U.S. Integrated Ocean Observing System (U.S. IOOS)
2013 Report to Congress

U.S. IOOS Program
March 2013

INTEGRATED OCEAN OBSERVING SYSTEM

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Vision

A fully integrated ocean observing system that enables the National Oceanic and Atmospheric Administration (NOAA) and its partners to provide service to the Nation through improved ecosystem and climate understanding; sustained living marine resources; improved public health and safety; reduced impacts of natural hazards and environmental changes; and enhanced support for marine commerce and transportation.

Mission

Lead the integration of ocean, coastal, and Great Lakes observing capabilities, in collaboration with Federal and non-Federal partners, to maximize access to data and generation of information products, inform decision making, and promote economic, environmental, and social benefits to our Nation and the world.

Program Overview

The U.S. Integrated Ocean Observing System (U.S. IOOS®) is envisioned as a major improvement to ocean observing capability, efficiently drawing together the vast network of disparate Federal and non-Federal observing systems to fulfill regional, national, and global needs for integrated ocean information; to gather specific data on key coastal, ocean, and Great Lakes variables; and to ensure timely and sustained dissemination and availability of these data.

The Integrated Coastal and Ocean Observation System (ICOOS) Act of 2009 mandated the establishment of this national system with NOAA as lead Federal agency. Acting as the program coordinator, NOAA established an Integrated Ocean Observing System Program, hereafter referred to as the U.S. IOOS Program. “U.S. IOOS” is used to refer to the integrated efforts of all partners.

At the national level, U.S. IOOS represents a partnership of 18 Federal agencies, 11 Regional Associations (RAs) for coastal and ocean observing, the Alliance for Coastal Technologies (ACT) a technology validation and verification organization, and the U.S. IOOS Coastal and Ocean Modeling Testbed. These organizations share a responsibility for the design, operation, and improvement of both the global, national, and regional networks of observations that link marine data and products in a compatible and easy-to use manner for the breadth of U.S. IOOS customers. The list of the U.S. IOOS Federal agency and RA partners can be found in Appendix A of this report.

U.S. IOOS is comprised of global and coastal components, and together these constitute the United States’ contribution to the Global Ocean Observing System (GOOS), the ocean component of the Global Climate Observing System (GCOS) and the Global Earth Observation System of Systems (GEOSS).

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The United States is a maritime Nation and depends on understanding the ocean and having the oceanographic data necessary to make informed decisions and policy for commerce, conservation, defense, public safety, recreation, and research. U.S. Congress, through the passage of the ICOOS Act of 2009, has authorized a concerted effort to both observe the ocean and provide necessary ocean services to the Nation. U.S. IOOS is the partnership between Federal agencies, academia, industry, tribal, and local governments to organize the data and products called for in the ICOOS Act. U.S. IOOS provides new observing capability and better organizes existing ocean data and products for new and ongoing uses.

During 2011 and 2012, the IOOC, the Federal interagency body responsible for cross-agency coordination under the ICOOS Act, completed many of the tasks requested by Congress. The IOOC developed contract certification standards for non-Federal data providers and provided an independent cost estimate for U.S. IOOS as required in the ICOOS Act. It sponsored the U.S. IOOS Summit in late 2012 to better coordinate regional, national, and global ocean observing efforts over the coming decade. It has increased communication across sectors through a series of events to foster engagement in U.S. IOOS. These included the Small Sea Changes Workshop co-hosted with Microsoft® Research in Redmond, WA; and the Small Sea Changes Workshop co-hosted with DTE Energy in Detroit, MI.

The IOOC recognizes that U.S. IOOS must be responsive to environmental crises while maintaining the regular long-term ocean observation infrastructure required to support operational oceanography and climate research. As a source of our Nation's ocean data and products, U.S. IOOS often serves as a resource for the development of targeted applications for a specific location or sector. At the same time, U.S. IOOS organizes data from across regions and sectors to foster the national and international application of local data and products broadly across oceans, coasts, and Great Lakes.

Events over the last few years, including Hurricane Sandy and the Deep Water Horizon oil spill have awakened U.S. communities to the value and necessity of timely ocean information. IOOC commends U.S. IOOS for responsive and capable support to the Nation in these events in addition to diverse everyday support to the Nation's maritime economy. We have much more work to do to build and organize the ocean-observing infrastructure of the Nation and look forward to working with Congress on this continuing challenge.

IOOC Co-Chairs

Bob Houtman **National Science Foundation**	**David Legler** **National Oceanic and Atmospheric Administration**	**Eric Lindstrom** **National Aeronautics and Space administration**

Letter from U.S. IOOS Program Director

In 2011 and 2012, the U.S. Integrated Ocean Observing System (IOOS®) continued its work to coordinate national, international, regional, and local ocean observation networks, modeling efforts, and data management and communications services to provide the Nation with information to safeguard life and property, sustain economic vitality, and protect ecosystems.

The U.S. has the largest high-frequency radar network providing real-time information on surface currents and proved valuable during Hurricanes Sandy and Irene. In support of the Group on Earth Observations, we are working with the international community to leverage additional data. Autonomous gliders and buoys now routinely deploy to improve knowledge of the subsurface ocean environment and in some areas providing up to 90% of the observations.

U.S. IOOS works to coordinate ocean models ranging from global to regional scales. On the global scale, the Global Real-Time Ocean Forecast System ocean model is part of the larger national backbone capability of ocean modeling at NOAA, developed in partnership with the U.S. Navy. On a regional scale, the U.S. IOOS California Regional Associations teamed up to run a statewide ocean model which contributed to the successful Orange County Sanitation District outflow diversion in 2012.

The U.S. IOOS Program Office has the mandate to lead the implementation of data management and communications (DMAC) services. Building on the development of the DMAC Implementation Plan in 2011, the U.S. IOOS Program is working closely with data management experts at the U.S. IOOS Regional Associations, NOAA, and other Federal agency partners to execute a series of coordinated and incremental enterprise-level solutions to improve the interoperability of ocean observations data using community-based technology standards and Web-based tools.

U.S. IOOS works to safeguard life and property, sustain economic vitality, and protect ecosystems. Before, during, and after extreme weather events such as Hurricane Sandy, U.S. IOOS partners provide vital safety information to help coastal authorities prepare for, mitigate, and respond to storm tides and coastal flooding. In support of economic vitality, U.S. IOOS supports the installation of *in situ* sensors on buoys and other platforms to monitor ocean acidification, bringing large economic benefits to the Pacific Northwest shellfish industry. IOOS is improving the tracking of toxic outbreaks, oil spills and other pollutants that will protect our environment for generations to come.

U.S. IOOS works with its eyes on the future. The successes of U.S. IOOS are achieved through cooperation and coordination among Federal agencies, U.S. IOOS Regional Associations, State and regional agencies, and the private sector. This cooperation and coordination requires a sound governance and management structure. In 2011 and 2012, program milestones called for in U.S. IOOS legislation were achieved, laying the groundwork for more success in the future. First, the U.S. IOOS Advisory Committee was established. Second, the Independent Cost Estimate was delivered to Congress. As part of the estimate, each of the 11 U.S. IOOS Regional Associations completed 10-year build-out plans, describing services and products to address local user needs and outlining key assets required to meet the Nation's greater ocean-observing needs.

Ten years after the first U.S. IOOS meeting at the Airlie House, the ocean observation community met again in November 2012 at the first-ever U.S. IOOS Summit. The Summit, led by the IOOC, brought together 200 stakeholder representatives from across the ocean observing community to review the past decade of progress and create a vision for the next 10 years. Looking at the successes of the past, I'm excited about the future of U.S. IOOS and our ability to continue moving forward to deliver its promise. U.S. IOOS works!

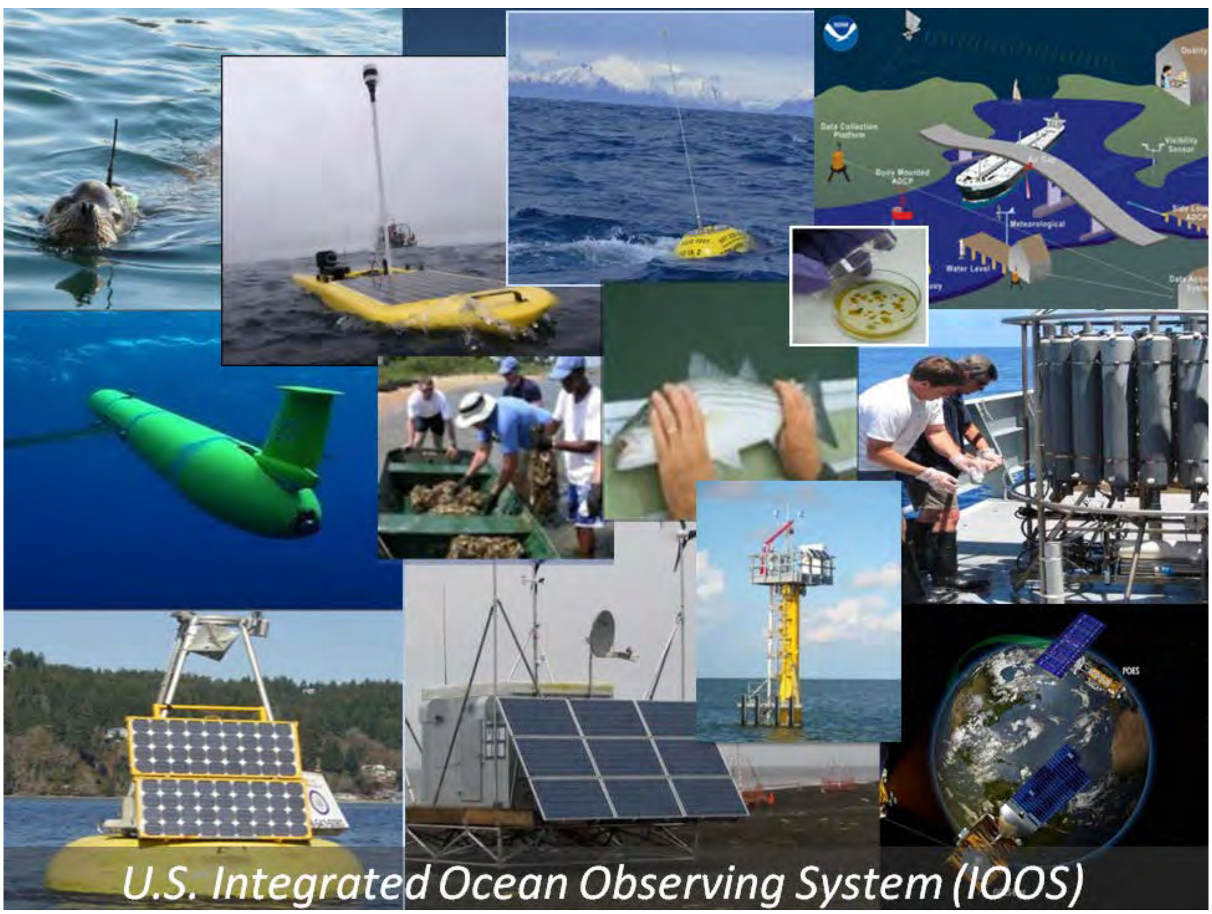
Zdenka S. Willis

Zdenka S. Willis, Director

Introduction

The ICOOS Act of 2009 directs the NOAA Administrator to prepare a report on progress made in implementing the Act and transmit the report to the National Ocean Research Leadership Council (NORLC)* for submission to Congress on a biennial basis.

The following report is an update to the 2009-2010 U.S. IOOS Report to Congress. The report provides information on the impact of U.S. IOOS activities and the current capabilities of ocean and coastal observations, including specific platforms; updates the status of the Data Management and Communications subsystem implementation; and describes the successful implementation of ICOOS-Act-mandated governance activities, such as the formation of the U.S. IOOS System Advisory Committee and the development of an Independent Cost Estimate.

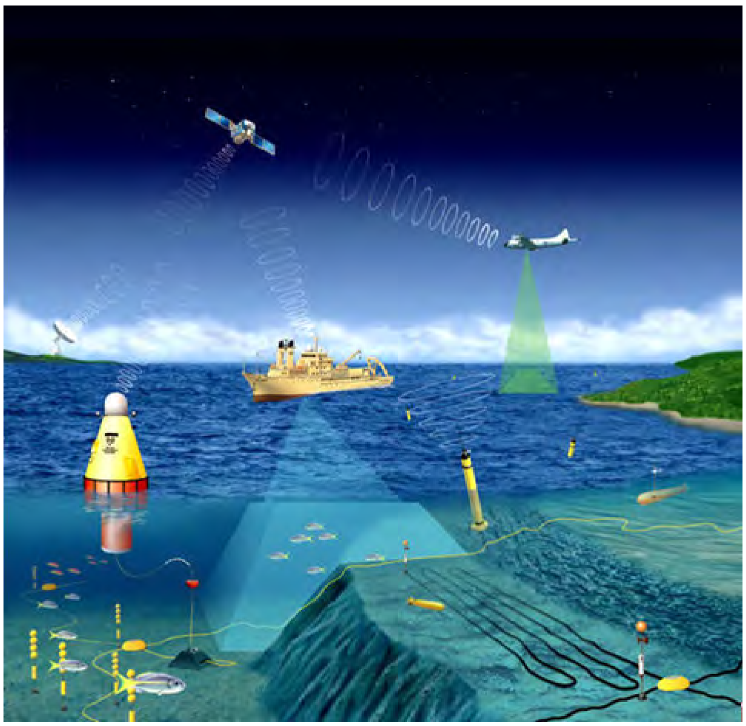


*Note: Under Executive Order 13547, the Deputy-level committee of the National Ocean Council assumed the duties of the NORLC.

Chapter 1
Coastal and Ocean Observations

U.S. IOOS provides essential data and information on our Nation's coasts, oceans, and Great Lakes. Such information is critical to protect marine commerce, public safety, healthy fisheries and ecosystems, and to plan and prepare for hazards such as Hurricane Sandy. U.S. IOOS accomplishes this through collection, storage, and delivery of ocean observations. These observations support a vast array of stakeholders and missions, helping the Nation track, predict, manage, and adapt to changes in our ocean and coastal environment, and also to deliver critical information to decision makers as they seek to improve safety, enhance our economy, and protect our environment. U.S. IOOS partners collect and distribute many types of ocean and coastal observation data, including *in situ* (fixed location) and remotely-sensed measurements, and derived products such as model outputs, forecasts of ocean conditions and educational tools. The data from observations may be available to users in near real-time or may be stored for further processing.

Within the context of the U.S. IOOS program, "observing" is one of three functional subsystems which provide technical capabilities as described in the *U.S. Integrated Ocean Observing System: A Blueprint for Full Capability* (Blueprint). The observing subsystem comprises the collection of sensor and non-sensor marine environment measurements and their transmission from regional and national platforms. This chapter highlights some of the current capabilities, as well as platforms used to support ocean observations.

