Bi-Weekly Z-GRAM 3 October 2008
www.IOOS.NOAA.gov

The Z-gram is an informal way of keeping you up to date on IOOS® activities. Please advise of additional addees, or if you are receiving and no longer want to receive. If you think others could benefit from the Z-gram please pass it on. If you want to see previous Z-grams go the IOOS website under program updates. Programmatics:

- Congressional Report: Continues through the formal NOAA administrative system.
- FY09: Happy New Fiscal Year! The President signed into law H.R. 2638, the "Consolidated Appropriations Act, 2009." This Act funds most Federal agencies including NOAA through March 6, 2009 via a Continuing Resolution (CR). . Of this emergency supplemental funding, NOAA is to receive $17 million to accelerate hurricane forecast improvements and $75 million for fisheries recovery. IOOS does not plan to issue a Federal Funding Opportunity for FY09.
- FY10: **No change.**
- FY11-15: Within the PPBES system we continue in the Programing Phase. The goal teams have received program guidance which is both recommendations from PA&E and fiscal guidance. We work within our goals to apportion these dollars to the alternatives that were developed through planning.

Initial Operating Capability - DMAC subsystem of IOOS®
In FY09 we are focused on 6 areas for this subsystem: (1) DIF support to Customer Applications: Harmful Algal Blooms forecast system; Integrated Ecosystem Assessments (IEAs); Coastal Inundation; Hurricane Intensity: (2) DIF Regional Implementation; (3) DIF Evolution & Enhancements; (4) Development of the best approach to DMAC (5) HFR – A National Network; and (6) Continue strong support, with the IWGOO, to the IOOS DMAC Standards Process and working with the DMAC Steering team and the first 5 areas

- IOOS DMAC Standards Process: DMAC Steering Team meeting 8-10 December. Anne Ball met with Becky to discuss biological data and the DMAC Steering Team and Standards process. Anne is interested in developing a plan/ project, for possible execution in the FY10 time frame, for how the Steering Team can more adequately handle and address issues relating to biology.
- What the DIF: Testing will begin soon by CSC to ensure that our two NOAA Providers and one RA are providing data in DIF format. We are also working to provide all DIF documentation and software on our IOOS website by the end of October. As we move into understanding and measuring the value of integration we have worked across NOAA to select projects in each of the areas defined in Dec 2006. I will report on each of these areas. These are not the only efforts through DIF or in these specific areas but are those that we will run through full testing to measure the value of integration but will also deliver capability to the operational and scientific operations.

- HAB: First phase is complete. Surface currents are being delivered into the Gulf of Mexico HAB bulletin. The second phase is a partnership between NCCOS and CO-OPS to evaluate how new data sources now available through DIF would have improved HAB forecasts and continue to work with CO-OPS as they design the next generation of HAB-FS. The discussions on HAB-FS must include our RAs so we get to a clear understanding of the efforts appropriate at the Federal level and those at the Regional and State Level. IOOS Program Lead: Becky
    - **COMPS Platforms' Update:** Three COMPS platforms (currents) are now reporting through NDBC, and therefore in DIF service formats. The data from these platforms will now be available for inclusion in the HAB-FS operational forecast Google Maps tool that is displaying currents from NDBC and CO-OPS. Platforms from COMPS are of great importance to the analysts as they are located within the area of the eastern Gulf most commonly affected by HAB events.
- Coastal Inundation: Partnership with CO-OPS and MDL, TPC and the WFOs – Slidell, and Wakefield to provide new visualization of waterlevel data and SLOSH. This will provide new capabilities by the 2009 Hurricane Season. IOOS Program Lead: Marcia
- Integrated Ecosystem Assessments: Partnership with SWFS - ERD division (Pacific Grove) and NCDDC. This effort focused on bringing DIF, REDM and ERDAP to provide the necessary baseline data for dynamic IEAs. IOOS Program lead: Becky
- Hurricane Intensity: Partnership with NCEP and AOML to provide synthetic temperature profile data and hydrographic data in DIF format into HYCOM and HWRF. We will begin with evaluating this data in previous storms to measure value and then input into the operational model. The goal is to have this operational at the start of the 2009 Hurricane Season – and we will work closely with NCEP to support them. IOOS Program Leads: Marcia/Gustavo Goni (IOOS LCDP/AOML)

- <u>National Surface Currents Project</u>: In FY 09 we will focus on the following:
    - National Server Development, O&M
        - Delayed Mode Database (Scripps)
        - Regional Portal O&M (Scripps, NDBC)
        - Real-time Network Diagnostics Dev & Impl (Scripps)
        - National Server O&M (NDBC, Scripps)
    - QC Algorithms
        - Development: MUSIC (Scripps)
        - Implementation: Previous Year's Dev (Scripps)
    - RF Engineering Studies for WRC
    - National Plan Development (IOOS Program Office and ACT). First draft will be available in November.

Interagency Project Collaboration: The Z-grams are certainly focused on providing information on IOOS® connections to these projects and it is not intended to provide programmatic updates of these specific projects because all of them have project leads.

- Army Corps of Engineers collaboration on a National Waves Plan: ACT is providing a revised way plan to Bill Birkemeier and Bill Burnett by 30 October and our goal is to have the next version out for approval by 15 November.
- NOAA-Navy collaboration on the GODAE server: **No Change**
- National Water Quality Monitoring Network: Ami and Rob (IOOS) have been in contact with representatives with USGS and EPA to become better informed about the National Water Quality Monitoring Network (NWQMN). On Monday, September 29, we discussed the NWQMN and possible areas of collaboration with Jon Scott (USGS); we have a call scheduled with Dwane Young (EPA) on October 3 to get information on EPA's role and perspective.
- OBIS: The OBIS-US Advisory Committee met. There are multiple action items to follow up on including re-review of the Business Plan and writing of a section of the plan. The next regular conference call of the Committee is scheduled for October 22. IOOS Program Lead: Becky.
- Final meeting of the GODAE project: Attached is paper requested by the GODAE project as a look to the future of US Ocean Observing Initiatives. A great collaboration across the Federal and Industry Partners.

