The Chesapeake Bay Interpretive Buoy System:

An IOOS Estuarine Archetype

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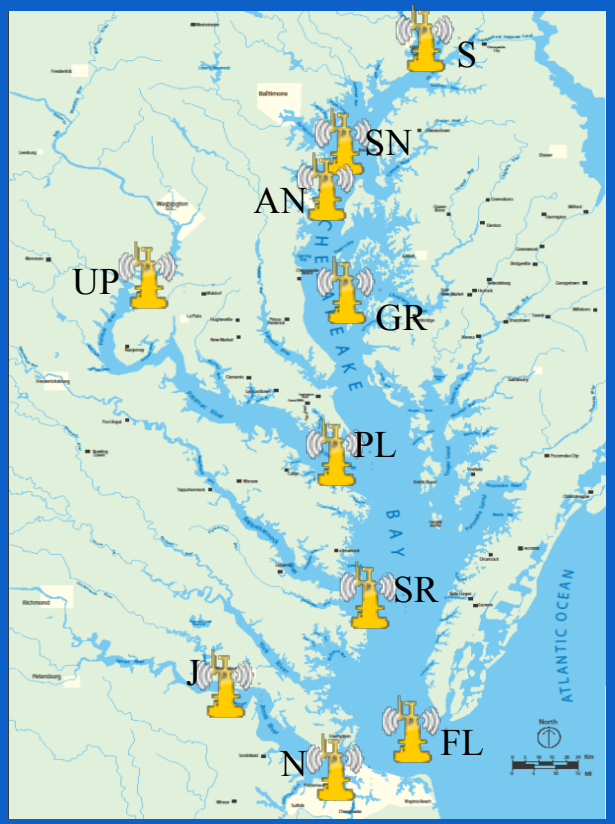
CBIBS: History and Status

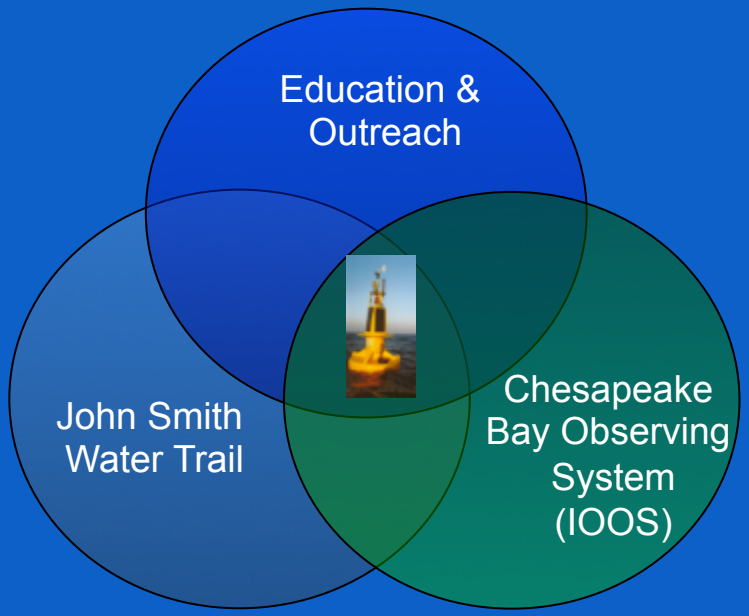
The Chesapeake Bay Interpretive Buoy System – CBIBS – was founded as an observational and interpretive component of the National Parks Service Captain John Smith Chesapeake National Historic Trail. CBIBS was designed to be an innovative system that collects, transmits, and interprets real-time environmental data from the Chesapeake Bay for a wide variety of constituents – including scientists, on-the-water users, educators, and natural resource decision makers – and fills critical observational gaps in the Chesapeake Bay.

The first buoy was placed in the James River in May 2007, coincident with the celebration of the 400th anniversary of the settlement of Jamestown. There are now 10 buoys in the System.



CBIBS: Objectives

The Chesapeake Bay Interpretive Buoy System (CBIBS) is a system to collect, transmit and interpret real-time environmental data from the Chesapeake Bay to a wide variety of constituents – including scientists, on-the-water users, educators, and natural resource decision-makers – and to fill critical observational gaps in the Chesapeake Bay.

