- (10) Complete a three-year, prioritized action plan and budget for MAST.
- (11) Work with Ocean.US to establish a Modeling and Analysis Interagency Oversight Working Group

(MA-IOWG).

The MAST will have 10-15 members nominated by the Task Team with advice from the EXCOM/IWGOO and (in collaboration with RAs). Appointments to the MAST will be made by the Director of Ocean.US following the approval of the EXCOM/IWGOO. Members of the MAST will represent both research and operational areas with expertise in data assimilation, modeling and observations for one or more of the following disciplines: marine meteorology, physical oceanography, waterborne pathogens, marine ecology and fisheries. The Chair of the MAST will be appointed by the Director of Ocean.US.

5.2.2 Community Modeling Networks

Historically, model development has occurred through the research of individual, entrepreneurial investigators and small teams within an institution. Such modeling efforts have led to significant advances in numerical modeling techniques. However, model evolution tends to occur slowly under these conditions and the exchange of capabilities and comparative analysis are limited. In addition, no single model can satisfy all of the data and information requirements for the diversity of IOOS applications. The range of applications and diversity of regimes are simply too great, especially in coastal marine and estuarine environments where ensemble modeling will be particularly important.²³

The establishment of Community Modeling Networks (CMNs) will enable efficient improvements in and expansion of operational modeling capabilities to address IOOS societal goals as follows:²⁴

- Engage user groups to define data and information needs (products and services);
- Develop and update inventories of modeling capabilities and activities that satisfy these data and information needs;
- Agree on requirements for boundary conditions and forcings;
- Define standard measures of model performance and user satisfaction;
- Establish test beds for validating performance and assessing the skill of model predictions;
- Share modeling expertise and software (models, data assimilation techniques, visualization and coupling code);
- Share computer resources; and
- Enable the development of non-proprietary, robust community software that is readily available via the World Wide Web (including the identification of server or client-server systems), documented with version control and quality assurance, and maintained and upgraded by

²³ Hallberg, R., Bleck, R., Chassignet, E., de Szoeke, R., Griffies, S., Schopf, P., Springer, S. and Wallcraft, A., 2004. A Vision For Ocean Circulation Models: Generalized Vertical Coordinates.

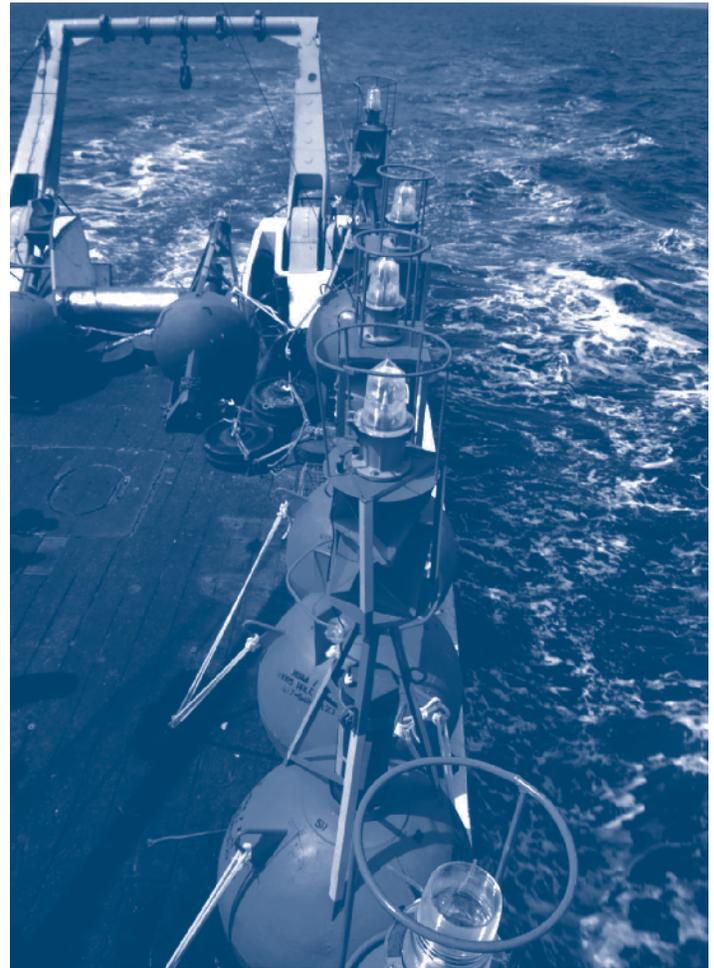
²⁴ <<http://www.ioos.org/documents/reports/GOOS-148-COOP-highres.pdf>>

permanent teams of professional software developers.

The MAST is charged with fostering development of a logical and efficient set of CMNs to address the seven societal goals of the IOOS. Each CMN will address a subset of these goals as specified by the MAST. CMNs will be comprised of the full spectrum of interested parties ranging from end users and operational forecasters to technical experts (from both research and operational groups with expertise in modeling and observations) and basic researchers.

To coordinate and facilitate this process, procedures and mechanisms are needed to engage existing CMNs and to promote the formation of new CMNs. Such procedures and mechanisms should involve CMNs and Regional Associations (and the user groups they represent) in the formulation of guidelines for developing operational modeling capabilities, promoting the establishment of common standards, defining performance metrics, and encouraging research and pilot projects for model development. To these ends, each CMN will have a coordinating committee (CCC, an executive committee which is a subset of the CMN) responsible for effective management of CMNs and efficient interaction with the MAST and other entities (e.g., RAs and the National Federation of Regional Associations [NFRA]). Members of CCCs will be drawn from their respective CMNs. Initially, members will be selected by the MAST in consultation with Ocean.US and Regional Associations. Once CCCs are established, membership will be renewed periodically by consensus of their respective CMNs. Below, we recommend generic terms of reference for a CCC which will be reviewed, tailored to CCCs for each CMN, and periodically updated by the MAST:

- (1) Using the *First IOOS Development Plan* and its updates for guidance, develop a detailed “spin-up” roadmap for identifying and documenting users and requirements and for advancing existing modeling capability into an initial operational system that meets these needs (e.g., validation/verification and operational demonstration benchmarks and plans for delivery of products).
- (2) Ensure that RAs are engaged in the formulation of the roadmap, and submit the roadmap to the MAST for approval and to promote coordination among CMNs).
- (3) In consultation with the MAST, create resource development and management plans sufficient to implement the initial operational system. Execute resource development plans.
- (4) Execute the roadmap and stand up the initial operational system.
- (5) Perform continued assessment of requirements for system improvements and sustainability including, but



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not limited to:

- Development of new models to meet societal goals for which no models existed initially;
 - Changes to initial models and products based on user feedback;
 - Need for new/better observations and/or models;
 - Computing power;
 - Manpower;
 - Funding stability; and
 - Barriers to the usability of the model results.
- (6) In view of these ongoing assessments, periodically modify the roadmap to reflect needed modifications on a schedule to be determined by the CMN (e.g., semi-annually).
 - (7) Execute the updated roadmap.

Achieving the objectives of CMNs will require funding, training and workshops that involve modelers, users and data providers. Ocean.US will work with the MAST and CMNs to provide the necessary support for training and workshops and to identify funding sources needed to

implement CMNs and sustain their activities.

5.2.3 Developing Operational Coastal System Modeling Capabilities

The typical time for research models to reach operational status is on the order of ten years, and the required resources are usually beyond those of any one organization. Similarly, the development of robust code to assimilate some of the new data streams (e.g., HF radar measurements of surface currents, ocean color from satellite-based remote sensing, and *in situ* measurements from AUVs) is challenging and will require the efforts of many experts from both public and private sectors.