Other:

- **Rutgers University - Across the Pond:** **http://rucool.marine.rutgers.edu/atlantic/** Scarlet Knight completed it's 4th month at sea. In those 4 months the glider has travelled over 5000km across the continental shelf, riding in the Gulfstream, and now navigating large ocean eddies. At this point, the glider is 650 km away from the Azores Island of Flores. Rutgers plans to fly the Scarlet Knight as close to Flores and then take a small boat out to check out Scarlet Knight. The plan is to pull the glide on board, give it a thorough cleaning and check out on shore, then send it back on its mission to the European mainland. As well, RU10, RU18 and RU22 are all deployed on the Mid Atlantic Continental Shelf on ONR, DoD and NOAA missions, respectively, coordinated with two NOAA fisheries cruises.
- **Coastal Coordinating Committee (CCC) Meets on Climate Change, Sea-Level Rise (26 September):** The meeting, co-chaired by NOS Assistant Administrator, Jack Dunnigan, Craig Hooks of the Environmental Protection Agency, and the Coastal States Organization (CSO) Chair Brian Baird, explored developing a framework for Federal and State agencies to work together on climate change issues. Representatives from many Federal and State agencies, the National Association of Counties, the Association of State Floodplain Managers. I along with John Haines (USGS) and Miki Schmidt, NOAA (CSC), represented IOOS and the IOCM on a panel and engaged in discussions on how these programs can be more involved as the States understand the data, models

and tools they need to develop Sea Level Rise Plans. While only three states have SLR plans, 80% of the coastal and Great Lakes States indicate that they will be developing a SLR. Molly McCammon, Steve Ramp, Rick Devoe and Mark Luther - AOOS, CeNCOOS and SECOORA and GCOOS also participated and provided a better understanding on the capabilities that can be brought to bear. NOAA further supported this meeting through the Office of Coastal Resources Management and the Climate Program Office. I know I came away with a better understanding of the issues that the States are faced with and thank Coastal States Organization for the opportunity to participate. The meeting materials are available on the CSO website.

- **GEOSS Architecture Implementation (AIP) Kickoff Meeting** – September 24-25; Boulder, CO. Jeff DLB attended the GEOSS Architecture Implementation Pilot (AIP) kickoff meeting in Boulder CO. The IOOS SOS implementations at NDBC and CO-OPS have been offered as resources for GEOSS, which is particularly interested in persistent, operational services providing real data. Interest in these IOOS servers was particularly high in the Disaster Management theme, which plans to use them in a scenario involving a hurricane hitting the Gulf coast in the GEOSS AIP demo in March 2009. (Note: The intent of GEOSS AIP is not merely to have a demo per se, but rather to demonstrate real advances in GEOSS implementation at the end of this phase.) The GEOSS participants in essence constitute a new, cost-free customer for IOOS. GEOSS offers resources that IOOS can use: a Registry of Services and Components, a searchable Catalog, a Portal providing user access. IOOS may also be able to use GEOSS Testing and Monitoring services. Jeff will register the IOOS SOS at NDBC & CO-OPS in the GEOSS Registry.
- **Upcoming IOCARIBE** meeting: US position papers are being drafted. Three are relevant to IOOS - IOCARIBE-GOOS, GLOSS, and ODINCARSA (data management body). Becky is working with NOS-International Affairs to ensure that CaRA is included in the development of these papers and the participation of these activities.

Congressional: No update

Communications:

- HiOOS was recently featured on the Hawaii Public Radio. www.hawaiipublicradio.org/markus/hioos_16.mp3

Upcoming Meetings:

- 19-22 October, Zdenka will participate in Oceans Innovation 2008 World Summit - St Johns, Newfoundland, CA.
- 22-23 October: MACOORA Annual Meeting, UMass-Darthmouth - Zdenka will participate from NOAA IOOS Program.
- 29-30 Oct, Frequency Management for Developing Countries – Jack Harlan

Cheers,
Zdenka

United States Ocean Observing Initiatives – A Look to the Future

A. Zdenka Willis[1], B. Kimberly Cohen[1], C. Dr. Jeff de La Beaujardiere[1], D. Ray Toll[2], E. Jessica Geubtner[3], F. Dr. Ralph Rayner[3], G. Dr. Alexandra Isern[4], H. Dr. Shelby Walker[4], I. Dr. Jonathan Berkson[5], J. Dr. John Haines[6], K. William Birkemeier[7], and L. Dr. Brian D. Melzian[8]

[1]*NOAA IOOS Program*
[2]*SAIC – Science Applications International Corporation*
[3]*Ocean.US*
[4]*National Science Foundation*
[5]*United States Coast Guard*
[6]*United States Geological Survey*
[7]*Unites States Army Corp of Engineers*
[8]*United States Environmental Protection Agency*

Abstract

The United States has a number of ocean observing and monitoring programs and initiatives aimed at understanding changes within our oceans, coasts, and Great Lakes. This paper discusses a number of ocean observing initiatives, such as the U.S. Integrated Ocean Observing System (IOOS®), the Ocean Observatories Initiative (OOI), the Integrated Ocean and Coastal Mapping (IOCM) approach, and the National Water Quality Monitoring Network (NWQMN) for U.S. Coastal Waters and Their Tributaries, including how they are linked to one another. As they mature, these initiatives are expected to advance beyond current science and management applications to become instruments of policy and governance.