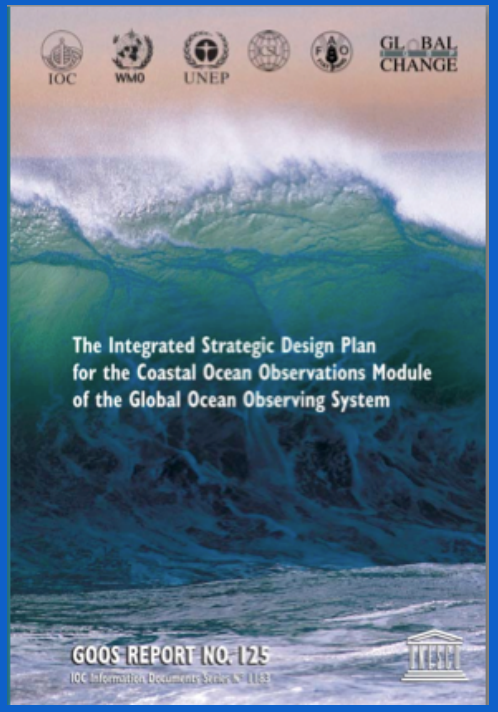


- Buoys are markers for the National Park Service's Captain John Smith Chesapeake National Historic Trail; they convey local and historic references.
- Buoys are versatile coastal observing platforms collecting a broad suite of measurements
- Buoys are Education cornerstones – buoy information is used in classrooms

- System is built around an Integrated information network - connects buoys, data, web, education, information resources – embracing IOOS concepts and standards.

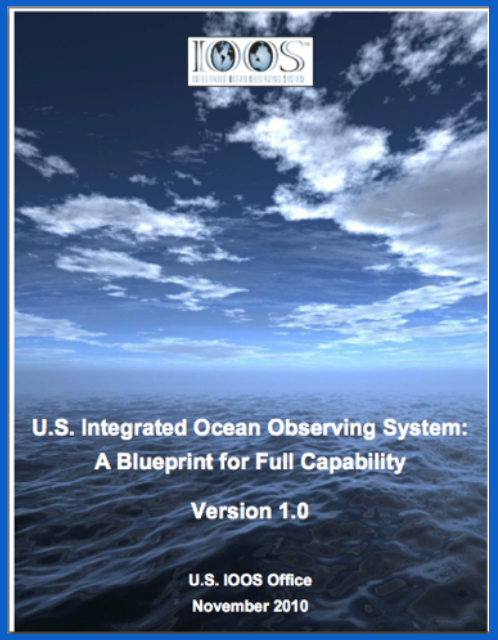
CBIBS, GOOS, and the US IOOS:

In addition to the Interpretive considerations that influenced the development of CBIBS, we were guided by the Coastal Strategy for GOOS, calling for "…**the development of an operational observing system for the marine environment that supports an integrated approach to detecting and predicting changes in coastal marine and estuarine systems.**"



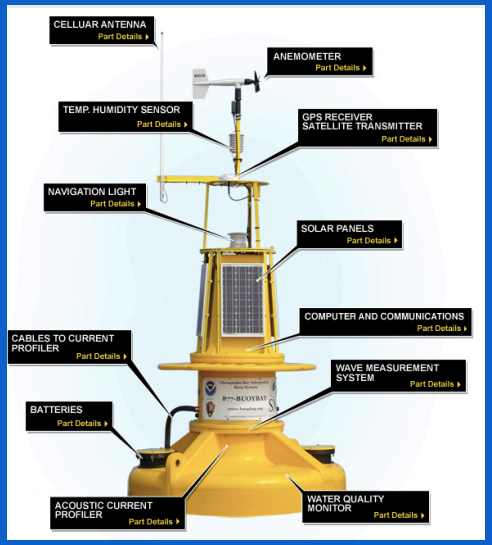
This Strategy is being implemented by the US Integrated Ocean Observing System. In describing CBIBS, its components, data, and products, we will show how it follows three sets of IOOS concepts:

- ***Core Variables***
- ***Societal Benefit Areas***
- ***Subsystem Structure***



Core Variables

The Ocean.US Workshop conducted at Airlie House in March 2002 identified 20 ocean observing core variables "required to detect and/or predict changes in a maximum number of phenomena of interest to user groups." US IOOS focuses on these and six others.



