# U.S. INTEGRATED OCEAN OBSERVING SYSTEM (U.S. IOOS®)

## *2015 Report to Congress*

PRODUCT OF THE
NATIONAL OCEAN COUNCIL

March 2016

EXECUTIVE OFFICE OF THE PRESIDENT
**NATIONAL OCEAN COUNCIL**
WASHINGTON, D.C. 20502

March 30, 2016

Dear Colleagues:

Enclosed is the U.S. Integrated Ocean Observing System 2015 Report to Congress, as required by the Integrated Coastal and Ocean Observing System Act of 2009 (P.L. 111-11, Title XII, Subtitle C) (ICOOS Act)).

The U.S. Integrated Ocean Observing System (U.S. IOOS®) is a national-regional partnership to provide data, tools, and forecasts needed to improve safety, facilitate economic activity, and protect the Nation's coastal environment. U.S. IOOS is composed of: 18 Federal agencies; 11 regional associations; the Alliance for Coastal Technologies (ACT), a technology validation and verification organization; and the U.S. IOOS Coastal and Ocean Modeling Testbed.

The U.S. IOOS Program, housed in the National Oceanic and Atmospheric Administration, prepared this report with input from Federal agencies through the Interagency Ocean Observing Committee, and from external partners, including the IOOS Association and the IOOS Regional Associations. The report addresses each of the reporting requirements listed in the ICOOS Act, including:

- Establishment of the U.S. IOOS Advisory Committee to provide advice to NOAA and the IOOC on the administration, operation, management, maintenance, expansion, and modernization of U.S. IOOS.
- Completion of Certification guidelines called for in the ICOOS Act.
- A description of benefits of the program to users of data and products resulting from U.S. IOOS.

We appreciate your interest in IOOS. We look forward to continued engagement with you on this important effort and other ocean issues.

Sincerely,

Christina Goldfuss
Managing Director, Council on Environmental Quality
Co-Chair, National Ocean Council

John P. Holdren, Ph.D
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy
Co-Chair, National Ocean Council

## About the National Ocean Council

The National Ocean Council (NOC) is charged with implementing the National Ocean Policy established in July 2010 under Executive Order 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes. The NOC released the National Ocean Policy Implementation Plan in April 2013 to translate the National Ocean Policy into specific actions Federal agencies will take to address key ocean challenges, streamline Federal operations, save taxpayer dollars, and promote economic growth. Federal agencies, States, tribes, and regional fishery management councils may choose to form regional planning bodies to provide communities greater collaborative input in these efforts. More information is available at www.whitehouse.gov/administration/eop/oceans.

## About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development (R&D) enterprise. One of the NSTC's primary objectives is establishing clear national goals for Federal science and technology investments. NSTC prepares R&D packages aimed at accomplishing multiple national goals. The NSTC's work is organized under five committees: Environment, Natural Resources, and Sustainability; Homeland and National Security; Science, Technology, Engineering, and Mathematics (STEM) Education; Science; and Technology. Each of these committees oversees subcommittees and working groups that are focused on different aspects of science and technology. More information is available at www.whitehouse.gov/ostp/nstc.

## About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President in policy formulation and budget development on questions in which science and technology are important elements; articulating the President's science and technology policy and programs; and fostering strong partnerships among Federal, state, and local governments, and the scientific communities in industry and academia. The Director of OSTP also serves as Assistant to the President for Science and Technology and manages the NSTC. OSTP co-chairs the National Ocean Council. More information is available at www.whitehouse.gov/ostp.

## About the Council on Environmental Quality

The Council on Environmental Quality (CEQ) coordinates Federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies and initiatives. CEQ was established within the Executive Office of the President (EOP) by Congress as part of the National Environmental Policy Act of 1969 (NEPA), and additional responsibilities were provided by the Environmental Quality Improvement Act of 1970. Through interagency working groups and coordination with other EOP components, CEQ works to advance the President's agenda. It also balances competing positions, and encourages government-wide coordination, bringing Federal agencies, state and local governments, and other stakeholders together on matters relating to the environment, natural resources and energy. CEQ co-chairs the National Ocean Council, along with OSTP. More information is available at www.whitehouse.gov/ceq.

## About the Subcommittee on Ocean Science and Technology

The purpose of the Subcommittee on Ocean Science and Technology (SOST) is to advise and assist on national issues of ocean science and technology. The SOST contributes to the goals for Federal ocean science and technology, including developing coordinated interagency strategies, and fosters national ocean science and technology priorities, including implementation of the National Ocean Policy. The SOST also serves as the Ocean Science and Technology Interagency Policy Committee (OST-IPC) under the NOC, and ensures the interagency implementation of the National Ocean Policy and other priorities for ocean science and technology objectives.

## About the Interagency Ocean Observing Committee

The Interagency Ocean Observation Committee (IOOC) was created by the Integrated Coastal and Ocean Observation System Act of 2009. The IOOC oversees efforts to develop the National Integrated Coastal & Ocean Observing System. Led by three federal Co-Chairs and supported by agency representatives and support staff, the Committee carries out various provisions of the Act for implementing procedural, technical, and scientific requirements to ensure full execution of the System. Interagency collaboration is essential to achieve ocean science and technology priorities and, in particular, for planning and coordination of the System. The IOOC is also making a concerted effort to engage stakeholders and private industries that receive benefits of the Integrated Ocean Observing System.

## About the U.S. Integrated Ocean Observing System

The U.S. Integrated Ocean Observing System (IOOS®) was created by the Integrated Coastal and Ocean Observation System Act of 2009. The U.S. IOOS coordinates national, international, regional, and local ocean and coastal observation networks, modeling efforts, and data management and communications services to provide the Nation with information to safeguard life and property, to protect valuable ecosystems, and sustain our Nation's economic vitality.

## About this Document

This document was developed by the U.S. IOOS Office. The document was published by NOC.

## Acknowledgements

This document was developed by the U.S. IOOS Office. The U.S. IOOS Regional Associations, the IOOS Association, the IOOC, and federal agencies and offices contributed both to the development of the Report and also to the continued success of the U.S. IOOS Program. The work of the editors of this Report, at LMI, Inc., must be acknowledged. Most of the actual work of typing, formatting and presentation of the report was performed by LMI's associates under tight deadlines.

## Copyright Information



Printed in the United States of America, March 30, 2016

## Report prepared by

## NATIONAL OCEAN COUNCIL

### National Ocean Council

*Co- Chairs*

**John P. Holdren, Ph.D.**
Assistant to the President for Science
and Technology and Director,
Office of Science and Technology Policy

**Christina Goldfuss**
Managing Director
Council on Environmental Quality

*Director*

**Beth Kerttula**

### National Ocean Council Deputies

*Co-Chairs*

**Whitley Saumweber, Ph.D.**
Associate Director for Oceans and Coasts
Council on Environmental Quality

**Tamara Dickinson, Ph.D.**
Principal Assistant Director for Environment and Energy
Office of Science and Technology Policy

*Deputy Directors*

**Fabien Laurier, Ph.D.**
Office of Science and Technology Policy

**Celeste Leroux**
Council on Environmental Quality

### National Ocean Council Staff

**Meg Larrea**
Ocean Policy Advisor

**Jerry Smith**
Policy Analyst

# National Ocean Council

Council on Environmental Quality

Office of Science and Technology Policy

Department of Agriculture

Department of Commerce

Department of Defense

Department of Energy

Department of Health and Human Services

Department of Homeland Security

Department of the Interior

Department of Justice

Department of Labor

Department of State

Department of Transportation

Environmental Protection Agency

Federal Energy Regulatory Commission

Joint Chiefs of Staff

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

National Science Foundation

U.S. Army Corps of Engineers*

U.S. Coast Guard

Office of the Director of National Intelligence

Office of Management and Budget

Office of the Vice President

National Security Council Staff**

Domestic Policy Council

National Economic Council

* *Member of the Deputy-level committee*

** *Includes the National Security Advisor and the Assistant to the President for Homeland Security and Counterterrorism*

"The sea, once it casts its spell, holds one in its net of wonder forever."

-Jacques Yves Cousteau

# Table of Contents

# Executive Summary

This report, called for in the Integrated Coastal and Ocean Observing System (ICOOS) Act of 2009, covers the period of 2013 and 2014. The U.S. Integrated Ocean Observing System (IOOS®) coordinates national, international, regional, and local ocean and coastal observation networks, modeling efforts, and data management and communications services to provide the Nation with information to safeguard life and property, to protect valuable ecosystems, and sustain this country's economic vitality.

IOOS' strength continues to be in its diversity—IOOS pairs the resources and reach of the Federal government with the efficiency, local know-how, and capability for innovation that our international and regional partners provide. Together the IOOS system provides new levels of observation reach, data integration from disparate IOOS and non-IOOS sources, and new decision support tools for Federal, State, local, tribal, and private-sector decision makers to protect lives and property.

IOOS made noteworthy progress, which will be covered in detail in this report, during the reporting period. Accomplishments include:

- At the global scale:
  - Tested Bio-Argo and deep Argo;
  - Initiated the Tropical Pacific Observing System 2020 project and Deep Ocean Observing System strategy.
- At the national level:
  - Deployed the National Oceanic and Atmospheric Administration's (NOAA) 23rd Physical Oceanographic Real-Time System (PORTS®);
  - Launched the Ocean Technology Transition effort;
  - Debuted an enhanced version of the IOOS Catalog at catalog.ioos.us, where users have access to more than 5,186 datasets and 4,900 data services;
  - Completed Certification guidelines called for in the ICOOS Act.
- At the regional level:
  - Increased amount and diversity of IOOS Regional Association (RA) funding from outside of the U.S. IOOS Program;
  - Operated over 37,500 glider days during the period of 2008-2014 with data available through the IOOS data catalog;
  - Operated the National High Frequency Radar Network at an average of 73 percent uptime; contributed observations through coastal and wave buoys; and increased the number of glider days:
  - Enhanced RA data portals resulting in standardized data delivery and increased the throughput of ocean, coastal and Great Lakes information.

Building on past success, IOOS continues to deliver vital ocean, coastal, and Great Lakes data and information to the Nation.

# Introduction

The Integrated Coastal Ocean Observation System (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 (now the National Ocean Council) for submission to Congress on a biennial basis.

This report updates the 2011-2012 Report to Congress. The report provides information on the impact of IOOS activities and the current capabilities of ocean and coastal observations, including specific platforms; updates the status of the Data Management and Communications (DMAC) subsystem implementation; and informs on the successful implementation of ICOOS Act-mandated governance activities.

# Chapter 1: IOOS—Enterprise Accomplishments

*'Oceans are the lifeblood of the interconnected global community, where seaborne trade is expected to double over the next 15 years. The free flow of commerce has enabled unparalleled global economic growth over the last 70 years. Ninety percent of trade by volume travels across the oceans. Approximately 70 percent of the world's population lives within 100 miles of the coastline. Likewise, most maritime activity—commercial, recreation, fishing, and oil and gas extraction—takes place within 200 miles of the shore.'—U.S. Navy*[1]

IOOS enables decision making every day and fosters advances in science and technology by bringing observing communities together to fulfill local, regional, national, and global needs for integrated ocean information. For this report, "U.S. IOOS Program" refers to the entity within the lead Federal Agency, the National Oceanic and Atmospheric Administration (NOAA), which coordinates the activity of IOOS. "IOOS" refers to the entire enterprise and the integrated efforts of all partners. The figure below shows IOOS in context of national and international structures.

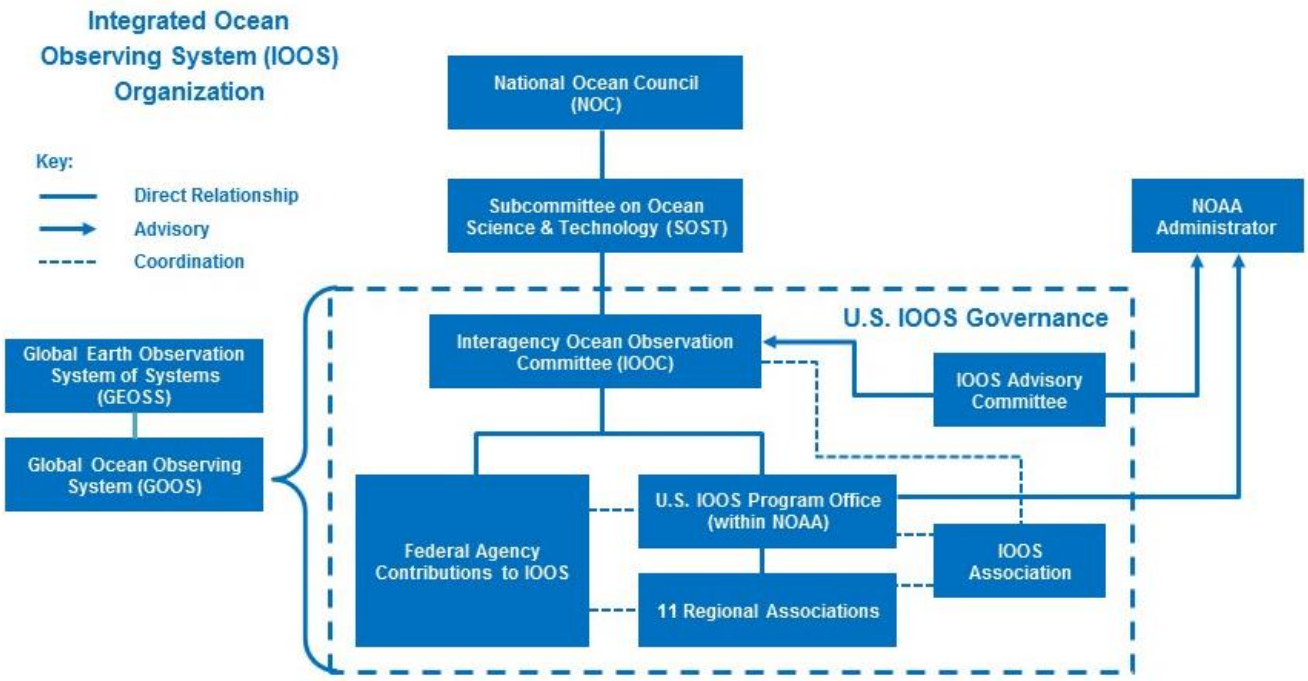


*Figure 1. IOOC Organizational Chart: www.iooc.us/organizational-chart. Credit: IOOC*

[1] United States Navy. *A Cooperative Strategy for 21st Century Seapower*. March 2015. U.S. Navy Website. 8 May 2015 www.navy.mil/local/maritime/150227-CS21R-Final.pdf

At the global level, the United States takes a leadership role though the National Aeronautics and Space Administration's (NASA) co-chairing of the Global Ocean Observing System (GOOS) steering committee and the Director of the U.S. IOOS Program chairing the GOOS Regional Council. In 2013 and 2014, the GOOS:

- Established the physical, chemical, and biological panels called for in the Framework for Ocean Observing; and
- Assessed the GOOS Regional Alliances, a modeling inventory and a new Regional Policy.