The Earth System Modeling Framework (ESMF) Project (Part II, section 4.2) and NOAA's operational climate and weather forecasting capabilities provide a foundation for developing prediction systems capable of meeting national needs in coastal marine and estuarine systems. To this end, a nationally organized effort led by Ocean.US is needed to establish CMNs that will develop families of operational models for each of the seven IOOS societal goals (section 5.2.2). Such an effort should begin with the establishment of a national framework for an integrated approach to modeling Earth systems. Given the large number of community models for the physical state of the ocean (Table II.11) and the cross-cutting importance of meteorology, hydrology, and physical oceanography to addressing the seven IOOS societal goals²⁵, the national framework should be based on an integrated approach to operational weather, climate, hydrodynamic and hydrological predictions as follows:

- Improve the skill of modular ocean-climate models for climate forecasting;
- Continue ongoing operational use, validation and improvement of hydrodynamic, wave and coastal inundation models;
- Develop dynamically coupled basin scale-coastal ocean-estuarine models for operational use; and
- Develop dynamically coupled hydrodynamic, wave, coastal inundation, watershed hydraulic, nutrient-sediment transport, and water quality models for operational use.

The HAZards U.S. Multi-Hazard family of models adopted by the Federal Emergency Management Agency is an example of this approach (Box III.4).

Box III.4. Assessing Coastal Inundation Risks

As the population density along U.S. coastlines increases, the risks of coastal inundation to human life and property have increased accordingly.

Thus, the HAZards U.S. Multi-Hazard (HAZUS-MH) model of the Federal Emergency Management Agency (FEMA)^a was created to inform decision makers of the likely scope of damage caused by earthquakes,^b floods^c and hurricane winds.^d HAZUS-MH is a GIS-based, multi-hazard risk assessment and loss estimation model that draws upon multiple national databases, national standardized loss estimates and risk assessment methodologies. The model is used to aid decision makers in anticipating the scope of hurricane and flood-induced damage, identifying vulnerable areas, assessing the vulnerability of infrastructure, estimating potential losses, and developing state and local risk assessments to inform mitigation efforts.

NASA and NOAA are working to enhance the hurricane portion of HAZUS-MH for predicting the combined effects of high winds, storm surge, astronomical tides, and waves. These enhancements will give “responders” (from real-time responders such as FEMA to longer term planners such as flood plain managers) powerful tools for predicting, managing and mitigating the effects of coastal inundation on real-time to decadal time scales.

^a <http://www.fema.gov/plan/prevent/hazus/hz_overview.shtml>

^b <http://www.fema.gov/plan/prevent/hazus/hz_eq.shtml>

^c <http://www.fema.gov/plan/prevent/hazus/hz_flood.shtml>

^d <http://www.fema.gov/plan/prevent/hazus/hz_wind.shtml>

²⁵ Improved forecasting capabilities for currents, waves, water levels, storm surges and sediment transport are important for addressing user needs related to mitigating the impacts of coastal inundation, erosion control, environmental protection and managing the harvest of living marine resources for sustainability.

6. Education and Public Awareness

The education and public awareness efforts allied with IOOS are described in the *First U.S. IOOS Development Plan*.⁸ A stepwise approach to achieve IOOS education goals is described in that plan and elaborated in the following sections for the years beyond those in Part II of this *IOOS Development Plan Addendum*:

- (1) Develop and sustain a community of educators across a broad education spectrum that uses IOOS information (e.g., data, careers, societal uses) to achieve its education objectives; and
- (2) Create the workforce needed to develop and sustain the IOOS and to produce allied information products, services and tools.

Consistent with IOOS design principles, education efforts recommended for this period will focus on Phase I items (*First IOOS Development Plan*, Part III, Figure 4) not addressed in Part II, recommendations from the planning efforts in Part II of this plan, and the recommendations in Phase II and III (*First IOOS Development Plan*, Part III, Figure 4). Collectively these items continue to build on and reinforce the infrastructure for education initiated in Part II and strive to sustain and expand the education and public awareness network-of-networks and expand the efforts of that network-of-networks in the workforce area.

6.1 Expanding and Sustaining the Impact of the Initial IOOS Education and Public Awareness Network-of-Networks

It is recommended that an IOOS national education network coordinating office be created using the plan created for its formation in Part II, section 6.3. The Education Network Coordinating Office will enable community-building activities that sustain, extend and mature a successful national IOOS education network-of-networks as articulated in the education strategy.²⁶ The education and public awareness network-of-networks will be expanded through the inclusion of local education-leader networks that use IOOS information assets. The highest priority networks for inclusion are the Global Learning and Observations to Benefit the Environment (GLOBE) Program, the American Meteorological Society (AMS), and the EPA-National Estuary Program (NEP) educator networks. Inclusion of these networks of educators will extend the reach of the network-of-networks because regional and state-based classroom and informal educators will then be members of the network.



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Learning materials will be created that target the gaps identified in Part II in the public's knowledge of the ocean's role in their lives and the education pipeline that supplies the science, technology and operational expertise required for the workforce allied with ocean observing systems. These learning materials will utilize IOOS information and data, key education messages and themes, the coordinated approach to the design, development and deployment of learning materials; and the best practices for learning materials that contain data developed in Part II sections 6.3 and 6.4. Outcomes of pilot projects in Part II, section 6.3 that target development of education assessment strategies will be used to establish and implement an assessment plan for IOOS education. The assessment plan will assess effectiveness of individual education projects and programs and the long-term effectiveness of the IOOS education program as measured by progress towards IOOS education goals.

6.2 Deepen the Workforce Reach of the Network-of-Networks

Those activities outlined as Phase III activities in the *First U.S. IOOS Development Plan*⁸ (Part II, Figure 5) will be addressed. Several areas are addressed with an emphasis on expanding career awareness, workforce and postsecondary activities. Recommended efforts include engagement of professional societies and others to sponsor and develop professional certification and continuing education programs, foster development of a community of practice for both ocean observing educators and practitioners, and address incentive systems for participation in education and public awareness.²⁷

²⁶ An *education network* is any organized collection of educators whose members are active in formal, informal or non-formal education. These members engage in a wide range of activities and possess many different titles, e.g., teacher, faculty members, youth leader, extension agent, interpreter, community liaison, instructor, continuing education specialist, media specialist, science writer, exhibit designer, etc.

²⁷ Promoting Lifelong Ocean Education: Using the IOOS to Shape Tomorrow's Earth Stewards and the Science and Technology Workforce (2004). Ocean.US Report No. 4. <<http://www.ocean.us/documents/workshop.jsp>>



APPENDICES

Appendix A: Federal Response to the Second Annual Integrated Ocean Observing System (IOOS) Implementation Workshop (3-4 May 2005)

Representatives of federal agencies that are signatories to the Memorandum of Agreement (MOA) creating the Ocean.US Office (NOAA, Navy, NASA, NSF, EPA, USACE, USGS, MMS, and USCG) considered recommendations for implementing a multi-hazard forecasting system for improved mitigation of the impacts of tropical storms, tsunamis and extra-tropical storms in general and for IOOS Data Management and Communications (DMAC) and Education in particular. As a body, the following declaration was agreed to:

We appreciate the work of the participants in the Second Annual IOOS Implementation Conference to formulate a clear set of consensus priorities for FY 05-08 IOOS implementation. We view the priorities in the context of both maintaining current IOOS activities (including observing systems, data systems, and product generating-delivery systems) and improving IOOS capabilities consistent with the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan*, the *Strategic Action Plan for the U.S. Integrated Earth Observation System (IEOS)*, and the *U.S. Ocean Action Plan*.

