The Chesapeake Bay Interpretive Buoy System: Recent Expansion and Advances

Doug Wilson
NOAA Chesapeake Bay Office
410 Severn Avenue, Suite 107A
Annapolis, MD 21403

The Chesapeake Bay Interpretive Buoy System (CBIBS) is an innovative 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. The first buoy was deployed in May 2007, and as of October 2009, the CBIBS has expanded to eight buoys. Locations span the length of the bay, from the Susquehanna River to Norfolk, and include open water and tributaries. In addition to collecting environmental information, the System supports educational and informational tools to interpret the Captain John Smith Chesapeake National Historic Trail.

Buoys are based on an AXYS Watchkeeper platform, with buoys in the initial system measuring weather, wind, waves, current profiles, and basic water quality parameters. Data are reported in real time via a comprehensive web site that includes not only data access and presentations but also buoy data-based educational curricula and historical, geographic, and ecological information associated with the buoy's location and environs. In addition to basic data products, there is an option for data delivery via mobile device, and access to informational audio tracks. These tracks, as well as audio access to data, are also available via the 877-BUOYBAY phone service.

Subsequently sensors have been deployed to measure in situ nitrate and phosphate, as well as water level via GPS in collaboration with the NOAA National Geodetic Service. A ninth CBIBS buoy is scheduled for deployment later in 2009 on an artificial fishing reef; it will collect and transmit acoustic fishfinder images for remote presentation over the internet as well as collect and transmit bottom water quality data from the reef. There have also been recent data analyses and validation experiments with buoy data to establish their accuracy and develop maintenance schedules. Examples of these are presented for currents, waves, nutrients, and dissolved oxygen measurements. The new enhancements - additional sensors and products, and data validation - broaden the utility of system components for both observational and interpretive purposes, and contribute to the already strong community-based support for the system in the Chesapeake Bay. The support has led to the development of partnerships to contribute buoys to the system; a siting plan exists for a built out twenty buoy system.

The system is a significant part of regional efforts to develop a new Chesapeake Bay Observing system based on U.S. Integrated Ocean Observing System (IOOS) principles.

CBIBS History

The Chesapeake Bay Interpretive Buoy System 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. While the primary initial purpose of the system was to mark the Captain John Smith Chesapeake National Historic Trail, the design of the system addresses the intersecting needs of three significant activities in the Chesapeake Bay:

- Users of the Chesapeake Bay, including recreational users, commercial interests, and visitors to the Captain John Smith Chesapeake National Historic Trail. CBIBS combines on-the-water sensor platforms that provide real-time data streams (including information on weather, waves, and currents) with methods to make these observations available to the public, as well as educational and informational tools to interpret the Captain John Smith Chesapeake National Historic Trail. NOAA is working with the National Park Service to incorporate CBIBS into the management plan for the trail.

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- The Chesapeake Bay Observing System (CBOS): CBIBS is a critical part of a broader observing network in the Chesapeake Bay region. As one of the only open-water components that collect data on such a wide variety of environmental parameters, CBIBS provides a suite of information that serves multiple constituent needs and interests. CBOS is a 'sub-regional' component of the Mid-Atlantic Coastal Ocean Observing System (MARCOOS), in turn a regional component of the US Integrated Ocean and Coastal Observing System, IOOS.

- Education and Outreach: Recognizing that efficient use of environmental information requires an environmentally literate audience, a major focus of CBIBS is developing curricula for the classroom that uses data from the buoys to teach science and history to the next generation of Chesapeake Bay stewards.

Fig. 1. First CBIBS buoy located off Jamestown Settlement, James River, VA; activated May, 2007.

The CBIBS web site, www.buoybay.org, is designed to deliver information to all types of users. It provides easy access to real-time data; plots of observation trends and archives; links to geographical and cultural information relevant to the vicinity of the buoys; and historical text and audio information about Captain John Smith's exploration of the Chesapeake Bay. In addition, www.buoybay.org provides high-quality educational content based on real-time and archived data and enhances meaningful watershed educational experiences designed to promote environmental stewardship of the Chesapeake Bay.

The NOAA Chesapeake Bay Office and Chesapeake Bay partners have developed a twenty-buoy CBIBS location plan (Fig. 2) which balances the needs of all the primary users. The first CBIBS buoy was placed in the James River directly off of Jamestown Island, the first permanent English settlement in North America, and activated 400 years to the day after John Smith landed. Additional buoys in 2007 were placed in the Chesapeake Bay near the mouth of the Potomac River (near Point Lookout, MD) and near the mouth of the Patapsco River (near Baltimore, MD). In 2008, three more buoys were placed: in Norfolk, Va, on the Elizabeth River; in the Chesapeake Bay near Stingray Point, VA near the mouth of the Rappahannock River; and at the mouth of the Susquehanna River, which provides over half the fresh water input to the Chesapeake Bay. In 2009, new buoys will be deployed in the Upper Potomac River, just downstream of Washington, D.C; and in the Chesapeake Bay near Annapolis, MD (nos. 8 and 9 in Figure 2).