At the national level, IOOS represents a partnership of 18 Federal agencies led by the Interagency Ocean Observation Committee (IOOC).


*Figure 2. U.S. IOOS Federal Agency Partners. Credit: U.S. IOOS*

The IOOC oversees and coordinates IOOS' development (see Appendix A for the list of IOOC members). The other members of the statutorily-mandated National Ocean Research Leadership Council (now the National Ocean Council) are also eligible to join the IOOC. The U.S. IOOS Program oversees the implementation of IOOS. In 2013 and 2014, the IOOC:

- Published the IOOS Summit Report and prioritized the summit recommendations;
- Established task teams to address recommendations:
  - The Biological Integration and Observing Task Team (BIO-TT) held a community workshop that produced a prioritized list of essential biological variables.
  - The Animal Telemetry Network Task Team is drafting an implementation plan to integrate work being done by Federal and non-Federal partners.
  - The IOOS Modeling Task Team is on pace to deliver a national modeling strategy in 2015.
- Engaged Federal agencies to identify contributions to IOOS—www.iooc.us/federal-efforts;
- Launched the Ocean Technology Transition effort;
- Debuted an enhanced version of the IOOS Catalog at catalog.ioos.us, where users have access to more than 5,186 datasets and 4,900 data services; and
- Published the U.S. IOOS Program certification criteria as called for in the ICOOS Act of 2009.

The regional component of IOOS consists of: 11 Regional Associations (RAs) for coastal and ocean observing; the Alliance for Coastal Technologies, a technology validation and verification organization; and the IOOS Coastal Ocean Modeling Testbed. The RAs are composed of state, local, and tribal governments; academia; and industry. The RAs provide 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. Because of the data management standards and protocols developed through IOOS, the RAs provide information in a manner that is accessible and useful to the national enterprise. Regional governance

structures are tailored to the regional needs requirements. A full list of the regional partners can be found in Appendix A.


*Figure 3. U.S. IOOS Regional Component. Credit: U.S. IOOS*

## 2013-2014 Regional Accomplishments (RAs):

- U.S. IOOS RAs continue to have broad sectorial representation and membership continues to grow (see Appendix B).
- Increased data provider participation in RAs based on the amount of data now visible through the U.S. IOOS RA data portals.
- Increased leveraging of resources by U.S IOOS RAs to maximize regional observations (see Appendix C for a sampling of this effort).
- Marked the 10th year of operations by the Alaska Ocean Observing System (AOOS), the Gulf of Mexico Coastal Ocean Observing System (GCOOS), and the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS).
- Marked the fifth year of operations by the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS).
- Established GCOOS as a non-profit organization.

## System Advisory Committee

The IOOS Advisory Committee, established in July 2012, has 13 members representing the broad cross-sector stakeholders of IOOS. The Committee's charge is to advise NOAA and the IOOC on ways to strengthen and grow the IOOS endeavor. The Committee delivered its vision statement for IOOS—"Benefits from Ocean Information in the Smartphone Era," located on the IOOS Program website at www.ioos.noaa.gov/advisorycommittee/welcome.html, in 2013. The Committee delivered several recommendations to the NOAA Administrator, entitled, "Elevating IOOS to a National Endeavor," in March 2015. These recommendations are located at: http://www.ioos.noaa.gov/advisorycommittee/ioosac_guidingprinciples_march2015.pdf.

## Ocean Enterprise Study Assesses Economic Impact of Ocean Data and Information

NOAA and IOOS launched a 3-year Ocean Enterprise Study in 2013 to quantify the scale and scope of business activity in ocean measurement, observation, and forecasting. Phase I of the study was completed in 2014, and concentrated on developing a comprehensive list of ocean observation-focused companies across the Nation. The full report on Phase I findings can be found at www.ioos.noaa.gov/ioos_in_action/yearonereport_st_1114.pdf

Phase II of the study began in 2015, which is focusing on quantifying the impact of this sector on the ocean enterprise.

### *U.S. Program Offers Certification to Regional Information Coordination Entities*

The U.S. IOOS Program began offering certification to its non-Federal partners in July 2014. After approval of an application for certification, the Regional Information Coordination Entity (RICE) will be incorporated into U.S. IOOS. Certification formally establishes the role of the RICE within IOOS, and ensures that the data collected and distributed by the RICE are managed according to best practices. This is a key step towards integrating the Federal and non-Federal IOOS observing assets, and towards making a unified ocean observing system with seamless data delivery from international to local scales.

# Chapter 2: Observation Systems

The ocean and coastal environment is a complex system that supports a multitude of marine life, sustains a vibrant seafood industry, and underpins maritime transport as well as coastal recreation and tourism. The ocean and the Great Lakes also play a significant role in the development of weather conditions both along the coast and inland.

IOOS works on the principle that Federal agencies provide observations to meet their mission mandates, but by contributing their efforts to IOOS, they can link together along with international and non-Federal regional assets to build efficiencies and to provide a greater public good. Further, the IOOS RAs work with researchers and others to provide access to data that are funded through other Federal and non-Federal programs or agencies (some only receive partial funding from the U.S. IOOS Program) but the data from those systems is provided to support a national network.

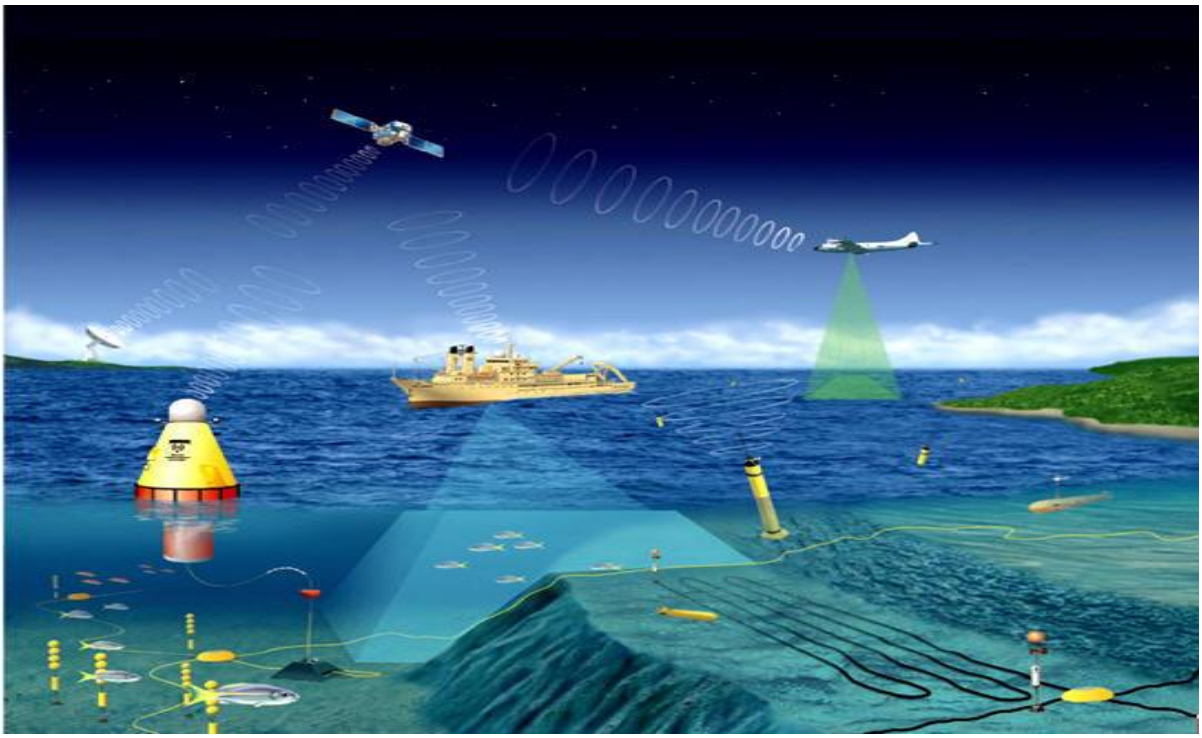

*Figure 4. Artistic rendering of the Integrated Ocean Observing System. Credit: NOAA celebrating200years.noaa.gov/visions/ioos/obs_system.html*

## 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. The HF radar network is managed by the U.S. IOOS Program and operated through the IOOS RAs. Over the last two years, the network has averaged a 73 percent uptime. This network is used by the U.S. Coast Guard (USCG) for search and rescue operations and NOAA's Office of Response and Restoration (OR&R) to support hazardous material response. The network supports safe commercial navigation and recreational activities, harmful algal bloom (HAB) monitoring, and fisheries management. For information about HF radar locations, please visit http://cordc.ucsd.edu/projects/mapping/maps/.

### *2013-2014 Accomplishments:*

- Integrated HF radar radial velocity and total vector velocity data into the National Centers for Environmental Prediction, giving NOAA modelers access to this data.
- NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) released a new HF radar web product to support marine navigation. It is available in the Chesapeake Bay, San Francisco Bay, and New York Harbor.
- Completed an operational plan and the software development to archive HF radar data at the National Centers for Environmental Information and began archiving HF radar data.
- Worked with the National Weather Service (NWS) to incorporate HF radar data into the Advanced Weather Information Processing System, which will provide all coastal Weather Forecast Offices (WFO) access to HF Radar data.
- Culminating an 8-year effort, the HF radar spectrum sharing plan was approved by the International Telecommunications Union (ITU). This lays the ground work to start the process for frequency allocation within the United States. A multi-agency process started in late 2014 enlisted both Federal agencies (via the National Telecommunications and Information Administration) and non-federal users (via the Federal Communications Commission) as stakeholders.
- Funded one new HF radar in the Caribbean Coastal Ocean Observing System (CariCOOS), replaced one HF radar in the Northwest Association of Networked Ocean Observing Systems (NANOOS), and a site in Core Banks, North Carolina, is now being supported to provide detailed maps of the Gulf Stream current.
- Increased access of global HF radar data with public dissemination of data from South Korea, Australia, and Spain through the Group on Earth Observations (GEO) project.

## Water Quality

Clean and safe water is one of our Nation's great natural resources, and keeping it that way requires a well-integrated system to monitor the water quality of our coastal waters, estuaries, rivers, streams, and the Great Lakes.

### *Toxic Blue-Green Algal Bloom in Lake Erie*

*Figure 5. 2014 Lake Erie Algal Bloom. Credit: NOAA*

NOAA's National Centers for Coastal Ocean Science (NCCOS) responded to a bloom of cyanobacteria, a toxic blue-green algae that contaminated drinking water in Lake Erie and left 400,000 people in Toledo, Ohio, without drinking water for 2 days. NOAA increased the frequency of the weekly Lake Erie HAB Bulletin, which provides information on the size and location of blooms and predict their movement, to twice a week to respond to the needs of Ohio water agencies. The HAB Bulletin for Lake Erie is produced jointly by NCCOS and NOAA's Great Lakes Environmental Research Laboratory. NOAA also provides or is in the process of developing HAB and hypoxia (low dissolved oxygen) forecasts for Lake Erie, the Gulf of Maine, the Chesapeake Bay, the Gulf of Mexico, and the Pacific Northwest.

### *Regional Level, 2013-2014 Accomplishments:*

- AOOS supported monthly oceanographic surveys conducted by NOAA's Kasitsna Bay Laboratory and the Kachemak Bay National Estuarine Research Reserve System to support HAB forecast development.
- CariCOOS developed regional algorithms for sediment loading using remotely sensed ocean color images. The suspended sediment data products, particularly in areas hosting coral reefs, have been made available to the Puerto Rico Department of Natural and Environmental Resources Coastal Zone Management Office.
- The Central and Northern California Coastal and Ocean Observing System (CeNCOOS) produced an experimental Predictive HAB model for California that provides forecasts of *Pseudo-nitzschia* (a marine diatom) blooms and domoic acid (the potentially harmful biotoxin *Pseudo-nitzschia* releases) probabilities. See www.cencoos.org/data/models/habs.
- CeNCOOS and Southern California Coastal Ocean Observing System (SCCOOS) provide weekly sampling including phytoplankton identification, toxin testing, bacteria monitoring, and nutrient analysis and operate a series of water quality stations.
- GCOOS co-authored the GCOOS/Gulf of Mexico Alliance (GOMA) "A Primer on Gulf of Mexico Harmful Algal Blooms," and developed time series for four major HAB species located at products.gcoos.org/bio/hab/time-series.
- Great Lakes Observing System (GLOS) improved visualization of chlorophyll satellite data. To support the further development of remote sensing algorithms and products, an extensive database of in situ optical water properties and coincident chemistry has been constructed to provide this data to the broader user community. This Great Lakes Optical Properties Geospatial Database can be found at www.glopgd.org.
- MARACOOS continues to support its Water Quality Working Group. Sub-regional groups now exist

in Delaware Bay, Chesapeake Bay, and Long Island Sound.

- NERACOOS' partner, the University of Rhode Island, continued its nutrient work. The university has developed and tested an alternative technological approach to integrate nutrient sensors to the Narragansett Bay Fixed-Site Monitoring Network in Narragansett Bay.
- The Pacific Islands Ocean Observing System (PacIOOS) deployed near shore water quality sensors at Kalama Beach Park in Kihei, Maui, and in Kahului, Maui, and released a Turbidity Plume model, which simulates large discharges from the Ala Wai Canal on Oahu due to heavy rains or other events generating a 'brown water' plume.
- SCCOOS provided the statewide website for HAB monitoring found at the following web link www.sccoos.org/data/habs/index.php and the County of San Diego's Department of Environmental Health uses the SCCOOS Tijuana River Plume Tracker to inform water quality warnings and beach closures.

### *Beach Monitoring and Swimming Advisories in the Southeast*

State public health agencies, in conjunction with local governments, routinely monitor the bacterial water quality of coastal swimming beaches. These monitoring data are used to post swimming advisories, so the public can make informed decisions about swimming in waters presenting a potential for adverse health effects.

In partnership with the South Carolina Department of Health and Environmental Control (SCDHEC), the University of South Carolina, a member of Southeast Coastal Ocean Observing Regional Association (SECOORA), and the University of Maryland, are enhancing a user application with new models and an automated, database driven tool for bacteria estimates and visualization of model results for enhanced prediction and analysis of this public health concern.

*Figure 6. Myrtle Beach, SC. Credit: Fotolia.com*

Geographic Information System (GIS)-based tools allow direct access to monitoring data, the models, and user-friendly presentations to provide processed information required for making swimming advisory decisions. These tools are available online via a website and as a downloadable app, 'How's the Beach?' howsthebeach.org. For more information about this project, please visit www.ioos.noaa.gov/ioos_in_action/stories/secoora_beach_monitoring.html.

## Ocean Acidification

Measurements indicate today's oceans are 30 percent more acidic than in pre-industrial times.[2] Marine organisms with calcium carbonate shells or skeletons—such as corals, oysters, clams, and mussels—can be affected by small changes in acidity. That is important, because shelled organisms are essential throughout the marine food chain. They are also vital to our economy, including shellfish hatcheries, which are struggling to adapt to changes in ocean chemistry that are impacting their daily operations.