Meteorology — Reported Every 10 minutes
All Buoys

Air Temperature — Relative Humidity
Wind Speed — Wind Gust
Wind Direction — Barometric Pressure

Waves — Reported every 60 minutes
SN, A, GR, PL, SR, J, FL

Maximum Wave Height — **Significant Wave Height**
Mean Wave Height — **Mean Wave Period**
Mean Wave Direction

Currents — Reported every 60 minutes
S, SN, A, GR, PL, UP, SR, J, FL

Near-Surface* Speed — **Near-Surface* Direction**
* Mean of upper 5 m or to the bottom, whichever is shallower; Individual 1 m bin data are archived

Water Quality — Reported every 60 minutes
All buoys ; located at 0.5 m

Temperature — **Conductivity / Salinity**
Dissolved Oxygen — Chlorophyll A
Turbidity

Non-Standard Sensors — Buoy

Full Bottom Water Quality — Hourly — GR
Nitrate concentration (SUNA) — Hourly — S
Acoustic Fish Tag Rcv (VEMCO VR2C) 10 min — J
GPS Water Level (presently removed) — N

Core Variables – Water Quality

Dissolved Oxygen, Salinity, Water Temperature, Chlorophyll A and **Turbidity** – were selected to match the parameters used by the Chesapeake Bay Program to assess estuarine health.

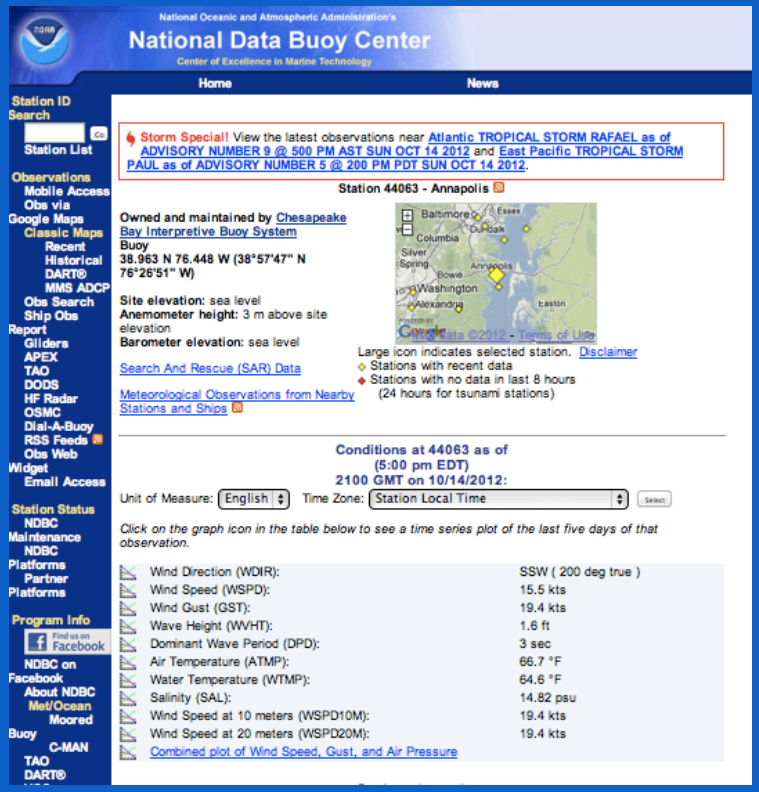
Data are collected and reported hourly. Efforts are made to ensure that all measurements have adequate Quality Assurance and Quality Control to be considered Climate Quality data. CBIBS participates in the Quality Assurance of Real-Time Oceanographic Data (QARTOD) workshops and is implementing QARTOD recommendations for quality assurance of data.