IOOS® is a user-driven, coordinated network of people, organizations, and technology that generate and disseminate continuous data about our coastal waters, Great Lakes, and oceans. IOOS® is intended to be a major shift in approach to ocean observing, drawing together the vast network of disparate, federal and non-federal observing systems to produce a cohesive suite of data, information, and products at a sufficient geographic and temporal scale to support decision-making.

OOI, planned by the National Science Foundation (NSF), will be operated by and for researchers and is driven by basic research questions related to how the earth-ocean-atmosphere system works. As currently planned, the OOI consists of four components: coastal observatories, a regional cabled observatory, a global system of moorings in high latitude and open ocean environments, and a cyberinfrastructure that provides data access and interaction for research and education.

The core purpose of the IOCM program is to promote the efficient and effective development and application of ocean and coastal mapping to support informed decision-making. The goal of the NWQMN is to provide information about the health of our oceans and coastal ecosystems and inland influences on coastal waters for improved resource management.

The power of all of these programs is in their partnerships. Partnerships span federal (national) agencies, state and local agencies, academic institutions, industry, regional associations, trade associations, professional societies, and public interest groups. This paper will discuss how federal agencies, state and local agencies, academic institutions, and the private sector are working together to forge a comprehensive ocean, coastal and Great Lakes monitoring system.

Key words: Integrated Ocean Observing System, IOOS®, Ocean Observatories Initiative, OOI, Integrated Ocean and Coastal Mapping, IOCM, U.S. National Water Quality Monitoring Network, NWQMN, Global Ocean Observing System, GOOS

1. Introduction

Reducing risks from a broad range of threats associated with the oceans, including waterborne toxins, storm surge, coastal flooding, climate change, and unsafe marine transportation depends on the ability to characterize and understand complex coastal-ocean phenomena, rapidly detect changes in marine ecosystems and living resources, predict changes in our coastal-ocean environments, and adapt to these changes. This requires a sustained effort to improve information development and delivery processes government-wide, connecting programs and integrating data and resources to maximize taxpayer return on investment in ocean observations, and to ensure that the derived information is available and delivered in a useful manner to managers and policy makers.

The Integrated Ocean Observing System (IOOS®), the Ocean Observatories Initiative (OOI), the Integrated Ocean and Coast Mapping (IOCM), and the National Water Quality Monitoring Network (NWQMN) for U.S. Coastal Waters and Their Tributaries, will enable the United States to make more effective use of existing resources, new knowledge, and advances in technology. Thousands of data collection and management systems—from satellites orbiting above the Earth to sensors trolling along the bottom of the ocean—are gathering data. Many of these systems collect, distribute, and archive the *same* data (temperature, salinity, etc.) but in *different* ways and for different components of the ocean system (e.g., sea surface, ocean bottom). This disparity results in data that cannot be combined or analyzed together, are not easily accessible, and may never be known to exist. Consequently, time and resources are wasted converting disparate data and potentially duplicating data collection. Realizing the full value of existing observing systems requires standards and procedures for linking and integrating the resulting data and products.

2. Integrated Ocean Observing System (IOOS®)

The Integrated Ocean Observing System (IOOS®) is the United States' contribution to the Global Ocean Observing System (GOOS)—the ocean component of a worldwide effort to build a Global Earth Observation System of Systems (GEOSS). IOOS® is a national endeavor, comprising a coastal (national) and global component. As described in the U.S. IOOS® Development Plan (Ocean US, 2006), the process of linking observations to the development of useful, environmental information products requires 'a managed, efficient, two-way flow of data and information among three essential sub-systems.' These sub-systems include:

- *Measurement and Monitoring*: Ocean observations collected from systems in the water, as well as land-based, airborne, or satellite platforms;
- *Data Management and Communications (DMAC):* The primary mechanism to integrate collected data so that they are compatible with one another and accessible to users; and
- *Modeling and Analysis:* Observation-based decision-support tools and services delivered to users, including related socio-economic research, outreach, training, and education.

The global component of IOOS® is part of the international Global Climate Observing System (GCOS, 2004), which is defined by 12 sub-systems. Each sub-system brings its unique strengths and limitations; and together they build the whole. The sub-systems are: Tide Gauge Stations; Surface Drifting Buoys; Tropical Moored Buoy Network; Ships of Opportunity; Argo Profiling Floats; Ocean Reference Stations; Ocean Carbon Networks; Arctic Ocean Observing Network; Dedicated Ships; Data and Assimilation sub-systems; Management and Product Delivery; and Earth Observing Satellites. There are presently 7723 *in situ* platforms maintained globally by the international community, which represents just over 60% of the complete implementation defined by the initial design targets (NOAA, 2008).

The coastal component is the result of a partnership across 17 federal agencies and 11 Regional Associations, and Regional Coastal Ocean Observing Systems that share responsibility for the design, implementation, operation, and improvement of IOOS®. While the GOOS and the global component of IOOS® are delineated

by observing sub-systems, the coastal component is defined in terms of common oceanographic variables. The difference in the characterization of the two programs reflects the global component's primary focus on the role of the ocean in climate variability and change. The coastal component supports many applications including regional and local climate change and impacts, coastal hazards, ecosystem-based management, the relationship between the oceans and human health, and the safe and effective movement of ships in and out of port. The coastal component identifies information needs as core variables collected across the physical, chemical, and biological domains. A complete list of core variables can be found both within the U.S. IOOS® Development Plan (Ocean.US, 2006) and the Implementation Strategy for the Coastal Module of the GOOS (UNESCO, 2005).