- (1) We acknowledge the U.S. IOOS as the ocean and coasts contribution to the Global Ocean Observing System (GOOS), the U.S. IEOS and the Global Earth Observation System of Systems (GEOSS).
- (2) To facilitate implementation of the priorities given below, we recommend that agencies initiate discussions to establish an IOOS interagency programming mechanism as an important step toward facilitating implementation of the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan*.

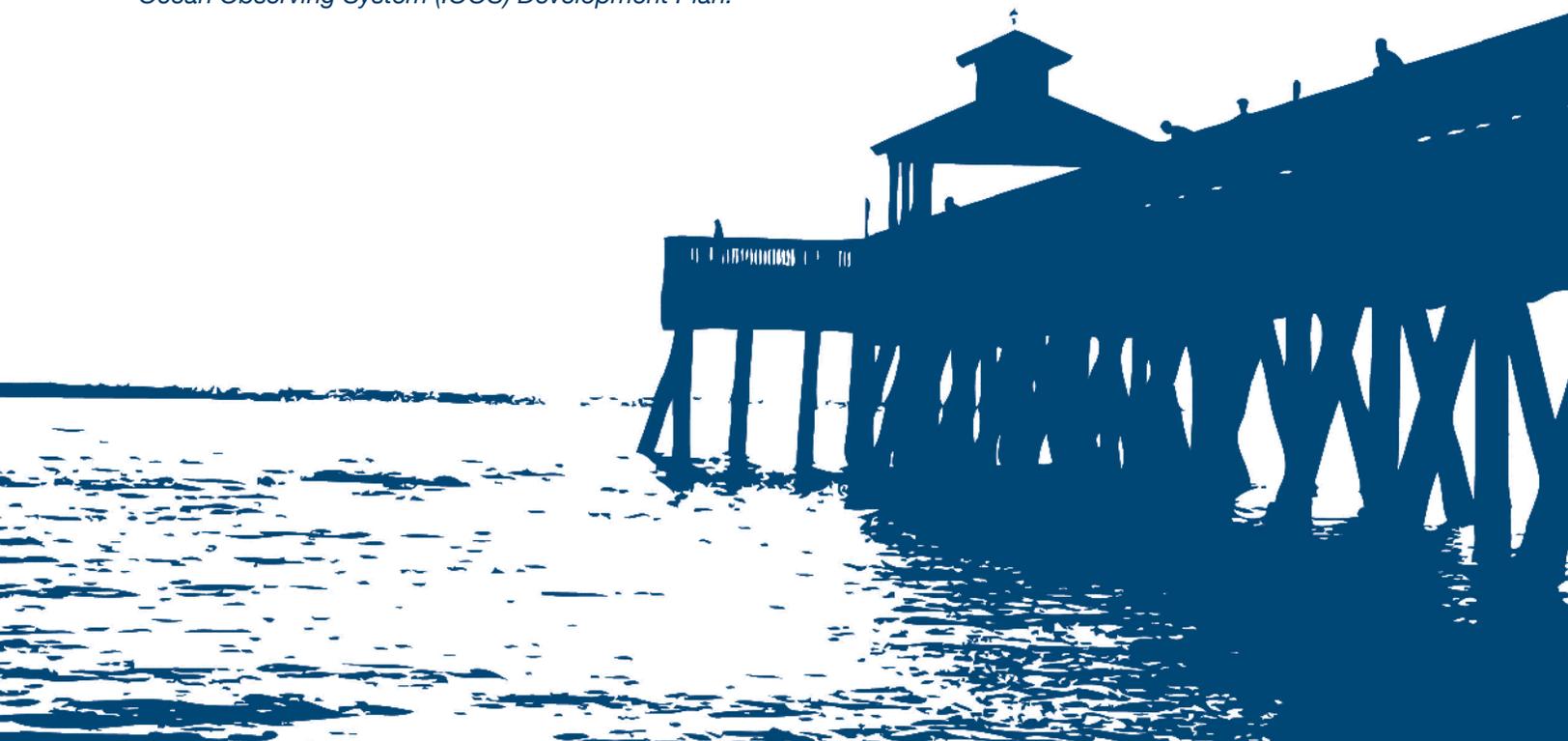
- (3) We reaffirm our 2004 support for the following priorities articulated in the *First U.S. Integrated Ocean Observing System (IOOS) Development Plan*:

- Develop Regional Associations (RAs) and the National Federation of Regional Federations;
- Implement the DMAC plan nationally and regionally; and
- Implement regional pilot projects.

- (4) We are committed to using the following consensus recommendations from the Second Annual IOOS Implementation Conference to guide the FY05 - FY08, Federal contribution (in terms of both supporting and operating) to IOOS development, especially as related to coastal inundation resulting from storms, and tsunamis:

- Implement the DMAC standards process as the first step toward facilitating data exchange and access within and among RAs and participating Federal Agencies;
- Support the completion of the ongoing Systems Engineering analysis as critical for the successful implementation of the IOOS;
- Implement the recommendations for establishing an IOOS Education Network as prioritized by conferees at the Second Annual IOOS Implementation Conference through close coordination with the Joint JSOST-SIMOR Education Task Force, once it is established.

Although participating Federal Agencies may focus on selected priorities and actions given above, the interagency consensus is to accept the priorities as a whole.



Appendix B: IOOS Successes



1. Improving Safety and Efficiency for Seafarers in the Gulf of Maine



2. NOAA Integration of Non-Federal Real Time Marine Weather Observations



3. Emergency Responders Use Measurements of Surface Currents to Mitigate Oil Spills



4. PORTS® Observing System Saves Shipping Industry Thousands



5. Future Expansion of IOOS Observations to Monitor the Nation's Coastal Currents



6. Tracking Pollutants and Monitoring Coastal Water Quality Near San Diego

Improving Safety and Efficiency for Seafarers in the Gulf of Maine

“Red sky at morning, sailors take warning doesn’t cut it anymore. We need quality, timely data to ensure the safety of our operations.”

— Jeff Cockburn, Penobscot Bay
River Pilots Association

“GoMOOS provides comprehensive, up-to-the-hour information on sea and weather conditions. I check the web site every morning.”

— Maine Lobsterman

Real-time data for real people

One product of the developing Gulf of Maine Ocean Observing System (GoMOOS) is a web site to provide seafarers real-time data they want for real-time uses. Daily users include fishermen, marine pilots, the Coast Guard, and recreational boaters.

Features of the web site

- Easy to use—designed by mariners to get them the latest conditions at sea
- Includes comparisons of conditions at different measuring locations
- Includes ability to view recent history of conditions
- Dial-A-Buoy telephone service provides access to hourly conditions when at sea

GoMOOS was designed to be part of the Integrated Ocean Observing System.

For more information

Contact Charles Spies, Chief Operating Officer, Gulf of Maine Ocean Observing System, (207) 228-1668 Charlie@gomoos.org. Visit www.gomoos.org



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NOAA Integration of Non-Federal Real Time Marine Weather Observations

A partnership between the National Data Buoy Center and operators of non-federal weather stations is providing “one-stop shopping” for forecasters and the maritime public.