Core Variables – Currents and Waves

Currents and waves are of particular interest to recreational users as well as Marine Safety and Marine Transportation. Confirmed regular CBIBS users in these categories include US Coast Guard stations, National Weather Service, and Virginia Pilots. Current measurements are made with hull-mounted, downward looking NORTEK AquaDopp 1 mHz acoustic current profilers, sampling in 1 meter bins. Wave measurements are made with AXYS Technologies TRIAXYS wave sensors centrally mounted in the buoy hull. The CBIBS buoys represent the only real-time wave measurements within the Chesapeake Bay. Results of a comparison between CBIBS buoy-mounted currents and waves and independent coincident data are presented in Wilson and Siegel, MTS/ONR Buoy Workshop, 2011.

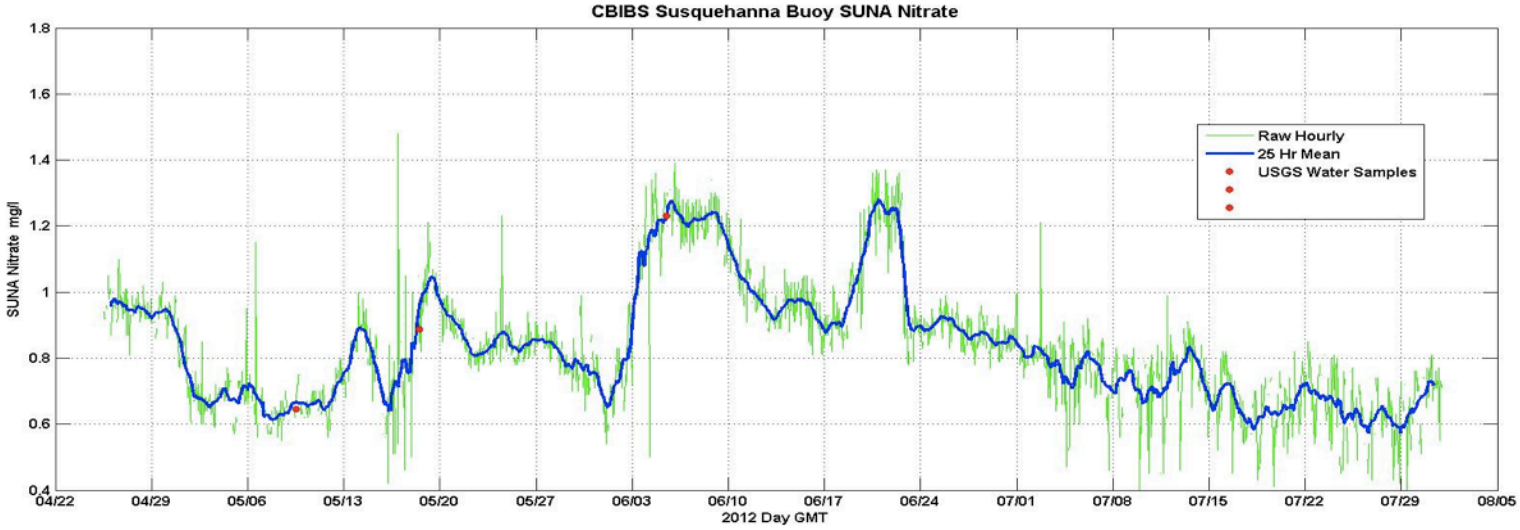
Core Variables – Meteorology

Buoys measure Wind (and Gust) Speed and Wind Direction, Barometric Pressure, Air Temperature, and Relative Humidity, all at approximately 3 meters above the water. Data are published through the National Data Buoy Center to the GTS; they are included in NOAA Weather Radio current conditions broadcasts. CBIBS provides the majority of the over-water winds measurements available to local forecasters.



Core Variables – Additional

Several individual CBIBS buoys have “one-off” sensors suited to their locations. The buoy at Gooses Reef (GR) has a bottom-mounted water quality suite transmitting hourly data to the buoy via AQUASENT acoustic modem and into the data system in real-time. The Jamestown buoy has a VEMCO VR2C acoustic tag receiver, providing real-time notification of tag receptions – in this case, primarily endangered Atlantic Sturgeon. The Susquehanna buoy, located at the primary input point of nutrients into the Chesapeake Bay, has a Satlantic SUNA nitrate sensor, used to continuously monitor and display nitrogen flux.