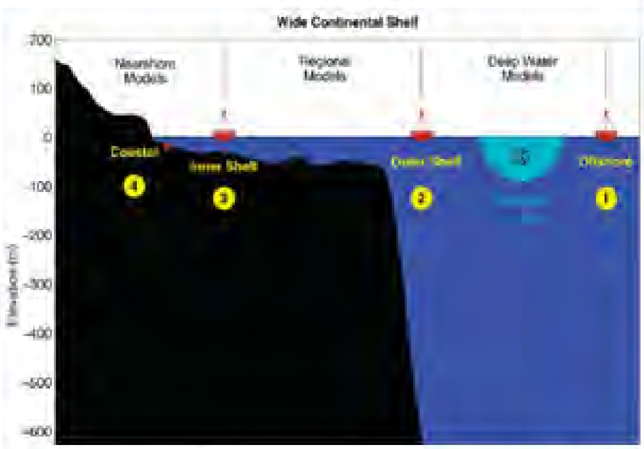


Waves

Surface waves have a profound impact on lives and livelihoods, affecting navigation, safety, off-shore operations, recreation, and the economic vitality of the Nation's maritime communities.

U.S. IOOS partners, the US Army Corps of Engineers (USACE), and NOAA's National Data Buoy Center (NDBC) are the Nation's leaders in wave observation programs, working to integrate surface wave data to support the large variety of users of this information.

Short-term and real-time data on waves are of great interest to stakeholders such as commercial fishermen determining conditions at their fishing grounds and recreational users such as surfers looking for that perfect wave. Other stakeholders include developers considering the use of waves to generate renewable energy systems and captains of seagoing vessels considering wave information for safe and efficient ship routing. For example, large waves outside of the Los Angeles/Long Beach port can delay entrance of trans-Pacific ocean tankers, often costing $100,000 to $200,000 per day to hold offshore.

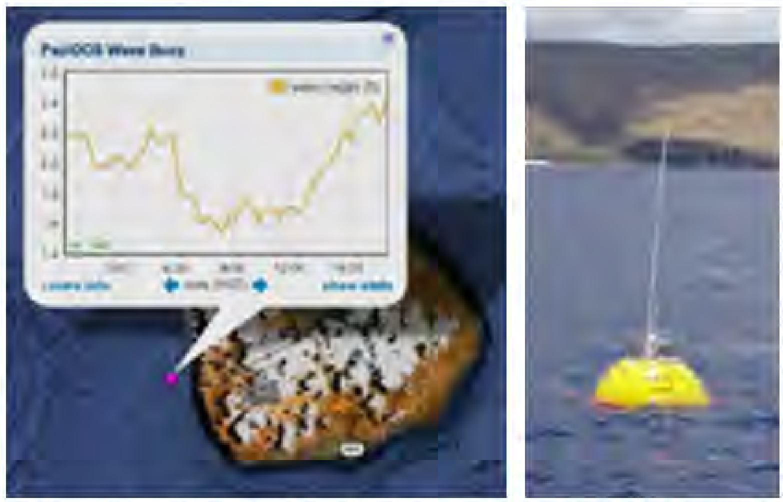


The *National Operational Wave Observation Plan* identified existing wave observation assets and presented a comprehensive integrated system design for establishing four 'along-coast' arrays of wave observation stations. These arrays, or subnets, include: (1) an offshore subnet in the deep ocean to observe approaching waves prior to their passage into coastal boundary currents; (2) an outer-shelf subnet along the deepwater edge of the continental shelf where waves begin to transition from deep to shallow water behavior; (3) an inner-shelf subnet on wide continental shelves to monitor near-shore wave amplitude and wind generation of waves; and (4) a coastal subnet monitoring shallow coastal waves to provide local, site-specific information.

Long-term records of waves are also of interest. Scientists studying climate change need accurate historical data on quantity and natural variations of waves to discern changes associated with frequency and intensity of storms. Lastly, engineers designing coastal and offshore structures use long-term wave records to understand expected waves at a particular location.

In 2009, the IOOC issued the National Operational Wave Observation Plan, developed as an interagency effort by USACE, NDBC, and the Alliance for Coastal Technologies (ACT), U.S. IOOS' sensor validation and verification partner. The plan proposed a comprehensive system design that established a standard level of accuracy, assessed the existing measurement locations, and proposed new observations in critical gaps.[1]

To date, the plan has not been fully implemented, but it is a key tool in planning wave-monitoring site relocations, capability upgrades, and service priorities. As of 2012, there are 218 active wave sites reporting data to NDBC, including 17 Canadian sites. The number of U.S. stations increased by 20 in 2012. It is important to note that this is the net increase between new and decommissioned stations. Some of the decommissioned stations were in locations critical to the wave network plan, but the decisions to decommission were made by the U.S.IOOS partners who owned them, demonstrating the challenge of maintaining a national array with assets that are not all Federally-funded. Of note, three U.S. IOOS regions, Pacific Islands Ocean Observing System (PacIOOS), Caribbean Coastal Ocean Observing System (CariCOOS), and Alaska Ocean Observing System (AOOS) deployed wave buoys to augment the USACE Coastal Data Information Program's (CDIP) efforts.

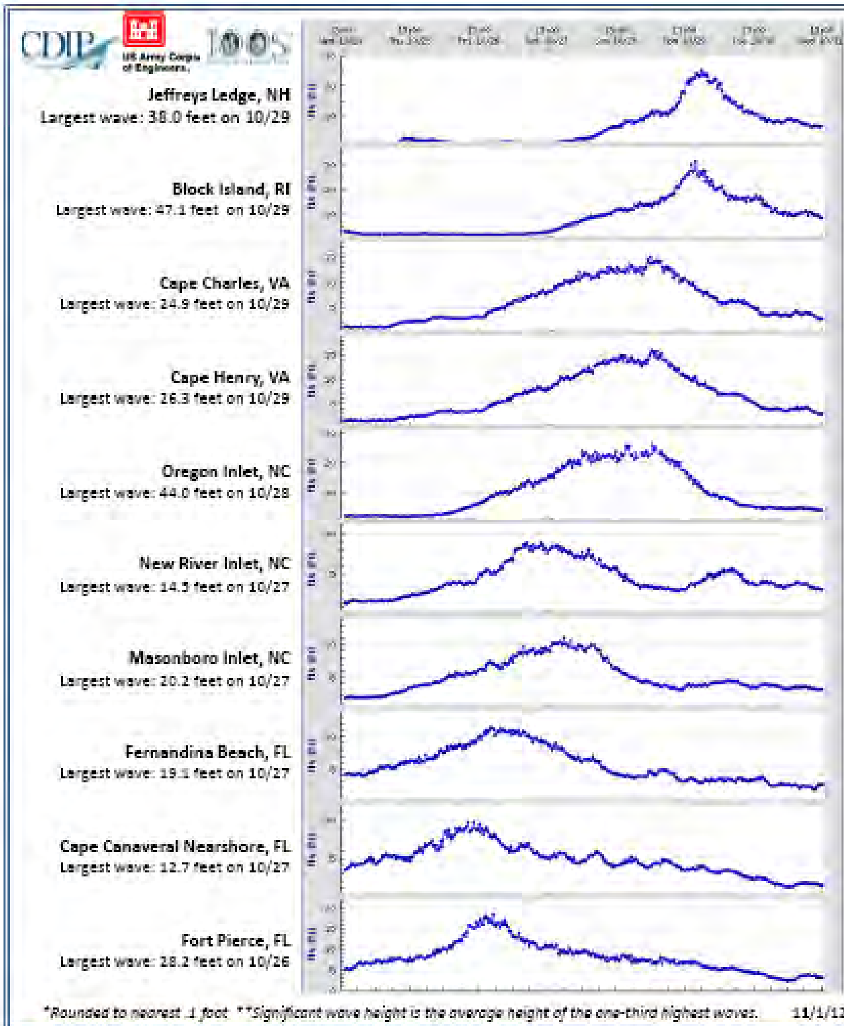


The Kaumalapau Harbor on Lāna'i is the most exposed harbor in the State of Hawai'i. In years past, the Lanai Oil Company would return 2-3 barges per year to Honolulu still full of fuel because ocean conditions were too rough for the barge to safely enter the harbor. Each time a barge returned to Honolulu, it cost about ~$22,000, a large expense to the small fuel operations and the people of Lāna'i. Since the Lanai Oil Company authorized fuel barges to enter the harbor 24 hours prior to arrival, knowing the expected surge conditions of the harbor for the barge's arrival was critical.

In response, the USACE, PacIOOS and the University of Hawai'i deployed a wave buoy just outside the harbor in 2007. With the deployment of the buoy, barge operators knew ahead of time when they could safely make the trip, and the Lanai Oil Company did not return a single barge from 2007- 2012.

The real-time wave information provided by the buoy was "extremely helpful in predicting the surge conditions within the harbor," said Terry McBarnet, President of the Lanai Oil Company, in 2010 when discussing the value of the buoy. "By taking the swell forecast 24 hours before the barge will arrive and comparing that information to what we see on the wave buoy, it helps us predict the surge conditions during that critical period when the barge will be pumping fuel into our storage tanks."

The U.S. IOOS community is currently updating the *National Operational Wave Observation Plan* to: reflect the present state of the wave observation network, better define priority placements and upgrades, improve integration between wave observations and wave modeling, identify the stations with the longest data records, and address current fiscal realities. The revised plan will be based on the existing 201 U.S. locations and proposes adding 37 new locations and upgrading the directional wave measurement of 88 stations. The revised plan will provide a design for a national wave observation network based on the sensors required to create a national perimeter of "Backbone Observations" for deep-ocean, continental shelf, and coastal wave observations. Continental shelf stations, particularly the outer locations, are able to serve wide regions and can provide forecasts to coastal regions, whereas coastal stations are important to spur renewable energy investment and to ensure safe marine operations.[2]



The Coastal Data Information Program (CDIP) is an extensive network for monitoring waves and beaches along the coastlines of the United States that is federally funded by the USACE and for certain sites, cost shared with the U.S. Navy and U.S. IOOS. During Hurricane Sandy, the CDIP wave buoy network on the East Coast provided continuous, near real-time wave observations (reported every 30 minutes) without failure or interruption. In fact, over 99% of all data produced by CDIP buoys during the storm were successfully transmitted. These historic data sets will also be available for use by researchers and coastal planners in the future. This chart shows plots of wave height observed by CDIP's buoys on the East Coast during the last week of October 2012 as Hurricane Sandy moved south to north. The chart also lists the single largest wave recorded by each buoy during that same period.

Animal Telemetry

Aquatic animal telemetry is an emerging technology that allows data measurements of animal movements and their environment to be made at a distance. Affixing tracking devices known as "tags" or "biosensors" to animals allows scientists to analyze their behavior. Data collected through animal telemetry provide important insights into regions of the ocean that are difficult and expensive to monitor. Animal telemetry user groups include, but are not limited to, fisheries and animal conservation and management organizations, private industry, the tourism sector, tribal communities, educational and research institutions, and Federal and State Agencies.

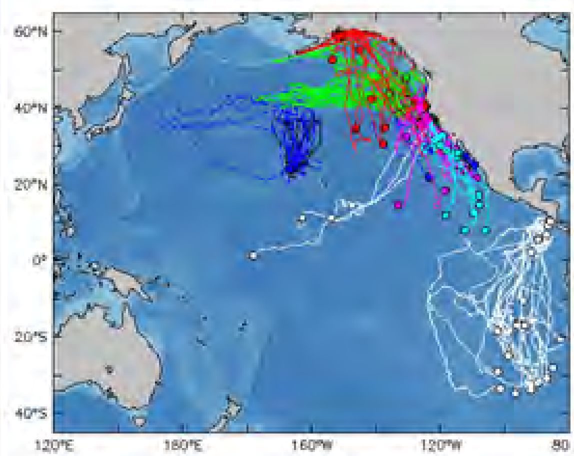
Animal telemetry yields detailed data about the physical environment through which aquatic animals move. Detailed observations of animal movements and their aquatic environment are significantly improving our understanding of ecosystem function and the evolutionary constraints of species. These data are critical for preventing extinctions, preserving biodiversity, and implementing ecosystem-based management of living resources.

Animal telemetry also delivers high quality physical oceanographic data at a relatively low cost. Animals are particularly adept at finding areas of interest to oceanographers (e.g., fronts, upwelling areas). Animal telemetry routinely provides vertical oceanographic profiles throughout the upper 1,500 meters of the water column and in some cases deeper (2,000 meters), providing important insights into regions of the ocean that are difficult and expensive to monitor, such as polar regions.

> The Great Lakes Observing System (GLOS) and the Great Lakes Fishery Commission launched the Great Lakes Acoustic Telemetry Observing System (GLATOS) tool in May 2012 to answer fisheries management and ecology questions in the Great Lakes. The system will track more than 1,700 fish of four species – lake trout, walleye, sea lamprey, and lake sturgeon – tagged between 2010 and 2013. Tracking information will influence a range of fish population restoration actions, including improved sea lamprey control, better data for fish stocking decisions, and enhanced understanding of fish spawning behavior.

Animal telemetry data have supported the development of predictive mapping tools that help the U.S. Navy avoid endangered whales and Central Pacific long-line fishermen minimize unintended capture of protected loggerhead sea turtles. On the West Coast of North America, discoveries about the unexpectedly large movements of the green sturgeon, listed as threatened under the Endangered Species Act, were used to designate Federally-mandated critical habitat for the species. Similarly, animal telemetry has revealed information critical to salmon conservation in West Coast river systems. For instance, animal telemetry has demonstrated that the survival rate for smolt migrating seaward through the Columbia River hydropower system was better than previously believed, and that survival through the Sacramento River Basin was uniformly poor throughout the river as opposed to being concentrated in the river delta.[3]

The U.S. IOOS Program hosted workshops in 2011 and 2012 with the Nation's marine animal tagging community to identify opportunities for collaboration and to advance the concept of a national marine animal telemetry network. Subsequent reports document recommended priorities, highlighting a community need to adopt standards-based protocols for data from tags. Based on recommendations from this community, U.S. IOOS has worked closely with data providers and users to describe standards for data format and content, and to promote the use existing tools for data sharing.



The map pictured here from TOPP shows the interweaving tracks of several pelagic (open-ocean) species we tag, including laysan albatross (blue dotted line in the western Pacific Ocean), leatherback turtles, (white tracks), salmon sharks (in red), and elephant seals (in green).