Previously, weather forecasters and the maritime public had to visit dozens of different web sites to see data gathered by stations supported at marine and coastal weather stations maintained to support the needs of state agencies, oceanographic researchers and industry. But before 2002, their measurements did not appear on well-known web sites, such as that of the National Data Buoy Center, a part of the National Oceanic and Atmospheric Administration (NOAA).

In 2002, the Buoy Center began working with these non-federal entities to integrate their marine observations with those made from federally-supported sites. The Buoy Center receives the observations, checks them for quality, distributes them in near real time into the Weather Service communications stream and onto NOAA web sites and archives them.

National Weather Service forecasters like this partnership because additional marine observations appear directly on their computer weather maps. The Weather Channel and local TV meteorologists like it because it provides additional data to



Stations in the Gulf of Mexico providing data to the National Data Buoy Center. Stations operated by the Buoy Center are shown in blue or red; partner stations are shown in other colors.

produce on-air graphics. The boating public benefits because they can easily find all the observations. Mariners who are away from the web can get the observations via telephone by calling the Dial-A-Buoy system. The non-federal data providers benefit because their observations are quality controlled by the Buoy Center. They also gain greater visibility because of wider distribution of their observations.

Information from non-federal stations now makes up more than 13 percent of all observations distributed by the Buoy Center. It operates approximately 150 stations in U.S.

waters and some 50 additional non-federal, partner stations provide data from moored buoys, beaches, piers and lighthouses and drifting surface buoys. Most stations measure winds, air and water temperature; some also measure tides, waves, salinity and currents. There are many more stations that can and will be integrated as part of the U.S. Integrated Ocean Observing System.

For more information

Contact Dave Gilhousen, National Data Buoy Center (228) 688-2840, Dial-A-Buoy (228) 688-1948. Visit <http://www.ndbc.noaa.gov>.



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Emergency Responders Use Measurements of Surface Currents to Mitigate Oil Spills

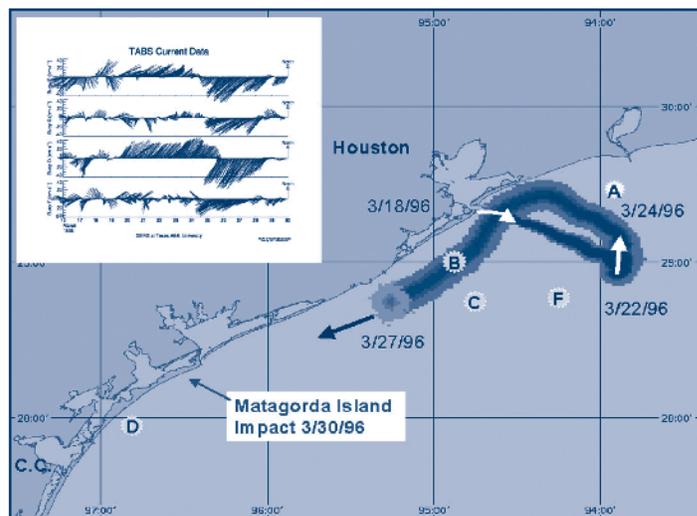
Emergency responders can deal with dangerous oil spills more effectively and at lower cost if they have information about surface currents at a spill area in real time. Their forecasts of oil trajectories can be even more accurate if predictions of surface currents are available.

To that end, the Texas General Land Office (TGLO) funds a network of surface current-measuring buoys known as the Texas Automated Buoy System (TABS). Since 1994 the network has reported the buoys' observations offshore Texas and Louisiana in the Gulf of Mexico in real time to validate a computer model that estimates and forecasts surface currents over the Louisiana-Texas shelf.

The importance of real time current data in spill response was demonstrated in March of 1996 when a barge spilled 5,000 barrels of fuel oil at the entrance of Galveston Bay. Working together, the National Oceanic and Atmospheric Administration (NOAA) HAZMAT modeling team and the TGLO's trajectory modeling team used TABS data and computer simulations to forecast the oil's movement to an unprecedented level of accuracy. The modelers knew the current's direction within minutes of the spill and it was continuously tracked for the next 24 days.

During the first half of the spill, currents were to the northeast, indicating a strong threat to Sabine Pass on the Texas-Louisiana border. Based on TABS data, the trajectory modelers predicted a switch in direction toward the southwest. A few hours later, they saw their prediction become reality, recorded in real time by a TABS buoy.

Managers discontinued the alert to the Sabine Pass area and refocused efforts on the area down the coast projected for impact. They were able to make this decision a full day earlier than would have been possible before the TABS network existed.



Path of oil from spill off Galveston on 3/18/96 to southwestern flow on 3/27/96. Locations of TABS buoys A, B, C, D, and F are shown as are surface currents measured at buoys B, C, D, and F.

Without the TABS data, preparations for protection of Sabine Pass would have continued, resulting in wasted time, effort and resources (\$225,000) in an area that was no longer threatened.

Since then, TABS has been called on to provide information for command decisions in more than two dozen spills along the Texas coast.

The data from the TGLO-funded system are integrated into the Integrated Ocean Observing System by the National Data Buoy Center of the National Oceanic and Atmospheric Administration.

For more information

Contact Dr. Robert (Buzz) Martin, Director of Scientific Support, Oil Spill Prevention & Response, Texas General Land Office, (512) 475-4611, buzz.martin@glo.state.tx.us. Visit tabs.gerg.tamu.edu/tglo.



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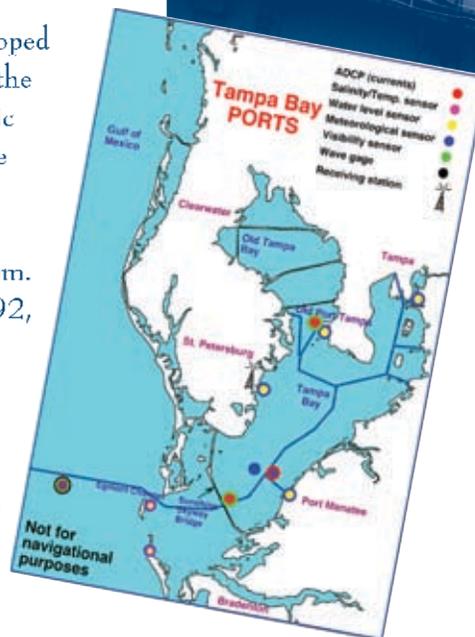
New Observing System Saves Shipping Industry Thousands

A technology that gathers and disseminates information about the marine environment is helping improve safety in the massive shipping industry.

In the five years after the Physical Oceanographic Real-Time System (PORTS) was installed in Tampa Bay, Florida the number of ship groundings dropped 60 percent. A single grounding can cost shipping operators hundreds of thousands of dollars in lost revenue, ship operation costs, tug boat fees, hull damage and environmental damage – even more if the hull is breached and hazardous cargo is spilled.

Tampa Bay PORTS was developed by the National Ocean Service of the National Oceanic and Atmospheric Administration, the local maritime community and the University of South Florida. It is part of the Integrated Ocean Observing System. In continuous operation since 1992, TB-PORTS integrates real-time current, water level, temperature, wave, visibility and wind measurements collected every six minutes at multiple location in Tampa Bay.

Because the bay's currents are influenced strongly by forces such as winds and river flow in addition to tides, the information provided by the system is important to recreational boaters, commercial



fishermen and professional pilots navigating its waters. Agencies responsible for search and rescue operations and for responding to hazardous spills also benefit from the accurate predictions generated by TB-PORTS. Even law enforcement officials have called on the system to determine the point of origin of bodies found in the water.