CBIBS Hardware

CBIBS selected the AXYS Technologies Watchkeeper buoy as the standard system platform. The buoys are small enough to be easily handled and anchored by the smaller boats available in the Chesapeake Bay, but large enough to withstand the occasional extreme conditions that can occur. The standard instrumentation consists of the following:

Platform: AXYS Technologies WATCHKEEPER Buoy, based on Tideland Signal SB-138P Sentinel
AXYS Watchman 500 Controller
2200# Steel Anchor
1" Mooring Chain w/ 2.5:1 Scope
Communications: Sierra Wireless Pinpoint E over Verizon Wireless CDMA EVDO network
Meteorology: RM Young 05103 Wind Speed / Direction
Rotronics Temperature / Relative Humidity
Vaisala Barometer
10 min sampling / averaging / reporting
Currents: NORTEK 1 mHz Aquadopp Profiler 600 1Hz samples vector averaged from :50 to top of each hour
Waves: AXYS Technologies TRIAXYS OEM Wave Sensor 20 min sample from :40 to top of each hour
Water Quality: WETLabs WQM measuring temperature, conductivity, pressure, dissolved oxygen, turbidity, and chlorophyll A 300 1 sec samples averaged :53 to :58 reported hourly

Data Management and Information Delivery System

The AXYS Watchman 500 data collection platform on each buoy reports every 10 minutes via fixed IP modems over the Verizon Wireless CDMA network. Data are collected using the AXYS DMS, which initially downloads data to an SQL data base; both run on a server based in Williamsburg, VA. All other applications run on virtual servers via a hosting service. XML-based Web Services connect the data 'back end' to data management 'middleware'. A Data Archive Handler performs transformations and preliminary QA/QC checks and stores the data. A Data Retrieval Handler interfaces with Storage and provides external and internal access to the data. The handler contains an OpenDAP server, access to external data sources, and a Client Data Request Handler. Requests include browser based or designated users (e.g., the Verizon voice IVR, NWS, CBOS, applications, and kiosks) via an API key.

Fig. 2. Existing and proposed future locations for an expanded Chesapeake Bay Interpretive Buoy System.

For internal management, applications provide notification for off-line buoys, erroneous sensors, or deviations from a geographic location ('anchor watch'). The system also supports applications for data delivery through RSS feeds and widgets, or any XML requests.

Of note is the ability to serve data in real time to the Verizon voice IVR accessed through the 877-BUOYBAY phone number. In addition to observational data, this service provides recorded historical, environmental, and geographic messages tailored to the location of each buoy. With over two years of phone data recorded, the buoy line has logged over 14,000 calls, with a busiest day in October 2008 of 180 calls.

Recent and Future Activities With six buoys in the water and two more in preparation for deployment in 2009, CBIBS activities could be considered to be in transition from 'prototype' or 'development' system to something closer to 'pre-operational'. Data validation and calibration activities are underway for currents, waves, and water quality. The resultant one to two year data time series are being prepared for analysis. Research and development tests are being conducted on new sensors. New applications are being developed to deliver data to the interested public, and new partnerships are being explored to put buoys in desired locations.

Preliminary analysis of an experiment comparing CBIBS buoy mounted current and wave sensors to a co-located bottom mounted Nortek AWAC was reported at Oceans '08[1]. To summarize, for all currents greater than 0.1 m/s, the mean of the absolute value of the difference in current magnitude was less than 0.01 m/s. The mean of the absolute value of difference in current direction was 5°. With this confidence in current accuracy, tidal current predictions have been calculated for the 5 buoys with current meters and will be displayed along with real time currents and non-tidal deviations. Wave studies are continuing, but preliminary results indicate that the heavy buoy damps the predominantly short, low-amplitude Chesapeake Bay waves, underestimating maximum wave height by about 50% - however that factor appears to be consistent enough to allow a linear correction. Further testing on wave accuracy and response will be conducted during Winter 2009-2010 using the new Annapolis buoy.