There are a number of activities underway across the three sub-systems of IOOS®. A notable success of the observational sub-system is the development of High Frequency Radar (HFR) systems to measure surface current velocities in near real-time. HFR systems represent an example of successful and effective partnership among federal and regional IOOS® components with shared cost and benefits at both national and local levels. HFR data support a range of applications, including search and rescue (SAR), oil spill response, harmful algal bloom monitoring, and coastal water quality assessments. The information can also provide value in ecosystem assessment and fisheries management, when evaluated retrospectively. As an example of IOOS benefits, the U.S. Coast Guard, which currently ingests surface data currents from HFR sites into its SAR operations center for the mid-Atlantic coast, estimated that access to HFR data in all U.S. coastal waters would save 26 to 45 more lives annually and reduce the $30 million per year currently spent on rescue flights. Recognizing potential benefits of access to national HFR data, the IOOS® program supported the National Oceanic and Atmospheric Administration's (NOAA's) National Data Buoy Center, Scripps Institution of Oceanography, and Rutgers University to develop a national HFR data delivery system to provide access to surface current data produced by radar sites around the country, integrating data from distinct installations to meet regional and national objectives.

3. Oceans Observatories Initiative (OOI)

The significance of the ocean and its interconnected nature to our nation and the world is evident and has been of increasing concern in recent years. In 2003 and 2004, respectively, the Pew Oceans Commission (2003) and the U.S. Commission on Ocean Policy (COP, 2004) published major reports with sweeping recommendations designed to improve society's use and stewardship of, and impact on, the coastal and global ocean. These recommendations highlight key areas that require continuous investigation to enable timely and sound decision-making and policy development. Global, regional, and local climate change and impacts, coastal hazards, ecosystem-based management and the relationship between the ocean and human health are amongst the critical issues noted in the Commissions' recommendations that explicitly require a sustained, research-driven, ocean observing capability.

The ocean science community has long recognized the inter-connectivity of the ocean with the Earth system as a whole on many temporal and spatial scales, and the need for a new way of studying the ocean to provide concurrent time-series data and responsive capabilities. The ocean exhibits complex, 3-dimensional, multi-parameter dynamical behavior that manifests itself on local, regional and global scales. While satellites provide continuous sampling on a global basis, they sample only the uppermost ocean for a very limited set of variables. Ships sample the deeper ocean and the seafloor on an episodic basis, with schedules determined far in advance. The very recent advent of autonomous platforms provides us access to the ocean's interior, though on a limited basis. The OOI, which is NSF's contribution to IOOS, represents a transformative, new capability for science in that it features the deployment of an adaptive network designed to observe and study the richness of ocean behavior at appropriate temporal and spatial scales (http://www.oceanleadership.org/ocean_observing).

This new mode of investigation will build on and enhance the more traditional shipboard expeditionary approach by providing the means to collect unique, sustained, time-series data sets. The perspectives these data will provide will stimulate new paradigms in our understanding of the dynamic biological, chemical,

physical and geological processes in the sea. The scientific problems driving the need for an ocean observing system are broad in scope and encompass nearly every area of ocean science including: ecological characterizations, the role of the ocean in climate, fluid dynamics, chemistry, and life in the oceanic crust, dynamics of the oceanic lithosphere and imaging the earth's interior, seafloor spreading and subduction, organic carbon fluxes, turbulent mixing and biophysical interaction, coastal ocean processes, and real-time regional modeling and forecasting. Scientific discoveries arising from the OOI will provide new opportunities for ocean education and outreach through capabilities for real-time data transmission and real-time display of visual images from the seafloor. The OOI will have a broad impact on education and training and will be a source of inspiration and innovation. The technology and instrumentation needed to conduct ocean research will be revolutionized by the newly available power, bandwidth and real-time instrument control provided by the systems of the OOI. The availability of these observational platforms will stimulate the development of innovative biological and chemical sensors to collect the long time-series data needed to understand changes in biogeochemical systems. Furthermore, the OOI will enable whole new strategies for adaptive sampling and observation using 'intelligent' instrumentation and autonomous vehicles.

The OOI will provide a sustained presence in critical areas of the ocean, capable of capturing both short-term events and longer-term processes in their entirety. As currently planned, the OOI consists of an integrated network of seafloor, water column and surface instruments and infrastructure, powered by seafloor cables or from surface moorings. The coastal and global scale nodes (a mix of cabled and tethered installations) will sample throughout the water column, and across the air-sea interface. In addition, autonomous underwater vehicles will sample the larger water mass around the moorings. The regional scale nodes will include a mix of seafloor and water column sensors, all powered and connected by fiber-optic cables. As planned, the coastal nodes in the Pacific Northwest would be nested within the larger footprint of a cabled, regional scale observatory. Novel and pioneering cyberinfrastructure will provide and deploy the information technologies that will enable unprecedented data access, archives, and sharing nationally and internationally – all designed to maximize the impact of ocean science for scientists, educators, students and citizens who will never go to sea in ships.

4. Integrated Ocean and Coastal Mapping (IOCM)

The most recent assessment of marine transportation reports that cargo moving through U.S. coastal water contributes annually over $742 billion in gross domestic product and 13 million jobs. This assessment also reports that over $111 billion is contributed to the U.S. economy from recreational and commercial fishing activities. In 1996, nearly 78 million people participated in recreational boating activities on as many as 16 million boats. These recreational boating activities were valued at about $19 billion (NOAA, 2006).

Ocean and coastal data and map products provide essential information required to assess and manage the dynamic coastal zone, ensure safe coastal and marine operations, and improve understanding of the interactions and impacts of human activities and coastal ecosystems. These data and products also support restoration and recovery operations, helping to identify ways to enhance the resilience of coastal ecosystems and human communities to extreme weather events, destructive human activities, and damaging natural processes. They provide the geospatial framework for observing system design and the development of forecast models.