NOAA established an Ocean Acidification Program (OAP) in 2011. The U.S. IOOS Program aligns its own efforts and those by the IOOS Regional Component with OAP to address its needs for monitoring, data integration and dissemination, and modeling of ocean acidification (OA). The accomplishments below focus on the excellent partnership between OAP and IOOS. For complete information on NOAA's OAP program, see oceanacidification.noaa.gov.

### *2013-2014 Accomplishments:*

- OAP leveraged monitoring assets in AOOS, CariCOOS, CeNCOOS, MARACOOS, NANOOS, NERACOOS, PacIOOS, SECOORA, and SCCOOS, thereby saving resources for development of new observing technologies and research on impact on marine ecosystems.
- IOOS' Ocean Technology Transition (OTT) Project, in collaboration with OAP, awarded a $604,420 grant to support OA sensor development and applications to assist the shellfish industry in Alaska, Hawaii, and along the west coast, and to launch the IOOS Pacific Region Ocean Data Portal (IPACOA) (www.ipacoa.org). More information about this project can be found at www.ioos.noaa.gov/marine_sensors/pacific_ocean_acid.html.
- OAP, in collaboration with OTT, awarded the University of Washington Applied Physics Laboratory a 3-year grant to address the needs of impacted and potentially vulnerable industries and stakeholders in the United States. More information about the project is located at: oceanacidification.noaa.gov/WhatsNew/OANews/TurningtheHighBeamsonOceanAcidification.aspx.
- The Subcommittee on Ocean Science and Technology's (SOST) Interagency Working Group on Ocean Acidification (IWG-OA) published the first strategic research plan to guide Federal research and monitoring on OA. The plan can be accessed via NOAA's Office of Oceanic and Atmospheric Research at oceanacidification.noaa.gov/IWGOA.aspx.
- The Alliance for Coastal Technologies released the final report, "Science Assessment of Chesapeake Bay Acidification: Toward a Research and Monitoring Strategy" in September 2014. The report is a first step towards better understanding Chesapeake Bay carbon chemistry dynamics and ultimately a Bay-wide acidification monitoring effort to help quantify and predict changes and to effectively protect natural resources. The report is available at: www.act-us.info/workshops.php. This report laid the scientific foundation for the State of Maryland OA Task Force which released its own report and recommendations (msa.maryland.gov/megafile/msa/speccol/sc5300/sc5339/000113/020000/020877/unrestricted/20150253e.pdf).
- AOOS hosted, with support from the Alaska Center for Climate Assessment and Policy (a NOAA Regional Integrated Sciences and Assessments team) and Alaska Sea Grant, a workshop on OA in

[2] Elperin, Juliet "Ocean Acidification Emerges As New Climate Threat." Washington Post, September 2012. Web. Accessed 16 November 2014, www.washingtonpost.com/national/health-science/ocean-acidification-emerges-as-new-climate-threat/2012/09/30/8457e6e8-08b8-11e2-afff-d6c7f20a83bf_story.html

Alaska that led to a statewide 'Call to Action.' AOOS is taking the lead on OA outreach and education efforts in Alaska.

- NERACOOS, in partnership with OAP, established the Northeast Coastal Acidification Network (NECAN), mirrored after the successful California Current Acidification Network, resulting in several States establishing legislative commissions to understand the effects of OA (www.neracoos.org/necan).
- SECOORA is now leading, in collaboration with OAP, the Southeast Ocean and Coastal Acidification Network (SOCAN) (secoora.org/socan).
- NOAA and IOOS led the establishment of the Global Ocean Acidification Observing Network (GOA-ON), publishing the first GOA-ON Requirements and Governance Plan. For more information see www.goa-on.org.

### *IOOS Pacific Regions Launch Ocean Acidification Data Portal*

Shellfish play a vital role in the environment, culture, and economy in many American coastal communities. The shellfish aquaculture community is the largest segment of marine aquaculture in the United States. Several thousand small farms nationwide harvest over $600 million worth of sustainable shellfish while providing tens of thousands of jobs in rural coastal communities.[3]

*Figure 7. Rock Point Oyster Company Shellfish Farm in Quilcene, WA. Credit: Jenifer Rhoades, IOOS.*

Shellfish farms and hatcheries along the Pacific coast can now get real-time, online OA data through IOOS. The data, ranging from carbon dioxide concentrations to salinity and water temperatures can be found through the IPACOA at www.ipacoa.org, which began operations in November 2014.

"This new portal provides critical environmental intelligence to researchers, coastal managers, and end users such as shellfish aquaculture farms," said Dr. Libby Jewett, Ph.D., Director of OAP. "We hope the data gathered through this system, combined with on-going research, can help NOAA and our partners provide information to support effective adaptation strategies and other coastal resource decision making."

The IPACOA features data streams from five shellfish hatchery/growing sites using monitoring systems, dubbed "burkolators," developed by Dr. Burke Hales, Ph.D., Oregon State University. The monitoring systems, measuring ocean acidification variables, including calculated aragonite saturation, were installed at several Pacific coast sites including: Alutiiq Pride Shellfish Hatchery in Alaska, Taylor Shellfish Hatchery in Washington, Whiskey Creek Shellfish Hatchery in Oregon, Hog Island Oyster Co. in central California, and Carlsbad Aquafarm in southern California. Without data from monitoring equipment, shellfish growers have no way to assess how the chemical make-up of the water will affect shellfish productivity.

[3] East Coast Shellfish Growers Association ecsga.org/Pages/Issues/Acidification/ClimateImpactsOnShellfishAq.pdf

## Wave Observations

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.

The U.S. Army Corps of Engineers (USACE), NOAA's National Data Buoy Center (NDBC), and IOOS RAs work together to provide wave observations. The USACE and the California Department of Boating and Waterways provide the funding for Coastal Data Information Program's (CDIP) central data management, which is a major contribution to IOOS. Several IOOS RAs have deployed the Datawell Waverider Mk III used by the Coastal Data Information Program and provide their information to the program along with their own Regional Portal.

As of 2014, there were 218 active wave sites reporting data to NDBC, including 17 Canadian sites. The number of stations in the United States increased by 20 in 2014. It is important to note this is the net increase between new and decommissioned stations. Some of the decommissioned stations were in locations critical to "A National Operational Wave Observation Plan," but difficult decisions to decommission the stations were based on the availability of funding.

## Marine Biodiversity Observing Network

An integrated picture of how biodiversity is changing within ecosystems is a key indicator of ocean health and critical to sustaining natural resources such as fisheries. The U.S. IOOS Program is partnering with NASA, NOAA's Office of Ocean Exploration and Research, the Department of the Interior's Bureau of Ocean Energy Management (BOEM), and Shell Oil to initiate the first American network to monitor marine biodiversity at scales ranging from microbes to whales. Three pilot projects will provide a prototype of how a National Marine Biodiversity Observation Network (Marine BON) could be developed. Such a network would serve as a marine resource management tool to conserve existing biodiversity, inform our ability to maintain critical ecosystem services, and enhance biosecurity against threats such as invasive species and infectious agents.

Selected from 19 proposals, the three pilot projects will conduct work in a number of locations: the Florida Keys, Flower Garden Banks, and Monterey Bay National Marine Sanctuaries; Santa Barbara Channel; and the Channel Islands National Marine Sanctuary; and on the continental shelf in Alaska's Chukchi Sea. The pilots will occur in different marine environments and integrate existing observations ranging from satellite observations to DNA sampling. In addition, new observations will fill current data gaps. The pilot projects will build partnerships with existing long-term biodiversity monitoring efforts, explore innovative uses of new in situ observations and genomic techniques, and improve access to integrated biodiversity data by utilizing existing IOOS data management capabilities.

To learn more about Marine BON, please visit www.ioos.noaa.gov/biodiversity/welcome.html.

## Global Component

As of December 2014, the in situ GOOS is 63 percent completed against initial design targets. These global systems, along with a network of satellite missions, provide the backbone GOOS that provides the foundation for a wide variety of research; weather, ocean, marine, and climate forecasts; and assessments of environmental changes (e.g. annual State of the Climate Report). Four of these global in situ efforts and their respective accomplishments are highlighted below.

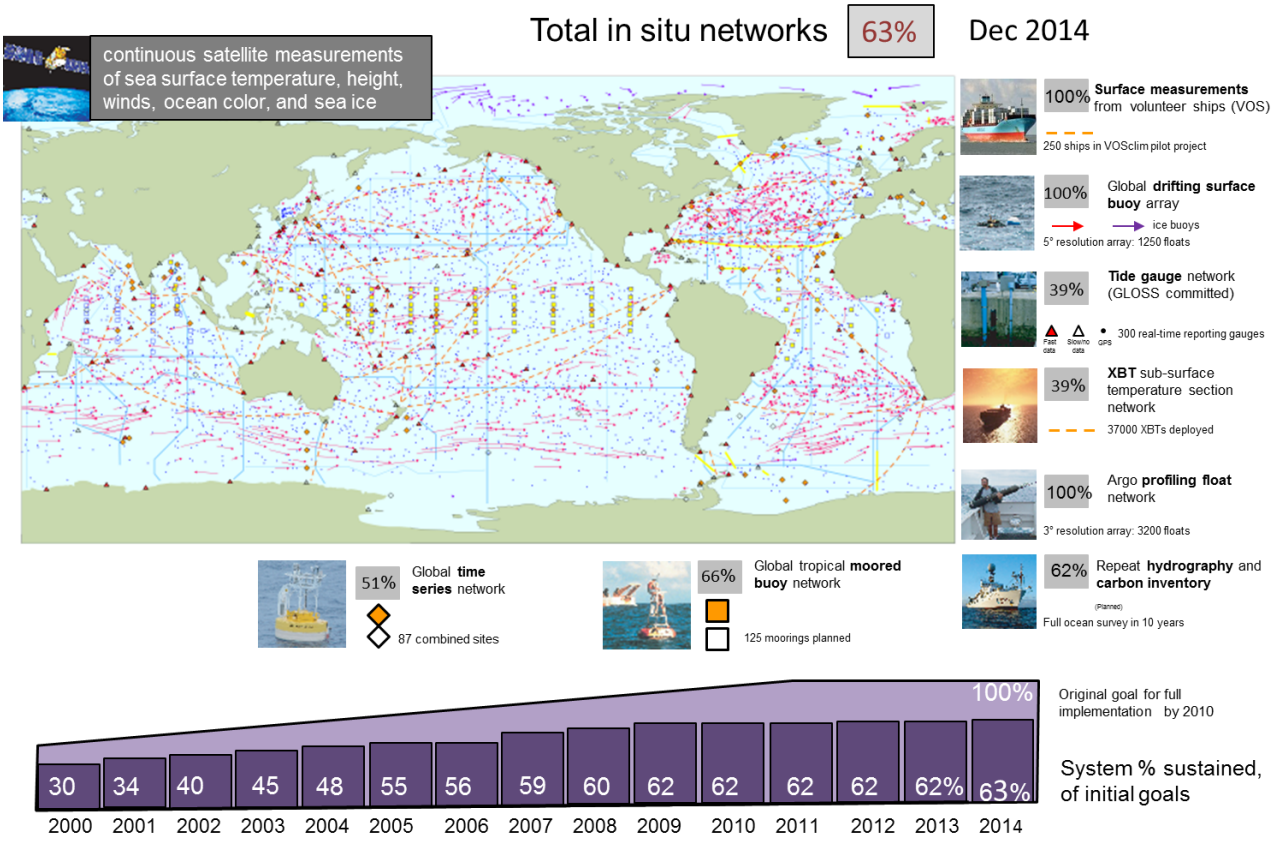


*Figure 8. U.S. IOOS Global Component. Credit: U.S. IOC*

### *Argo*

Argo is a global array of more than 3,500 free-drifting profiling floats that measure temperature and salinity in the upper two thousand meters of the ocean.

The Argo array provides routine observations of the upper ocean for forecasts of weather extremes, climate, defense, and marine conditions. Argo data also help describe current, and predict future, sea-level changes. The need for a deep-ocean component of Argo, called 'Deep Argo,' has been addressed through support for both instrumentation development and pilot deployments. Deep Argo floats provide a profile of ocean conditions, including deep ocean temperature and salinity measurements, from the surface to a depth 6,000 meters to improve the understanding of the ocean. The first two prototype Deep Argo floats were deployed in June 2014 in the Southwest Pacific using technology designed at Scripps Institution of Oceanography. The floats are presently both operating to a depth of 5,500 meters, and are taking full profiles every 3 days. The floats will be recovered in August 2015 to evaluate the technology and develop an array of approximately 12 instruments to be deployed in the same region for an operational time period of 4 years.

Along with the Deep Argo floats, a new-generation sensor system combining measurements of temperature, salinity, and pressure was tested against the challenging accuracy and stability requirements for observing the ocean's depths. The National Science Foundation's (NSF) Southern Ocean Carbon and Climate Observations and Modeling project (SOCCOM), supported by NSF's Division of Polar Programs, is outfitting Argo with bio-geochemical sensors. SOCCOM is led by the Princeton Environmental Institute at Princeton University. As part of SOCCOM, the University of Washington and Scripps Institution of Oceanography share the leadership role on this project developing and deploying the new sensors. As of December 2014, 13 floats with the new sensors have been deployed in the Southern Ocean.[4] The SOCCOM floats measure pH, dissolved oxygen, and nitrate complementing the core sensors of Argo.

### *Tropical Pacific Observing System 2020*

The Tropical Pacific Observing System (TPOS) 2020 Project is a GOOS Project in collaboration with NOAA and Japan Agency for Marine-Earth Science and Technology. TPOS will evaluate, and where necessary change, all elements contributing to the TPOS based on a modern understanding of tropical Pacific science. In 2014, NOAA, Japan Agency for Marine-Earth Science and Technology, and the Ocean Observations Panel for Climate convened a review of TPOS, and TPOS-2020 Project was initiated. The goals of the project include redesigning and refining TPOS to observe the El Niño Southern Oscillation and advance scientific understanding of its causes; determining the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services; and advancing understanding of tropical Pacific physical and biogeochemical variability and predictability. An international steering committee, task teams, distributed project office, and resource forum have been established to advance the project. For more information about TPOS 2020, please visit www.tpos2020.org.

### *Deep Ocean Observing Strategy*

The Deep Ocean Observing Strategy is being developed as a multi-disciplinary project, designed to expand the current observing system into the deep ocean. The deep ocean is a dynamic and sometimes highly responsive environment that can change radically within scales of meters to kilometers. Direct and targeted observations have facilitated the investigation of the deep-sea realm, resulting in the discovery of new ecosystems and abyssal activities, and the finding of highly heterogeneous deep sea floor habitats. During the next 10 years, the deep ocean research community will define and develop observations of essential physical, chemical, geological, and biological variables. For more information, please visit www.ioc-goos.org/doos.

