An Ocean Observing System for Harmful Algal Bloom Detection and Tracking

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***Abstract*-The toxic dinoflagellate *Karenia brevis* forms harmful algal blooms (HABs) in the Gulf of Mexico. The toxins produced by *K. brevis* cause massive fish kills, contaminate bivalves such as clams and oysters, and produce toxic aerosols. These HABs result in closure of commercial seafood production, disruption of recreational fishing enterprises, and despondent tourists due to the dead fish and toxic aerosols at the beach. Our HAB Observing System is designed to begin to fulfill the critical need to detect and track these toxic blooms over economically relevant spatial/temporal scales. The two primary components in our HAB Observing system are the Optical Phytoplankton Discriminators (OPDs) placed on a variety of ocean platforms and the Beach Conditions Reporting System (BCRS). Data generated by the two systems are transferred in near-real-time providing critical information on HAB presences, absence, and impacts for the research community, resource managers, government agencies, and the general public. The two components, OPD and BCRS, have both seen major growth in the number of units/locations since implementation. The major challenges in keeping our HAB Observing System operational have been engineering, funding, and the natural environment. The OPD data have assisted the research community greatly in sampling strategies, whereas the BCRS data provide beachgoers with needed information to optimize their beach experience.**

I. Introduction

The toxic dinoflagellate *Karenia brevis* forms harmful algal blooms (HABs) in the Gulf of Mexico. The toxins produced by *K. brevis* cause massive fish kills, contaminate bivalves such as clams and oysters, and produce toxic aerosols [1]. These HABs result in closure of commercial seafood production, disruption of recreational fishing enterprises, and despondent tourists due to the dead fish and toxic aerosols at the beach. There is a critical need to detect and track these toxic blooms over economically relevant spatial/temporal scales. This requires long-term monitoring to delineate the 3-dimensional distribution of phytoplankton genera. Although remote sensing has demonstrated success detecting and tracking surface expressions of *Karenia sp.* blooms [2], subsurface events remain problematic.

Our observatory for *Karenia sp.* incorporates twelve *in situ* Optical Phytoplankton Discriminators (OPD, a.k.a. BreveBuster) that analyze particulate absorbance spectra for similarity to *Karenia sp.* Recent modes of deployment include shipboard, moorings, channel markers, piers, and autonomous underwater vehicles. Results from this array of instruments are received at the Sarasota Operations of the Coalition of Ocean Observing Laboratories (SO COOL) for analyses, visualization, and dissemination. Deployment and operation of these resources over the past five years has demonstrated the utility of a HAB observatory on the central west coast of Florida.

Along the way, it became obvious that HAB observations did not have to come only from inanimate observers. Many useful near-real-time manual observations of HABS were being made for the Beach Conditions Reporting System (BCRS). Those observations needed to be incorporated in the automated information flow.

II. System Description

A. Optical Phytoplankton Discriminator Network

The OPD is an *in situ* instrument that evaluates the fourth derivative of measured particulate absorbance spectrum of an unknown sample and compares that fourth derivative spectrum to a standard spectrum for *K. brevis*. The first *in situ* OPD, optical-based HAB detector, was deployed May 20, 2003 on a Teledyne Webb Research Slocum Glider.

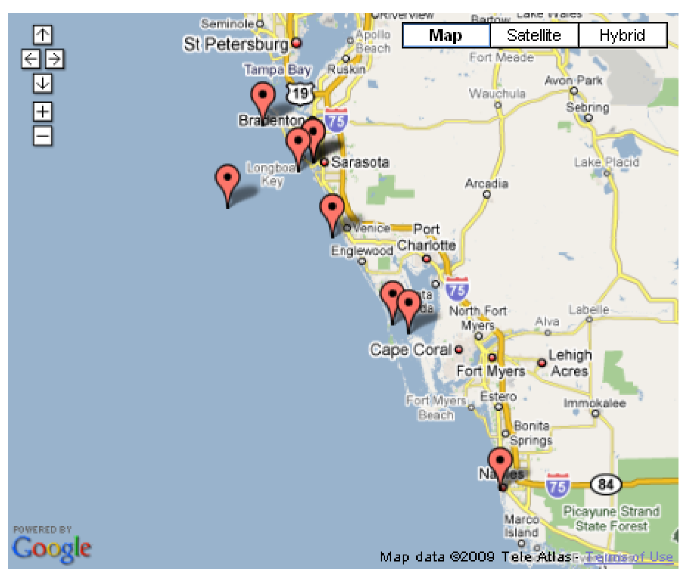

Fig. 1. Locations of regular OPD deployments on fixed platforms along the Southwest coast of Florida.