The community is also developing a strategic plan to establish a U.S. Animal Telemetry Network (ATN) under U.S. IOOS. As part of this effort, U.S. IOOS collaborated with the Office of Naval Research (ONR), the Naval Oceanographic Office (NAVOCEANO), the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP), and the Tagging of Pacific Predators (TOPP) Program at Stanford University's Hopkins Marine Station. This 6-month collaboration ended in June 2012 with a goal of making integral, but hard-to-get, below-surface physical oceanographic data collected by animals carrying biosensors more accessible to ocean modelers from NAVOCEANO and NCEP. The project proved that Animal Borne Sensors data are sufficiently accurate and of high enough quality to be useful in filling existing observation gaps in under-sampled ocean regions (i.e. boundary currents, ocean fronts) and to improve operational ocean models. Participants expressed enthusiasm about the project, as they are now able to access 8,138 observations from TOPP they could not access before.

As a related initiative, AOOS is working with Canadian and Russian partners to develop an Arctic Animal Tagging Network to increase ocean and animal observations in remote Arctic waters. In addition, PacIOOS supports animal tagging by University of Hawaii researchers as well as acoustic arrays throughout the Pacific. The resulting data, along with animal tracking data from collaborating agencies, is made accessible and used by management bodies responsible for sanctuary and marine protected area designations.

Water Quality

A clean, safe water supply is one of our Nation's great natural resources; maintaining it requires a well-integrated system of monitoring for changes in temperature, salinity, dissolved oxygen, pH, pathogens, nutrients, and contaminants. Our coastal waters, estuaries, rivers, streams, and Great Lakes are monitored for protection of the environment as well as to ensure their waters are safe for drinking and recreation. Each year, Federal and State Government agencies, industry, academia, and private organizations devote significant time, energy, and money to monitor, protect, manage, and restore water resources and watersheds.

U.S. IOOS has identified several important variables related to monitoring water quality in our Nation's waters: temperature, salinity, ocean color, dissolved oxygen, pH, pathogens, dissolved nutrients, optical properties, total suspended matter, colored dissolved organic matter, and contaminants.

Water quality data are collected from sensors attached to a Chesapeake Bay Interpretive Buoy System (CBIBS) buoy.

Abundance and type of plant and animal fauna are also important indicators of water quality conditions. The data collected through monitoring activities can be used to detect trends, identify emerging concerns, and to evaluate effectiveness of pollution control programs.

Monitoring water quality can use a variety of methods, such as hand collection or monitoring by *in situ* sensors deployed on buoys or stationary platforms, and can occur at regular intervals or when a specific need arises.

Real-time decisions are often made based on water quality data supplied by U.S. IOOS partners. As an example, Great Lakes Observing System (GLOS), in partnership with NOAA's Great Lakes Environmental Research Laboratory, is supporting monitoring activities that provide oxygen levels, water temperature, and wave heights. The Cleveland Division of Water tracks the data, allowing them to make informed decisions regarding unsafe drinking water and human health. This information acts as a warning system to allow the utility to avoid drawing in hypoxic (low levels of dissolved oxygen) waters or

California's farmed abalone industry produces more than 550,000 pounds of abalone annually worth approximately $9 million (2008). In 2012, the Central and Northern California Ocean Observing System (CeNCOOS) partnered with the Monterey Abalone Company and deployed a station in Monterey Bay to monitor ocean conditions that can affect abalone health and daily farming operations.

enable it to treat affected water appropriately. Other municipalities receive similar information from U.S. IOOS partners, which allow them to monitor their drinking water as well.

Environmental conditions on the Mid-Atlantic Bight have been monitored by the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) to support Federal, State and local agencies. MARACOOS, Rutgers University, the U.S. Environmental Protection Agency (EPA), and the New Jersey Department of Environmental Protection (NJDEP) have deployed gliders in summer months to monitor stratification and collect related measurements of dissolved oxygen, water temperature, chlorophyll, and salinity. Hypoxic conditions in New Jersey coastal waters in summer are common but not well understood. The impact of hypoxic conditions can be significant to bottom-dwelling marine creatures, and the data collected can be used by State and regional officials to decide how to respond when these events take place.

The immense value of integrated observations is also demonstrated by the huge difference even small monitoring and observation efforts can make. An example is found in the Pacific Northwest, where oyster hatcheries on the verge of collapse just a few years ago are again major contributors to the $111 million West Coast shellfish industry. U.S. IOOS, the Northwest Association of Networked Ocean Observing Systems (NANOOS) and NOAA's Ocean Acidification Program are helping to restore commercial hatcheries and support shellfish growing operations. Using real-time data both offshore and at water intakes, oyster hatcheries in the Pacific Northwest are again in good health. Real-time data from offshore buoys provide an early warning system for the shellfish industry, signaling the approach of cold, acidified seawater 1 to 2 days before it arrives in the coastal waters where sensitive larvae and young shellfish are cultivated. The data enable hatcheries and growing operations to schedule hatching, growing, and harvesting to maximize production by knowing when and where water quality is best for their operations.

Gulf of Mexico Coastal Ocean Observing System (GCOOS) partners at the University of South Florida College of Marine Science and Mote Marine Laboratory are coordinating glider missions to gain a better understanding of the dominant Gulf of Mexico red tide organism *Karenia brevis*. The goals of the current mission are twofold. First, the science mission is to use tandem gliders to catch a red-tide bloom in progress to gain a better understanding of how to forecast and track harmful algal blooms. One focus is to determine if concentrations of *K. brevis* at the boundary between surface and deep layers of the ocean can help predict red tides. The second goal is to work with GCOOS to establish protocols for glider data acquisition for numerical models and integration with satellite data.

GCOOS also conducted a pilot project to test the feasibility of bringing "rivers to ocean" water quality data sets together. Building on their success working with 10 non-Federal data providers to standardize local data network nodes and import the data into the U.S. IOOS NDBC data stream, GCOOS determined that there are sufficient near shore stations to warrant the development of an Integrated Water Quality Network (IWQN) for the Gulf of Mexico. Water quality monitoring is a high priority for Gulf of Mexico State public health, environmental and marine resource managers. This effort consists of identifying water quality stations with high quality data, engaging the associated data providers with GCOOS, incorporating their data sets into the GCOOS Data Portal, and eventually developing products that tie the data from the rivers (head of tide) to the estuaries, to the coast, to the shelf, and to the deep-water ocean in forms useful to managers and other users. The IWQN will be developed in four phases. The initial target area is Florida from the Keys to Tampa Bay; the south and central coast of Texas will be targeted in the second phase; the third phase will incorporate the States of Louisiana, Mississippi, and Alabama; the fourth and final phase will include the Florida panhandle.

The Southern California Coastal Ocean Observing System (SCCOOS) along with the National Science Foundation (NSF), NOAA's National Centers for Coastal Ocean Sciences (NCOOS) Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) project, and Liquid Robotics®, Inc. supported California's Orange County Sanitation District (OCSD) temporary diversion of wastewater effluent from the main discharge pipe located five miles offshore of Los Angeles between September and October 2012. Support provided to OCSD included providing observing assets to monitor the diversion event to ensure the beaches and coastal waters remained safe. NCOOS deployed Slocum gliders and moored Environmental Sample Processors to measure hydrographic conditions, chlorophyll, and abundance of *Pseudo-nitzschia* and other harmful algal blooms remotely. Liquid Robotics, Inc. provided a 2-week demonstration of instrumented wave gliders. The NSF Rapid Response Research grant provided pH and CO_2 sensors. SCCOOS provided gliders, high frequency radar, and a number of water quality monitoring sites. Lastly, all the data collected to support OCSD for the wastewater diversion was integrated and made accessible through the SCCOOS website.

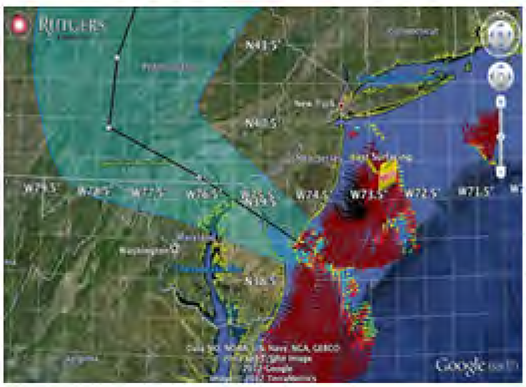
Location of the OCSD long ocean outfall and short ocean outfall off Huntington Beach (Los Angeles), California (image courtesy of the OCSD)

2012, U.S. IOOS completed an initiative to make U.S. water quality data available to international partners. The U.S. IOOS Program, NANOOS, the Southeast Coastal Ocean Observing Regional Association (SECOORA), the European Environment Agency (EEA) and the Environmental Systems Research Institute (Esri®), Inc., partnered collaboratively to enable U.S. IOOS data on the Eye on Earth Network online portal. Eye on Earth, collaboratively developed by EEA, Microsoft® and Esri®, is a "global public information network for creating and sharing environmentally relevant data and information online through interactive map-based visualizations." The network launched in 2008 with WaterWatch, an interactive map that presents the latest available water quality data, to provide European citizens information about their environment. Today, the Eye on Earth Network presents a breadth of environmental information from thematic areas such as biodiversity, coastal erosion and oil spills. The collaboration between U.S. IOOS and EEA has helped to broaden the Eye on Earth Networks' reach of environmental observations beyond its European boundaries.

Alaska Ocean Observing System (AOOS) partners deployed the first ocean acidification buoys in Alaska near Resurrection Bay and in the eastern Bering Sea. They are the first in a series of buoys that will help scientists monitor ocean pH levels and better understand how oceans are being affected by climate change. A third subsurface monitoring ocean acidification mooring is currently deployed in the Chukchi Sea.

High Frequency Radar

High frequency (HF) radar systems measure the speed and direction of ocean surface currents in near-real-time and are effective even under cloudy or stormy conditions, when satellite sensors are rendered ineffective. Much like winds transport gases, liquids, and particles through the atmosphere, currents move objects through the water from one location to another. Surface currents will transport objects on the water's surface, so the ability to collect accurate data on surface current direction and speed is critical for providing reliable information to support pollutant tracking, search and rescue, harmful algal bloom monitoring, navigation, and ecosystem assessment.



Display of HF Radar observational data along Mid-Atlantic Coast during Hurricane Sandy

Many stakeholders rely on understanding surface current velocities. The U.S. Coast Guard (USCG) search and rescue operators use HF radar data to make lifesaving decisions when rescuing disabled vessels and people stranded in the water. Commercial and research fisheries use HF radar to monitor the dispersal of commercial fish larvae and juvenile fish survival. Decision makers are provided with critical information concerning the flow and trajectory of hazards during oil spills and accidental releases of wastewater or other contaminants. In addition, HF radars located in Japan and California detected and measured current flows during the March 11, 2011, Japanese Tsunami. This was the first time a tsunami was captured with radar observations and indicates the technology has the potential to support future detection and monitoring by tsunami warning centers.[4]

While more than 95 percent of the HF radar platforms in the United States are operated by U.S. IOOS regional partners in support of the applications required in their regions, the U.S. IOOS program supports the development of both national and regional HF radar capabilities through operations, maintenance, and technical assistance. This support includes ensuring that adequate radio frequency licensing is in place to meet operational and research needs and hosting a technical steering committee to guide additional development of a national HF radar network. The HF radar community published *A Plan to Meet the Nation's Needs for Surface Current Mapping* in 2009 to present the uses of HF radar, define the requirements that drive the measurement of ocean surface

HF Radar antenna in Barrow, Alaska.

currents, and plan the implementation design for a 5-year build-out. The plan identified the need for an additional 208 HF radar systems to address the requirements identified in the gap study conducted to inform the plan. The plan was updated in September 2012 to reflect the latest information from the technical steering committee and U.S. IOOS partners continue to use the plan to guide collaborative development of a national HF radar network.[5]

In 2012, the World Radio-communication Conference (WRC) assigned a number of primary frequencies in the 3 to 50 megahertz range for operation of oceanographic radars. The technical work required to support approval of these frequencies had been underway for more than 5 years, with NOAA taking a leadership role in the effort and working alongside experts from the U.S. commercial sector and representatives from Japan, Australia, Korea, Canada, France, and Germany. The WRC decision provides stable segments of spectrum for oceanographic radar operations and safeguards these frequencies from interference from other applications.

There are at least 300 HF radars currently deployed in at least 10 countries, and several countries have begun using HF radar-derived ocean currents for their operational oceanographic needs. U.S. IOOS is leading the global HF radar task under the 2015 Group on Earth Observations (GEO) work plan to: make HF radar data available in a single standardized format in near real-time; develop a worldwide quality assurance/quality control (QA/QC) standard; assure HF radar data assimilation in ocean and ecosystem modeling; and develop emerging uses of HF radar in the areas of ecosystem, tsunami, and climate.

At present, there are 132 radars deployed within the U.S. with four variations of resolutions and maximum ranges: Very High Resolution (20km), Standard High Resolution (45 km), Standard Range (75 km), and Long Range (150km). Resolutions vary from 0.5 km for the Very High Resolution system to 6.0 km for the Long Range systems.

Robotic Gliders

Gliders and autonomous underwater vehicles (AUVs) are buoyancy-driven vehicles that vertically profile the ocean and can travel great distances over long time periods without servicing. These characteristics, along with advancements in sensor technologies, are making gliders more and more important as tools for collecting ocean data.

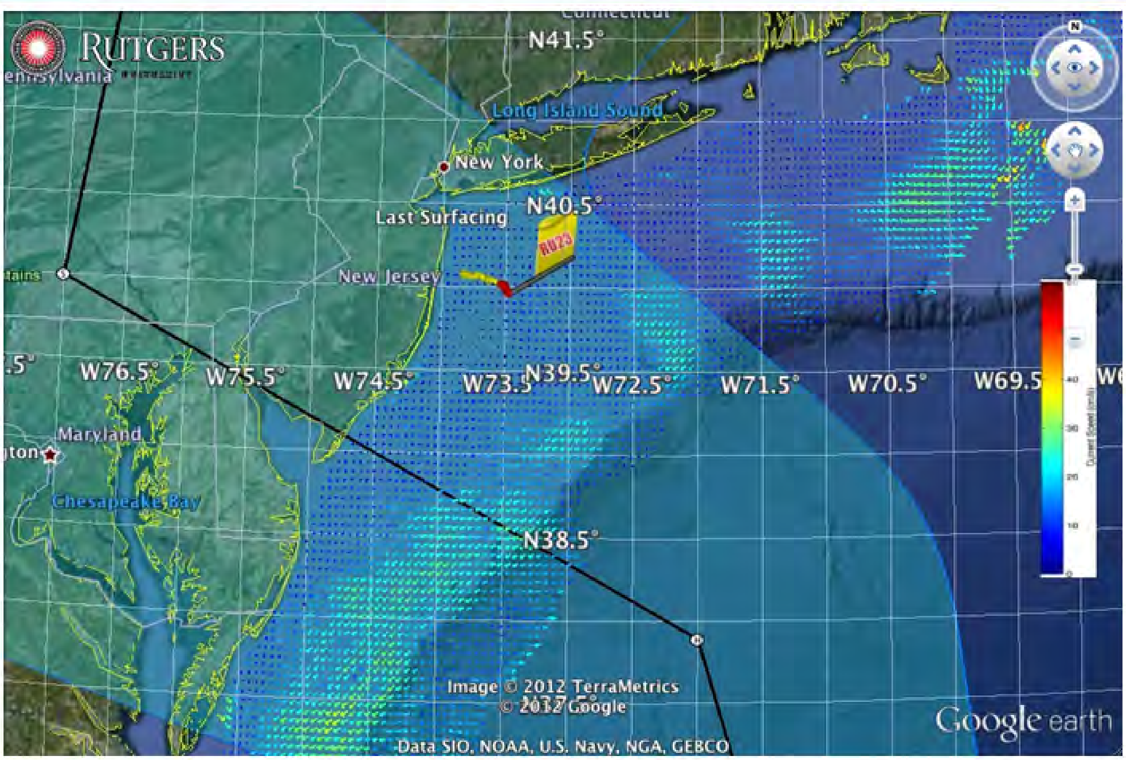
Gliders are used to monitor water currents, temperature, and biological information such as dissolved oxygen and nitrate. This information offers a more complete picture of what is happening at and below the ocean surface, and may allow scientists to detect trends that otherwise might have gone undetected. Gliders are assuming a prominent and growing role in ocean science due to their unique capabilities for collecting data safely and at relatively low cost in remote locations, both in deep water and at the surface. An advantage of gliders is that they can be quickly deployed to areas of greatest need.