### *Ocean Biogeographic Information System*

The Global Biodiversity Information Facility and the Intergovernmental Oceanographic Commission (IOC) aim to improve the volume and quality of information available to policy makers for conservation and sustainable use of the ocean's biological resources. The two institutions signed a Letter of Agreement that recognizes the IOC as a Global Biodiversity Information Facility Affiliate and the Global Biodiversity Information Facility as an International Oceanographic Data and Information Exchange Associate Data Unit. The agreement promotes and facilitates closer collaboration between GBID and IOC's International Oceanographic Data and Information Exchange/Ocean Biographic Information System, specializing in marine biodiversity data.

[4] soccom.princeton.edu/soccomviz.php

## Satellite Data and Information

The ocean comprises over 70 percent of Earth's surface, which makes satellite remote sensing a logical and significant component of an overall effort to meet societal needs for weather and water information; support commerce with information for safe, efficient, and environmentally sound transportation; and provide information for better coastal preparedness.

### *JASON-3*

Jason-3 is an international cooperative mission in which NOAA's National Environmental Satellite, Data, and Information Service is partnering with the Centre National d'Etudes Spatiales (France's governmental space agency), European Organisation for the Exploitation of Meteorological Satellites, and NASA. Jason-3, which was launched in January 2016, is the newest satellite in a series designed to maintain long-term satellite altimetry observations of global sea surface height. These data provide critical ocean information that forecasters need to predict devastating hurricanes and severe weather before they arrive onshore. Over the long term, Jason-3 will help track global sea level rise, an increasing threat to the resilience of coastal communities and to the health of our environment.

Jason-3's highly accurate altimetry measurements will be used for a variety of scientific, commercial and operational applications, including:

- Hurricane intensity forecasting;
- Surface wave forecasting for offshore operators;
- Forecasting tides and currents for commercial shipping and ship routing;
- Coastal forecasting for response to environmental problems like oil spills and HABs;
- Coastal modeling crucial for marine mammal and coral reef research; and
- El Niño and La Niña forecasting.

For more information about Jason-3, please visit www.nesdis.noaa.gov/jason-3.

### *Multi-Sensor Improved Sea-Surface Temperature*

Knowledge about sea-surface temperature (SST) is important to coastal and marine spatial planning, global weather prediction, climate change studies, search and rescue, and ecosystem-based management. SST is derived from measurements taken by numerous satellites carrying infrared and microwave radiometers, and measured from moored buoys, drifting buoys, and ships. Since FY 2011, NOAA and NASA have jointly funded a project focused on improving the quality of the satellite SSTs from existing and new sensors, producing multi-sensor blended gap-free SSTs from the United States and international datasets, and successfully broadening the use of these products by specifically targeting coastal applications and U.S. IOOS regional partners. The NOAA-NASA Multi-Sensor Improved Sea-Surface Temperature (MISST) project is the American component of the global Group for High Resolution Sea Surface Temperature (GHRSST) effort. It relies on a substantial, internationally-coordinated data management backbone to make gap-free SST data sets available in a standardized format, and has greatly reduced overhead to make SST data sets available to users, including the IOOS Regional Associations.

This project completed its last year of funding in FY 2015.

### *Aquarius Satellite*

In 2014, three successful years of the Aquarius Mission were celebrated. Aquarius is a focused effort to measure sea-surface salinity and provides the global view of salinity variability. The mission is a collaboration between the NASA and the Space Agency of Argentina (Comisión Nacional de Actividades Espaciales). During 2013 and 2014, scientists working with data from the Aquarius instrument have released worldwide maps of soil moisture, showing how the wetness of the land fluctuates with the seasons and weather phenomena. Data from Aquarius are also revealing how rainfall, evaporation, river outflows, and melting ice are linked to salinity, ocean current and climate variations.

### *Ocean Surface Winds Team*

Knowledge about ocean surface vector winds is important to understand and predict the short-term and longer-term processes that drive our planet's environment. As the largest source of momentum for the ocean surface, winds affect the full range of ocean movement, from individual surface waves to complete current systems. Winds along the ocean surface regulate interaction between the atmosphere and the ocean via modulation of air-sea exchanges of heat, moisture, gases, and particulates. With the ocean covering almost three quarters of Earth's surface, this interaction has significant influence on global and regional climate.

The Ocean Surface Winds Team of the Center for Satellite Application and Research, in NOAA's National Environmental Satellite, Data, and Information Service, applies remotely-sensed data received from operational and research satellites. The team provides science support for remotely-sensed ocean surface wind products through product development, product validation, product improvement and user education and outreach. Its objective is to improve utilization of these data within NOAA and to provide guidance and support in planning for current and future missions. The team works closely with operational forecasters in the NWS and other parts of NOAA, and thus, much of its research, development and validation is in support of the near real-time product stream. In support of these activities, the Team operates several near real-time satellite product processing systems and supports the Ocean Winds flight experiment program with the NOAA P-3 aircraft.

## National and Regional Component

The breadth of observations at the national and regional level are extensive, and for this report, we selected a few notable accomplishments.

### *National Ocean Service Support to IOOS*

NOAA's National Ocean Service (NOS) established three priority areas and published a roadmap in 2014 to achieve those priorities. One focus area of the Roadmap, 'Coastal Intelligence,' utilizes principles similar to IOOS by leveraging NOAA capabilities in support of national issues. For example, the expansion of the Panama Canal is driving an increase in cargo ship size, which requires more precise navigation capabilities. In response to this navigation requirement, NOS launched a pilot project in 2014 to support the development of an under-keel clearance decision tool to ensure the safe transit of loaded oil tankers in the port of Long Beach, CA. Five offices with the NOS, two offices within NWS and SCCOOS along with private sector partners, Jacobsen Pilots and ProTide, have accomplished the following to support the development of the under keel clearance decision tool:

- Initiated development of a high resolution wave model.
- Installed wave buoys to validate the wave model.

- Completed high-resolution hydrographic survey of Los Angeles and Long Beach.
- Delivered processed high-resolution bathymetric data.

### *NOAA PORTS*

NOAA PORTS is an integrated system of oceanographic and meteorological sensors that provides mariners with reliable real-time information about environmental conditions in a seaport, greatly enhancing the safety and efficiency of maritime commerce. On July 23, 2014, NOAA's CO-OPS inaugurated a new PORTS—the Nation's 23rd and second largest—in the Port of Jacksonville, Florida.

*Figure 9. NOAA Administrator Kathryn Sullivan (left) and James McLaughlin, Executive Director, Jacksonville Marine Exchange, dedicate the Jacksonville, Florida, PORTS, on July 23, 2014. Credit: NOAA*

### *National Data Buoy Center*

The National Data Buoy Center is working on the next-generation system named the Self-Contained Ocean Observing Payload (SCOOP). SCOOP takes advantage of the latest in technology and uses modular meteorological and oceanographic observing systems that can be constructed, assembled, and installed on a variety of moored and fixed platforms, including a new smaller moored buoy that can be deployed and serviced by a less expensive vessel. SCOOP is expected to provide the same high-quality data as the existing National Data Buoy Center buoy stations but be significantly smaller, less expensive, and more reliable. In addition, the system will provide ocean temperature profiles that will assist hurricane forecasters.

The design is based on a distributed multi-processor architecture making use of the center's Smart Module technology. Data messages are being formatted using Extensible Markup Language, an accepted industry standard. Processed data messages are transmitted exclusively via Iridium satellites allowing for more frequent transmission, thus decreasing the data latency, as well as transmission retry capability. SCOOP modularity allows for additional auxiliary devices in the architecture for new or third party sensors to be integrated into the system. This will provide additional expansion of ocean observation capability. The power system consists of a small lightweight lithium-ion smart battery/charging system allowing for easier replacement, health monitoring, and remote power management. The overall system is lightweight and self-contained, making it easier to replace in the field and removing the need for piecemeal repair.

The project, funded by the Disaster Relief Appropriations Act of 2013, began in September 2013. Testing of three buoys began in December 2014. When completed, SCOOP will deploy a total of 20 units including 6 buoys in the hurricane network.


*Figure 10. Deployment of a 3-Meter Olympic Buoy Station. Credit: NOAA/National Data Buoy Center*

### *National Science Foundation—Oceans Observatories Initiative*

In 2014, the Oceans Observatories Initiative moved toward completion of the construction phase with 8 deployment cruises installing 34 moorings, 9 instrumented seafloor sites, 16 gliders, and approximately 550 instruments. These successful deployments occurred in the northern hemisphere global sites (Station Papa, Irminger Sea), within the coastal domain of the Atlantic and Pacific (Pioneer and Endurance Arrays), and along the cabled array on the Juan de Fuca Plate. Pre-commissioned data are being telemetered from the deployed un-cabled systems, and are flowing from the cabled seafloor-mounted systems.

The Oceans Observatories Initiative is in its final deployment phase and preparing for the delivery of data to the Oceans Observatories Initiative user community. The installation of the remaining two global arrays, Southern Ocean and Argentine Basin, occurred in February and March 2015, respectively, while the final Endurance and Pioneer Array deployments were completed in the spring 2015. The autonomous underwater vehicles, fuel cell, and dock were deployed in the fall 2015 for the Pioneer Array and completed all installations.

### *National Estuarine Research Reserve System*

Through a new mobile website tool, coastal residents, decision makers and researchers now have instant access to real-time weather and water quality data available from the National Estuarine Research Reserve System's System Wide Monitoring Program (see figure 11).

Whether a user is out in the field or without internet access, this new mobile website tool provides access to useful data from any mobile device, smartphone, or tablet, regardless of operating system. Users can locate monitoring stations nearest to them from the 28 reserves around the country, view station locations on Google maps, bookmark their favorite stations, view near real-time data, and create quick charts. The mobile website tool can be found at www.nerrsdata.org/mobile and complements the Centralized Data Management Office's other data access resources found at www.nerrsdata.org.

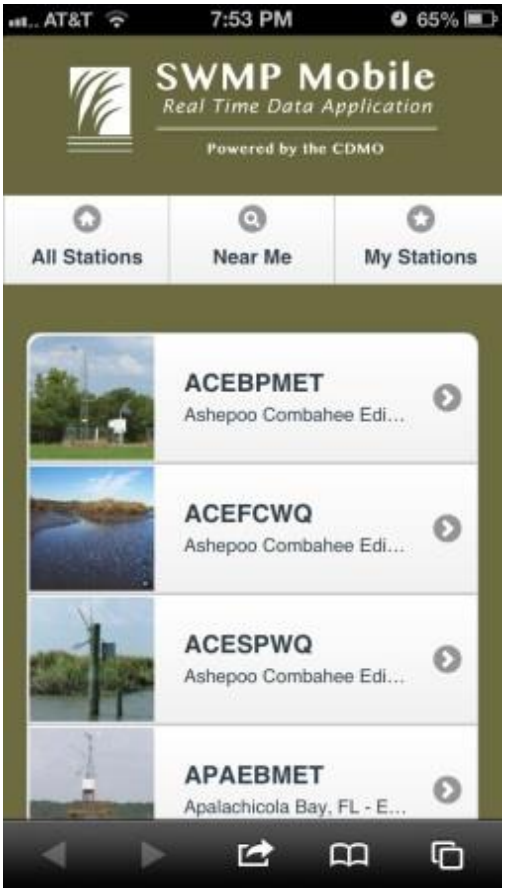


*Figure 11. System Wide Monitoring Program Mobile App. Credit: NOAA*

# Chapter 3: Marine Sensor Innovation

The U.S. IOOS Program launched the Marine Sensor Innovation Project in FY 2013. There are three components to this project: Sensor Testing and Evaluation, the Coastal and Ocean Modeling Testbed (COMT), and Ocean Technology Transition (OTT).

## Sensor Testing and Evaluation

The lead organization for IOOS' Sensor Testing and Evaluation Project is the Alliance for Coastal Technologies (ACT), a partnership 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. In FYs 2013 and 2014, ACT focused on evaluation and innovation activities on in situ pH, dissolved oxygen, and nutrient sensors to address critical issues such as ocean acidification, hypoxia, eutrophication, and HABs. When completed, the results of these evaluations are made available at www.act-us.info/evaluations.php.

### *Nutrient Sensor Challenge*

The U.S. IOOS Program funded ACT to support an interagency effort to explore the frontiers of nutrient sensor capabilities and envision next-generation sensors. As part of this effort, ACT coordinated a workshop in November 2014, which focused on accelerating the development and adoption of aquatic nutrient sensors, and included the involvement and cooperation of the Challenging Nutrients Partners, a coalition of federal agencies, the Everglades Foundation, Tulane University and the Partnership on Innovation Technology and the Environment. In particular, the workshop focused on opportunities in the user market, performance parameters, "usability" requirements, cost considerations, and feasibility. Ultimately, the goal of the workshop was to build consensus on technical requirements and other recommendations to inform the Nutrient Sensor Challenge. More information about ongoing Nutrient Sensor Challenge activities can be accessed at www.act-us.info/nutrients-challenge.

## Coastal and Ocean Modeling Testbed

COMT's mission is to use applied research and development to accelerate the transition of scientific and technical advances from the coastal and ocean modeling research community to improve operational ocean products and services. Coastal waters and lowlands of the United States are threatened by climate change, sea-level rise, flooding, oxygen-depleted "dead zones," oil spills, and unforeseen disasters. IOOS, with coordination from the Southeastern Universities Research Association, built strong and strategic collaborations among experts from academia, Federal operational centers, and industry to create the IOOS COMT.

One example of a successful result from the use of the COMT was achieved by the NWS' National Hurricane Center. As a result of the testing done in the COMT, the National Hurricane Center was able to increase the resolution and geographical coverage of the Sea, Lake, and Overland Surges from hurricanes model to produce coupled run-off, tide, wave, and inundation forecasts.

For more information about COMT, please visit www.ioos.noaa.gov/modeling/comt/whatis.html.

### *Virginia Institute of Marine Science (VIMS) Research Helps Improve Estimates of "Dead Zone" Size.*

New modeling methodology has important implications for Bay management. Gauging the size of the low-oxygen "dead zone" that afflicts Chesapeake Bay each summer is both difficult and important—difficult due to the extent and variability of the problem, and important as a bellwether of Bay health. Now, a study led by researchers at VIMS, and supported by IOOS' COMT, offers an improved method for estimating the dead zone's magnitude and duration, one in which fewer field observations could provide a more accurate and efficient means to measure the long-term progress of Bay restoration efforts. The study is authored by VIMS post-doctoral research associate Aaron Bever, VIMS professors Marjy Friedrichs and Carl Friedrichs, Malcolm Scully of the Woods Hole Oceanographic Institution, and Lyon Lanerolle of NOAA.