For More Information Contact Mark Luther,
University of South Florida
College of Marine Science, (727) 553-1528,
luther@marine.usf.edu.

Visit www.marine.usf.edu/PORTS
<<http://www.marine.usf.edu/PORTS>> .



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Future Expansion of IOOS Observations to Monitor the Nation's Coastal Currents

Search and rescue responders, fishermen, boaters, pollution managers and others can find information about the coastal ocean off New Jersey with the click of a mouse. Maps showing coastal currents at the ocean's surface are updated hourly from measurements made at high-frequency radar units along the coast and posted on a web site maintained by the Coastal Ocean Observations Laboratory at Rutgers University.

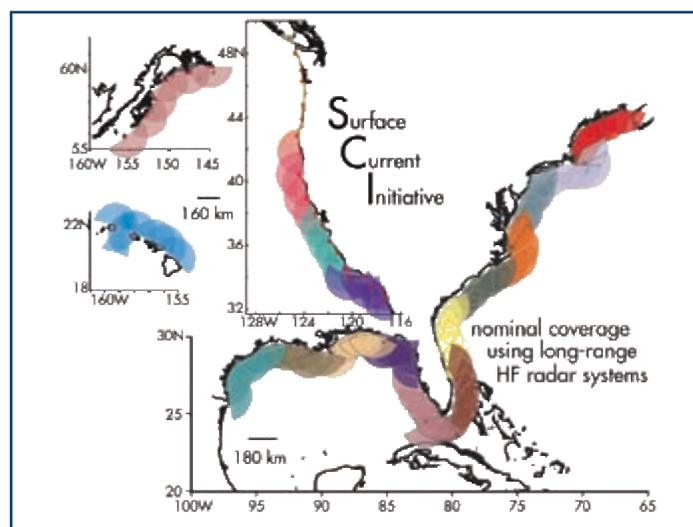
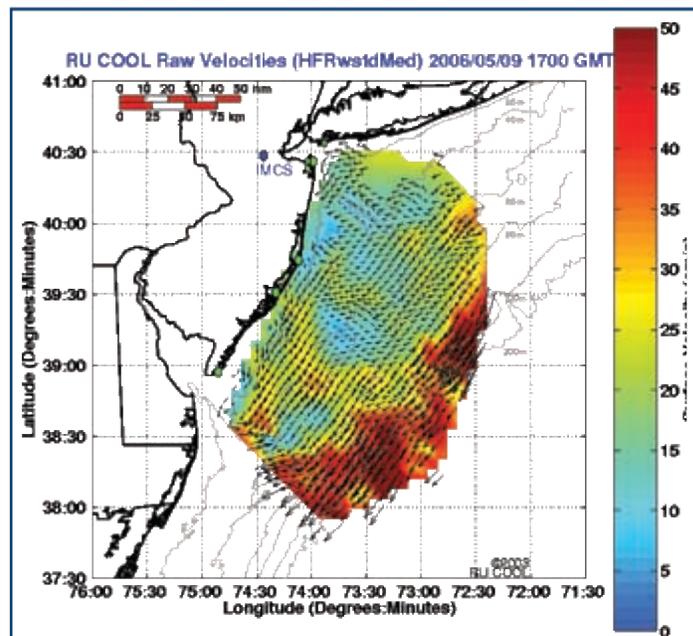
The New Jersey coastal radar is only one of some 20 now being operated in the coastal waters of the United States for research or operational purposes.

European researchers have used high-frequency radar to measure surface currents for more than a decade, but U.S. scientists began to use the World War II-era technology for that purpose only in the past five years. While the conventional method of measuring surface currents (moorings with current meters attached) is highly accurate, the meter measures the current only at the exact spot it is located. Radar, on the other hand, can take measurements across a large area and some 75 to 125 miles out to sea from the coast.

Planning is underway for a nation-wide network of radars at 100 to 200 locations monitoring all the nation's coasts, including the Great Lakes, Alaska and Hawaii. The design of the Integrated Ocean Observing System Surface Current Mapping Initiative began September 2003 directed by the Ocean.US Office. The system, if funded, would cost an estimated \$15 to \$44 million and operating costs would be \$5.3 to \$13.5 million annually.

For more information

Contact Larry Atkinson, NSF Liaison,
(757) 683-4926, LAtkinso@odu.edu
Visit www.marine.Rutgers.edu/mrs.



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Tracking Pollutants and Monitoring Coastal Water Quality Near San Diego

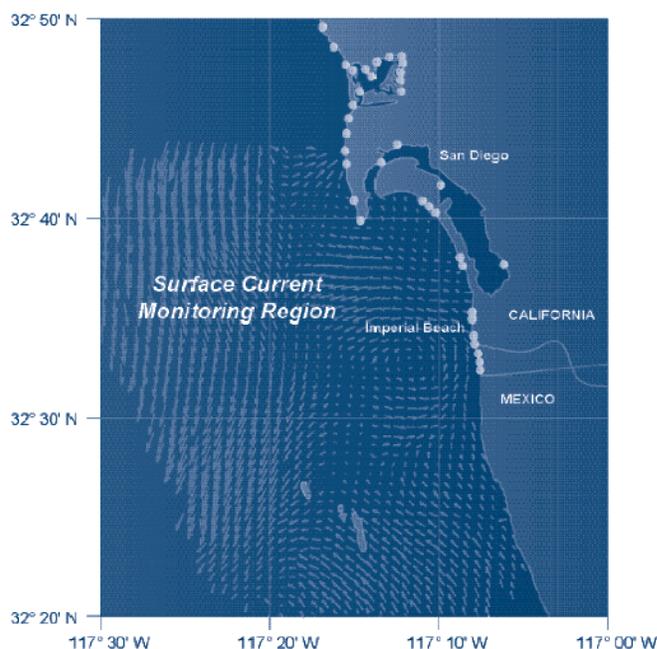
Public health officials routinely use the San Diego Coastal Ocean Observing System (SDCOOS) to help make timely decisions about local water quality. SDCOOS provides a single point of entry to find and archive agency-sponsored water quality data together with other observing system products, including surface currents, satellite images, bathymetry, weather information, and archived data. It also serves as a regional test bed for developing observing system products directed toward coastal water quality issues.

In response to numerous beach closures attributed to high levels of bacteria, the City of Imperial Beach, Scripps Institution of Oceanography, the San Diego County Department of Environmental Health, the State Water Resources Control Board, and the California Regional Water Quality Control Board—Region 9 San Diego teamed to monitor currents and the flow of pollution in the waters off the coast of southern California on a 24-hour basis. This project began in late 2001 with support from the State of California and the City of Imperial Beach. The initial focus of the system was to identify the sources of pollution and track its movement.

Since its inception, SDCOOS has responded to numerous water quality events in the region. It provides a direct link between the information generated by this observing system and a wide variety of end-users including local and regional agencies, policy makers, researchers, and the public at large.

SDCOOS Users Are Enthusiastic

"SDCOOS allows us to make more accurate and timely notifications to protect public health, as well as reduce unnecessary economic hardship on local communities."—County of San Diego Department of Environmental Health



Region of SDCOOS operations. The dots indicate water quality monitoring sites.