In order to understand and manage the environmentally and economically important coastal zone, agencies at all governmental levels and the private sector collect and map many types of geospatial information. These data are required and collected at many different spatial and temporal scales, using a wide variety of specifications. With such a large and varied user community our ability to share and leverage mapping activities and products is severely challenged. Three principles will enable and enhance an effective integrated ocean and coastal mapping effort, both now and in the future. The following principles require a sustained and substantial commitment by the national mapping community to advance the IOCM:

- *Coordination*: Most existing mapping programs have resources only to address the specific objectives for which they were designed. However, interests, needs, and objectives overlap; and better coordination will reduce duplication, expand annual coverage, increase efficiency, facilitate sharing of best practices, and help ensure that the products of individual mapping programs are effectively applied beyond their original scope.
- *Collaboration*: Existing mapping programs cannot individually meet all the requirements for data collection and integration, map production, and tool and technology applications.
- *Communication*: Ensuring effective development and application of mapping resources requires persistent communication within the mapping community, with other users of geospatial data, and with the public (NOAA, 2008).

The IOCM, through the Interagency Working Group on Coastal and Ocean Mapping, has focused initial efforts on developing an inventory of data, programs, and plans to facilitate coordination, collaboration, and communication. An inventory project team has partnered with Geospatial One-Stop (GOS) administrators to improve the discoverability of ocean and coastal metadata records. By posting best practices and answers to frequently asked questions, the team is assisting federal agencies in incorporating the publication of metadata into the planning process for data acquisition activities. The ocean and coastal mapping community's commitment to developing the inventory has brought new metadata publishers to GOS and has especially increased metadata submissions for data acquisition activities. More information is provided on the Federal Geographic Data Committee's Oceans and Coasts community page (http://www.geodata.gov).

5. The National Water Quality Monitoring Network (NWQMN)

The National Water Quality Monitoring Network (NWQMN) for U.S. Coastal Waters and Their Tributaries is intended to provide information about the health of our oceans and coastal ecosystems, and inland influences on coastal waters for improved resource management. The Environmental Protection Agency (EPA), the United States Geological Survey (USGS), and NOAA co-lead this effort with participation from other federal agencies. Each year, government agencies, industry, academia, and private organizations devote significant time, energy, and money to monitor, protect, manage, and restore water resources and watersheds. Differences in project design, methods, data analysis, and data management have often made it difficult for monitoring information and results to be shared and used by all. The restoration and protection of water quality is dependent upon detailed, understandable, easily accessible data and information.

In 2007, the NWQMN conducted three pilot projects in the Delaware River Basin, Lake Michigan, and San Francisco Bay; examining current monitoring and gaps in relation to the proposed Network design specifications. At the conclusion of these projects, the most important priorities were identified. As an example, the Delaware River Basin project listed its top priorities as: (1) improved linkages between science and management; (2) comprehensive conceptual framework describing key elements of the estuary ecosystem; (3) implementation of ecosystem management approaches; (4) expansion of the monitoring infrastructure with links to indicators and goals; (5) improved data coordination, compatibility, quality, sharing, access, and archiving; and (6) stronger public education programs that broaden understanding of the defining traits and issues in the Delaware Estuary[1].

Implementation of IOOS® will provide data and information from ocean observing *in situ* and remote platforms to help address the NWQMN objectives. The NWQMN data will in turn provide information on the effects of upland watersheds on coastal ecosystems and on other coastal and ocean conditions and resources. Because both IOOS® and the NWQMN require many of the same measurements and tests for similar environmental parameters, the two programs will be mutually supportive. In addition, the non-ocean and Great Lakes atmospheric variables (e.g., wind vectors, aerosol concentrations, and precipitation) and

[1] Information about the NWQMN Pilot Projects can be found at: http://acwi.gov/monitoring/network/pilots/

terrestrial variables (e.g., river and stream flow, ground water discharge, transport of sediments, nutrients, and contaminants) explicitly included in the NWQMN will support IOOS® (Ocean.US, 2006) requirements to link earth, atmospheric, and marine systems.

Both IOOS® and the NWQMN are similar in that they are using a regional approach to develop national monitoring systems by linking regional systems that measure a common set of 'core variables' (IOOS®), or 'constituents' (NWQMN). By linking the two infrastructures, we can address a number of water and habitat quality issues (Rowe et al., 2006) by:

- Supporting the development of a long-term baseline and measurements of short-term impacts on local and regional changes in water and habitat qualities, improving the ability to measure biogeochemical fluxes across the near coastal areas and continental shelves, and providing long-time series of salinity, temperature, ocean currents, and other geochemical and physical properties;
- Determining the fate and transport of pathogens, organic chemicals, toxic metals, chemical (oil) spills, and other pollutants, as well as hypoxia/anoxia events that may adversely impact humans and the environment;
- Increasing the understanding of recruitment and population dynamics of 'keystone' and 'indicator' species (e.g., American oyster, blue crab, resident fish species) by determining the impacts of physical events, pollutants, and hypoxia et al. on recruitment success;
- Improve the ability of managers to undertake ecosystem management, and to assess the health status of living resources by providing a better understanding of the dynamics related to atmospheric depositions, sediment transport, temperature, and salinity;
- Fulfilling the needs for environmental information, navigation and transportation (hazards and dredging), and security needs (emergency management);
- Improving decision making in regard to water flow (quantity) and water withdrawals, and how these activities may influence the management of the 'species of interest'; and
- Providing additional resources (e.g., satellites) needed to determine the effects of habitat fragmentation (e.g., forest fragmentation, urbanization) on carbon, nutrients, and sediment loads in order to track landscape-scale ecosystem changes that are linked to biological or water quality measurements.