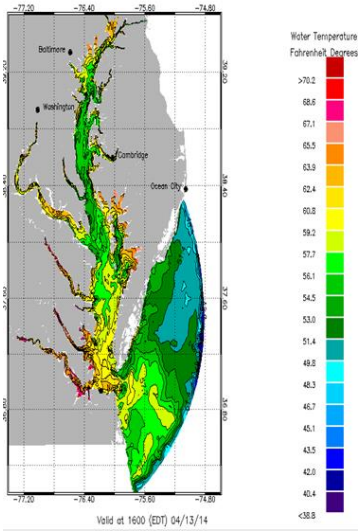


*Figure 12. VIMS Chesapeake Bay Dead Zone Model Output. Credit: U.S. IOOS*

## Ocean Technology Transition

The OTT Project sponsors the transition of emerging marine observing technologies, for which there is an existing operational requirement and a demonstrated commitment to integration and use by the ocean observing community, to operational mode.

OTT utilizes the Technology Readiness Levels ontology. The Technology Readiness Levels are used as a systematic metric/measurement system that supports assessments of the maturity of a particular marine observing technology, and enables a consistent comparison between different types of technologies. OTT focuses on technology that is at and/or above Technology Readiness Level Six, which means OTT-funded technology has been demonstrated in a relevant or operational environment.

*Figure 13. Prototype Dissolved Inorganic Carbon (DIC) buoy next to PacIOOS C02 buoy of the south shore of Oahu. Credit: University of Hawaii*

As of December 31, 2014, the two year-old OTT Project has awarded nearly $4 million in grants in academic and private sector partnerships to: provide ocean acidification data and information to shellfish growers in the States of California, Oregon, Washington, and Alaska; advance HAB detection in Washington State, the Gulf of Maine and the San Francisco Bay; develop an economical sensor package using existing sensors in a new manner to accurately predict the onset of ice formation in the Arctic; and transition state-of-the-art nutrient sensing technology to develop an Operational Nutrient Observatory for the northeastern United States.

For more information on the Ocean Technology Transition Project, please visit the OTT website at www.ioos.noaa.gov/marine_sensors/ocean_tech.html

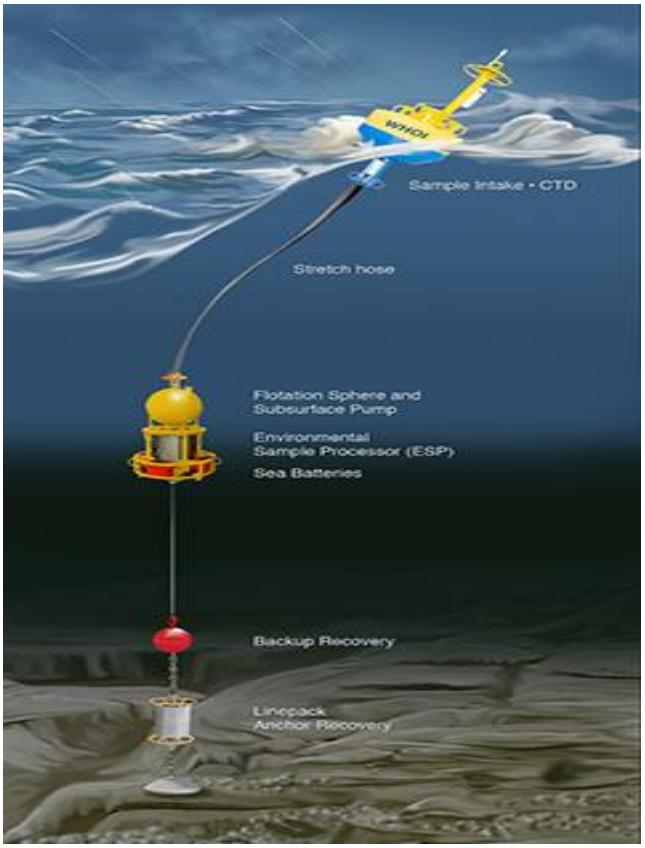


*Figure 14. The Environmental Sample Processor automatically collects a sample of water and then rapidly tests it for DNA and toxins that are indicative of targeted species and the substances they may produce. Credit: Paul Oberlanfer, Woods Hole Oceanographic Institution*

# Chapter 4: Modeling and Analysis

Dynamic and statistical computer models of the ocean are used by scientists to forecast future states of the oceans and the Great Lakes, and to deconstruct existing or past conditions to determine what factors affect the ocean and coastal environment. The U.S. IOOS Modeling and Analysis subsystem provides the ability to analyze, interpret, and forecast events in the coastal oceans that can be used by government agencies, industry, academia, non-governmental organizations, tribal entities, professional organizations, and the general public.

## 2013-2014 National Accomplishments:

- NOAA has the primary responsibility for weather- and basin-scale physical modeling. NOAA's NWS runs the global Real-Time Ocean Forecast System to provide initial and boundary conditions for operational basin-wide, regional, coastal, and coupled ocean forecast systems. The system is based on an eddy-resolving 1/12 degree global Hybrid Coordinate Ocean Model and serves as part of a larger national backbone capability of ocean modeling at NOAA in strong partnership with the U.S. Navy. Global Real-Time Ocean Forecast System runs once a day and produces 2-day nowcasts and 8-day forecasts using daily initialization fields from the Navy.
- NOAA's NOS operates a national network of coastal and estuarine Operational Forecast Systems. CO-OPS released enhancements to the Northern Gulf Operational Forecast Systems by adding two higher-resolution nested models for the northwest and northeast areas of the Gulf of Mexico, released a new Operational Forecast Systems for the San Francisco Bay region, and upgraded its system in New York/New Jersey Harbor and in Florida's St. Johns River, extending their forecast horizons from 24 to 48 hours.
- The U.S. Geological Survey (USGS) is applying IOOS data standards and common services to its data and modeling systems. For example, the USGS Coupled Ocean-Atmosphere-Wave-Sediment Transport Modeling System, which joins several models together to study processes affecting coastal change, will enhance capabilities for understanding and forecasting coupled ocean, coastal and climate processes for scientists and other users. "The standardized IOOS-supported structure will facilitate collaborative modeling work across these ocean research communities and will improve access for modeling data and outputs to be integrated with other model and observational data and information from other agencies and partners," said Suzette Kimball, Director, USGS.

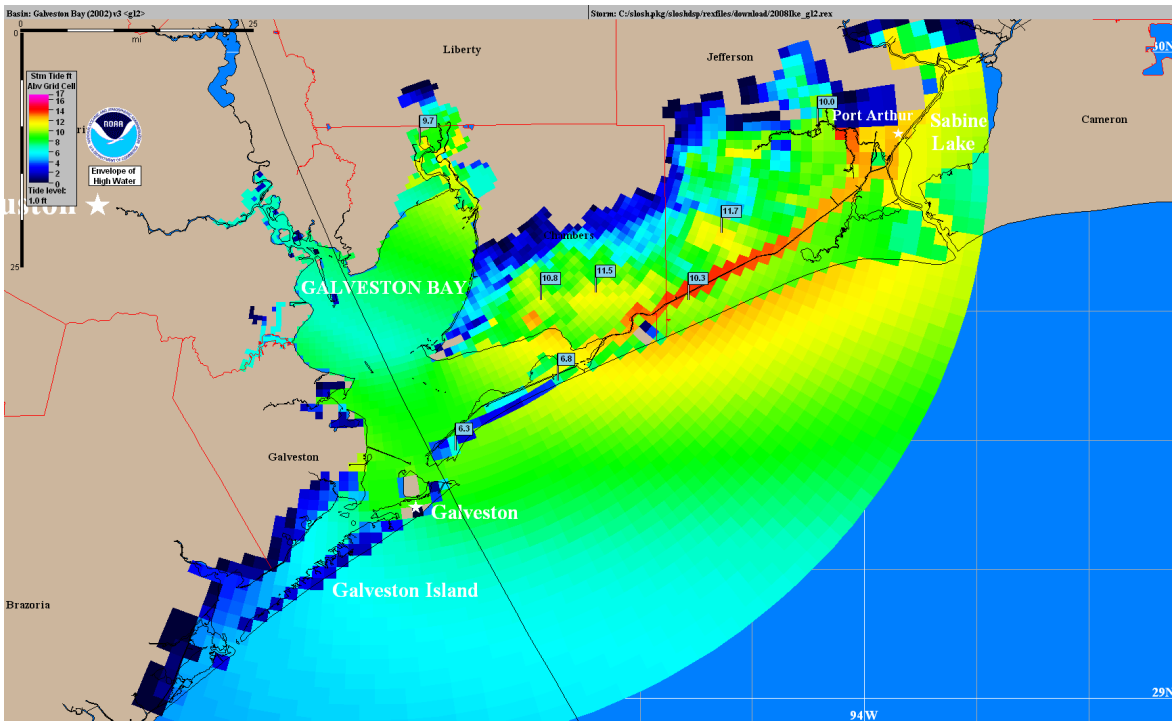


*Figure 15. Sample output of the Sea, Lake, and Overland Surges from Hurricanes model for Hurricane Ike as viewed within the display program. Source: NOAA www.nhc.noaa.gov/surge/images/gl2_ike2008.png*

### *San Francisco Bay Operational Forecast System*

NOS CO-OPS introduced a new San Francisco Bay Operational Forecasts System in May 2014. The new system significantly benefits a range of maritime activities including recreational boating, fishing, sailing, shipment and vessel transect planning, storm effect tracking, hazardous material tracking, and search and rescue. In partnership with NOAA's National Center for Environmental Prediction, the model is integrated with the Weather and Climate Operational Supercomputing System (WCOSS), which produces weather and climate forecasts used by NWS meteorologists nationwide.


*Figure 16. San Francisco Bay Operational Forecast System. Credit: NOAA/NOS/CO-OPS*

The system provides water level, current, temperature and salinity nowcasts, and forecast guidance based on nearby real-time observation data, meteorological forecasts, and astronomical predictions. Successful implementation of the system resulted from CO-OPS collaborations with NOAA's OR&R and NWS' Monterey, CA WFO, the USGC, and CeNCOOS.

The downscaled models were used by the U.S. Fish and Wildlife Service's Aleutian/Bering Sea Islands Landscape Conservation Cooperative and USGS's Alaska Science Center to assess the vulnerability to climate change of key species in the Bering Sea and Aleutian Islands.

## 2013-2014 Regional Accomplishments:

- AOOS funded downscaling of five national climate models and two emission scenarios for winds, sea ice concentrations and sea surface temperature in Alaska's coastal waters that are now served up through the AOOS Ocean Data Explorer.
- CariCOOS: 1) finalized Storm Surge Maps (Atlas) for Puerto Rico—these along with the maps issued last year for the U.S. Virgin Islands, provide for appropriate urban development and response planning for the CariCOOS archipelago (excluding the uninhabited Navassa); and 2) the CariCOOS-Sea Grant Nearshore Breaker Model is fully operational and the breaker height predictions are provided to NWS San Juan for use in their rip current risk prediction for Puerto Rico and the USVI system.
- CeNCOOS developed a fully coupled physical-biogeochemical data assimilation system operating in near real-time to improve forecasts for the California Current a Pacific Ocean current that moves southward along the western coast of North America, beginning off southern British Columbia and ending off southern Baja California.
- CeNCOOS and SCCOOS partnered with the NASA Jet Propulsion Laboratory to operate a three kilometer Regional Ocean Modeling System ocean circulation model along the California Coast.

- GCOOS enhanced the Model Resources Center by including a new tool for accessing animations and data of sea surface height anomaly. See products.gcoos.org/model-resources/ssha.
- MARACOOS developed an algorithm to de-cloud composite satellite SST imagery. The output from the algorithm is ingested into real-time atmospheric simulations with the Rutgers University version of the Weather Research and Forecasting model to generate a high resolution (two-kilometer grid spacing) SST product that resolves coastal upwelling and surface-ocean cooling from strong coastal storms.
- NANOOS partnered with the Joint Institute for the Study of the Atmosphere and Ocean and NOAA's Northwest Fisheries Science Center to develop a seasonal forecast system (Seasonal Coastal Ocean Prediction of the Ecosystem) for the Washington and Oregon coasts. This system forecasts SST, chlorophyll, hypoxia, sardine habitat, and regional climate indices 6 to 9 months into the future to support the California Current Integrated Ecosystem Assessment.
- NERACOOS upgraded the Northeast Coastal Ocean Forecast System to a three-way fully coupled WRF/SWAVE/FVCOM system into 24/7 operations. In addition to the forecast of wind, surface air pressure, air temperature, ocean currents, temperature and salinity, SWAVE has provided the high-resolution forecast for surface waves up to a horizontal resolution of 300 meters. These data are delivered to the NWS WFO at Taunton, Massachusetts on a daily basis.
- PacIOOS developed and operates the high-resolution Regional Ocean Modeling System ocean circulation models for the Waikiki area, Samoa, Western Pacific, and the Mariana Islands; wave models for the Northwestern Hawaiian Islands and Samoa; WRF atmospheric models for the Western Pacific, Mariana Islands, Guam, and Samoa; and Wave Run-Up Forecast for Majuro Atoll in the Republic of the Marshall Islands.
- SECOORA exposed ocean model output of sea surface temperature, sea surface height, salinity, wave height, currents, and inundation from three of its academic partners.

## Strategies and Priorities to Advance Modeling Capabilities for the Coastal Ocean

The project to develop strategies and priorities to advance modeling capabilities for the coastal ocean was initiated in 2013. The strategies and priorities, once finalized, will serve two purposes: 1) provide technical input to advance the IOOS modeling capability for the next 8 years and 2) enhance collaboration between IOOS Regional Associations and IOOS Federal partner modeling efforts to address common needs and requirements. The strategy and priorities are expected to be finalized in the summer of 2016.

### *NOAA's Ecological Forecasting Roadmap*

NOAA's Ecological Forecasting Roadmap is a plan to deliver coordinated, accurate, and resource-efficient ecological forecast products. This long-term approach will allow NOAA to meet key mandates tied to protecting life, property, and human health, while maintaining its role as stewards of the environment. IOOS is a primary partner in the execution of the roadmap, which is working toward developing a national protocol for ecological forecasts while allowing the agency to continue to target development and implementation of region-specific forecasts.

# Chapter 5: Data Management and Communications

The IOOS Data Management and Communications subsystem, or "DMAC," is the central operational infrastructure for assembling, disseminating, integrating, and refining information derived from ocean observations. The U.S. IOOS Program, per the ICOOS Act, has the overall responsibility for DMAC. The program has activities aimed at technical solutions (requirements/standards/software) and large scale implementation and developing a community.

In the last 2 years, IOOS has developed and deployed a single in situ observation service; developed a new registry and catalog; proven the viability of IOOS DMAC through a systems integration test; advanced quality control of the data; established a Glider Data Assembly Center (DAC) and an Animal Telemetry Network DAC; and supported the integration of biological observations data.

## Data Services

All IOOS RAs' data management systems have been configured to use a single data standard to disseminate in situ data. This is a tremendous milestone, which is not always appreciated because it takes place 'behind the scenes.' The use of web services alone are not sufficient to achieve the level of interoperability IOOS requires; these web services must be configured to output specific file formats adhering to specific information models and conventions. IOOS configured the Sensor Observation Service (SOS) Open Geospatial Consortium standard (akin to agreeing to a recipe) for IOOS and developed two software packages, 52N and SOS, to assist in implementation.