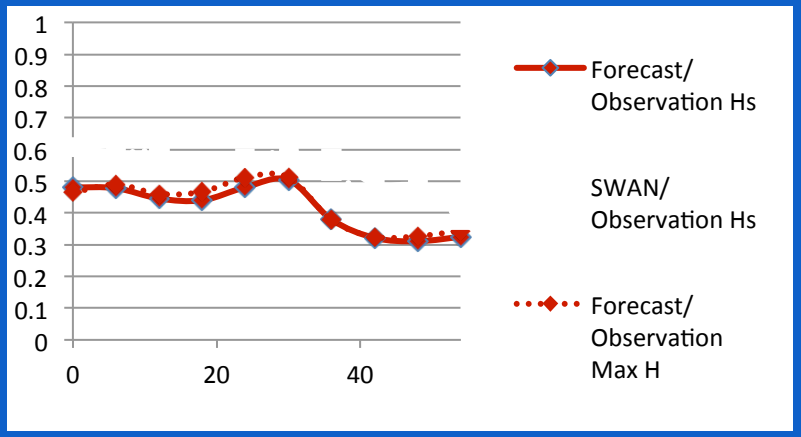
IOOS Seven Societal Benefits

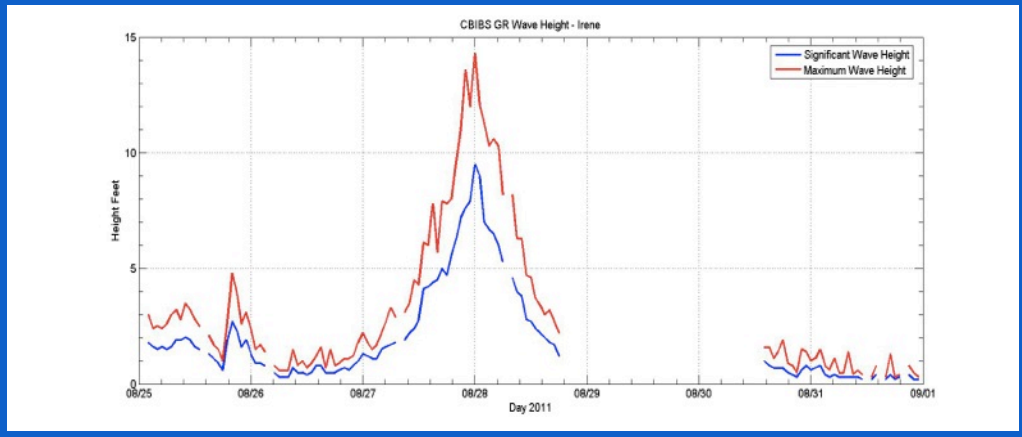
- Improve predictions of climate change and weather, and their effects on coastal communities and the nation
- Improve the safety and efficiency of maritime operations
- More effectively mitigate the effects of natural hazards
- Improve national and homeland security
- Reduce public health risks
- More effectively protect and restore healthy coastal ecosystems
- Enable the sustained use of ocean and coastal resources.1

During pre-deployment planning stages, the NCBO met with user groups representing many of the seven ***IOOS Societal Benefit Areas***, and as the system has been implemented and expanded, communications have continued with those groups and other new ones. For example:

Weather and Climate

Selected meteorological and marine data from all CBIBS buoys are delivered to the Global Telecommunications System via NDBC with less than 10 minute latency; the three Chesapeake Bay NWS WFOs all use the data extensively, as it provides the bulk of available over-water measurements. Conditions are reported on NOAA Weather Radio, and are presently being used to develop a new SWAN wave model for the Chesapeake Bay at the Sterling, VA WFO. CBIBS buoys are being considered as part of the Chesapeake Bay Sentinel Site Cooperative; as we continue to apply QARTOD recommended QA/QC procedures, the data archives are becoming valuable climate data sets.





Safety and Efficiency of Marine Operations

Via the CBIBS web interface and the XML-based data access system, Chesapeake Bay Pilots use a custom data feed from CBIBS at their Virginia Beach control center. CBIBS buoy data are used by local Coast Guard teams in preparing their daily operations plans.