6. Connectivity achieved through Agencies, Programs, shared Infrastructure, and Data Management

Because many agency missions extend to our oceans, coasts, and Great Lakes, there are a number of opportunities to achieve greater efficiency by enhancing connections among existing programs, infrastructure, and data management procedures. The OOI is envisioned as a research-based counterpart to IOOS®, which will be oriented towards applications. OOI contributions will include development of novel observing, data assimilation, and data management techniques, as well as advancement of current understanding of ocean phenomena upon which accurate predictions and forecasts depend. IOOS® will provide additional context to the OOI network, whose footprint and sensor deployment are determined by research priorities. OOI and IOOS® cyber infrastructures will converge over time to enhance interoperability of these two national systems. The science drivers motivating the OOI represent not only national ocean research questions, but also questions that have global interest and impact.

Last year, the IOCM initiative and IOOS® leveraged each other's infrastructure with NOAA partnering with the IOOS® Regional Associations (RAs) within the state of California for the acquisition of nearly 2200 square nautical miles of high-resolution bathymetry and acoustic backscatter data. The acquisition of these data via a contract was managed and overseen by NOAA's Office of Coast Survey; and the USGS provided expertise and resources for interpretation and product generation. By working together, and by collecting the data using the same standards and protocols, the State of California and federal partners will have access to the data and products that can be used to meet a variety of research, management, and other needs. Through

this collaborative effort, the resulting data are assured to meet the standards and protocols necessary for broad application, avoiding the need for multiple surveys for multiple uses

After IOOS® and the NWQMN are fully operational, the complementary data and information that will be collected by these national monitoring systems will be appropriate for: (1) describing current environmental conditions and detecting trends in 'system attributes' that could impair the sustainable use of coastal and estuarine resources; (2) linking human activities and use of resources to changes in coastal and estuarine water quality, including the freshwater delivery to estuaries; (3) relating contaminant and nutrient flux measurements to their ecological and human health impacts; (4) assessing effects of habitat losses and modifications on biological integrity, biodiversity, and ecosystems' productivity; and (5) enhancing numerical modeling and ecological forecasting capabilities to evaluate the effectiveness of pollution control and mitigation activities and programs (Rowe et al., 2006).

Often, federal agencies' resources or activities may support the needs and requirements of other federal agencies. For example, the U.S. Coast Guard (USCG) is a military, multi-mission, maritime service and one of the nation's five armed services. Its mission is to protect the public, the environment, and U.S. economic interests in the nation's ports and waterways, along the coast, on international waters, or in any maritime region, as required to support national security. Although no Coast Guard assets are solely dedicated to ocean observations, they collectively perform a variety of functions in support of ocean observations. These efforts include vessel and aircraft support for Arctic, Antarctic, and coastal zone observations, as well as participation in programs such as the Integrated Precipitable Water Vapor Demonstration Network, the Voluntary Observing Ship Program (http://www.vos.noaa.gov/), and the Marine Reporting Station Network (http://www.ncdc.noaa.gov/oa/climate/stationlocator.html). USCG provides personnel and vessel support to the NOAA National Data Buoy Center and (with Navy and NOAA) manages the tri-agency National Ice Center. The Coast Guard conducts the International Ice Patrol (IIP) under the provisions of the Safety of Life at Sea Convention (SOLAS). The IIP uses sensor-equipped aircraft to patrol the Grand Banks of Newfoundland and to locate and track icebergs that pose a hazard to North Atlantic shipping. IIP determines the geographic limits of the iceberg hazard and, twice daily, broadcasts iceberg warning bulletins and ice facsimile charts which define the limits of the iceberg threat during the iceberg season (spring and summer). IIP archives data annually on all confirmed and suspected icebergs, and forwards these data to the National Snow and Ice Data Center.

The success of these ocean observing programs and initiatives depends on the development of a consistent data management infrastructure that will link observations to the data and information needs of multiple users at the global, national, regional, and state levels. Currently, there are few commonly accepted and applied standards for data format and transport, except for some specific applications. Consequently, data are not easily assembled from numerous diverse sources to meet the geographic coverage, vertical and horizontal resolution, accuracy, timeliness, and data processing needs of multiple ocean models, assessments, or other end users.

In 2007, the NOAA IOOS® Program began a project called the Data Integration Framework (DIF) to improve management and delivery of a subset of ocean observations (i.e., ocean currents, temperature, salinity, water level, waves, chlorophyll, and surface winds). The DIF is intended to provide the initial operating capability for a nationwide IOOS® Data Management and Communications (DMAC) capability, to enable the evaluation of interoperability specifications, and to demonstrate the feasibility and value of providing integrated ocean observations. Establishment of this DIF began in 2008 with the implementation of a standardized, interoperable web service layer atop key NOAA data providers to provide integrated access to data from both NOAA and regional partners. Using existing consensus or international standards where possible, the standards and protocols used are designed to be broadly applicable. A working group with representatives from 12 NOAA offices, 7 IOOS® RAs, and one non-governmental organization was established to guide these efforts. No single web service type or data format will satisfy all users. The DIF project has broadly identified three general classes of scientific information — *in situ* data, gridded data, and images of data — and has recommended a web service and encoding convention to be used in each case.

These recommendations are intended to standardize a small number of data access methods and enable a single client application to obtain data from multiple providers, and to harmonize the representation of data from different providers. These services can be established instead of, or in addition to, prior arrangements between individual providers and customers (Figure 1) (de la Beaujardière, 2008).