*Figure 17. The IOOS Catalog. Credit: U.S. IOOS [www.ioos.noaa.gov/catalog/welcome.html](www.ioos.noaa.gov/catalog/welcome.html)*

### *2013-2014 Regional Accomplishments*:

The RAs all support regional data portals and websites. The portals serve both the data collected by their systems and data collected by others data providers, thus serving as regional clearinghouses for data that previously was scattered and hard to find. IOOS data management standards are enabling increased data quantity, while ensuring both data quality and data interoperability. The following are some notable regional data service achievements:

- AOOS Ocean Explorer, the Flagship of the AOOS Ocean Portal framework which provides access to the entire catalog of data resources contained within AOOS data system, added 28 new operational model/remotely sensed data sets.
- CariCOOS developed IOOS iPhone and Android apps for access to CariCOOS data.
- CeNCOOS significantly expanded their portal, to expose a wide array of numerical models, remotely sensed and GIS data layers.
- GCOOS enhanced their data portal to include a new data provider, Everglades National Park, and new stations from the Sanibel-Captiva Conservation Foundation; improved presentation of the statistics of GCOOS assets; and added monitoring modules available to the public as series of tools.
- GLOS funded four mini-data management projects to help local data providers build the technical capacity to make their data available on the web. GLOS also replaced their observation portal with a data portal and added a number of new data sets including: time series from the Michigan Tech Research Institute Ranger III ferry; Great Lakes Optical Properties Geo-Database data; satellite data from MODIS or "Moderate Resolution Imaging Spectroradiometer;" USGS Great Lakes Restoration Initiative data; and USACE water level data and Great Lakes Commission Historical Water Data.
- MARACOOS developed the MyMARACOOS web page and app allowing users to tailor their data stream.
- NANOOS released five updates to the NANOOS Visualization System (NVS) platform (nvs.nanoos.org/Apps). These included v3.2, which added additional content to the NVS help content along with improvements to the Timeline feature; v3.3 added a new 'Boaters' app (introduced below); v3.5 resulted in minor updates to the NVS coding; v3.7 provided enhancements to the NVS layout; and v3.8 introduced a new 'Climatology' web app, which helps users view long-term trends and averages versus today's conditions.
- NERACOOS implemented a Regional Data Management Framework to streamline access to partner data.
- PacIOOS Voyager Mobile version was released. Additional data sets include: marine life distribution data sets from the Hawaii Institute of Marine Biology at the University of Hawaii at Manoa and the Cascadia Research Corporation; near real-time tiger shark tracks; global ship traffic; real-time atmospheric oceanic carbon dioxide data from 13 moored buoys across the insular Pacific; and wave glider data from Liquid Robotics.
- SCCOOS incorporated the State of California Areas of Special Biological Significance portal into the SCCOOS data portal. The State of California designates 34 coastal regions in the California Ocean Plan as areas of special biological significance in an effort to preserve these unique and sensitive marine ecosystems for future generations.
- SECOORA integrated the Marine Weather Portal product that was developed by the University of North Carolina Wilmington, Second Creek Consulting, the University of South Carolina, and the University of South Florida, in cooperation with NOAA's NWS. The Marine Weather Portal provides marine observations, forecasts and short- and long-fuse warnings for the coastal waters of North Carolina, South Carolina, northern Georgia, and the Atlantic and Gulf Coast areas of the Southern Region. Currently it is being used by Wilmington, North Carolina, Brownsville, Texas and Corpus Christi, Texas NWS WFOs.

## IOOS Registry and Catalog

In October 2014, U.S. IOOS Program launched an upgraded version of the IOOS Catalog at catalog.ioos.us. This version provides a landing page for users to explore national and regional observing assets, models and data services. IOOS is seen as a model by many agencies and as a data management success story—a number of national and international agencies now look to the IOOS DMAC standards and implementation as a blueprint on how disparate data providers can share data using open standards.

The catalog indexes hundreds of terabytes of data spread across over 4,000 data access services that are available to anyone with an internet connection. It also provides basic service monitoring and can be used as a tool for improving the service metadata. The catalog will be used for on-going DMAC system improvement, e.g. identifying datasets with poor or incomplete metadata, or non-compliant web services. Finally, it is a landing page connecting users to each IOOS RAs' data portal and can be used to provide the vast amount of data and services available from the federated system and highlight the value of IOOS RAs and Federal partners.

## Systems Integration Test

IOOS completed a year-long systems integration test in November 2014 that demonstrated how a distributed network can provide access to data and solve real-world problems. The systems integration test was conducted by using scripts, or sets of software instructions, that attempted to discover, access, and use data from the distributed network to answer realistic questions. Over 15 different scenarios or questions were posed as part of the test.

The resultant software scripts, available online, represent a tool for engineers to use to implement improvements in the design and implementation of DMAC. The scripts also provide an educational resource for current and future scientists and developers to understand how best to use a distributed data network that represents the future of data management in geosciences. Additional information from the test can be viewed at github.com/ioos/system-test.

## Quality Assurance of Real Time Ocean Data

The Quality Assurance of Real Time Ocean Data (QARTOD) is a sustainable, community-based project to establish authoritative procedures for quality assurance and quality control for measuring ocean conditions for U.S. IOOS. The QARTOD effort had just begun when the 2011-2012 report was submitted, and has grown in prominence both nationally and internationally. QARTOD will also be key to the RICE certification process.

### *2013-2014 Accomplishments:*

- Six QARTOD manuals have been published: Wind Speed and Direction; Temperature and Salinity; Waves; Currents; Water Level; and Oceanographic Data Quality Control Flags (www.ioos.noaa.gov/qartod/welcome.html).

## Glider Network and Data Assembly Center

Gliders and other autonomous underwater vehicles are buoyancy-driven vehicles that vertically profile the ocean and can travel great distances over long time periods without servicing. Gliders are used to monitor water currents, temperature, and chemical and biological information such as dissolved oxygen and nitrate levels. IOOS RAs and academic partners have flown over 37,500 glider days during the period of 2008-2014.

### *2013-2014 Accomplishments:*

- U.S. IOOS Program led the development of a white paper entitled, "Toward a U.S. Underwater Glider Network" in August 2014. This paper is archived on the IOOS website at www.ioos.noaa.gov/glider/strategy/glider_network_whitepaper_final.pdf.
- Established the Glider DAC at MARACOOS (data.ioos.us/gliders).

### *Gliderpalooza*

The 2014 "Gliderpalooza" was a coordinated deployment of more than a dozen gliders from four IOOS regions along the east and gulf coasts of the United States, the U.S. Navy, and Canada's Ocean Tracking Network. It was focused on collecting oceanographic data to support forecasting and analysis of severe coastal storms along the mid-Atlantic coast. Funding sources included IOOS, NASA, NSF, Environmental Protection Agency (EPA), and private donors. MARACOOS led the project with Rutgers University. Built upon the successful 2013 Gliderpalooza, scientists deployed gliders in early September 2014 for 3 to 8 weeks, from Nova Scotia to Georgia.

Glider deployments during "Gliderpalooza" – a true grass-roots effort: 14 gliders, 2.5 months, 17 deployments (Courtesy of Mike Crowley, MARACOOS).

IOOS Regions on the West Coast – led by Scripps Institution of Oceanography, the Monterey Bay Aquarium Research Institute, Oregon State University, and the University of Washington and with support from NOAA – deployed more than a dozen gliders in the fall 2014. IOOS Regions on the west coast–led by Scripps Institution of Oceanography, the Monterey Bay Aquarium Research Institute, and the University of Washington and with support from NOAA – deployed more than a dozen gliders in the Fall 2014. These gliders tracked changes in the California Current, such as those caused by El Niño, and their effect on the ocean ecosystem. IOOS Regions in the Gulf of Mexico, Alaska, and Hawaii have also deployed gliders as part of their sustained ocean observing systems to better predict how coastal processes affect local communities.

## Animal Telemetry Data Assembly Center

Acoustic animal telemetry is an emerging technology that allows remote data measurements of animal movements and their environment. 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 and improve our understanding of ecosystem function and the life cycles and environmental constraints of many species. 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.

### *2013-2014 Accomplishments:*

- The IOOC published the "Strategic Plan and Recommendations for a National Animal Telemetry Network" in August 2014. The plan is archived on the IOOS website at www.ioos.noaa.gov/observing/animal_telemetry/national_atn_sp_draft_final1.pdf.

- Deployed the Animal Telemetry Network DAC 1.0. This DAC is the first portal that handles all variety of tags, compared with other programs, which are typically limited to a singular tag type.

## Biological Observations Data

The U.S. IOOS Program led the promotion of biological data standards and interoperability to help IOOS customers and end-users access observations from a wide variety of sources and formats. This effort aims to improve access to data from diverse sources, such as independent fisheries surveys conducted by NOAA, local state fisheries agencies, USGS, the U.S. Navy, BOEM, and other government agencies.

### *2013-2014 Accomplishments:*

- Successfully tested the extensibility of the IOOS biological standards in 2013.
- Developed the IOOS DMAC Biological Data Services (BDS) enrollment procedures in 2014 to facilitate the implementation of BDS in all 11 IOOS RAs. Once implemented, BDS will improve access to biological data.
- Enrolled the GCOOS Comparative Assessment of Gulf Estuarine Systems Program data into BDS.
- Enrolled the SECOORA Florida Fish and Wildlife Conservation Commission Fisheries Independent Monitoring Surveys data (myfwc.com/research/about/programs/mfr) and South Carolina Department of Natural Resources, Marine Resources Monitoring, Assessment and Prediction Program data into BDS.

# Chapter 6: Success Stories

The complexities of the coastal environment and the inherent variability in regional ecology call for partnerships that not only cut across Federal agencies but also reach out to regional managers, academia, industry, non-governmental organizations, and the general public. Congress created the regional component of IOOS to enhance the ability of Federal agencies to provide the depth or scale of information needed to solve national issues that manifest themselves at regional and local levels. IOOS' RAs provide regional expertise, through direct and local connections to stakeholders, to address the diversity of ocean and coastal data and information needs across the Nation.

Throughout this report, some examples of success stories at the national and regional level have been provided (e.g., SECOORA's example on page 14). Each RA has had notable successes in serving its local and regional communities to the benefit of the entire Nation. These successes include: enhancing kindergarten through college-level education curriculum on ocean and coastal science; supporting improved HAB and hypoxia detection and forecasting; providing critical coastal and ocean data to support NWS WFOs and the Nation's sea ports; and supporting fishery management and safe seafood consumption. The following are summaries of success stories from each RA. For more detailed information on these and other success stories, please visit http://www.ioos.noaa.gov/ioos_in_action/stories/welcome.html.

*Figure 18. Retrieval of a Drifting Acoustic Spar Buoy Recorder following a test off of California. Credit: NOAA www.flickr.com/photos/nmfs_northwest/15791126640*

## NANOOS Hosts Hands-On Workshop for Educators

*Figure 19. NANOOS Educator Workshop Cruise Credit: NANOOS*

To help educators develop ocean based science curriculum in their own classrooms, NANOOS provided 20 sixth-grade through community-college-level educators a free, 2-day workshop entitled "Finding a Story in Data" on August 15-16, 2014. The workshop provided the educators with hands-on experiences to help them improve their students' understanding of ocean acidification, pH, fragile marine ecosystems, and environmental impacts in the Puget Sound. During the workshop, educators met with ocean experts, participated in a research cruise, visited NOAA's Pacific Marine Environmental Lab, and were introduced to online sources of data and information.

In addition to the specialized knowledge, hands-on training, and research experience gained, the educators were also offered $50 stipends to provide follow-up activities in their own classrooms. The workshop was organized by NANOOS, NOAA, Centers for Ocean Sciences Education Excellence, Ocean Inquiry Project, Washington Sea Grant, and the Northwest Aquatic & Marine Educators. This event demonstrates the diverse partnerships that are developed in the IOOS regions and is an example of the commitment the IOOS regions have to educating the local community about ocean science.

## GCOOS Supports Gulf Coast Hypoxia Monitoring Demonstration

*Figure 20. Gliders prepared for Gulf of Mexico hypoxia monitoring*
*Credit: Texas A&M University Geochemical and Environmental Research Group*

Hypoxia occurs when the concentration of dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms. The northern portion of the Gulf of Mexico experiences an annual hypoxia or "dead zone" event every summer where over-enrichment of nutrients in the water results in very low oxygen levels. The Gulf of Mexico hypoxic zone is currently the largest in

the United States and the second largest in the world. It has been closely monitored by shipboard survey since 1985.

An innovative project to demonstrate the use of gliders in monitoring hypoxia in the Northern Gulf of Mexico was conducted during the 2014 hypoxia season. The gliders were deployed in conjunction with shipboard hypoxia measurements from a cruise directed by Chief Scientist Dr. Steven DiMarco, Texas A&M University Geochemical and Environmental Research Group with support from NCCOS/Center for Sponsored Coastal Ocean Research. The gliders measured dissolved oxygen, water temperature, salinity, chlorophyll concentration, and the concentration of colored dissolved organic matter. The coordinated mission allowed for efficient and effective comparisons between the glider- and cruise-collected data in a highly vertically stratified, shallow, and heavily ship-trafficked region of the Gulf of Mexico. Data from the project has been made available in near-real time on the GCOOS Data Portal and on the Gulf Gliders Experiment map located at gcoos.org/products/maps/gulf_gliders on which you can view the tracks of where the gliders have traveled.

While no fully coupled hydrodynamic water quality model has been validated to forecast the hypoxic zone, the use of innovative monitoring technologies such as underwater gliders will contribute critical data toward developing better models, aid in identifying the extent of the hypoxic zone, and be used to validate data collected during cruises.

## MARACOOS' Modeling Improves Northwest Atlantic Fishery Yields and Revenues

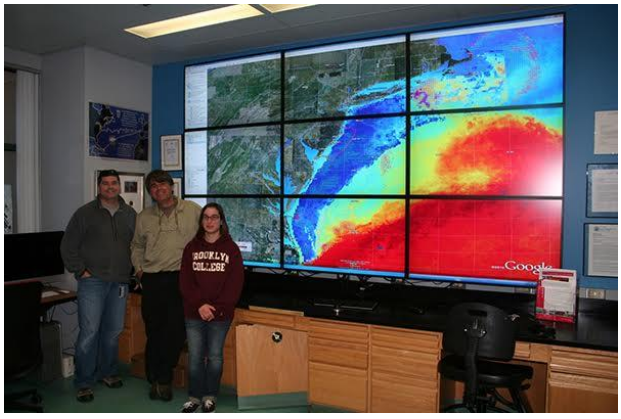

Figure 21. Statistical fish model output. Credit: Rutgers University

Managing wild capture fisheries requires large amounts of information to accurately estimate fish population size. Most models of fish population dynamics are based on fisheries-independent surveys, fixed over a particular area during a specific season, and rarely cover the entire range of habitat fish use. An important short-lived pelagic forage fish in the Northwest Atlantic, the Atlantic Butterfish (*Peprilus traicanthus*), is an example of a fish population characterized by Federal fishery regulators as a "data poor" stock. In addition, the fishing industry had been constrained in the past by butterfish incidental catches which served as a "choke" species on the economically important squid fishery.