A National Glider Asset Map was deployed by the U.S. IOOS program in 2012 and will include all historic and current glider flights once it is completed. The map shown on the right includes data from glider missions since 2005 from Southern California (SCCOOS), the Pacific Northwest (NANOOS), Central and Northern California (CeNCOOS) and the Mid-Atlantic (MARACOOS) regional glider operations. The glider asset map can be viewed at: [http://www.ioos.noaa.gov/observing/observing_assets/glider_asset_map.html.](http://www.ioos.noaa.gov/observing/observing_assets/glider_asset_map.html)

Screen Capture of the National Glider Asset Map

The U.S. IOOS community demonstrated its continued interest in the development of glider technology by partnering in an effort to collect important data along the Gulf Coast. In the summer of 2012, scientists in partnership with Shell Oil Company®, the U.S. IOOS program, and the NDBC launched an iRobot Seaglider to measure temperature, conductivity, salinity, dissolved oxygen, and dissolved organic matter down to 1,000 meters in various areas of the Northern Gulf of Mexico. NDBC staff pilot the Shell-owned glider and have collected and disseminated more than 250 profiles of data to date.

In August 2012, U.S. IOOS partners held a workshop to plan the development of a national glider strategy. The team defined the mission and scope for a National Glider Network and created an outline for what will become the National Glider Network Plan, assigning authors to each section.[6] Critical to IOOS efforts to establish a national network of remotely operated gliders, is the establishment of a data management plan that provides guidelines for the end-to-end process of getting data from the individual sensors through a quality assurance/quality control (QA/QC) process and then to users of the data. The draft glider plan includes a detailed section on how observations would be transmitted in standard formats to a data aggregation center, run through a series of QA/QC checks, and then distributed via standard formats and services to end users. U.S. IOOS scientists and data managers are also defining a detailed controlled vocabulary for glider terms and variables and conventions for file formats and data processing. Each of these steps are important for ensuring that glider data from different providers or institutions can be widely shared and combined or integrated for various types of analysis and forecasting.



During Hurricane Sandy in October 2012, a MARACOOS glider was deployed to monitor sea surface temperature and the mixing layer off the New Jersey coast. Its data were available until power was lost at the main communications hub in New Jersey, however the glider continued to provide information to the backup communications hub. Additionally, throughout the hurricane a Liquid Robotics wave glider and two Sonardyne undersea nodes continued to transmit temperature and pressure data every ten minutes without failure. The collaboration effort includes Liquid Robotics, Sonardyne, Rutgers University, MARACOOS, and the U.S. IOOS Program Office.

Buoys and Gauges

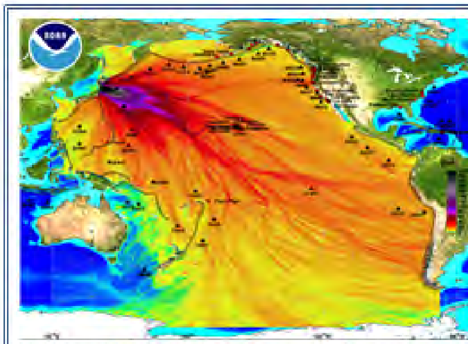
NOAA's NDBC, Chesapeake Bay Office, and the Center for Operational Oceanographic Products and Services (CO-OPS) maintain coastal buoys, the Coastal-Marine Automated Network (C-MAN) stations, tide gauges, the Physical Oceanographic Real-Time System (PORTS), and the National Water Level Observation Network (NWLON). These networks and systems, along with U.S. IOOS Regional buoys located in the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS), SECOORA, CariCOOS, CeNCOOS, NANOOS, PacIOOS and AOOS, form our Nation's surface and subsurface coastal observation capability. These networks support Federal, State, and local agencies; decision makers; and marine based industries in making life-saving and operational decisions on a daily basis. For example, activity on the NERACOOS website routinely spikes daily at 4am as fisherman and others who depend on the sea check the buoys to ensure the safety of their crew and the sustainment of their livelihood.

"I trust the weather buoys with my life. Thank you." - Maine Fisherman; "Love your service…I believe your service is a lifesaver. Thanks!" -Dave, Pilot; and "I would like you to know that information you are providing us not only aids us in our work, it almost certainly has saved lives." -Roy Atkinson, Fisherman.

Due to the efforts of national and regional partners, the NWS has data from offshore buoys to support critical marine forecasting in the Caribbean and Pacific Islands. CariCOOS, for example, provides 15 hurricane hardened coastal weather stations in partnership with WeatherFlow™ Inc., which represent the only coastal meteorological stations in Puerto Rico and the U.S. Virgin Islands. In addition, PacIOOS maintains 11 (and counting) wave buoys around the entire Pacific Ocean that provide critical input to the NWS's marine forecasts and natural disaster alerts, tracking, and predictions for many low-lying fragile islands and ecosystems.

Two major events in 2011, the Japanese Tsunami and Hurricane Irene, demonstrated the value of these systems at a national level.

Japanese Tsunami – March 2011:



Forecast Model of the Japanese Tsunami from NOAA Pacific Marine Environmental Laboratory's (PMEL) Short-term Inundation Forecasting for Tsunamis (SIFT) using NDBC's DART Buoy data.

NOAA's Deep-ocean Assessment and Reporting of Tsunami (DART®) Network and CO-OPS NWLON tide gauges—both U.S. IOOS components—provided data vital to issuing warnings and other information with specific regard to the tsunami's impact on the United States. Real-time water level data from 72 CO-OPS coastal tide stations positioned in U.S. coastal areas throughout the Pacific enabled NOAA's Tsunami Warning Centers (TWC) to issue timely warnings and information to at-risk States and territories. These data assisted NOAA's TWCs, as well as other Federal and

State scientists and emergency managers, to determine which U.S. coastal areas were most at risk to flooding, surges, and wave action.

At the Regional level, RAs saw a five to ten-fold increase in web-based traffic, proving that the public trust and look to their RAs for local guidance during national and international distress. PacIOOS provided real-time water level (tsunami arrival) and turbidity (debris) measurements for Waikiki Beach. NANOOS featured their “Tsunami Evacuation Zones for the Oregon Coast,” which has now been expanded to an on-line portal and free smart phone app for the entire Pacific Northwest. SCCOOS measured the tsunami signal documented by the NOAA tide gauge on the Scripps Institution of Oceanography pier and by pressure sensors at the four SCCOOS automated shore stations. CeNCOOS captured the tsunami passage in Humboldt, San Francisco, and Morro Bays using the Monterey Accelerated Research System.

Hurricane Irene – August 2011:

Buoys from both NOAA NDBC and U.S. IOOS RAs were critical to forecasting the impact of Hurricane Irene. NOAA used the buoys from CariCOOS, SECOORA, and NERACOOS to track the Hurricane, and initialize and verify forecasts.

NDBC Stations within 300 nautical miles of Hurricane Irene’s Track 20-29 Aug 2011

John Cannon of the NWS Weather Forecast Office (WFO) Gray, Maine, said, “Buoy ‘A’ and ‘B’ were our focus at the NWS (WFO) Gray, Maine, for this storm due to their unique positioning along and just upstream the Seacoast of New Hampshire and Southwestern populated beaches in Maine to determine the extent for the potential of coastal flooding...splash-over and beach erosion in real-time with Irene. With south southeasterly winds...the buoy waves held below 20 feet as Irene approached due to the short fetch in the region as Cape Cod acted as a buffer. We have a very limited climatology of tropical systems creating winds from this direction so the real-time information was crucial for our needs. Short Term Forecasts (STFs) were lowered to account for the ongoing situation during Irene's approach. The observation of limited wave action was a critical benchmark which caused our office to (accurately) limit our forecast and warnings for coastal flooding to ‘minor;’ this indeed verified to be the case. Higher waves (over 20 feet) were anticipated and reported at Buoy ‘E’ and ‘I’ in the more exposed wave situation along the Mid-coast Region and our concern shifted to that area. The Maine Geological Survey visited Popham Beach after the storm and confirmed up to 10 feet of beach erosion in that area.”

Additional Buoys and Gauge successes include:


Giant container cranes passing under the Chesapeake Bay Bridge

In 2012, CO-OPS' PORTS was instrumental in the transport of four giant container cranes by the Merchant Vessel Zhen Hua 13 under the Chesapeake Bay and Francis Scott Key Bridges en route to the Port of Baltimore. The cranes are the biggest of their kind in the maritime industry and are designed to handle the containers of larger vessels soon to arrive when the Panama Canal expansion is completed in 2014. CO-OPS provided bridge clearance and oceanographic data to assist the vessel in the final leg of its two-month journey from China. An air gap sensor on the Chesapeake Bay Bridge measured the distance from the bottom of the bridge to the surface of the water, providing an accurate clearance measurement to ensure safe passage for the cranes. CO-OPS' hydrodynamic model provided a forecast of water levels, currents, winds, and other environmental parameters that were crucial to deciding when the vessel would travel to the port. Actual clearance from the bottom of the bridge to the top of the cranes was nearly 10 feet, more than twice the minimum clearance of four feet needed by the vessel.

Another contribution by NOAA to U.S. IOOS is the Chesapeake Bay Interpretive Buoy System (CBIBS). CBIBS is a network of observing buoys that collect meteorological, oceanographic, and water-quality data and relay that information using wireless technology to a variety of users. The latest data from key points up and down the Chesapeake Bay is available at http://buoybay.noaa.gov, by calling toll-free 877-BUOY-BAY, by visiting the mobile version of this website, or via apps available for Android® and iPhone® smartphones. The CBIBS "smart buoys:"

- Deliver real-time data on weather, water conditions, and water quality
- Support high-quality science education and enhance the delivery of experiential outdoor education
- Interpret points along the Captain John Smith Chesapeake National Historic Trail and enhance the experience of trail users

This year, two CBIBS partners released free apps for smartphones to help people explore the Chesapeake Bay's National Wildlife Refuges, including locations near CBIBS buoys. Chesapeake Conservancy worked with the National Geographic Society, with support from the U.S. Fish and Wildlife Service, to create the "National Wildlife Refuges: Chesapeake Bay" app (currently available via iTunes®; Android version to come). The app incorporates the popular Project Noah wildlife photo-sharing service. Using the app, visitors to national wildlife refuges in the Chesapeake area can take photos and share them with a worldwide community of wildlife enthusiasts and experts. Users can earn virtual "patches" by visiting refuges and posting photos. The app also includes information on refuge locations, maps, hours, and more.

The National Park Service (NPS) “Chesapeake Explorer” app is available in the iTunes store and in the Android market. Based on their location, the app helps users find national and State parks, trails, and historic sites near them in the Chesapeake Bay watershed. The app helps users match up their interests—like hiking, biking, bird watching—with locations in the area. It contains abundant information on all those places, like location, hours, and other details. The Captain John Smith Chesapeake National Historic Trail and Star-Spangled Banner National Historic Trail—each marked at points by CBIBS buoys—are among the trails highlighted via this app.

Evaluation of New and Existing Observation Technologies

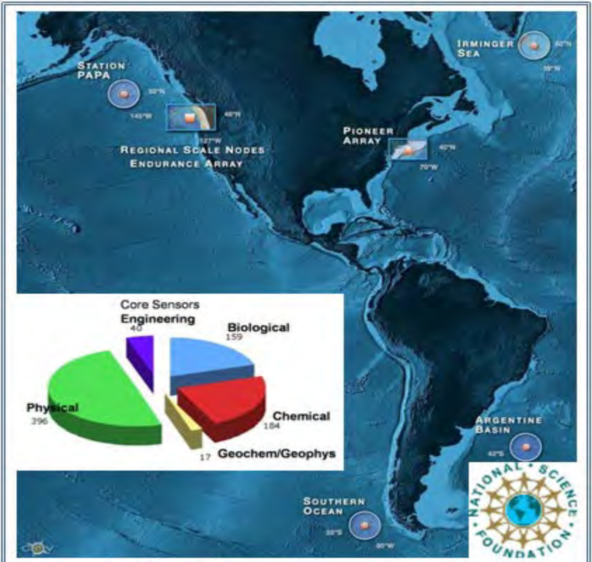
Public and private sectors have an increasing demand for ocean and coastal observations, which allow for better understanding of basic science, improved forecasting abilities, and informed management decisions. To meet this demand, the United States needs not only observations assets to be in place, but also assurance that the data collected from those observation technologies are accurate and reliable. A U.S. IOOS partner, the Alliance for Coastal Technologies (ACT), is a collection of research institutions, resource managers, and private sector companies dedicated to fostering the development and adoption of effective and reliable sensors and platforms for use in coastal, freshwater and ocean environments. ACT works with the U.S. IOOS program to bring about fundamental changes in the transition of technology and the adoption of new practices in coastal and ocean monitoring.

ACT has helped advance NOAA’s efforts to evaluate and exploit new ocean observing approaches by serving as:

- A third-party testbed for quantitatively evaluating the performance of new and existing coastal technologies, both in the laboratory and under diverse environmental conditions
- A forum for capacity-building through technology-specific workshops that review the current state of instrumentation, build consensus on identification of future trends, and enhance communications between users and developers
- An information clearinghouse, provided through a searchable, online database of environmental technologies and community discussion boards

ACT has evaluated a total of 49 sensors from 25 international companies and conducted 235 tests of instrument performance. ACT’s Information Clearing House currently connects users with over 300 companies and nearly 4,000 commercial instruments.[7] In FY 2011 and 2012, ACT focused on evaluations of *in situ* pH and pCO2 sensors (to address ocean acidification) and hydrocarbon sensors (to address oil spill detection and response). The results of these tests, the Performance Demonstration Statements, are available at: www.act-us.info/evaluation_reports.php.