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Deployments as fixed installations on buoys and channel markers began in the summer of 2004. Presently, there are three OPD-equipped gliders and eight regularly instrumented fixed sites for OPDs(Fig. 1).

B. Beach Conditions Reporting Systems

The BCRS provides subjective, practical information regarding the conditions at the beach twice daily using park rangers and lifeguards as sentinels. These people were chosen as sentinels for their knowledge of their beaches and also as they are available to make reports 365 days/year. Information such as the presence/amount of dead fish on the beach, amount of respiratory irritation, and water color are important parameters beachgoers need to decide which beach to go to. In particular, people with preexisting lung disease, such as asthma, need to avoid beaches when the toxic aerosols are present [3,4]. The BCRS becomes an important public health tool for these people. This beach specific information is also important for the HAB forecasters for predicting beach impacts [5]. Data are input directly from the beach site using Blackberries, uploaded via wireless internet to the SO COOL server, and automatically displayed to the end user on a Google map (Fig. 2).

C. Data Flow

Initially observations were recorded internally for collection after the return of the instrument. From that simplified beginning the information technology aspect of our HAB Observatory has grown, in many ways, faster than the instrument technology itself. Very shortly after the first *in situ* deployments of our HAB detection technology the idea of waiting until the device was recovered to obtain the findings was simply unacceptable. Thus began our effort to produce near-real-time and subsequently real-time information about the presence/absence of HABs for the research community, resource managers, government agencies and the public (Fig. 3).

We used a variety of data transfer methods including direct cable, wireless network, VHF radio, cell phone and satellite phone depending on remoteness and available resources. Those data were initially received by desktop computer and viewed in tabular form for the instrument user. This quickly transitioned to an automated data server function that archived all received information and relayed only the salient pieces of information to the system manger or research scientist. A short but significant step from that point allowed customized data extractions to be sent to any requesting activity including the IOOS Web Service. The diagram below, with all of its IT nomenclature, is representative of our current information flow.

Data handling for the SO COOL system is built on a foundation of six Dell PowerEdge servers running CentOS 5.3. The servers are combined into three primary functional groups: data communications, data dissemination/visualization and storage/backup.

Data communications are accomplished using a collection of perl, python and java applications. OPDs communicate with the communications server using tcp/ip sockets and the inbound data are parsed with a perl script and stored in a MySQL database. Gliders access the server through the Iridium satellite network and two Hayes modems located in the SO COOL server closet. Glider data are initially collected by a vendor-supplied java application (dockserver) but this data are stored as raw text log files, making searching and sorting difficult. We use several python-based applications to parse the glider log files and generate SQLite and MySQL databases. The SQLite databases are file-based and are used to provide sorting/searching capabilities. The MySQL

Fig. 2. Beach Conditions Reporting System Website splash page. Outlined counties are those currently participating in the program.

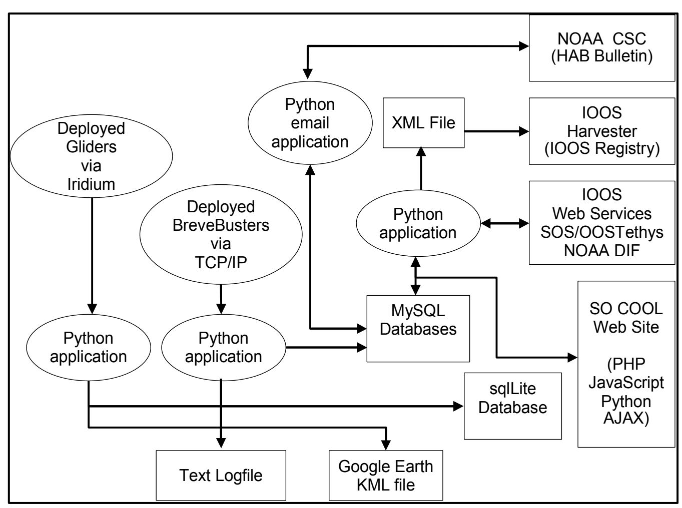

Fig. 3. Schematic diagram of data flow from OPDs to, through and out of the SO COOL.

databases provide long-term storage of collected glider data.