To better account for shifting habitat distributions in butterfish population assessments, MARACOOS formed a multidisciplinary study group of experts in marine ecology, physical oceanography, and stock assessment from the fishing industry, government, and academia. The objective of this study group was to develop a statistical fish habitat model to forecast ocean conditions to predict where butterfish species are likely to inhabit. To do this, dozens of commercial fishermen from five Mid-Atlantic States joined with government and academic parties to form the Open Ocean Working Group. The working

group met in fall 2013 to compare their different butterfish models with the objective to develop a new model for stock assessment.

By developing this new model for stock assessment, they determined that the butterfish population can support a directed fishery with a quota of 20,000 metric tons. The previous quota was only 1,500 metric tons. This change in fishery status has huge economic benefits for the local fishery industry as they now have a quota high enough to maintain local markets and support the development of international markets. In 2014, a small directed fishery was allowed a landings limit of 3,200 metric tons. The proposed landings limit for 2015 was 21,408 metric tons, which translates into a $31.7 million dollars in revenues.

## NERACOOS Is Improving Red Tide Forecasts in the Gulf of Maine

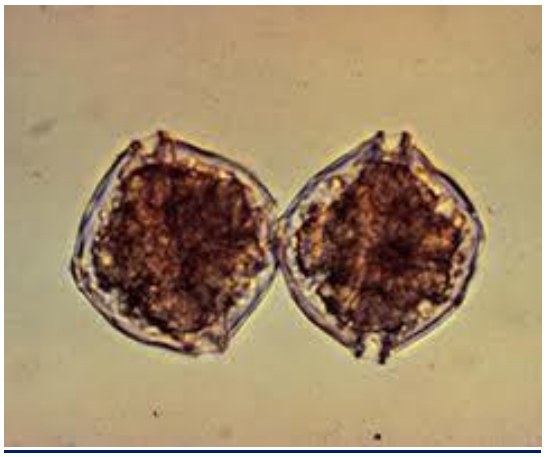

*Figure 22. Alga Alexandrium Fundyense. Credit: Dr. Don Anderson, Woods Hole Oceanographic Institution*

HABs, also known as 'red tides,' are associated with a diverse array of impacts, including human illness and death from the consumption of seafood contaminated with HAB toxins, mass mortalities of fish and other marine animals, and disruption of ecosystems. The primary HAB in the Gulf of Maine, also known as New England red tide, is caused by the alga *Alexandrium fundyense*. The alga produces a toxin that can cause paralytic shellfish poisoning. The toxin can concentrate in shellfish and, when eaten, can cause illness in humans by affecting the nervous system, causing muscle paralysis, and even result in death.

The potential health impacts from paralytic shellfish poisoning are a major concern for the $50 million a year Northeast shellfish industry. Accurate HAB forecasts are needed so coastal managers, health officials, and the shellfish industry can be better prepared for potential impacts and can more effectively deploy coastal monitoring efforts. Improved forecasts will also result in minimizing health impacts and maximizing sustainable shellfish harvesting. Since 2006, a team from NOAA and Woods Hole Oceanographic Institution has delivered, with funding support from NCCOS/Center for Sponsored Coastal Ocean Research and the NSF, an annual HAB forecast (forecast web site www.whoi.edu/page.do?pid=24039) in the spring prior to the HAB season.

Researchers typically base the annual red tide forecast on the abundance of cysts in bottom sediments combined with a computer model that simulates a range of bloom scenarios based on previous years' conditions. While this approach provided useful forecasts for most of the years since 2006, the bloom potential for both 2010 and 2013 was not realized. In those years warmer, fresher (less salty), low-nutrient waters in the Gulf of Maine were present, which likely suppressed the blooms.

In order to determine why the potential forecasts were not realized, and improve the forecast model to more accurately predict HAB blooms, the researchers needed access to oceanographic data such as water temperature, salinity, pH, and nutrient concentration. For this, the researchers looked to NERACOOS. Buoys funded by NERACOOS and maintained and operated by the University of Maine provided critical oceanographic data that allowed the research team to identify the water mass that likely suppressed the blooms.

The oceanographic data from the NERACOOS buoys have helped forecasters improve the HAB forecast and refine it based on real-time changing oceanographic conditions. The buoy system also provided critical oceanographic data that was used in the development of the physical model that underpins the weekly red tide forecast model.

## GLOS Provides Critical Lake Erie Data


*Figure 23. Lake Erie Weather Buoy. Credit: GLOS*

Boaters, scientists, and weather forecasters now have more Great Lakes coastal information at their fingertips. The Regional Science Consortium, a collaborative, non-profit organization that focuses on coordinated educational and research projects for Lake Erie and the upper Ohio River Basin, deployed a new buoy on Lake Erie in May 2014. The buoy provides information about the lake's wind and wave conditions, as well as water temperature. NOAA's Coastal Storms Program funded the purchase of the buoy in partnership with GLOS. GLOS also coordinates a near-shore observing network which provides critical data used by NOAA's NWS forecasters. This buoy will provide real time weather and water quality data for Lake Erie. Data includes parameters on wind, rain, solar radiation, barometric pressure, relative humidity, wave direction, wave period and wave height as well as some water quality measurements like water temperature.

As the only weather buoy in the Pennsylvania waters of Lake Erie, this asset provides critical near real-time data to decision makers, weather forecasters, and boaters that was not previously available. Before the new buoy was deployed, predictions were made using land-based sensors or a weather buoy in the lake near Sandusky, Ohio. Boaters and fisherman will now have more accurate information to safely plan their trips. Data collected by the buoy will be used to improve models and forecasts for the area. In addition to NWS using the data, the Pennsylvania Fish and Boat Commission is using the information for fish studies, while local water authority Erie Water Works is watching the temperature and turbidity readings.

## SCCOOS Ensures Safe Passage at the Ports of Los Angeles and Long Beach

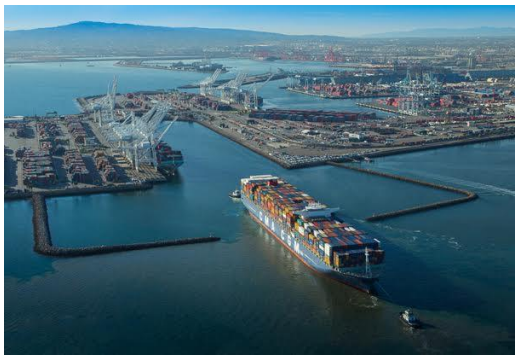

*Figure 24. Cargo Ship entering the Port of Long Beach, California. Credit: Jacobson Pilots, Ltd.*

The Port of Los Angeles and the Port of Long Beach combined are the fifth busiest ports in the world. Together these ports have the competitive edge with record-setting cargo operations, and serve as the world's leading gateway for United States-Asia trade. The largest challenge for American ports is to assure all commercial traffic, including cargo, fishing, harbor pilots, and recreational boaters transit to and from the harbor safely.

It is essential for harbor pilots to know the harbor entrance conditions before embarking on a transfer into the ports, oftentimes with a 200 foot (60 meter) or larger tanker. Wave swell conditions (wave direction, time period, and height) determine whether a 200 foot or larger tanker can come into port. When swell conditions may result in supertankers pitching and deep draft vessels hitting the bottom, the pilots will hold these vessels offshore. The cost to the ports of holding vessels offshore during these dangerous swell conditions is $100,000 per day.

SCCOOS worked with the Ports of Los Angeles and Long Beach, the Marine Exchange, and California's Department of Parks and Recreation on a 3-year effort to provide one product with enhanced wave and surface current conditions to facilitate improved navigation, search and rescue, and emergency response capabilities. Before the project was completed, there was no existing wave or currents component for the Los Angeles/Long Beach Harbor Ports. The Marine Exchange requested SCCOOS develop a customized website to provide wave and current data for the Ports of Los Angeles/Long Beach.

The resulting website integrates wave data from the Coastal Data Information Program and provides nowcasts and forecasts. The wave data are updated every 30 minutes from regional offshore buoys, supported collaboratively with the USACE and the California Department of Boating and Waterways. The website also includes HF radar surface currents, wind, weather data, sea surface temperature, and tide data from SCCOOS, and nautical charts and shipping/ferry routes from NOAA.

## AOOS Delivers Digital Atlas Detailing Alaska's Sea Ice History Since 1850

*Figure 25. Arctic landscape of ice floes and melt pools. Credit: Dr. Pablo Clemente-Colon*

Want to know how much of the Beaufort Sea was covered in ice in January 1850? You can now do so, thanks to the new historical sea ice atlas, developed with support from AOOS, located at www.aoos.org/historical-sea-ice-atlas.

The new portal is a result of a collaboration between the Alaska Center for Climate Assessment and Policy, the Scenarios Network for Alaska and Arctic Planning and AOOS. It is the first digital atlas of historical sea ice concentration for Alaska's Beaufort, Chukchi, and Bering Seas, and provides historical records that span nearly two centuries. The portal allows users to view and download sea ice concentration data from 1850 to the present, and provides researchers with a reliable tool to evaluate climate change impacts.

Users can select particular dates and locations and watch animations of how open water seasons have varied in time and space. Requests for data can also be processed in graphic or map formats. The atlas also includes a detailed glossary on types of sea ice and information on original data sources and how the data were compiled.

Users of the site range from coastal community residents, fishermen and hunters, the oil and gas energy industries, military and maritime shipping agencies, and scientists, and it can be a powerful educational classroom tool as well. AOOS has integrated these data layers into their statewide portal so users can view them alongside real-time conditions, forecast models, and a variety of GIS data. The portal is located at tinyurl.com/n3tldwl.

## CariCOOS Grows Regional Partnerships in the Caribbean

*Figure 26. Memorandum of Understanding Signing Ceremony with Miguel A. Ríos (Director, PREMA) and Julio M. Morell (Executive Director, Caribbean Regional Association for Coastal Ocean Observing) Credit: CariCOOS*

The development of partnerships at the regional level is one of the integral components of the success of IOOS. Working together with these important stakeholders not only leverages efforts and resources, but also allows for making critical data and information available to decision makers and the public.

The Caribbean Regional Association for Coastal Ocean Observing held its Sixth General Assembly in March 2014. More than 100 stakeholders representing diverse sectors attended the event aimed at informing all interested parties about the status, advances, and new initiatives of CariCOOS. The highlight of the meeting was the presentation and signature of a Memorandum of Understanding between the Puerto Rico Emergency Management Agency (PREMA) and the Caribbean Regional Association for Coastal Ocean Observing by their respective program directors, Miguel A. Rios and Julio Morell. This Memorandum of Understanding formalizes the use of information products developed by CariCOOS on the part of PREMA as unique and valuable instruments for disaster planning and response, at municipal and state levels.

With this agreement, PREMA adopted the CariCOOS-Sea Grant Nearshore Breaker Model, developed as a collaborative effort between CariCOOS and the University of Puerto Rico Sea Grant Program, as an operational product for nearshore breaker predictions geared towards drowning prevention. This project has led to an unprecedented agreement between the NWS San Juan WFO and CariCOOS/Sea Grant in which NWS San Juan will use the breaker height predictions provided by the CariCOOS system to emit their rip current forecasts and warnings. In Puerto Rico, an average of 25 beach drownings occur per year and most are due to the fact that beachgoers are not well aware of surfzone dangers. Through this partnership, municipal and local beach managers as well as the general public will have better access to information that may prevent the loss of life.

Continued partnerships with other Federal agencies were highlighted by Roberto García and Ernesto Díaz, Directors of the NWS San Juan office and the Puerto Rico Department of Natural and Environmental Resources Coastal Zone Management Program, respectively, discussing the progress of significant initiatives through partnerships between their offices and CariCOOS. New and on-going partner initiatives including the deployment of Seaglider autonomous underwater vehicles in the Caribbean Sea and tropical Atlantic with the goal of improving hurricane strengthening forecasts, the IOOS-sponsored COMT Program for numerical modelling and field experiments to understand the impact of tides, storm surge, and extra-tropical swell waves in Puerto Rico, and the CariCOOS Assets

Explorer tool were also presented to Caribbean Regional Association for Coastal Ocean Observing associates.

Enthusiastic stakeholder participation denotes the trust stakeholders place on CariCOOS products and services while the diversity of participating stakeholders attests to the wide reach of the CariCOOS portfolio. Meetings such as this offer an opportunity for stakeholders to assess the System's progress and provide feedback for future planning, while encouraging exchange of ideas and networking.

## PacIOOS Supports the NWS' Mission to Protect Lives and Property in Guam

*Figure 27. PacIOOS Datawell Directional WaveRider Buoy. Credit: PacIOOS*

The beautiful warm weather and water of Guam's beaches lure residents of and visitors to the island to take part in various activities such as swimming, snorkeling, sunbathing, and playing near the shore. A large swell is making its way to Guam's shores, yet those on the beach are unaware of the approaching hazard. Without advanced notice of the changing conditions, beachgoers are caught off guard and cannot react in time to the high surf and strong rip currents. Unfortunately, many have drowned in situations like this, including a young teenage boy who died in June 2012 at Ritidan Point at the northwest tip of Guam.

To address this urgent need, the NWS Guam WFO strongly and effectively advocated for PacIOOS to deploy additional Datawell Directional WaveRider Buoys in the region. PacIOOS responded, and a new wave buoy was deployed off Ritidian Point, Guam on October 20, 2012. Another was moored off Tanapag, Saipan on October 24, 2012.

In late January 2013, the value of the PacIOOS wave buoys was put to the test. It was a sunny day, with fair weather and small surf, but NWS was forecasting a large north swell. Conditions such as these have caused devastating problems in the past for unaware recreationalists. "Fortunately," Landon Aydlett, NOAA NWS Meteorologist noted, "the PacIOOS wave buoys enabled us to produce accurate high surf forecasts and advisories and surf zone forecasts that warned beach-goers of the coming hazard. We were able to indicate inundations of 1-2 feet could occur on north and northwest exposures." Once the advisories were issued, NWS Guam spread the word via their website, Facebook, NOAA Weather Radio (available in Mariana Islands by dialing 211), local radio and television stations, local newspapers, and live interviews. The public was well informed; residents and visitors had time to prepare for the impending hazard.

## CeNCOOS Supports Safe Seafood Consumption in Central and Northern California

*Figure 28. Collecting phytoplankton samples in the Santa Cruz, California Wharf. Photo Credit: CeNCOOS*

Exposure to toxins in seafood can result in hospitalization, cause paralysis, and even be potentially fatal to humans. When detected, HAB events in the United States result in the closure of shellfish fisheries and beaches. These closures cost commercial fisheries, public health, recreation, and tourism industries nationally at least $82 million per year in direct costs. Closures are necessary however for the safe harvesting and consumption of seafood, providing immeasurable benefits. They prevent consumers from getting sick and reduce loss of income and health care costs for consumers and seafood harvesters.