The Ocean Observatories Initiative



OOI Station Map and number of core sensors

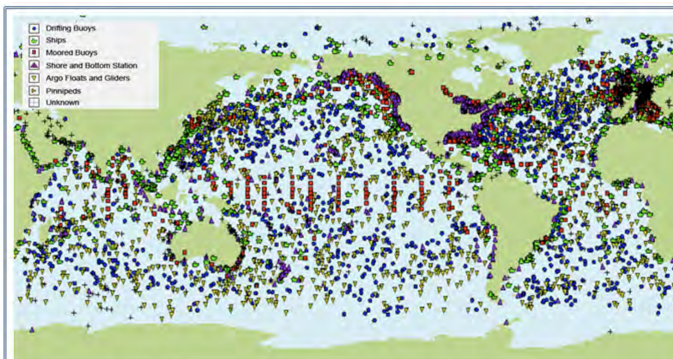
NSF's Ocean Observatories Initiative (OOI) is a long-term program to provide 25-30 years of sustained ocean measurements. The OOI program will construct a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor. Greater knowledge of these variables is vital for improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems, and climate.

The OOI program is managed and coordinated by the OOI Project Office at the Consortium for Ocean Leadership, in Washington, DC, and is responsible for construction and initial operations of the OOI network. Several implementing organizations are responsible for construction and development of the overall program. Woods Hole Oceanographic Institution and its partners, Oregon State University and Scripps Institution of Oceanography, are responsible for the coastal and global moorings and their autonomous vehicles. The University of Washington is responsible for cabled seafloor systems and moorings. The University of California, San Diego, is implementing the cyber infrastructure component. Rutgers, The State University of New Jersey, with its partners University of Maine and Raytheon® Mission Operations and Services, is responsible for the education and public engagement software infrastructure.

The OOI will enable powerful new scientific approaches for exploring the complexities of Earth/ocean/atmosphere interactions. The OOI is expected to foster new discoveries that will move ocean research in unforeseen new directions. For more information on the OOI, please visit http://www.oceanobservatories.org/.

Global and National Observation Programs

U.S. IOOS and its partners contribute towards the GOOS—the oceanographic component of GEOSS—and GCOS, which are coordinated and managed internationally under the auspices of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization and the World



Global *in situ* ocean observations assets

Meteorological Organization (WMO). Direct contact between national observation systems (such as U.S. IOOS and Australia's Integrated Marine Observing System (IMOS)) as well as through international research organizations and funders (e.g., the United Kingdom's (UK) Natural Environmental Research Council, the Japan Agency for Marine-Earth Science and Technology) has also proven beneficial in allowing for the exchange of information to support implementation of both national and international systems. Emerging ocean observing systems such as the UK's Integrated Marine Observing Network (UK-IMON) plan to take lessons learned from both U.S. IOOS and IMOS as they establish their networks.

Under the GOOS umbrella, there have been a number of milestones achieved, all relying on international partnerships. Foundational observing systems such as the Tropical Ocean-Atmosphere – Triangle Trans-Ocean Buoy Network (TAO-TRITON) array of buoys across the tropical Pacific continue to provide critical detection, understanding and prediction capabilities for El Niño and La Niña, and serve as platforms for research to improve our knowledge of ocean-atmosphere interactions that affect regional weather and climate variability on seasonal, interannual, and longer time scales. In the tropical Atlantic Ocean, the Prediction and Research Moored Array of buoys in the Atlantic (PIRATA), is complete. The Indian Ocean's Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA), has reached more than two-thirds completion. Through these systems, NOAA and its international partners monitor the tropical ocean-atmosphere environment which is vital for understanding and predicting climate variability and extremes (e.g. drought over parts of the U.S.).

The global array of Argo profiling floats that measure temperature and salinity in the upper 2,000 meters of the ocean expanded to more than 3,000 distributed floats and achieved its millionth profile in October 2012. The Global Surface Drifting Buoy Array reached a global 5x5 degree array of 1,250 satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of *in situ* observations of mixed layer currents and sea surface temperature, with a subset of drifters measuring atmospheric pressure, winds and salinity–of particular value to weather prediction efforts. Global Positioning System (GPS) has been installed on more than half of the Global Sea Level Observing System (GLOSS) tide gauge stations to improve the accuracy and our understanding of long term trends in sea level.

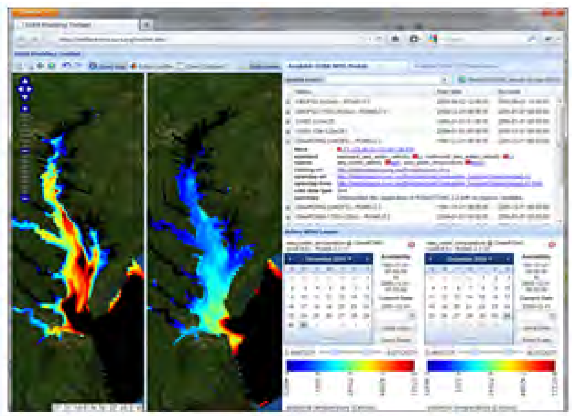
> In June 2011, the Aquarius satellite was launched. This is a focused effort to measure Sea Surface Salinity and will provide the global view of salinity variability needed for climate studies. The mission is a collaboration between the National Aeronautical and Space Agency (NASA) and the Space Agency of Argentina (Comisión Nacional de Actividades Espaciales Asset Map)

The ability to share ocean information is part of the U.S. contribution to GOOS and GOESS. The Global Ocean Data Assimilation Experiment (GODAE) Array for Real-time Geostrophic Oceanography (ARGO) and the Global High Resolution Sea Surface Temperature (GHRSST) programs demonstrate the ability to reach consensus on common standards. We have seen the emergence of global solutions to facilitate sharing of biodiversity data, to include the Global Biodiversity Information Facility (GBIF), the International Ocean Biogeographic Information System (OBIS), and their associated regional nodes (e.g. OBIS-USA) and focused taxonomic nodes (e.g. OBIS-Seamap).

Chapter 2
Modeling and Analysis

Computer models of the ocean are used by scientists to forecast future states of the ocean and to deconstruct existing or past conditions to determine what factors affect the ocean and coastal environment. These models, when constrained by observations, are used to make comprehensive ocean state estimates or ocean predictions of physical oceanographic variables such as currents, temperature, salinity, external and internal tides, surface waves, storm surges, harmful algal blooms, and hypoxia.

The U.S. IOOS modeling and analysis subsystem produces information that can be used for customer products. This subsystem provides the integrated and forecast data that are used by Federal and non-Federal organizations and agencies, industry, academia, non-governmental organizations, tribal entities, professional organizations, and the general public. Intermediate users or customers synthesize and evaluate those data, products, and services to forecast the state of the marine environment and provide the results via reports, alerts, model outputs, or tailored analytical products to various end users/customers.



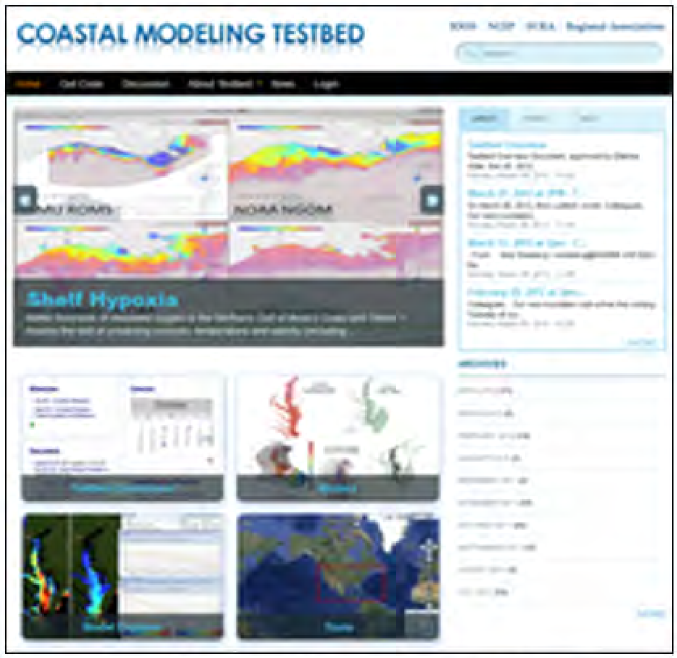
Model Example: Sea Water Temperature in the Chesapeake Bay

Coastal and Ocean Modeling Testbed

Coastal lowlands of the United States are threatened by storm-induced flooding, harmful algal blooms, oil spills, oxygen depleted "dead-zones", contamination and nutrient run-offs, sea-level rise, and other unforeseen disasters. Ocean and coastal models are used to predict and study the ocean and coastal environment and to apply model output to support forecasting, hindcasting, risk assessments, and management activities. The user community for these models includes Federal agencies such as NOAA, NAVOCEANO, EPA, USACE, USCG, the U.S. Geological Survey (USGS), and the Federal Emergency Management Agency (FEMA); State and local governments; and the private sector.[8]

U.S. IOOS initiated the Coastal and Ocean Modeling Testbed (COMT) as a pilot project in June 2010 through a cooperative agreement competitively awarded to the Southeastern University Research Association (SURA). The purpose of the pilot was to investigate the utility of a permanent testbed by selecting two important coastal processes, hypoxia and inundation, and investigating model skill in several regions rich with historical data. The mission of the COMT is to accelerate the transition of models from the coastal ocean modeling research community to improve operational products and services. The vision of the program is to increase the accuracy, reliability, and scope of operational coastal and ocean forecasting products.

Based on the early success of the COMT, a second cooperative agreement was competitively awarded to SURA in August 2011 to define what a sustained COMT should look like and to develop a permanent framework and future plan for the COMT. Between 2011 and 2012, SURA facilitated strategic collaborations among experts from academia, Federal agencies, and industry and guided the COMT through its first highly productive phase. Some successes of the COMT pilot include:



Screen capture of the COMT, located at http://testbed.ioos.us

- Enabled positive community-building (within the modeling community), including enhancing collaboration between modelers in academia and the users of the model outputs in Federal agencies
- Increased spatial and temporal accuracy of hypoxic "dead zone" conditions in the Chesapeake Bay. Dead zones have a significant impact on living marine resources and marine based industries such as crabbing and oyster harvesting. Accurate predictions of hypoxic conditions in the Bay are crucial for sustaining the marine industry
- Demonstrated the capability for predicting the timing, duration, geographical extent, and severity of the Gulf of Mexico dead zone
- Demonstrated improved hurricane related storm surge forecasting by coupling the widely used storm surge model--Sea, Lake, and Overland Surges from Hurricanes (SLOSH)--with a wave model
- Improved modeling for more accurate and timely information about waves and rip currents for use by beachgoers
- Produced during Hurricanes Isaac and Sandy in 2012, a group of Advanced Circulation (ADCIRC) storm surge forecasts on five different grids (with varying resolutions in different areas) on four different high performance computing systems. NOAA, USACE, USCG and others used the tool to access over 200 storm surge forecasts during the storms

In Fiscal Year 2013, funding dependent, the U.S. IOOS Program plans to maintain the infrastructure of the COMT and expand its geographical coverage and focus areas through a 5-year competitive cooperative agreement with a non-Federal partner. The planned effort will focus on enhancing the transfer of research to operations and expanding engagement with multiple Federal agencies.

National Modeling

For decades, mariners in the United States have depended on NOAA's tide tables for the best estimate of expected water levels. These tables provide accurate predictions of the astronomical tide—the change in water level due to the gravitational effects of the moon and the sun and the rotation of the Earth—but they cannot predict water-level changes due to wind, atmospheric pressure, and river flow, which are often significant. In 2012, the Center for Operational Oceanographic Products and Services developed two operational forecast systems for the Northern Gulf of Mexico Operational Forecast System (NGOFS) and the Columbia River Estuary Operational Forecast System (CREOFS) to provide mariners with short-term predictions of wind, water levels, water currents, water temperatures, and salinity in the northern Gulf of Mexico and Columbia River Estuary. NGOFS outputs are already used for emergency response by the USCG and NOAA’s Office of Response & Restoration (OR&R) for Search and Rescue (SAR) and hazardous materials operations. Developed in partnership with the Office of Coast Survey, the NWS, and the University of Massachusetts, NGOFS uses a hydrodynamic model to generate nowcast (past few days to the present) and forecast information for the continental shelf and coastal areas between Pensacola, Florida, and Corpus Christi, Texas.

In 2011, CO-OPS unveiled three new Operational Forecasts Systems developed in a joint project with the Office of Coast Survey's Coast Survey Development Laboratory. The systems are based on Rutgers University's three-dimensional Regional Ocean Modeling System and are used to forecast water levels, currents, temperature, and salinity for Chesapeake Bay, Delaware Bay, and Tampa Bay. The models run on NOAA's high-performance computers in a new Coastal Ocean Modeling Framework. The forecasts support the maritime user communities in navigation, emergency response, and ecological forecasts with present and future conditions of water levels, currents, temperature, and salinity. In addition, the Great Lakes Operational Forecast System (GLOFS) was transitioned to a central computer system. GLOFS provides nowcasts and short-term forecast guidance of the physical conditions of the five Great Lakes, including two-dimensional water levels and three-dimensional water currents, and water temperature. This information, combined with wind and wave forecasts, provides users with a complete forecast package of marine conditions in the Great Lakes.

By the end of 2012, CO-OPS operated 13 operational forecast systems, with ten running on NOAA’s high-performance computers, which are also used for all other NOAA operational forecast systems developed by NWS. CO-OPS disseminates all operational modeling products and graphics via the internet to ensure reliable and timely access by the public.

Regional Modeling

Regional modeling augments efforts at the national level by providing the detailed resolution needed to address local and regional issues. All 11 RAs support coastal modeling to provide an integrated and comprehensive look at the ecosystem and to provide forecasting capabilities that so many users demand. The U.S. IOOS website has a feature called Modeling Galleries, http://www.ioos.noaa.gov/modeling/galleries.html, with links to on-going ocean modeling and forecasting activities across U.S. IOOS, including the RAs and key Federal partners.

Specific examples of Regions providing modeling and analysis capability to support their stakeholders are plentiful. One example is a joint research project between NOAA's Auke Bay Lab and Alaska Department of Fish & Game (ADFG), which has shown a strong correlation over the past 51 years between certain oceanographic conditions and salmon run timing. Over the past 2 years, AOOS, ADFG, and NOAA have partnered to help share data to further explore the ability of this relationship to provide fisheries biologists with the best possible oceanographic information to manage the run. Using the percent of spring ice cover between St. Lawrence Island and the Yukon delta, April air temperatures in Nome, and marine surface temperatures just offshore of the delta in May, the members of the team predicted the timing of the run in the last two seasons to within three days of the actual timing before the start of each run.