Data Type	Web Service	Encoding
In-situ data (buoys, piers, towed sensors)	OGC Sensor Observation Service (SOS)	XML based on OGC Observations and Measurements (O&M)
Gridded data (model outputs, satellite)	OpenDAP and/or OGC Web Coverage Service (WCS)	NetCDF using Climate and Forecast (CF) conventions
Images of data	OGC Web Map Service (WMS)	GeoTIFF, PNG etc. -possibly with standardized styles

Figure 1. NOAA IOOS® Data Integration Framework (DIF) service types and encodings
(OGC = Open Geospatial Consortium; XML = Extensible Markup Language; OpenDAP = Open-source Project for a Network Data Access Protocol; NetCDF = Network Common Data Format; GeoTIFF = Geospatial Tagged Image File Format; and PNG = Portable Network Graphics)

In mid-2008, implementations of the DIF web service layer occurred at three NOAA data providers and one IOOS® RA (i.e., National Data Buoy Center, the Center for Operational Oceanographic Products and Services, the National Environmental Satellite Data and Information Service CoastWatch program, and the Southeast Coastal Ocean Observing Regional Association). The activity described above represents only the first steps in a National DMAC capability – much work is yet to be done. Highlights of NOAA's upcoming DIF activities are listed below:

- *Testing, evaluation and refinement of encoding specifications:* Interoperability testing to confirm that the implementations are compatible. Harmonize with ongoing Open Geospatial Consortium (OGC) work to evolve the Sensor Web Enablement schema and with the evolving Climate Science Modeling Language, derived in part from OGC Observations and Measurements.
- *Registry implementation:* Registry development to provide a catalog of the available services and data holdings. The IOOS registry intends to build upon the existing GEOSS registry rather than developing a new and distinct service.
- *Metadata:* Development of data documentation to find and make data usable.
- *Quality assessment:* Continued efforts with the Quality Assurance of Real-Time Ocean Data (QARTOD) to OGC's (Q2O) project to determine how best to represent QA/QC information in Sensor Model Language (http://vast.uah.edu/SensorML/) descriptions.
- *Data integration service:* Continued development of DIF's Sensor Observation Service (SOS) implementations at NOAA centers, which provide integrated access to their respective holdings. No service currently exists that can aggregate data records from multiple independent SOS into a single record while removing duplicates and ensuring consistency.
- *Data translation service:* Service to accommodate the various formats and encodings applied within IOOS and OOI. The NOAA National Marine Fisheries Service's Southwest Fisheries Service Center developed a data translation and visualization service known as the Environmental Research Division's Data Access Program (ERDDAP). ERDDAP can access data in a variety of formats and

protocols and transform to other formats or representations desired by the user. NOAA's objective is to enable ERDDAP to read and translate from the SOS implementations that use the DIF XML encoding specification. NOAA will work with OOI's cyberinfrastructure effort to establish a distributed, reliable translation service to test this approach to providing seamless access to data.

- *Customer development:* Inclusion of customer areas such climate and marine transportation.
- *Additional variables:* Inclusion of additional variables and sources (e.g., satellite sea surface temperature and sea surface height to complement *in situ* temperature and water level).
- *Additional providers:* Linkage of more data providers from across U.S. federal agencies and RAs.

In addition to DIF-related efforts, IOOS® is addressing the challenges of data consistency and interoperability through an interagency standards review process, established in October, 2007 in accordance with the Ocean.US DMAC plan. This process will identify appropriate standards, best practices, and other protocols to establish a common foundation for integration. To date, 12 standards have been 'submitted'; and 4 have reached 'proposed' status. While none has achieved 'recommended' status due to the required period of testing, this has been a very successful standards review process since its inception.

Since data standards transcend any one nation, the United States (through the NOAA IOOS® Program) and the Government of Flanders hosted the first session of the United Nation's Intergovernmental Oceanographic Commission's (IOC) International Oceanographic Data and Information Exchange (IODE)/World Meteorological Organization Joint Commission for Oceanography and Marine Meteorology (JCOMM) Forum on Oceanographic Data Management and Exchange Standards. This forum was held January 21-25, 2008 at the IOC Project Office for IODE. The objective of this forum was to obtain general agreement and commitments to adopt key standards related to ocean data management; thereby facilitating exchange between oceanographic institutions. The results of the meeting included: (1) establishment of a pilot project organized under the IODE that will further refine the transition of the U.S. DMAC standards process to an international process; (2) documentation of the standards process, and initiation of steps to promote it at national and international meetings; (3) establishment of close collaborations with other organizations such as GEOSS to widely advertise and promote the adopted standards; and (4) creation of a new Web site (http://www.oceandatastandards.org) with a clear identity related to ocean data standards to further promote the process and adoption of standards.

7. Partnering with the Private Sector

To fully succeed, IOOS® needs to be an effective partnership between the private and public sectors as the respective skills and resources of each will be required to secure sufficient financial commitments, and to underpin implementation and long-term sustained operation. In 1997, the National Ocean Partnership Program (NOPP) was established by the U.S. Congress (Public Law 104-201) to:

- Promote the national goals of assuring national security, advancing economic development, protecting quality of life, and strengthening science education and communication through improved knowledge of the ocean; and
- Coordinate and strengthen oceanographic efforts in support of those goals by:
    - Identifying and carrying out partnerships among federal agencies, academia, industry, and other members of the oceanographic scientific community in the areas of data, resources, education, and communication; and
    - Reporting annually to Congress on the Program.

In 2005, Admiral James Watkins (USN; Retired), former Chairman of the U.S. Commission on Ocean Policy reaffirmed that the role of industry in the design, implementation, operation, and maintenance of IOOS® should be clearly defined. He further stated that industry should not be viewed solely as a provider of technology or a user of the system, but as a full partner in planning, implementation and operation.