CeNCOOS is assisting California State officials to prevent consumption of seafood contaminated by HABs. With CeNCOOS' support, Raphael Kudela's lab at the University of California (UC) Santa Cruz collects and processes weekly phytoplankton samples from the Santa Cruz and Monterey wharves, as well as from other locations outside Monterey Bay. Kudela's lab sends the results of its processed samples to California Department of Public Health officials, who then issues harvest/consumption warnings if the collected data indicates the presence of toxins that may make the seafood unsafe for human consumption.

Based on the data from CeNCOOS, the California Department of Public Health issued an anchovy, sardine, and crab warning in April 2014. Consumers who otherwise may have eaten the seafood benefited from these warnings by avoiding potentially serious health issues. In addition, recreational fishers, anchovy and sardine fishermen, and the aquaculture industry in the Monterey Bay area avoided harvesting seafood that may have harmed them or their customers.

## SECOORA Is Increasing Available Wave Data

*Figure 29. Deployment of sub-surface mooring in the Straits of Florida. Credit: Jodi Brewster*

One of the major consumers of coastal ocean observations is the NWS. NWS forecasters need real-time coastal and ocean data and information to make accurate marine weather forecasts. Waves and currents are key parameters of these forecasts, but in many areas in the Southeast region there is either no or very limited wave data available to support marine forecasting. To address this issue, SECOORA funded the Wave Heights And Currents in the Florida Straits (WHARF) project.

WHARF is intended to provide a quality control index for the extraction of real-time significant wave height using HF radars. HF radar systems provide data over a broad area of the coastal ocean. The overall goal of WHARF is to evaluate and prove HF radars can be used to provide near real-time wave data, in addition to the surface current data, without having to deploy expensive new equipment. NWS forecasters will use WHARF results to improve marine forecasts of waves and currents across the Florida Straits, which holds one of the fastest moving currents in the world. The WHARF project could increase coverage areas where wave data is currently unavailable. Those that play or work in these waters are dependent on accurate wave height and surface current information to safely navigate.

# Chapter 7: The Future/Way Forward

IOOS has demonstrated substantial progress toward the vision of a fully integrated ocean observing system that provides the Nation with information to safeguard life and property, to protect valuable ecosystems, and to sustain our economic vitality.

IOOS is seen as a model by many agencies for interagency coordination, for partnering with the regional systems and industry, and for data management. Our continued investment in the implementation of data standards is yielding success as all 11 RAs are serving their data in a common format and users of the IOOS DMAC are now able to explore over 9,000 national and regional observing assets, models and data services. As we move into the future, IOOS will continue to build upon its data management success by streamlining the process to archive data through a partnership with the National Centers for Environmental Information. IOOS will continue to work on the technological, organizational, and social impediments to ingesting, curating, and sharing data and information with a wide range of users in ways that are convenient for them.

IOOS continued to make strides to implement actions codified in the ICOOS Act. In July 2014, the U.S. IOOS Program began offering certification to its non-Federal partners. The RICEs began to apply for certification starting in 2015. This is a key step towards integrating the Federal and non-Federal IOOS observing assets, and towards making a unified ocean observing system with seamless data delivery from international to local scales.

IOOS established the Marine Sensor Innovation Project in 2013 to advance observation and forecasting capabilities for ocean chemical, biological, and physical parameters at multiple spatial and temporal scales in the oceans, coasts, and Great Lakes. Marine Sensor Innovation will continue to increase observational capabilities by making smart investments in innovative marine sensors and other advanced observing and forecasting technologies to improve our ability to monitor our waters with greater efficiency.

IOOS' investment in observing systems, modeling and analysis, and data management is delivering real-time decision making support to: industries such as shellfish hatcheries and fisheries, and traditional and renewable energy; maritime transportation; and government agencies that ensure public health and safety including NWS, USCG, and USGS.

The value of IOOS to integrate ocean systems is demonstrated by its success stories. The ability of 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 to produce economic, societal, and environmental benefits to the Nation. IOOS must continue to expand, improve and sustain the system to continue addressing the growing societal needs for ocean observations and information and to fully integrate the United States' contributions to GOOS into the U.S. IOOS structure.

# Appendix A: IOOS Partners

## Federal Partners

Federal agencies provide active support, funding, guidance, or advice to IOOS. Below is a list of some of 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 *

CSREES Department of Agriculture, Cooperative State Research, Education, and Extension Service

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 *

USGS U.S. Geological Survey *

## Regional Components


IOOS' Regional components 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.

The 11 regional associations (RAs) and their associated Regional Coastal Ocean Observing System provide the regional component of IOOS and, once certified, will serve in the capacity of regional information coordination entities as described in the ICOOS Act. The eleven RAs are:

| | |
|---|---|
| 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 |

The Alliance for Coastal Technologies 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.

The Coastal and Ocean Modeling Testbed (COMT) serves as a conduit between the federal operational and research communities and allows sharing of numerical models, observations and software tools. The COMT supports integration, comparison, scientific analyses and archiving of data and model output needed to elucidate, prioritize, and resolve federal and regional operational coastal ocean issues associated with a range of existing and emerging coastal oceanic, hydrologic, and ecological models. The Testbed has enabled significant community building (within the modeling community as well as enhancing academic and federal operational relations) which has dramatically improved model development.

# Appendix B: IOOS Regional Association Governance Structure

| Region | Type of Governance | Distribution of Governance Board Membership | | | | | | | | Total Number of Board Members |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Government | | | | Non-Government | | | Foreign (all sectors) | |
| | | State* | Local | Tribal | Federal | Research Institute | Industry | NGO** | | |
| AOOS | MOU | 4 | | | 4 | 7 | 2 | 2 | | 19 |
| CaRA | MOA | 3 | | | | 1 | 6 | 2 | | 12 |
| CeNCOOS | MOA | 1 | | | 3 | 6 | 1 | 3 | | 14 |
| GCOOS | 501(c)(3) | 2 | | | 4 | 5 | 4 | 1 | | 16 |
| GLOS | 501(c)(3) | | | | | 1 | 2 | 2 | 2*** | 7 |
| MARACOOS | 501(c)(3) | 1 | | | 1 | 7 | 3 | 3 | | 15 |
| NANOOS | MOA | 2 | | 2 | 2 | 4 | 3 | 2 | | 15 |
| NERACOOS | 501(c)(3) | 5 | | | 3 | 8 | 2 | 1 | 2 | 21 |
| PacIOOS | MOA | 5 | | | 3 | 4 | 2 | 4 | | 18 |
| SCCOOS | MOU | 9 | 5 | | 10 | 13 | 2 | 5 | 1 | 45 |
| SECOORA | 501(c)(3) | 1 | | | 0 | 11 | 4 | 1 | | 17 |
| ACT | | | | | | 4 | 1 | | | 5 |

* includes Sea Grant and territorial governments

** includes Fishery Management Councils

*** "bi-national" International Joint Commission

# Appendix C: Regions Leveraging Resources

The table below represents funding the IOOS RAs receive outside of the foundational dollars that come through the U.S. IOOS Program Regional Coastal Ocean Observing System. It is important to note these dollars do not replace the resources from the U.S. IOOS Program but indicate the annual funding by IOOS gives the IOOS RAs the ability to attract additional resources.

| Regional Association | Funding Source | Product |
|---|---|---|
| AOOS | • Bering Sea/Aleutian Islands Landscape Conservation Cooperative (U.S. Fish and Wildlife Service) and USGS Climate Science Center<br>• Western Alaska Landscape Conservation Cooperative (U.S. Fish and Wildlife Service)<br>• Kenai Peninsula Fisheries Habitat Partnership<br>• BOEM<br>• NOAA/Shell Oil/BOEM<br>• Exxon Valdez Oil Spill Trustee Council; North Pacific Research Board; Russian-US Long-term Census of the Arctic<br>• NOAA<br>• U.S. IOOS Program | • Data portal and climate vulnerability assessment<br>• Wave buoy<br>• Expand Response Tools and Training<br>• MARES<br>• MBON<br>• Arctic EIS<br>• Data management Services<br>• Ocean Acidification<br>• Ocean Technology Transition |
| CARICOOS | • NOAA<br>• DNER/NOAA<br>• Fisheries Council<br>• Buckeye LLC | • Nearshore Breaker Model; Glider; Ocean Acidification<br>• Storm Surge modeling<br>• Study of Marine Protected areas<br>• Under Keel Clearance |
| CeNCOOS | • Tenera Environmental<br>• Orange County Sanitation District<br>• NSF<br>• National Parks Service<br>• Navy<br>• Morro Bay National Estuary program; Packard Foundation<br>• NASA<br>• CA Sea Grant, California Ocean Protection Council, NASA<br>• NASA,NOAA,BOEM<br>• U.S. IOOS Program | • Consultation for environmental review<br>• Lessons learned report<br>• Enhance research observing platforms<br>• Reconstruction of buoy<br>• Shore Station operations; Vessel tracking<br>• Modeling<br>• Uses CeNCOOS data and models<br>• Operationalize HAB predictions<br>• Marine biodiversity<br>• Ocean Technology Transition |
| GLOS | • NSF<br>• EPA<br>• NOAA<br>• Great Lakes Restoration Initiative<br>• Boat U.S. | • Moorings<br>• Wave Glider<br>• Coastal Storms Program<br>• Enterprise Architecture Report<br>• Buoy support |
| GCOOS | • Nature Conservancy<br>• BOEM<br>• GOMA | • Lionfish invasion product<br>• Economic Benefits Study<br>• Data Portal |

| Regional Association | Funding Source | Product |
|---|---|---|
| | • NASA | • NASA ROSES grant |
| MARACOOS | • >60 grants either leverage IOOS funding or that MARACOOS leverages: NOAA, NASA, Navy, NSF, DHS, BOEM, DOE, EPA; Foundations, New Jersey, New York, Associated Universities and Horizon Marine | • Funds gliders operations, modeling research, observation platform enhancement, |
| NANOOS | • NOAA<br>• Puget Sound Institute<br>• Puget Sound Partnership<br>• U.S. IOOS Program | • Ecosystem modeling; Ocean Acidification<br>• Data Management support<br>• Operation of buoys<br>• Ocean Technology Transition |
| NEARCOOS | • 13 grants either leverage IOOS funding or NERACOOS leverages: NASA, NOAA, NSF, Associated Universities, Nature Conservancy, Canada<br>• National Fish and Wildlife Foundation<br>• Northeast Regional Ocean Council<br>• U.S. IOOS Program | • NERACOOS data, models and infrastructure<br>• Storm surge<br>• Data management<br>• Ocean Technology Transition |
| PacIOOS | • USACE, University of Hawaii, NSF, DOE, Maui community college<br>• Young Brothers limited<br>• Conservation International<br>• City and County of Honolulu<br>• NOAA<br>• NOAA and University of Hawaii<br>• U.S. IOOS Program | • Maintain, operate observing platforms<br>• Vessel support for buoy operations<br>• Purchase of observing equipment<br>• Data management<br>• Host NOAA's Hawaii Flash Flood Tool; Ocean Acidification<br>• Host SLR/Shoreline Erosion Tool<br>• Ocean Technology Transition |
| SCCOOS | • NOAA<br>• Orange County Sanitation District<br>• U.S. IOOS Program | • Glider lines<br>• Monitoring<br>• Ocean Technology Transition |
| SECOORA | • Governor's South Atlantic Alliance<br>• NOAA | • Informational Portal<br>• Ocean Acidification |

# Appendix D: Acronyms

| | |
|---|---|
| ACT | Alliance for Coastal Technologies |
| AOOS | Alaska Ocean Observing System |
| BOEM | Bureau of Ocean Energy Management |
| BDS | Biological Data Services |
| CariCOOS | Caribbean Coastal Ocean Observing System |
| CeNCOOS | Central and Northern California Ocean Observing System |
| COMT | Coastal Ocean Modeling Testbed |
| CO-OPS | Center for Operational Oceanographic Products and Services |
| DAC | Data Assembly Center |
| DMAC | Data Management and Communications |
| DOE | Department of Energy |
| DOI | Department of Interior |
| DOS | Department of State |
| DOT | Department of Transportation |
| EPA | Environmental Protection Agency |
| FDA | Food and Drug Administration |
| FY | Fiscal Year |
| GCOOS | Gulf of Mexico Coastal Ocean Observing System |
| GIS | Geographic Information System |
| GLOS | Great Lakes Observing System |
| GOA-ON | Global Ocean Acidification Observing Network |
| GOMA | Gulf of Mexico Alliance |
| GOOS | Global Ocean Observing System |
| HAB | Harmful Algal Bloom |
| HF | High Frequency |
| ICOOS | Integrated Coastal and Ocean Observing System |
| IOC | Intergovernmental Oceanographic Committee |
| IOOC | Interagency Ocean Observation Committee |
| IOOS® | Integrated Ocean Observing System |
| IPACOA | IOOS Pacific Region Ocean Acidification Data Portal |
| J-SCOPE | Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE) |
| MARACOOS | Mid-Atlantic Regional Association Coastal Ocean Observing System |
| NANOOS | Northwest Association of Networked Ocean Observing Systems |
| NASA | National Aeronautics and Space Administration |
| NCCOS | National Centers for Coastal Ocean Science |
| NDBC | National Data Buoy Center |
| NERACOOS | Northeastern Regional Association of Coastal and Ocean Observing Systems |

| | |
|---|---|
| NOAA | National Oceanic and Atmospheric Administration |
| NOS | National Ocean Service |
| NSF | National Science Foundation |
| NVS | NANOOS Visualization System |
| NWS | National Weather Service |
| OA | Ocean Acidification |
| OAP | Ocean Acidification Program |
| OTT | Ocean Technology Transition |
| PacIOOS | Pacific Islands Ocean Observing System |
| PORTS | Physical Oceanographic Real-Time System |
| PREMA | Puerto Rico Emergency Management Agency |
| QARTOD | Quality Assurance of Real-Time Ocean Data |
| RA | Regional Association |
| RICE | Regional Information Coordination Entities |
| SCCOOS | Southern California Coastal Ocean Observing System |
| SCOOP | Self-Contained Ocean Observing Payload |
| SECOORA | Southeast Coastal Ocean Observing Regional Association |
| SOCAN | Southeast Ocean and Coastal Acidification Network |
| SOS | Sensor Observation Service |
| SOST | Subcommittee on Ocean Science and Technology |
| SST | Sea Surface Temperature |
| TPOS | Tropical Pacific Observing System |
| USACE | U.S. Army Corps of Engineers |
| USCG | U.S. Coast Guard |
| USGS | U.S. Geological Survey |
| WFO | Weather Forecast Office |
| VIMS | Virginia Institute of Marine Science |