Protect and Restore Healthy Coastal Ecosystems

CBIBS data provide information used by the EPA-led Chesapeake Bay Program in evaluating Chesapeake Bay health and regulating nutrient inputs. Maintenance and use of CBIBS are required in response to Executive Order 13508: Protecting and Restoring the Chesapeake Bay Watershed. The recent addition of a Nitrate sensor to the Susquehanna CBIBS buoy, along with coincident current meter data, allows the direct computation of real-time Nitrate flux into the Chesapeake Bay.

Sustainable Resource

CBIBS installed the first VEMCO VR2C cabled acoustic receiver and presently delivers real-time fish tag identifications to scientists tracking endangered Atlantic Sturgeon in the James River. This deployment has led to the funding of a real-time network of acoustic tag receivers in the Lower Chesapeake Bay.

IOOS Subsytems

The System Design of CBIBS is organized around the same ***Subsystem Structure*** as IOOS. The U.S. IOOS Blueprint architectural framework divides U.S. IOOS into six distinct subsystems. Three functional subsystems —

Observations
Data Management and Communications
Modeling and Analysis

— provide the technical capability to readily access marine environment data and data products. Three cross-cutting subsystems —

Governance and Management
Research and Development
Training and Education

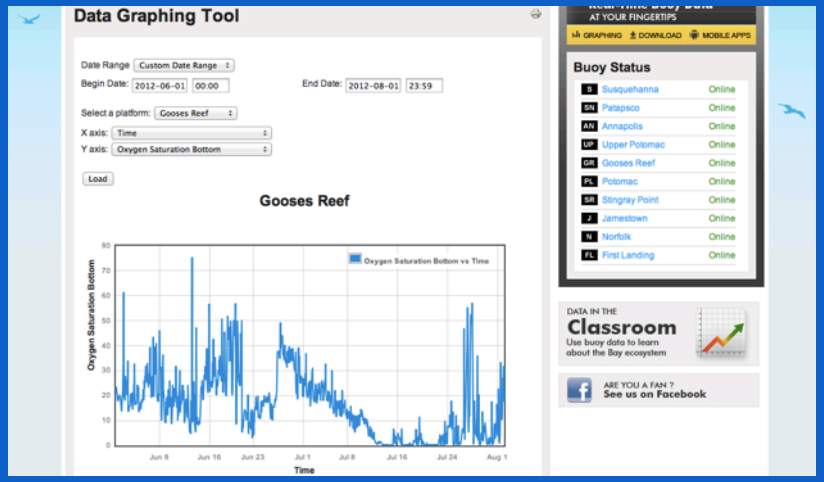
—enable sustainment of, and improvement to, the System and its usage.

The Observation Subsystem

Includes the ten buoys and associated sensors, including a remote bottom platform relaying real-time data through a nearby buoy via acoustic modem. The broad user base and excellent outreach have raised public awareness of the observing system; two of the CBIBS buoys have been donated by local groups; the Norfolk buoy by the Nauticus Maritime Museum, and the Gooses Reef by the Dominion Power Foundation. A buoy purchased by the Virginia Commonwealth University Rice Center will soon be added to the system in the James River.

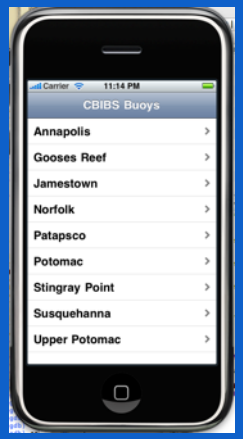
Data Management and Communications (DMAC) Subsystem

A key to CBIBS' success has been a robust, expandable, and broad-reaching Data Management infrastructure. Conceived as a 'Smart Buoy' system, with an emphasis on delivering both the buoy data and relevant information to a broad cross-section of the public, CBIBS communicates in many ways. In addition to a comprehensive web site, the initial '877-BUOYBAY' telephone access system allows callers to hear real-time observations and interesting, professionally written and recorded information about the history, geography, and seasonal ecology of the regions near each buoy.