A series of python applications runs on a daily basis and generates XML files that are harvested by the IOOS Registry harvester. These scripts also parse the Beach Conditions Reporting System database and send daily email updates to NOAA. Data dissemination and visualization is done through our main web portal, http://coolgate.mote.org. The visualization interface is powered by a combination of python, php and javascript and uses jpgraph for real-time charting. During glider missions a python application generates Google Earth KML files that display glider location, track, OPD data and ARGOS locations.

We currently have 3 terabytes of storage for collected data on a CentOS 5.3 storage server. Access to the data are via Samba, which provides fast and secure file and print services to Windows clients. All data are backed up regularly on a dedicated backup server using Bacula, an open-source backup and recovery application.

III. Operations

A. Detector Network

The OPDs have been operational since June of 2004. The findings from the fixed-position instruments have been reported on the SO COOL website (http://coolgate.mote.org/) in tabular form (Fig. 4.) and in graphic form on sub-pages accessible by clicking on the parameter of interest. To date we have accumulated approximately 1,500 fixed-position detector-days. The gliders have conducted over 40 missions ranging from one-day test flights to 18-day surveys. Near real-time plots of the glider mission with HAB findings were presented on Google Earth charts.

Data from the fixed-position have also been feed to the IOOS Registry since May 2008 through a GCOOS data node portal (Fig. 5). These data have also been relayed to the

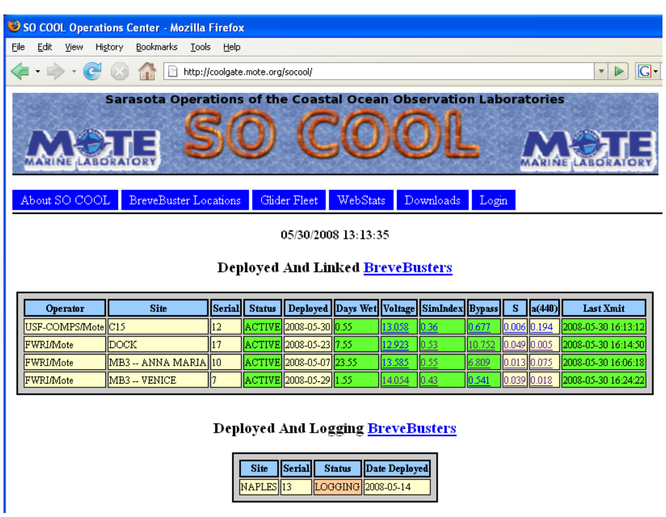

Fig. 4. The SO COOL OPD tabular data webpage. Each underlined parameter values has a time series bar graph accessible by clicking on the value.

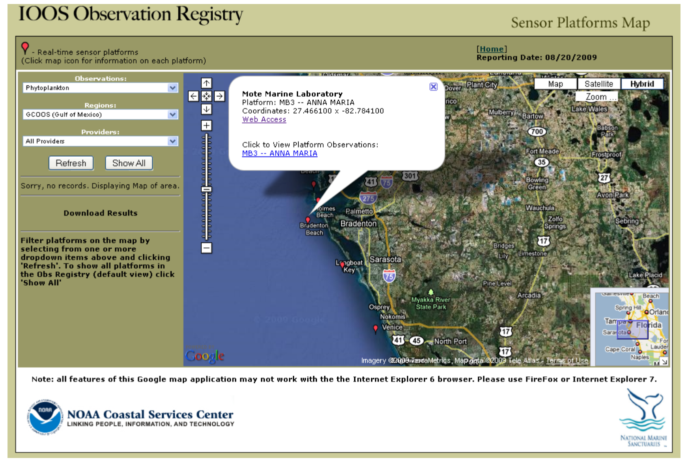

Fig. 5. IOOS Registry Map shown locations of fixed-location OPD installations that are linked to the site.

NOAA HAB Bulletin team as ground truth for their forecasting efforts.