"With SDCOOS, Wildcoast has a scientific tool to help improve ocean water quality along the U.S.-Mexico border. Access to SDCOOS also allows us to provide real time water quality information to hundreds of our members on an almost daily basis through our Wildcoast Ocean Report email service."—Serge Dedina, Executive Director, Wildcoast

"SDCOOS is a great resource for lifeguards by providing real-time information not only for water quality issues, but also on daily weather and ocean conditions."—Robert Stabenow, Lifeguard Captain, City of Imperial Beach

For more information, contact Eric Terrill, Southern California Coastal Ocean Observing System: eterrill@ucsd.edu; (858) 822-3101. <http://sdcoos.ucsd.edu>



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Appendix C: Regional Contributions to IOOS

AOOS - Alaska Ocean Observing System (www.aoos.org)

- **Global Ocean Ecosystem Dynamics Monitoring Program** – <http://www.ims.uaf.edu/GLOBEC/> - US Global Research Program; NSF
- **Gulf of Alaska Ecosystem Monitoring and Research Program** – <http://www.evostc.state.ak.us/Monitoring/index.htm#> - Exxon Valdez Oil Spill Trustee Council; State of Alaska
- **Prince William Sound Nowcast-Forecast System** - http://pws-nfs-osri.rsmas.miami.edu/toc_cs.html - Oil Spill Recovery Institute
- **Prince William Sound Observing System** - http://ak.aoos.org/pws/observing_system_components.html - Oil Spill Recovery Institute
- **Sea-Air-Land Modeling and Observing Network (SALMON)** - <http://www.ims.uaf.edu/salmon/CODAR/CODAR.html> - University of Alaska Fairbanks

CarloOS – Caribbean Integrated Ocean Observing System (<http://cara.uprm.edu/>)

- **Coral Reef Early Warning System** – <http://www.coral.noaa.gov/crews/> - NOAA
- **Experimental Real-Time Intra-Americas Sea Ocean Nowcast/Forecast System** - http://cara.uprm.edu/ias_sst.html - Naval Research Laboratory

CeNCOOS – Central and Northern California Coastal Ocean Observing System (<http://www.cencoos.org/>)

- **Bodega Ocean Observing Node** - <http://www.bml.ucdavis.edu/boon/> - Bodega Marine Laboratory
- **California Cooperative Oceanic Fisheries Investigations** - <http://www.calcofi.org/newhome/data/data.htm> - NOAA NMFS
- **California Sea Otter Survey** - <http://www.werc.usgs.gov/otters/ca-surveyspr2005.htm> - USGS
- **Center for Integrated Marine Technologies** - <http://cimt.ucsc.edu/> - NOAA COTS
- **Center for Integrative Coastal Observation, Research, and Education** - <http://cicore.org> – NOAA COTS
- **CoastWatch West Coast Regional Node** - <http://coastwatch.pfel.noaa.gov/> - NOAA
- **Humboldt Bay Harbor, Recreation and Conservation District** - <http://www.humboldtby.org/> - Humboldt Bay Harbor, Recreation and Conservation District
- **Innovative Coastal-Ocean Observing Network** - <http://www.oc.nps.navy.mil/~icon/index.html> - NOAA COTS
- **Land/Ocean Biogeochemical Observatory in Elkhorn Slough** - <http://www.mbari.org/lobo/> - MBARI
- **Network of Environmental Observations of the Coastal Ocean** - <http://www.es.ucsc.edu/~neoco/> - University of California System
- **Pioneer Seamount Acoustic Observatory** - <http://www.physics.sfsu.edu/~seamount/> - San Francisco State University
- **Rapid Environmental Assessment Laboratory** - <http://www.oc.nps.navy.mil/~stanton/miso/misohome.html> - Naval Postgraduate School
- **San Francisco Public Utilities Commission Beach Monitoring Program** - <http://sfwater.org/Custom/LIMS/beachmain1.cfm> - San Francisco Public Utilities Commission
- **Monterey Bay Aquarium Research Institute Ocean Observing System** - <http://www.mbari.org/data/> - MBARI
- **Monterey Inner Shelf Observatory** - <http://www.oc.nps.navy.mil/~stanton/miso/> - Naval Postgraduate School
- **San Francisco Bay Surface Currents** - <http://norcalcurrents.org/COCMP/Home.html> - California Coast Conservancy
- **Pacific Coast Ocean Observing System** - <http://www.pacoos.org/> - NOAA

GCOOS – Gulf of Mexico Coastal Ocean Observing System (<http://www-ocean.tamu.edu/GCOOS/>)

- **SAIC's DODs Server for the Gulf of Mexico** - <http://www.saicocean.com/> - MMS
- **Northern Gulf of Mexico Littoral Initiative** - <http://128.160.23.41/Project> - CNMOC; EPA
- **Texas Automated Buoy System** - <http://tabs.gerg.tamu.edu/Tglo/> - Texas General Land Office
- **Texas Coastal Ocean Observation Network** - <http://lighthouse.tamucc.edu/TCOON/HomePage> - TAMU-Conrad Blucher Institute
- **Gulf of Mexico Distributed Ocean Data System** - <http://seawater.tamu.edu/NOPPDODSGOM/> - NOPP
- **Galveston Bay Estuary Program** - <http://www.gbep.state.tx.us/solutions-partners/data-mapping.asp> - Galveston Bay Estuary Program; USGS; EPA
- **Louisiana Universities Marine Consortium Environmental Monitoring** - <http://weather.lumcon.edu/> - LUMCON
- **Wave Current Surge Information System** - <http://wavcis.csi.lsu.edu/> - NOAA COTS
- **Mississippi Department of Marine Resources Data** - <http://ms.water.usgs.gov/rt/biloxi/> - USGS
- **Mississippi Beach Monitoring Program** - <http://www.usm.edu/gcrl/msbeach/index.cgi> - EPA; MS DEQ
- **West Florida Coastal Ocean Monitoring and Prediction System** - <http://comps.marine.usf.edu/> - NOAA COTS
- **Florida Inshore Marine Monitoring and Assessment Program** - http://www.floridamarine.org/features/category_sub.asp?id=3448 - EPA
- **Florida Marine Research Institute Red Tide Monitoring** - http://www.floridamarine.org/features/view_article.asp?id=9670 - NOAA
- **SEAKEYS/C-MAN Project** - <http://www.coral.noaa.gov/seakeys/index.shtml> - NOAA



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GLOS – Great Lakes Observing System (<http://www.glos.us/>)

- NOAA Center of Excellence for Great Lakes and Human Health - <http://www.glerl.noaa.gov/res/Centers/HumanHealth/> - NOAA
- Large Lakes Observatory - <http://www.d.umn.edu/llo/> - University of Minnesota Duluth
- The Beach Network - <http://www.beachnet.info/> - USGS; Great Lakes Beach Association; Great Lakes Information Network

MACOOS – Mid-Atlantic Coastal Ocean Observing System (<http://www.macoora.org/>)