Additional regional modeling efforts include, but are not limited to:

- CariCOOS is running five sub-regional wave and circulation models for the near shore areas of San Juan and Ponce Harbors, and validation of these models have shown improvements in the harbor forecasts. SCCOOS and CeNCOOS released a California-wide high resolution ocean model. The Regional Ocean Model has a 3-km resolution with real-time data assimilation and nowcasting/forecasting capabilities. The model is now running continuously, and is producing nowcasts every 6 hours and a daily 72-hour forecast for the California domain.
- PacIOOS developed high sea level forecasting products for nine areas around the Pacific. The forecasts are available to the public online and provide a 7-day advance notice of the potential for high sea level and coastal inundation. Each of the nine sites is either a busy harbor or a low-lying atoll, two environments that experience and react to ocean 'sea and swell' differently and are greatly impacted by high water level events. The sites are: Hilo and Kawaihae Harbor, Hawai'i; Honolulu, Moku o Lo'e O'ahu; Kahului, Maui; Nawiliwili, Kaua'i; Pago Pago, American Samoa; Kwajalein, Majuro, Marshall Islands.
- NERACOOS developed the Scituate Inundation Forecast System for forecasting coastal hazards: Nor'easters, hurricanes, and other coastal storms; and was used in both Hurricanes Irene and Sandy.
- SECOORA is running the South Atlantic Bight Gulf of Mexico (SABGOM) model on a 24/7-basis, providing 3-dimension regional ocean predictions of currents, salinity, water temperature, and height in both forecast and hindcast modes. SECOORA also supports a high-resolution storm surge inundation model that covers the entire SECOORA domain. In addition to directly supported SECOORA models, access to operational ocean models is provided at http://secoora.org/maps/interactivemodelmap.php.

Chapter 3
Data Management

Observations are of little value if they cannot be found, accessed, and transformed into useful products. The U.S. IOOS Data Management and Communications subsystem, or "DMAC," is the central operational infrastructure for assessing, disseminating, and integrating existing and future ocean observations data. As a core functional component for U.S. IOOS, establishing DMAC capabilities continues to be a principal focus for the program and a primary responsibility of the U.S. IOOS Program Office in NOAA.

Importance and Objectives of DMAC

Although DMAC implementation remains a work in progress, a fully implemented DMAC subsystem will be capable of delivering real-time, delayed-mode, and historical data. The data will include *in situ* and remotely sensed physical, chemical, and biological observations as well as model-generated outputs, including forecasts, to U.S. IOOS users and of delivering all forms of data to and from secure archive facilities.

Achieving this requires a governance framework for recommending and promoting standards and policies to be implemented by data providers across the U.S. IOOS enterprise, to provide seamless long-term preservation and reuse of data across regional and national boundaries and across disciplines. The governance framework includes tools for data access, distribution, discovery, visualization, and analysis; standards for metadata, vocabularies, and quality control and quality assurance; and procedures for the entire ocean data life cycle. The DMAC design must be responsive to user needs and it must, at a minimum, make data and products discoverable and accessible, and provide essential metadata regarding sources, methods, and quality.

The overall DMAC objectives are for U.S. IOOS data providers to develop and maintain capabilities to:

- Deliver accurate and timely ocean observations and model outputs to a range of consumers; including government, academic, private sector users, and the general public; using specifications common across all providers
- Deploy the information system components (including infrastructure and relevant personnel) for full life-cycle management of observations, from collection to product creation, public delivery, system documentation, and archiving
- Establish robust data exchange responsive to variable customer requirements as well as routine feedback, which is not tightly bound to a specific application of the data or particular end-user decision support tool

U.S. IOOS data providers therefore are being encouraged to address the following DMAC-specific objectives:

- A standards-based foundation for DMAC capabilities: U.S. IOOS partners must clearly demonstrate how they will ensure the establishment and maintenance of a standards-based approach for delivering their ocean observations data and associated products to users through local, regional and global/international data networks
- Exposure of and access to coastal ocean observations: U.S. IOOS partners must describe how they will ensure coastal ocean observations are exposed to users via a service-oriented architecture and recommended data services that will ensure increased data interoperability including the use of improved metadata and uniform quality-control methods
- Certification and governance of U.S. IOOS data and products: U.S. IOOS partners must present a description of how they will participate in establishing an effective U.S. IOOS governance process for data certification standards and compliance procedures. This objective is part of an overall accreditation process which includes the other U.S. IOOS subsystems (observing, modeling and analysis, and governance)

Progress on DMAC

Since the completion of the U.S. IOOS Data Integration Framework project in 2010 and the development of a DMAC implementation plan in 2011, the U.S. IOOS Program has been working closely with data management experts at the RAs, NOAA, and other Federal partners to execute a series of coordinated and incremental enterprise-level solutions to improve the overall interoperability of ocean observations data via community-based technology standards and tools, using a web-services oriented architecture. This process is being carried out through a consensus-building approach in which drivers and decisions are openly and extensively documented online and shared widely. Highlights of this progress are presented below.

Core Web Services

The infrastructure for our digital world today is the World Wide Web, which is also the infrastructure for DMAC. This fundamental decision means U.S. IOOS is not building infrastructure. Instead, it is leveraging the web's existing architecture and building the base layer for digital exchange on web services, not web sites.

Working closely with data management experts from partner organization, the U.S. IOOS Program Office is in the process of deploying and testing open-source software for web-based data access services that operate and behave consistently across data providers. The work is based on accumulated experience and best practices by the U.S. IOOS community.

Clear documentation of these services and concerted dissemination and deployment efforts will result in highly consistent data services across providers, while supporting broader ocean data interoperability and standards-adoption efforts. Adoption should also ease configuration management and community-wide deployment of future enhancements. The resulting system-of-systems will provide a functional foundation for the emerging U.S. IOOS Catalog for data discovery and access to existing services. Future refinements and enhancements will be prioritized, tested, and agreed on through a continuation of the successful community process that has been put in place, balancing the pragmatic needs of data providers and consumers with new developments in technology and standards.

Partners in this process include the 11 U.S. IOOS RAs, three NOAA organizations (NWS/NDBC, the National Ocean Service (NOS) CO-OPS, and the National Marine Fisheries Service (NMFS) Chesapeake Bay Office) and the USACE. The new capabilities are expected to help meet the rapidly evolving expectations of U.S. IOOS customers and enable data providers to reach a wider audience of potential consumers than ever before. The system-of-systems created by this network of providers and resources will also serve as a foundation for U.S. IOOS interactions with overlapping data interoperability systems, such as ones focusing on hydrology and water quality in continental waters.

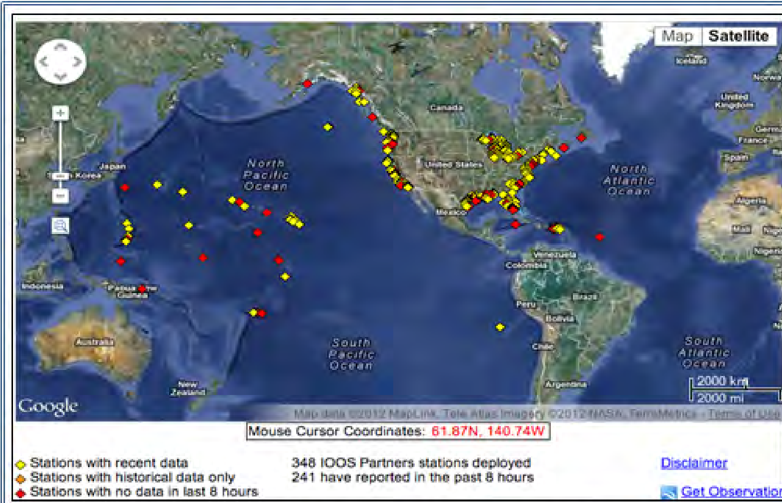
Registry and Catalog

A services registry and a catalog of assets are essential and complementary features for a successful DMAC subsystem. The registry provides a searchable list of on-line ocean observing web services, or storefronts, where consumers can browse or download data. The catalog is a discovery portal that displays locations, operational status, and other information about the observing assets or instruments published through these same data services. As these functions emerge and mature, they will provide a seamless, authoritative access point for ocean observations, simplifying system monitoring and enabling powerful data integration for all types of users.

Preliminary versions of the U.S. IOOS registry and catalog are accessible through the U.S. IOOS website, where the number of registered data services is steadily increasing. Enhanced versions of both functions will be deployed in 2013. Implemented in tandem with the U.S. IOOS core services described above, the registry and catalog functions will significantly enhance existing information technologies that are already being broadly leveraged across U.S. IOOS, delivering data and products to an interdisciplinary set of users.

The planning and execution of the registry and catalog are being conducted in close collaboration with many different technical partners, including staff and contract partners at in the RAs, several NOAA programs that specialize in data collection and data stewardship (NDBC, CO-OPS, National Geophysical Data Center, and the National Oceanographic Data Center), and several Federal agencies including NASA, USGS, and USACE.

U.S. IOOS Data Assembly Center



Stations in the U.S.IOOS DAC operated by NDBC

Early in the formulation of the U.S. IOOS vision, the NDBC took on the task of becoming the U.S. IOOS Data Assembly Center (DAC), collecting data from regional ocean observing systems, quality controlling the data, and distributing it in real-time via the Global Telecommunications System (GTS), and via their website and netCDF files. As a result of the NDBC efforts, there are approximately 350, non-Federal observing stations in the coastal ocean and Great Lakes contributing to the Federal data stream that goes out over the GTS.

NOAA's CO-OPS, NDBC, and the U.S. IOOS Program Office have been collaborating for several years on a data integration project that aim to increase interoperability between data providers and the user community. The joint effort has recently focused on the implementation of NDBC and CO-OPS' Sensor Observational Service (SOS) as part of a suite of web services, offering various new protocols, formats, and an expanded set of sensor variables. This suite of new web services enhanced the data and services that CO-OPS and NDBC were already providing through traditional web pages and facilitated machine-to-machine data transfer over the internet.

Vocabularies

The use of standard terms or vocabularies to describe ocean observations data is critical to facilitating broad sharing and integration of data. Working closely SECOORA and the community-based Marine Metadata Interoperability Project, U.S. IOOS has published nine recommended vocabularies over the past 12 months for review by the ocean observing community including lists for platforms, parameters, core variables, and biological terms. These efforts are helping lead the ocean observing community towards significantly improved levels of consistency via an improved semantic framework through which users can adopt recommended vocabularies or convert their vocabularies to terms that are perhaps used more widely.

Biological Observations Data Project

The objective of the Biological Observations Data Project (BDP) is to support the development of an efficient and effective information infrastructure for biological observations data (i.e., fish species and abundance) and adding components and web links as necessary to serve customers and end-users. It is designed to promote biological data standards and interoperability to help U.S. IOOS customers and end-users access observations from a wide variety of sources and formats.

Databases currently in use have been developed by disparate organizations, institutions, and individuals for differing purposes, and result in databases with locally-specific structures, contents, methods, and policies. In addition, these data and applications are diverse and may change over time. As such, data from one source might contain different variables depending on when it was collected. These differences can make retrieving data across databases a time-consuming and ineffective process. This U.S. IOOS BDP project aims to improve access to data from these diverse sources, such as independent fisheries surveys conducted by NOAA, local State Fisheries Agencies, USGS, the U.S. Navy, Bureau of Ocean Energy Management (BOEM), and other government agencies.

The U.S. IOOS BDP project consists of three planned phases. The first phase was completed in September 2011 and focused on reconciling community data/metadata content and access standards based on existing international standards for biodiversity data (e.g., IOC, OBIS, and GBIF Biodiversity Information Standards). These standards were published in 2011 and implemented in PacIOOS to improve access to reef fish data collected by NOAA's NMFS and NOS, the Department of Interior (DOI), and NPS. This reef fish data is now used to establish reef fish Annual Catch Limits for the U.S. Pacific Islands as defined by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA).

The second and current phase of the BDP project is focused on conducting an extensive test on the portability of the standards developed in the first phase to other U.S. IOOS regions and for other type of biological data. In 2012, U.S. IOOS began testing the data standards in two RAs, GCOOS and SECOORA. Once the current phase is completed, U.S. IOOS will initiate the third phase to implement the biological data content and access standards in all 11 RAs to improve access to biological data to support and sustain our living marine resources.

Quality Assurance of Real-Time Ocean Data

As part of the U.S. IOOS DMAC core services, the U.S. IOOS Program Office initiated a sustainable, community-based project to establish written authoritative procedures for the quality control of real-time ocean sensor data collected for U.S. IOOS. This project is entitled the Quality Assurance of Real-Time Ocean Data (QARTOD), and formalizes cumulative efforts from previous community efforts and meetings. All of the known QA/QC programs in existence today provide parts to the solution, but none consolidates them in one document. The result of this effort is to develop consistent practices that can become formal U.S. procedures for data from the RAs and the ocean observing community at large.

The objective is a sustainable process that will:

- Establish authoritative QA/QC procedures for each of the 26 U.S. IOOS core variables as necessary, including detailed information about the sensors and procedures used to measure the variables
- Produce written manuals for these QA/QC procedures
- Define baseline QA/QC procedures from the list of individual QA/QC procedures and guidelines developed that can be used for certification of Regional Coastal Ocean Observing System (RCOOS) data providers
- Facilitate QA/QC integration with GOOS and other international ocean observation efforts
- Engage the Federal agencies and RAs that are part of, or contribute to, U.S. IOOS that will use the established QA/QC procedures
- Work efficiently, without duplication of effort, to facilitate the implementation of common QA/QC procedures amongst U.S. IOOS partners

The first document from this process is a procedure manual on dissolved oxygen measurements published in December 2012. U.S. IOOS will publish manuals on waves, currents, temperature, and salinity in 2013.

DMAC Steering Committee

The DMAC Steering Team (ST) is an advisory body on the execution and management of DMAC commissioned by the Interagency Ocean Observation Committee per their responsibility to oversee the overall execution and management of U.S. IOOS. The purpose of the ST is to:

- Provide the IOOC with strategic guidance on DMAC-related activities and challenges
- Maintain focus on DMAC subsystem elements (i.e., discovery, transfer, access, archive)
- Identify and solve specific data management challenges within the ocean observing realm
- Serve as a forum for collaboration among U.S. IOOS agencies and partners on DMAC issues

ST members are from Federal agencies that sit on the IOOC, though interested stakeholders from State and regional government, academia, industry, and non-profit organizations routinely attend the meetings and participate in discussions. The ST meets approximately twice a year to discuss technical issues, share information about DMAC challenges and success, and work together on DMAC priorities identified by the ST Chair and IOOC members. It provides a useful and important forum for informing the broad U.S. IOOS community about DMAC progress and for working together to facilitate the definition and wide use of key standards and protocols.