Data Management and Communications (DMAC) Subsystem

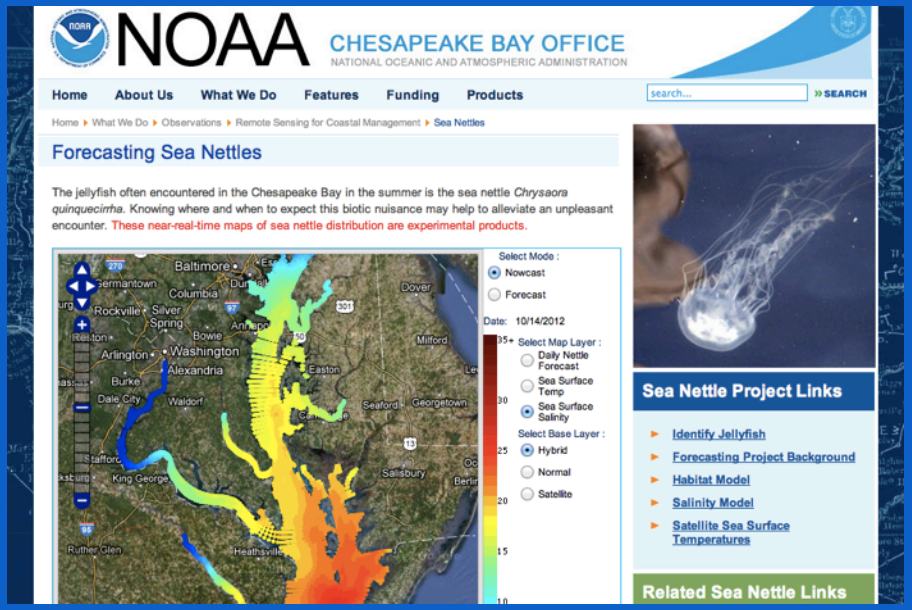
CBIBS has also developed smartphone apps for both Android and iOS, with more than 15,000 downloads. All components of the DMAC system are now based on secure, remote servers, guaranteeing that the data system will be operational at all times. The CBIBS data acquisition, management, and delivery software is primarily open source, Web 2.0 friendly, and conforms to IOOS DMAC concepts and standards. CBIBS IT staff are involved in IOOS DMAC initiatives, as well as the QARTOD process.



Modeling and Analysis; Research and Development

Emphasis on timely data delivery using advanced standards makes the CBIBS data set useful and accessible for ***Modeling and Analysis*** applications.

In support of the cross-cutting ***Research and Development*** Subsystem, the CBIBS observing system presently uses no less than four instruments that were initially deployed as industry prototypes. Additionally CBIBS has provided test and analysis deployments for several others.



Training and Education

At the core of the CBIBS program is a commitment to ***Training and Education***. The "Interpretive" nature of the system, including descriptive geographical, environmental, and historical web content, continuing outreach events, and a K-12 curriculum developed and published based on CBIBS and other real-time data, Chesapeake Exploration.

Through education and outreach events like children's Build-a-Buoy workshops and CBIBS presentations to local marine and environmental groups, the System and the information it delivers connect Chesapeake Bay watershed residents to the marine ecosystem.

Acknowledgements

The creation and success of the Chesapeake Bay Interpretive Buoy System is the result of the efforts of many individuals and organizations, including:
The Conservation Fund
The Chesapeake Conservancy
The Chesapeake Bay Foundation
The National Parks Service
US Integrated Ocean Observing System
Dominion Power Foundation
Nauticus Museum
NOAA National Data Buoy Center
Maryland Department of Natural Resources
Virginia Institute of Marine Science

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Tucker Pierce and Tellus Applied Sciences
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Summary

The Chesapeake Bay Interpretive Buoy System was planned from the outset using IOOS principles. The attention to integration, focus on meeting the needs of diverse users, leveraging platforms to deliver accurate measurements of as many core variables as possible, and subsystem structure, have made for an efficient, widely appreciated, and successful system. We hope that it can serve as a model for other coastal and estuarine systems – regardless of platform or sensor details - in other regions. With this is mind, NOAA and MARACOOS are considering how to form a cooperative arrangement to manage CBIBS as a regional resource.