- Martha's Vineyard Coastal Observatory - <http://mvcodata.whoi.edu/cgi-bin/mvco/mvco.cgi> - WHOI
- My Sound - <http://www.lisicos.uconn.edu/> - NOAA COTS
- Sound Science - <http://www.sunysb.edu/soundscience> - EPA
- New York Harbor Observing System - <http://onr.dl.stevens-tech.edu/webnyhos3/> - ONR; NJ DOT
- New Jersey Shelf Observing System - <http://www.marine.rutgers.edu/cool/> - ONR; NSF; NOAA, NJ
- Coastal Ocean Observation Lab CODAR Surface Current Maps - <http://www.marine.rutgers.edu/mrs/codar.html> - ONR; NSF; NOAA, NJ
- Weatherflow - <http://www.iwindsurf.com/support.iws?topic=About+Us> - Weatherflow, Inc.
- Delaware Bay Observing System - <http://www.udel.edu/dbos/> - UDel; NOAA Sea Grant
- Eyes on the Bay - <http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm> - NOAA; USACE; MD DEQ; VA DEQ; Harford County, MD; Anne Arundel County, MD
- Chesapeake Bay Observing System - <http://www.cbos.org/> - NOAA; EPA
- NASA/Goddard Space Flight Center Wallops Flight Facility Coastal Ocean Observation Laboratory - <http://www.nasa.gov/centers/goddard/home/index.html> - NASA
- US Army Corps of Engineers, Field Research Facility - <http://frf.usace.army.mil/> - USACE
- Chesapeake Bay Mouth Monthly - <http://www.ccpo.odu.edu/~jay/cheshome.html> - Old Dominion University
- Alliance for the Chesapeake Bay Citizen Monitoring Program - <http://www.acb-online.org/project.cfm?vid=87> - Alliance for the Chesapeake Bay
- New Jersey Coastal Monitoring Network - <http://cmn.dl.stevens-tech.edu/> - Stevens Institute of Technology
- Long Island Sound CODAR data - <http://nopp.uconn.edu/CODAR/index.html> - NOPP

NANOOS Northwest Association of Networked Ocean Observing Systems (<http://www.nanoos.org/>)

- NANOOS Pilot Project – Pacific Northwest Estuaries and Shores - <http://www.ccalmr.ogi.edu/nanoos/> - OR DOGAMI; OR OCMP; OR OPRD
- Surface Currents of the Oregon Coastal Ocean - <http://bragg.oce.orst.edu/ORCoast/> - NSF
- Bodega Ocean Observing Node - <http://www.bml.ucdavis.edu/boon/> - Bodega Marine Laboratory
- Columbia River Estuary Real-Time Observation and Forecasting System - <http://www.ccalmr.ogi.edu/CORIE/> - Oregon Health and Science University
- Oregon State University Coastal Observations - <http://ltop.coas.oregonstate.edu/~ctd/index.html> - US Global Research Program; NSF - and <http://damp.coas.oregonstate.edu/coast/> - NSF
- Pacific Coast Ocean Observing System - <http://www.pacoos.org/> - NOAA
- Coastal Storms Program - <http://www.csc.noaa.gov/csp/> - NOAA CSC

NECOOS – NorthEast Coastal Ocean Observing System (<http://www.gomoos.org/>)

- Gulf of Maine Ocean Observing System - <http://www.gomoos.org/> - ONR COTS
- Martha's Vineyard Coastal Observatory - <http://mvcodata.whoi.edu/cgi-bin/mvco/mvco.cgi> - WHOI
- New Jersey Coastal Monitoring Network - <http://cmn.dl.stevens-tech.edu/> - Stevens Institute of Technology
- Coastal Ocean Observation Laboratory - <http://www.marine.rutgers.edu/cool/> - ONR; NSF; NOAA, NJ
- My Sound - <http://www.lisicos.uconn.edu/> - NOAA COTS
- Coastal Ocean Observing and Analysis System - <http://www.coa.unh.edu/index.jsp> - NOAA COTS

PacIOOS – Pacific Islands Integrated Ocean Observing System (<http://research.eastwestcenter.org/PacIOOS/>)

- **Hawaii Surface Current Data** - <http://radlab.soest.hawaii.edu/hfradar/> - NSF
- **Asia-Pacific Data-Research Center** - http://apdrc.soest.hawaii.edu/w_data/data3.html - Asia-Pacific Data-Research Center
- **Asia Pacific Natural Hazards Information Network** - <http://www.pdc.org/mde/explorer.jsp> - Pacific Disaster Center
- **Global Ocean Data Assimilation Experiment** - <http://www.usgodae.org/cgi-bin/datalist.pl?generate=summary>- ONR
- **Global Change Master Directory** - <http://gcmd.gsfc.nasa.gov/KeywordSearch/Keywords.do?Portal=GCMD&KeywordPath=Parameters%7COCEANS&MetadataType=0&homepg> - NASA
- **National Virtual Ocean Data System** - <http://ferret.pmel.noaa.gov/NVODS/servlets/dataset> - NOAA
- **NESDIS/NODC/NCDDC Hawaii/Pacific Islands Liaison** - <http://ilikai.soest.hawaii.edu/HILO/> - NOAA
- **NOAA Coral Reef Information System** - <http://www.coris.noaa.gov/metadata/map-search/viewer.htm> - NOAA
- **Oceanographic In-situ Data Access** - <http://www.epic.noaa.gov/epic/access/index.html> - NOAA
- **OceanSITES Deep Water Reference Stations** - <http://www.whoi.edu/virtual/oceansites/trish/data/index.html> - NOAA
- **Pacific ENSO Applications Center** - <http://www.soest.hawaii.edu/MET/Enso/data/data.html> - NOAA
- **Pacific Region Ocean Data and Information Portal** - <http://www.nodc.noaa.gov/PRODIP/> - NOAA
- **Permanent Service for Sea Level** - <http://www.pol.ac.uk/psmsl/datainfo/> - UK Natural Environment Research Council
- **Physical Oceanography Distribute Active Archive Center** - <http://podaac.jpl.nasa.gov/catalog/> - NASA
- **Research Vessel Surface Meteorological Data Center** - <http://www.coaps.fsu.edu/RVSMDC/html/data.shtml> - NASA, NOAA, NSF, ONR, DOA
- **Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment Data Information System** - <http://www.ncdc.noaa.gov/oa/coare/> - NOAA
- **U.S. Pacific Islands Near-Real-Time Meteorological and Oceanographic Data** - http://crei.nmfs.hawaii.edu/ocean_data.html - NOAA
- **Western Pacific Fisheries Information Network** - <http://www.pifsc.noaa.gov/wpacfin/> - NOAA
- **World Seabed Data** - <http://instaar.colorado.edu/~jenkinsc/dbseabed/goseabed/interactive/> - University of Colorado
- **Hawaii-Pacific Regional Ocean Observing System** - <http://kela.soest.hawaii.edu/HI-POIS/index.html> - U of HI
- **Hawaii Ocean Time-series Program** - http://hahana.soest.hawaii.edu/hot/hot_jgofs.html - NSF
- **Coral Reef Ecosystem Investigation (CREI) Monitoring Network** - <http://www.nmfs.hawaii.edu/cred/> - NOAA

SCCOOS - Southern California Coastal Ocean Observing System (Automated Shore Stations)

- **California Cooperative Oceanic Fisheries Investigations** - <http://www.calcofi.org/newhome/data/data.htm> - NOAA; CA Fish and Game
- **Center for Integrative Coastal Observation, Research, and Education** - <http://cicore.org> – NOAA COTS
- **Southern California Coastal Water Research Project Authority** - <http://www.sccwrp.org/> - SCCWRP; EPA
- **Coastal Data Information Program** - <http://cdjp.ucsd.edu/> - USACE; CA Dept of Boating and Waterways
- **Pacific Coast Ocean Observing System** - <http://www.pacooos.org/> - NOAA

SECOOS – SouthEast Coastal Ocean Observing System (<http://www.secoora.org/>)