Chapter 4
Governance and Management

Introduction

One of the central objectives of the U.S. IOOS program is to fully establish the governance and management structure to support the program in terms of policy, plans, guidance, resources, processes, tools, and management infrastructure. By providing guidance and policy, requirements may be prioritized and user needs addressed through the coordinated efforts of the U.S. IOOS partners. In addition, the establishment of a certification process for non-Federal assets will ensure their eligibility for integration into the System.

Federal Agency Governance

As directed by the ICOOS Act, the IOOC was chartered in June 2010 as a Federal interagency committee that oversees and coordinates U.S. IOOS development efforts. Under their charter, the IOOC assumed and is expanding the role of the former Interagency Working Group on Ocean Observations (IWGOO), which was originally established by the National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology (JSOST) under the previous Administration’s Ocean Action Plan. In coordination with the National Ocean Policy established in July 2010, the IOOC will carry out various provisions of the Act for implementing procedural, technical, and scientific requirements to ensure full execution of the system. The IOOC is led by three Federal co-chairs and is comprised of representatives from 11 Federal agencies. See Appendix A for the list of IOOC members. The other members of the statutorily-mandated NORLC are also eligible to join the IOOC.

Regional Governance

The 11 U.S. IOOS RAs provide U.S. IOOS with regional expertise and a direct, local connection to users that the system depends on to address the diversity of needs across the Nation. Each RA is a partnership of marine and estuarine data providers and stakeholders that serve the Nation’s coastal communities, including the Great Lakes, the Caribbean and the Pacific Islands and territories. The RAs have users from Federal, State, local, and tribal agencies; private industry; non-

governmental institutions; and academia that provide a connection to and understanding of regional and local user needs. RAs are responsible for managing system development within the region and working with stakeholders to prioritize observations, products, and services that are most important, given available resources. Each has an established governance structure guided by a Memorandum of Understanding, Memorandum of Agreement, or non-profit organization guidance to formalize relationships among the many partners involved in the region. A full list of the regional partners can be found in Appendix A.

The RAs are collectively represented by the IOOS Association (formerly called the National Federation of Regional Associations for Coastal and Ocean Observing (NFRA)), which is a non-profit organization formed by the RAs in support of U.S. IOOS. Each of the 11 RAs appoints two representatives to serve on the Board of Directors which meets biannually to promote the integration and coordination of the regional systems into an integrated national system.

Prior to FY 2011, each U.S. IOOS regional partner received two Federal funding awards—one for development of the RCOOS and one for planning and stakeholder engagement by an RA. Starting in FY 2011, U.S. IOOS made a single competitive 5-year award to each RA to provide coordination with regional stakeholders and contribute data and other outputs to the national system.

Certification

With passage of the ICOOS Act, the IOOC was directed to:

> “develop contract certification standards and compliance procedures for all non-Federal assets, including regional information coordination entities, to establish eligibility for integration into the System and to ensure compliance with all applicable standards and protocols established by the Council, and ensure that regional observations are integrated into the System on a sustained basis.”

In 2010, the IOOC chartered two working groups of subject matter experts to draft certification criteria for U.S. IOOS data partners and the RAs, who function as the regional information coordination entities. These criteria assure the necessary policies, standards, data, information, and services associated with the System are appropriately established, coordinated, overseen and enforced.

The IOOC approved the draft criteria in October 2011 and then released the draft criteria for public comment. After a sixty-day public comment period and subsequent adjudication of comments received, the IOOC approved final certification criteria. The final criteria were announced in the Federal Register in May 2012, and are available at: http://www.iooc.us/wp-content/uploads/2012/05/IOOS-Certification-Criteria_4-25-12.pdf.

NOAA was also directed under the ICOOS Act to promulgate program guidelines to certify and integrate non-Federal assets, including RAs, into U.S. IOOS. The program guidelines identify the process and requirements for certifying RAs that satisfy the IOOC approved criteria. When certified, the RA is incorporated into U.S. IOOS. After incorporation, for the purposes of determining liability arising from the dissemination and use of observation data, the RA shall be considered part of NOAA, and with respect to tort liability, designated employees of the RA will be deemed to be employees of the Federal Government.

The U.S. IOOS Program Office is preparing to publish the draft program guidelines in the Federal Register as a Notice of Proposed Rulemaking. After publication, the program guidelines will be available for comment and review. After adjudication of comments received, the final program guidelines will be published. The U.S. IOOS Program Office plans to offer the opportunity for certification by summer 2013.

System Advisory Committee

An additional requirement of the ICOOS Act was for the NOAA Administrator to establish a System Advisory Committee to provide advice to NOAA and the IOOC on the administration, operation, management, maintenance, expansion, and modernization of U.S. IOOS.

In July 2012, NOAA formally established this Federal advisory committee, named the U.S. IOOS Advisory Committee. The committee is composed of thirteen members, appointed by the NOAA Administrator, who are qualified by education, training, and experience to evaluate scientific and technical information related to the design, operation, maintenance, or use of U.S. IOOS, or use of data products provided through U.S. IOOS. The committee held its first meeting on August 29 and 30, 2012, and plans to release a visionary statement in 2013 for messaging to the new Presidential Administration, as well as the community at large.

Initial Members of the IOOS Advisory Committee and the Designated Federal Officer (DFO) Staff. Members represent industry, academia, and non-governmental organizations

Chapter 5
System Assessments

Overview

The ICOOS Act calls for an external independent programmatic audit of U.S. IOOS, but while progress has been made in establishing the infrastructure for U.S. IOOS both programmatically and technically, it is a complex system that will take multiple years to fully implement. As such, it has not reached the maturity or functionality that would make an independent program assessment beneficial at this time.

U.S. IOOS, however, is fully committed to providing an unbiased evaluation of progress and capabilities, and in the past 2 years the program has undertaken several assessments of the system. Chief among these assessments was the IOOC-led independent cost estimate for operating and maintaining U.S. IOOS. The IOOS Program Office also conducted an assessment of the current state of the program infrastructure, using the activities listed in the Blueprint as the baseline for evaluation. And finally, U.S. IOOS is currently conducting an assessment of observation coverage.

Independent Cost Estimate

In accordance with the ICOOS Act, the IOOC obtained an Independent Cost Estimate (ICE) of U.S. IOOS, and NOAA delivered the ICE to Congress in November 2012. The purpose of the ICE is to provide Congress and the Administration with an independent analysis of the cost of the Nation's integrated ocean observing systems. The scope of the analysis includes many existing Federally-run programs, such as the nationwide tide gauges network maintained for safe navigation, and existing Federally-funded programs, such as the HF radar network maintained regionally to measure surface currents in coastal areas. In addition, the analysis includes the 'system of systems' that provides the capabilities required to provide the Nation with integrated, multi-functional datasets, products and services that are useful to inform coastal, Great Lakes, and ocean decisions. The ICE is located at http://www.ioos.noaa.gov/ice/welcome.html.

The ICE identifies costs in three distinct components: Federally operated, non-Federally operated, and central functions:

- Federal – Agencies that are executing appropriated national ocean observing programs
- Non-Federal – Regional, non-Federal entities, focused on meeting regional and local constituent needs, using Federal and non-Federal funding

- Central Functions – U.S. IOOS-unique functions required to develop, operate, maintain, coordinate and manage the System to deliver to the Nation ocean, coastal, and Great Lakes information in an easily accessible and usable form

The cost estimate spans 15 years, comprised of a 10-year build-out period followed by 5 years of sustained operations. The ICE does not include the acquisition cost of assets already in use, nor does it include unfunded Federal agency requirements. It does include costs to replace equipment during the 15-year span of the ICE.

Blueprint Assessment

U.S. IOOS Blueprint for Full Capability (the Blueprint) is a framework for U.S. IOOS program development and execution, which describes in detail the activities and structure necessary for progressing toward full capability. The Blueprint incorporates all the tasks for coordination and execution of an effective U.S. IOOS as stated and implied in foundational U.S. IOOS community guidance documents and ICOOS Act mandates. The larger system was described in terms of six subsystems: observation management; DMAC; modeling and analysis; education and training; research and development; and governance and management of the system. The architectural guidance and documentation in the Blueprint are used to do the following:

- Establish initial requirements
- Describe what needs to be accomplished, who executes it, and in what order
- Provide functional descriptions, including working relationships among U.S. IOOS components

In 2011, based on the framework established in the U.S. IOOS Blueprint, the U.S. IOOS Program Office completed an assessment of each of the Federal partners and the RAs to determine which functions and activities are currently being performed and which activities remain to be developed.

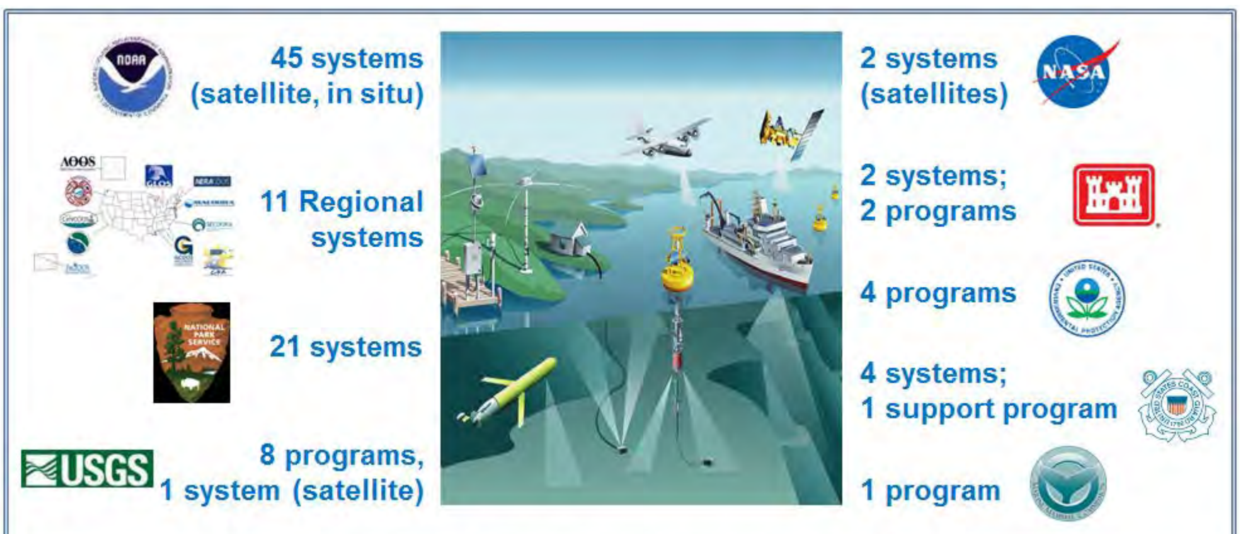
This assessment reviewed program requirements as described in the Blueprint, not user and customer observation requirements (the products and services provided by U.S. IOOS partners). The figure to the right further explains this distinction with a high-level depiction of partner roles. The assessment collected data from Federal and non-Federal U.S. IOOS partners in the blue and green areas (core functional activities and U.S. IOOS assets).

Roles of U.S. IOOS Partners

The assessment found some Federal partner activity in all the major functional activities, with the exception of education and training. However, because of their various missions, most Federal partners do not routinely perform core functional activities needed by U.S. IOOS. In addition, as to be expected, the findings revealed significant diversity in the capabilities and capacities of its member organizations. A noteworthy finding includes identification of areas where various Federal partners have the capability and routinely perform activities that can fill known observational gaps in other organizations. The assessment recommended pursuing partnership agreements between partners to provide these capabilities.

Regarding Regional progress, the assessment found that there is also a variation in the level of capability among the RAs; however, they are generally active in all subsystems listed in the Blueprint due to their primary mission of U.S. IOOS-related activities. The RAs collectively provide an initial solid foundation of U.S. IOOS capabilities and are generally strongest in the governance and management subsystem, with significant capability in terms of marketing, outreach, and engagement, plans and operations, and customer needs.

While the major focus of the Blueprint assessment was to review program activities, an additional feature of the assessment survey was to request information identifying the observing systems that contribute to U.S. IOOS. The following graphic provides a high-level view of the organizations that supply observation data.



Observing systems or programs that contribute to U.S. IOOS

Observation Gap Analysis

U.S. IOOS continues to work towards awareness and integration of all available observational assets; however, the U.S. IOOS community currently lacks a fully integrated view of observing gaps and a mechanism to express those gaps. The need for a central collection point and process for gap assessment is a universal and enduring problem, regardless of the observing platform. However, the program is working to address that need and, while U.S. IOOS as an enterprise lacks an integrated understanding of observation gaps, each Federal and regional partner has an understanding of their current capabilities, requirements, and resulting gaps. In addition to the Federal effort described in this section, the RAs completed 10-year build out plans, which also serve as a baseline for full capability and the gaps that exist. More detail about the RAs' build out plans is provided in the next section of the document.

Since late 2011, the U.S. IOOS Program Office has worked to capture all existing observation capabilities as well as user observation requirements. The U.S. IOOS Program Office coordinated with the NOAA Technology, Planning and Integration for Observation (TPIO) office to have U.S. IOOS Federal and regional observational assets included in the NOAA Observing Systems Architecture (NOSA), a database for observing capabilities. In addition, the Program Office began formally coordinating with TPIO to employ NOAA's Consolidated Observation Requirements List (CORL) database to catalog the requirements for U.S. IOOS observations.

Once U.S. IOOS observing assets are in the NOSA database and U.S. IOOS observation requirements are in the CORL database, U.S. IOOS can make use of established TPIO analytic methodologies to assess which U.S. IOOS partners can best meet which observation requirements across the community. This analysis is central to ongoing efforts by U.S. IOOS to integrate ocean and Great Lakes observing capabilities, and will inform U.S. IOOS partner planning for, and management of, ocean and Great Lakes current and future observing capabilities.

Starting in 2012, the U.S. IOOS Program Office also began the development of an automated inventory of partner observational assets for the U.S. IOOS enterprise. This asset inventory will provide near real-time and historical status of datasets and instruments and will be an important tool to: benchmark development of U.S. IOOS observing capabilities and DMAC services in future years, answer budgetary inquires, assist with real-time operations, update the NOSA database, and facilitate gaps analyses. It will use previously defined controlled vocabularies and will be compatible with future metadata and web service developments. The first phase of the inventory, focusing on regional observational assets, is expected to be completed by September 2013.

Regional Build-Out Plans

The 11 RAs have also developed regional build out plans for the next 10 years which, taken together, describe the observing and data requirements for a fully capable coastal component of U.S. IOOS. The IOOS Association through support from the U.S. IOOS Program Office has synthesized these plans into a larger regional build out document to provide a long term vision for integrating with U.S. IOOS partners.