Fig. 3. Interactive CBIBS kiosk located in view of the Elizabeth River buoy at the Nauticus Museum in Norfolk, VA

A major problem with moored water quality measurements is bio-fouling. The WETLabs WQM has a pumped pathway for temperature, conductivity, and dissolved oxygen water flow, with a chlorine bleach injection system Following each 10 min/hour average, a dilute bleach solution is pumped through the system. Optical sensors for chlorophyll-A and turbidity are kept clean by a copper wiper, and Temperature and Conductivity sensors are enclosed in copper cylinders. it appears that these sensors only require removal for external cleaning, rinsing, and bleach replenishment at no less than three month intervals even in summer, with annual refurbishment and recalibration. An in situ test bed has been deployed for CBIBS instrument testing in the Severn River near Annapolis, with facilities capable of controlled sensor measurements, sampling for nutrients, chlorophyll, and turbidity analysis at a local laboratory, and in-house dissolved oxygen titration using a potentiometric auto-titration system[2] .

An example of a new application has been the installation of a dedicated interactive kiosk at the Nauticus Maritime Museum in Norfolk, Virginia (Fig. 3). The kiosk is in sight of the Norfolk buoy, and allows museum visitors to access real-time data and interpretive information from all the buoys via the buoy-shaped, audio, touch-screen structure.

Additional sensors have been acquired and are being tested for integration into the system, including a Satlantic ISUS V3 Nitrate Sensor and a new WETLabs Cycle Phosphate sensor. In cooperation with the NOAA National Geodetic Service, the Norfolk

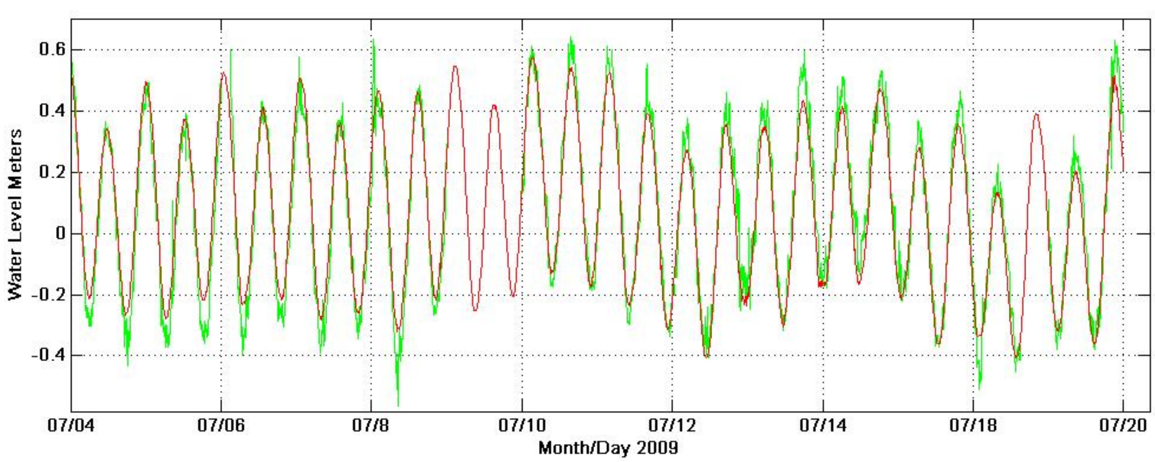

Fig. 4. Comparison of water level data taken from a GPS mounted on the Norfolk CBOBS buoy with tide gauge data from Sewell's Point, about 1 nm downstream. GPS have been demeaned and offset for best fit. Data processing courtesy of G. Mader, NOAA NGS.

CBIBS buoy has been operating a GPS receiver to measure water level. Initial results are quite promising (Fig. 4), with buoys clearly able to provide water level information of adequate accuracy to monitor inundation events at locations not served by fixed tide gauges. In Figure 4, CBIBS GPS data (green) are collected at 15 sec intervals and averaged over 6 minutes for comparison with a nearby (about 1 mile downstream) NOAA tide gauge. Further studies of the impact of the buoy dynamics on the WL data are required, as well as a direct comparison with pressure data taken at the buoy to remove true differences due to geographic separation.

The ninth CBIBS buoy, to be deployed in early 2010, shows the importance of community involvement in system expansion, development, and sustainability. Through a grant from the Dominion Power Foundation, a CBIBS buoy will be placed over anew artificial fishing and oyster reef complex in Chesapeake Bay. In addition to the standard sensor suite, the buoy is slated to have a bottom YSI 6600 water quality sensor, communicating with the surface buoy via a WFS Radio Modem. Tests are also underway to collect acoustic images from beneath the platform using a Lowrance Structure Scan sonar and transmit to shore for web visualization.

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