- **Southeast Atlantic Coastal Ocean Observing System** - <http://www.seacoos.org/> - ONR COTS
- **Coastal Ocean Research and Monitoring Program** - <http://www.cormp.org/indexreal.php> - NOAA COTS
- **FerryMon** - <http://www.ferrymon.org/> - NC DENR; NC DOT; Duke University; UNC
- **Carolinas Coastal Ocean Observing and Prediction System** - http://nautilus.baruch.sc.edu/carocoops_website/index.php - NOAA COTS
- **South Atlantic Bight Synoptic Offshore Observational Network** - <http://www.skio.peachnet.edu/research/sabsoon/> - NC DNR; NOAA; EPA; ONR
- **West Florida Coastal Ocean Monitoring and Prediction System** - <http://comps.marine.usf.edu/> - NOAA COTS
- **East Florida Shelf Information System** - <http://efsis.rsmas.miami.edu/> - ONR COTS
- **Explorer of the Seas** - <http://www.rsmas.miami.edu/rccl/index.html> - NOAA; ONR
- **SEAKEYS/C-MAN Project** - <http://www.coral.noaa.gov/seakeys/index.shtml> - NOAA
- **South Florida Ocean Measurement Center** - http://www.sfomc.org/SFOMC_Start.htm - ONR
- **Florida Inshore Marine Monitoring and Assessment Program** - http://www.floridamarine.org/features/category_sub.asp?id=3448
- **Florida Marine Research Institute Red Tide Monitoring** - http://www.floridamarine.org/features/view_article.asp?id=9670 - EPA
- **Neuse River Remote Monitoring and Data Acquisition Project** – NC State University
- **North Carolina Coastal Ocean Observing System** - <http://nccoos.unc.edu/> - ONR COTS

Appendix D: Acronyms

ACWI	Advisory Committee on Water Information
ADCP	Acoustic Doppler Current Profiler
AMS	American Meteorology Society
AOOS	Alaska Ocean Observing System
ATI	Along-track Interferometry
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automatic Weather Station
BEACH	Beaches Environmental Assessment and Coastal Health
CaRA	Caribbean Region Association
CCC	CMN Coordination Committee
CDA	Command and Data Acquisition
CDC	Centers for Disease Control and Prevention
CTD	Conductivity-Temperature-Depth
CeNCOOS	Central and Northern California Ocean Observing System
CENR	Committee on Environment and Natural Resources
CEQ	Council on Environmental Quality
CMN	Community Modeling Network
CO-OPS	Center for Operational Oceanographic Products and Services
COSEE	Centers for Ocean Science Education Excellence
COTS	Coastal Observation Technology System
DAC	Data Assembly Center
DCS	Data Collection System
DART	Deep-ocean Assessment and Reporting of Tsunamis
DMAC	Data Management and Communications
DMPA	Data Management Program Area
EA	Enterprise Architecture
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
ERS	European Remote Sensing

ESMF	Earth System Modeling Framework
ET	Expert Team
ETDMP	Expert Team on Data Management Practices
EXCOM	Executive Committee
FEA	Federal Enterprise Architecture
FEMA	Federal Emergency Management Agency
FTP	File Transport Protocol
FWIS	Future WMO Information System
FY	Fiscal Year
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GCOS	Global Climate Observing System
GEO	Group on Earth Observation or Geostationary Earth Orbit
GEOSS	Global Earth Observation System of Systems
GFO	GEOSAT Follow-On
GHRSSST	GODAE High Resolution Sea Surface Temperature
GIS	Geographic Information System
GLOBE	Global Learning and Observations to Benefit the Environment
GLOS	Great Lakes Observing System
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GRA	GOOS Regional Alliance
GSSC	GOOS Scientific Steering Committee
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunication System
HFR	High Frequency Radar
HTTP	Hyper-Text Transfer Protocol

I-GOOS	Intergovernmental Committee for GOOS
ICOSRMI	Interagency Committee on Ocean Science and Resource Management Integration
ICSU	International Council for Science
IGOS	Integrated Global Observing Strategy
IEOS	Integrated Earth Observation System
IOC	Intergovernmental Oceanographic Commission
IOOS	Integrated Ocean Observing System
IOWG	Interagency Oversight Working Group
IR	Infrared
ISO	International Standards Organization
ISU	Iridium Subscriber Units
IWG	Interagency Working Group
IWGOO	Interagency Working Group on Ocean Observations
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JSOST	Joint Subcommittee on Ocean Science and Technology
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
MACOORA	MidAtlantic Coastal Ocean Observing Regional Association
MA-IOWG	Modeling and Analysis Interagency Oversight Working Group
MAST	Modeling and Analysis Steering Team
MEO	Medium Earth Orbit
MOC	Meridional Overturning Circulation
MODIS	Moderate Resolution Imaging Spectrometer
NANOOS	Northwest Association of Networked Ocean Observing Systems
NASA	National Aeronautics and Space Administration
NASQAN	National Steam Quality Accounting Network
NAVOCAENO	Naval Oceanographic Office
NB	National Backbone
NCAP	National Coastal Assessment Program
NCEP	National Centers for Environmental Prediction

NCOM	Navy Coastal Ocean Model
NDBC	National Data Buoy Center
NEP	National Estuary Program
NERA	Norhwest Regional Association
NERRS	National Estuarine Research Reserves System
NESDIS	National Environmental, Satellite and Data Information Service
NFRA	National Federation of Regional Associations
NGO	Non-governmental Organization
NMN	National Water Quality Monitoring Network
NMSP	National Marine Sanctuary Program
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NORLC	National Ocean Research Leadership Council
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSF	National Science Foundation
NSGO	National Sea Grant Office
NSIP	National Streamflow Information Program
NSTC	National Science and Technology Council
NWLON	National Water Level Observation Network
OAP	Ocean Action Plan
OMB	Office of Management and Budget
ONR	Office of Naval Research
OOI	Ocean Observatories Initiative
OOPC	Oceans Observations Panel for Climate
OPeNDAP	Open-source Project for a Network Data Access Protocol
ORRAP	Ocean Research and Resources Advisory Panel
ORION	Ocean Research Interactive Observatory Networks
OSTM	Ocean Surface Topography Mission
PacIOOS	Pacific Integrated Ocean Observing System
POES	Polar Operational Environmental Satellite

POGO	Partnership for Observations of the Global Ocean
PORTS®	Physical Oceanographic Real-Time System
QA/QC	Quality Assurance/Quality Control
QARTOD	Quality Assurance Real Time Oceanographic Data
RA	Regional Association
RCOOS	Regional Coastal Ocean Observing System
RF	Radio Frequency
SAR	Synthetic Aperture Radar
SCCOOS	Southern California Coastal Ocean Observing System
SECOORA	Southeast Coastal Ocean Observing Regional Association
SIMBIOS	Sensor Intercomparison for Marine Biological and Interdisciplinary Ocean Studies
SIMOR	Subcommittee on Integrated Management of Ocean Resources
SSH	Sea Surface Height
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
TAO	Tropical Atmosphere Ocean
TCP/IP	Transmission Control Protocol/Internet Protocol
TRMM	Tropical Rainfall Measuring Mission
UNEP	United Nations Environmental Programme
UNOLS	University-National Oceanographic Laboratory System
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USGEO	U.S. Group on Earth Observations
USGS	U.S. Geological Survey
VIIRS	Visible Infrared Imager/Radiometer Suite
VOS	Volunteer Observing Ship
WIS	WMO Information System
WMO	World Meteorological Organization
XBT	Expendable Bathythermograph



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