Industry participation should not be limited to companies within the maritime arena. Examples of the contributions that industry could provide are:

- Transforming the IOOS® initiative from research to operations;
- Systems engineering and integration;
- Provision of integration of existing infrastructure owned and operated by industry;
- Provision of sensor systems to expanding existing networks
- Development of new sensors to fulfill the IOOS® mission;
- Deployment of monitoring and measurement capabilities using existing industry infrastructure (e.g. work boats, cable lay vessels, remotely operated vehicles and the skilled staff needed);
- Operation of IOOS® as a nationwide 24x7 managed network;
- Maintenance of the system;
- Production of value added services for a wide range of end users (e.g., shipping, recreation/tourism, fisheries and energy); and
- Hardware, software, and services required for data collection, processing and distribution.

Effective program management is key for an interagency IOOS® to be successfully implemented. The government's primary role and expertise is in defining the requirements and desired outcome. The primary role of industry is effective delivery of elements of the IOOS® plan. Appropriate systems engineering contracts with industry will help make IOOS® a reality. Creating a solid framework for continuously accepting new developments in sensors, algorithms, and models from the scientific community and industry sources will permit the addition of new applications meeting new user demands, all within a common framework.

8. Conclusion

While it is intuitive that the United States needs to be able to observe, monitor and predict conditions of our oceans, along our coasts, and the Great Lakes, ocean observing initiatives are often asked to provide an economic argument for these investments (Kite-Powell, 2004). Integrating ocean observations will save lives. Observing is the foundation of understanding. By increasing our understanding of how oceans impact severe weather and natural hazards, agencies can better predict when such events will happen in the future. More accurate and timely predictions of severe weather and natural hazards increase our ability get more people to safety before disaster strikes while avoiding the social and economic costs of unnecessary evacuations. Ocean and coastal information is also important for understanding and predicting climate change and changes to our precious marine resources. Understanding the impacts of climate change on our coastal communities will lead to better adaption and response to changes such as sea level rise, coastal flooding, and rising temperatures.

The programs and initiatives discussed in this document are working together to create a major shift in approach to ocean observing, drawing together the vast network of disparate, federal and non-federal observing systems to produce a cohesive suite of data, information, and products at a sufficient geographic and temporal scale to support decision-making. Current efforts only scratch the surface of what we need to know about our oceans and coasts to fully assess their impact on commerce and transportation, weather and climate, and ecosystems. Fortunately, given technological improvements in our ability to acquire, process, and analyze data**,** these complementary U.S. ocean observing initiatives are now possible.

References

de la Beaujardière, Jeff (2008) The NOAA IOOS Data Integration Framework: Initial Implementation Report. Presented at Oceans MTS/IEEE 2008 Conference.

GCOS (2004) Implementation Plan for the Global Observing System for Climate in support of the UNFCCC (GCOS-

92), the Global Climate Observing System, October 2004, GCOS #92, WMO/TD #1219.

Joint Subcommittee on Ocean Science and Technology (2007) Ocean Research Priorities Plan and Implementation Plan <http://ocean.ceq.gov/about/sup_jsost_prioritiesplan.html>

Kite-Powell, Hauke, et. al. (2004) Estimating the Economic Benefits of Regional Ocean Observing Systems.

Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM), Joint Subcommittee on Ocean Science and Technology (2008) National Ocean and Coastal Mapping Strategic Action Plan, in press.

National Oceanic and Atmospheric Administration (NOAA) (2006) Economic Statistics for NOAA, Fifth Edition. Office of Program Planning and Integration. http://www.publicaffairs.noaa.gov/pdf/economic-statistics-april2006.pdf

NOAA (2008) Program Plan for Building a Sustained Ocean Observing System for Climate. Office of Oceanic and Atmospheric Research Climate Program Office, Climate Observation Division <http://www.oco.noaa.gov/docs/programplan_current.doc >

NSTC/JSOST (2007) Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy. National Science and Technology Council (NSTC)/ Joint Subcommittee on Ocean Science and Technology (JSOST). Washington, D.C. <http://ocean.ceq.gov/about/docs/orppfinal.pdf>

Ocean.US (2006) The First U.S. Integrated Ocean Observing System (IOOS) Development Plan. A report of the National Ocean Research Leadership Council (NORLC) and the Interagency Committee on Ocean Science and Resource Management Integrations (ICOSRMI). (Publication No. 9, Arlington, VA., 86 pages)

Pew Ocean Commission (2003) America's Living Ocean: Charting a Course for Sea Change. A Report to the Nation. Pew Oceans Commission, Arlington, Virginia. <http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Protecting_ocean_life/env_pew_oceans_final_report.pdf>

Rowe, P.M., M.J. Hameedi and M.P. Weinstein (Eds.) (2006) Linking Elements of the Integrated Ocean Observing System (IOOS) With the Planned National Water Quality Monitoring Network. Proceedings from the NOAA-Supported Workshop, September 2005. (NOAA/NCCOS/CCMA. Silver Spring, MD. 96 pages.)

UNESCO (2005) An Implementation Strategy for the Coastal Module of the Global Ocean Observing System. GOOS Report No. 148; IOC Information Documents Series N°1217.

U.S. Ocean Action Plan (OAP) (2004): The Bush Administration's Response to the U.S. Commission on Ocean Policy. <http://ocean.ceq.gov/actionplan.pdf>

U.S. Commission on Ocean Policy (COP) (2004) An Ocean Blueprint for the 21st Century. Final Report. Washington, D.C., ISBN#0-9759462-0-X. (http://oceancommission.gov/documents/full_color_rpt/welcome.html)