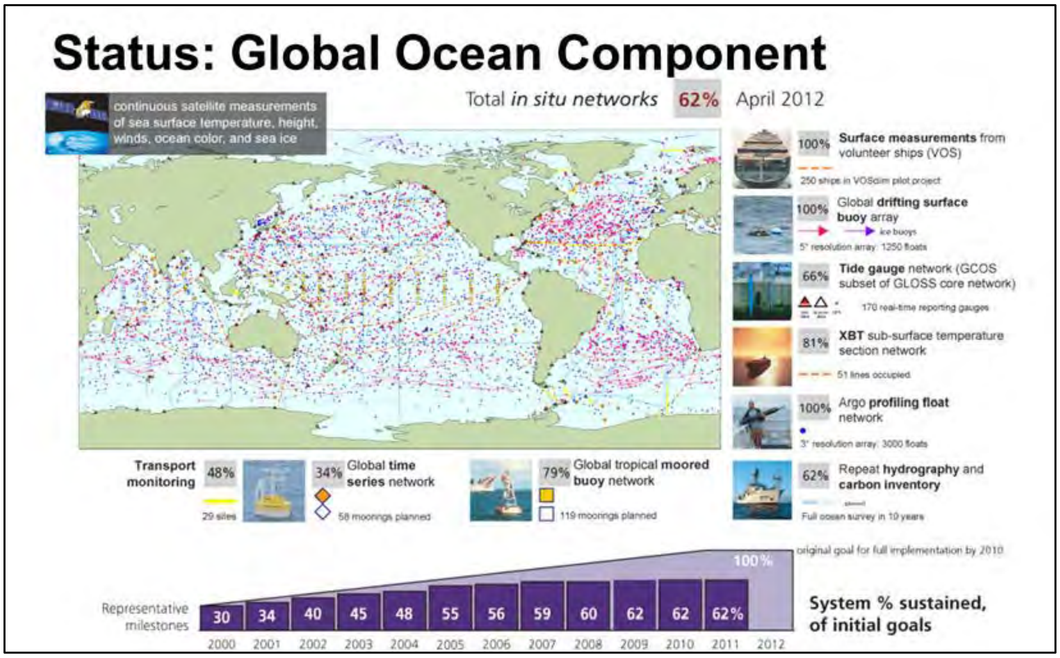
The RAs consolidated the priority user needs in four categories: 1) marine safety and operations; 2) coastal, beach and near shore hazards; 3) long-term trends in coastal conditions; and 4) water quality and ecosystem. These broad themes and specific user needs associated with them are based on many years of interaction by the RAs with users in their regions and nationwide. Each RA projected what the priorities needs would be in their regions over a 10 -year period and designed an observing system (models and observations, data management, product development and governance) that would be needed to fulfill those needs.

Observations assets identified in the consolidated Regional Build Out Plan

The plans clearly highlight major gaps in observing capacity, particularly for biological information. A national synthesis of the 11 regional plans identifies common elements across the regions as well as the importance of a regional approach to address the unique and diverse needs of users. The national synthesis document defines 29 common products and services that should be available in all the regions after a 10-year implementation period, and is located at [http://www.ioosassociation.org/sites/nfra/files/documents/ioos_documents/regional/BOP%20Synthesis%20Final.pdf.](http://www.ioosassociation.org/sites/nfra/files/documents/ioos_documents/regional/BOP%20Synthesis%20Final.pdf)

Future Analysis

The various gap assessment projects underway will lead to the definition of the desired initial end state for U.S. IOOS, similar to that developed by the GOOS. GOOS has established an official end state as shown in the below figure, which describes the global goal of sustained ocean observing systems.



A similar understanding of what will constitute initial success for U.S. IOOS does not exist; therefore the assessments are collecting information on candidate observing, data management and research infrastructure from the Federal agencies. The Blueprint assessment identified current assets contributing to U.S. IOOS, and the next steps are to identify how they fit together and where are the observation gaps.

Chapter 6
The Way Ahead for U.S. IOOS

U.S. IOOS has demonstrated substantial progress toward the vision of a fully integrated ocean system that enables service to the Nation through: improved ecosystem and climate understanding; sustained living marine resources; improved public health and safety reduced impacts of natural hazards and environmental changes; and enhanced support for marine commerce and transportation. For the first time, the U.S. has the integrated capability that allows observations from the regional, national, and global levels to be brought to bear on critical societal needs.

U.S. IOOS investments in remote and *in situ* observations, environmental modeling, improved interoperability between diverse systems, and the implementation of data standards is supporting real-time decision making by: industries such as shellfish hatcheries, traditional and renewable energy, maritime transportation; government agencies that ensure public health and safety including NWS, USCG, and USGS; and public utilities who provide safe drinking water and energy services to their local communities.

U.S. IOOS has made significant strides in the last 2 years to continue to implement actions codified in the ICOOS Act. In July 2012, NOAA formally established the System Advisory Committee which held its first meeting in August 2012. The IOOC obtained and NOAA delivered the Independent Cost Estimate to Congress providing an analysis of the full capability cost of U.S. IOOS. The IOOC delivered certification criteria for non-Federal assets in 2012, and the U.S. IOOS Program Office expects to begin offering non-Federal assets the opportunity for certification in 2013.

In 2011, U.S. IOOS used the framework established in the U.S. IOOS Blueprint to complete an assessment of each of the Federal partners and the RAs to determine which functions and activities are currently being performed and identify gaps in activities and structure to achieve a full capability. In addition, the RAs developed build out plans, which describe the observing and data requirements for a fully capable regional component of U.S. IOOS. The U.S. IOOS Program Office also began the process of developing an automated, on-line inventory of partner observational assets that will be used to facilitate a future gap analysis. These assessments will lead to the definition of the desired end-state for U.S. IOOS.

The IOOC convened the U.S. IOOS Summit 2012 in November 2012 to review progress toward development and implementation of U.S. IOOS since the foundational workshops held between 2002 and 2005. The 200 summit participants acknowledged the notable successes over the past 10 years to develop a functional U.S. IOOS. They recognized the significant maturation of U.S. IOOS including the establishment of the initial operating capability that supports real-time decision making. The initial operating capability has resulted in communities of practice being developed around IOOS, its subsystems, and regional responses to coastal information challenges that have strengthened ocean science contributions to address societal needs. A declaration was signed at the summit, stating that U.S. IOOS will provide the knowledge needed by society to protect life and property, to sustain a growing economic vitality, to safeguard ecosystems and to advance quality of life for all people. Building upon progress over the past several decades, the U.S. must continue to expand, improve and sustain the system to address the growing societal needs for ocean observations and information.

The value of U.S. IOOS to integrate ocean systems is demonstrated by its success stories. The ability of U.S. IOOS to achieve a fully integrated ocean observing system is dependent upon the combined efforts of all of its Federal agencies, regional associations, and industry to collaboratively provide integrated data and information to its users that result in informed decisions that produce economic, societal, and environmental benefits to the Nation.

Appendix A: U.S. IOOS Partners

Federal Partners

Federal agencies provide active support, funding, guidance, or advice to U.S. IOOS. Below is a list of some of U.S. IOOS' Federal partners. The asterisks in the list below denote the 11 Federal partners who are active members of the Interagency Ocean Observation Committee (IOOC).

BOEM	Bureau of Ocean Energy Management *
DOE	Department of Energy
DOS	Department of State
DOT	Department of Transportation
EPA	Environmental Protection Agency *
FDA	Food and Drug Administration
MMC	Marine Mammal Commission *
NASA	National Aeronautics and Space Administration *
NOAA	National Oceanic and Atmospheric Administration *
NPS	National Park Service
NSF	National Science Foundation *
JCS	Oceanographer of the Navy, representing the Joint Chiefs of Staff *
ONR	Office of Naval Research *
USARC	U.S. Arctic Research Commission
USACE	U.S. Army Corps of Engineers *
USCG	U.S. Coast Guard *
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey *

Regional Partners

Regional U.S. IOOS partners provide increased observation density, distinctive knowledge, and technology competencies related to local environments (sea ice, coral reefs, Great Lakes, etc.), as well as support regional and local user needs. Eleven regional associations (RAs) and their associated RCOOS provide the regional component of U.S. IOOS and, once certified, will serve in the capacity of regional information coordination entities as described in the ICOOS Act.

AOOS	Alaska Ocean Observing System
CariCOOS	Caribbean Coastal Ocean Observing System
CeNCOOS	Central and Northern California Ocean Observing System
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GLOS	Great Lakes Observing System
MARACOOS	Mid-Atlantic Regional Association Coastal Ocean Observing System
NANOOS	Northwest Association of Networked Ocean Observing Systems
NERACOOS	Northeastern Regional Association of Coastal and Ocean Observing Systems
PacIOOS	Pacific Islands Ocean Observing System
SCCOOS	Southern California Coastal Ocean Observing System
SECOORA	Southeast Coastal Ocean Observing Regional Association

Evaluation of New and Existing Observation Technologies

The Alliance for Coastal Technologies (ACT) is a competitively selected NOAA-funded partnership of research institutions, resource managers, and private sector companies dedicated to fostering the development and adoption of effective and reliable sensors and sensor platforms for environmental monitoring and the long-term stewardship of coastal ocean resources. It provides the validation and verification of observing sensors, ensuring their accuracy.

U.S. IOOS Modeling Testbed

U.S. IOOS initiated the Coastal Ocean Modeling Testbed (COMT) as a pilot project in June 2010. The Southeastern University Research Association (SURA) is the current project lead through a competitively awarded cooperative agreement. COMT includes partners from six Federal agencies; two private companies and 24 partners from research institutions in the United States and Canada. The mission of the COMT is to accelerate the transition of models from the coastal ocean modeling research community to improve operational products and services.

Appendix B: Acronyms

ACT	Alliance for Coastal Technologies
ADCIRC	Advanced Circulation and Storm Surge Model
ADFG	Alaska Department of Fish & Game
AOOS	Alaska Ocean Observing System
ARGO	Array for Real-time Geostrophic Oceanography
ATN	Animal Telemetry Network
AUV	Autonomous Underwater Vehicle
BDP	Biological Observations Data Project
BOEM	Bureau of Ocean Energy Management
C-MAN	Coastal-Marine Automated Network
CariCOOS	Caribbean Coastal Ocean Observing System
CBIBS	Chesapeake Bay Interpretive Buoy System
CDIP	Coastal Data Information Program
CeNCOOS	Central and Northern California Ocean Observing System
COMT	Coastal and Ocean Modeling Testbed
CO-OPS	Center for Operational Oceanographic Products and Services
CORL	Consolidated Observation Requirements List
CREOFS	Columbia River Estuary Operational Forecast System
DAC	Data Assembly Center
DART®	Deep-ocean Assessment and Reporting of Tsunami
DFO	Designated Federal Officer
DMAC	Data Management and Communications
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
DOT	Department of Transportation
ECOHAB	Ecology and Oceanography of Harmful Algal Blooms
EEA	European Environment Agency
EPA	Environmental Protection Agency
Esri®	Environmental Systems Research Institute
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
GBIF	Global Biodiversity Information Facility
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GCOS	Global Climate Observation System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHRSST	Global High Resolution Sea Surface Temperature
GLATOS	Great Lakes Acoustic Telemetry Observing System

GLOFS	Great Lakes Operational Forecast System
GLOS	Great Lakes Observing System
GLOSS	Global Sea Level Observing System
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GTS	Global Telecommunications System
HF	High Frequency
ICE	Independent Cost Estimate
ICOOS	Integrated Coastal and Ocean Observing System
IMON	Integrated Marine Observing Network
IMOS	Integrated Marine Observing System
IOC	Intergovernmental Oceanographic Commission
IOOC	Interagency Ocean Observation Committee
IOOS®	Integrated Ocean Observing System
IWGOO	Interagency Working Group on Ocean Observations
IWQN	Integrated Water Quality Network
JCS	Joint Chiefs of Staff
JSOST	Joint Subcommittee on Ocean Science and Technology
MARACOOS	Mid-Atlantic Regional Association Coastal Ocean Observing System
MMC	Marine Mammal Commission
MSRA	Magnuson-Stevens Fishery Conservation and Management Reauthorization Act
NANOOS	Northwest Association of Networked Ocean Observing Systems
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCEP	National Center for Environmental Prediction
NCOOS	National Centers for Coastal Ocean Sciences
NDBC	National Data Buoy Center
NDEP	New Jersey Department of Environmental Protection
NERACOOS	Northeastern Regional Association of Coastal and Ocean Observing Systems
NFRA	National Federation of Regional Associations for Coastal and Ocean Observing
NGOFS	Northern Gulf of Mexico Operational Forecast System
NFRA	National Federation of Regional Associations
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NORLC	National Ocean Research Leadership Council
NOS	National Ocean Service
NOSA	NOAA Observing Systems Architecture
NPS	National Park Service
NSF	National Science Foundation
NWLON	National Water Level Observation Network
NWS	National Weather Service
OBIS	Ocean Biogeographic Information System Observing Systems

OCSD	Orange County Sanitation District
ONR	Office of Naval Research
OOI	Ocean Observatories Initiative
OR&R	Office of Response & Restoration
PacIOOS	Pacific Islands Ocean Observing System
PIRATA	Prediction and Research Moored Array in the Atlantic
PMEL	Pacific Marine Environmental Laboratory
PORTS	Physical Oceanographic Real-Time System
QA	Quality Assurance
QARTOD	Quality Assurance of Real-Time Ocean Data
QC	Quality Control
RA	Regional Association
RAMA	Research Moored Array for the African-Asian-Australian Monsoon Analysis and Prediction
RCOOS	Regional Coastal Ocean Observing System
SAGBOM	South Atlantic Bight Gulf of Mexico
SAR	Search and Rescue
SCCOOS	Southern California Coastal Ocean Observing System
SECOORA	Southeast Coastal Ocean Observing Regional Association
SIFT	Short-term Inundation Forecasting for Tsunamis
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SOS	Sensor Observational Service
ST	Steering Team
STF	Short Term Forecast
SURA	Southeastern Universities Research Association
TAO	Tropical Ocean-Atmosphere
TOPP	Tagging of Pacific Predators
TPIO	Technology, Planning and Integration for Observation
TAO-TRITON	Tropical Ocean-Atmosphere – Triangle Trans-Ocean Buoy Network
TWC	Tsunami Warning Center
UK	United Kingdom
UK-MON	United Kingdom’s Integrated Marine Observing Network
USACE	U.S. Army Corps of Engineers
USARC	U.S. Arctic Research Commission
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
WFO	Weather Forecast Office
WMO	World Meteorological Organization
WRC	World Radio-communication Conference

END NOTES

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