B. Beach Conditions Reporting System

Over the three-year period, the site has average 5,900 clicks per month. The 2009 usage logs are examples of the growth of use of the site. The logs indicate an average of 68,000 web hits per month with about 3300 unique visitors each month. Of no surprise, when the visitors are mapped by location, the majority of users are in Florida (see Figure 6). But also of note is the large number of people along the eastern seaboard who are interested in the conditions at Florida beaches. A brief two-item questionnaire on the site asks respondents if they find the information useful and if they want the

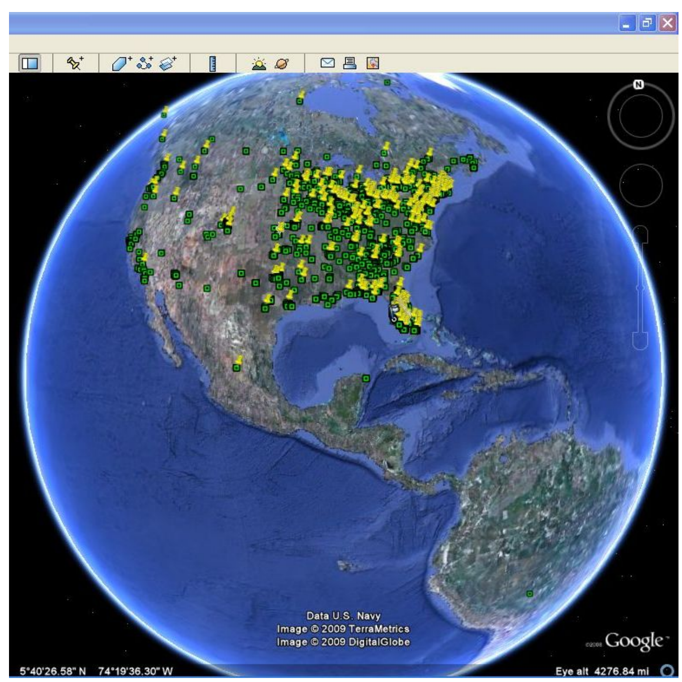

Fig. 6. Symbols indicate locations of IP addresses of Beach Conditions Reporting System users. Green squares indicate single use, yellow pushpins indicate multiple use.

information year round or only during negative impacts at the beach. Although this is a convenience survey of only users who chose to complete the questionnaire, results for question 1 are 98% favorable and for question 2, 95% responded that they want the reports year round, not just during negative beach impacts.

IV. Discussion

Besides the many engineering and funding complications that had to be addressed, there have been and continue to be many issues that must be dealt with on a day by day basis. For instance: Hurricane Charley removed our first fixed installation just weeks after it was deployed; cables, no matter how well secured, work loose on open water installations; satellite phone data telemetry can be interrupted by higher priorities; VHF radio telemetry rarely meets the manufacturers range specifications; installers and operators make mistakes; and of course there is biofouling. In addition to these ‘mechanical’ issues there are the issues of how to handle the information output. The internet provides a very functional dissemination infrastructure, but there have been many questions about who the end users should be and in what format should the information be presented.

Our efforts to evaluate the usage rates and the types of users have produced a wide range of utility. The more esoteric data products including graphs of OPD similarity indexes have value for the research community to help guide response sampling, but those data are not of use to the general public who have difficulty interpreting the meaning of such measures. The Beach Conditions Reporting System has a high usage rate by the general public and resource managers as well as providing a time series of HAB impacts used by scientists to evaluate the relationship between environmental conditions and respiratory irritation by toxic aerosol.

Acknowledgment

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References

[1] Kirkpatrick B, et al., Literature review of Florida Red Tide: implications for human health. *Harmful Algae* Vol 3(2): 2004, 99-115.

[2] Tomlinson, MC, et al., Evaluation of the use of SeaWiFS imagery for detecting Karenia brevis harmful algal blooms in the eastern Gulf of Mexico. *Remote Sens. Envir*. 91: 2004, 293-303.

[3] Fleming LE, et al., Initial Evaluation of the Effects of Aerosolized Florida Red Tide Toxins (Brevetoxins) in Persons with Asthma. *Environ Health Persp* . May; 113(5): 2005, 650-7.

[4] Fleming LE, et al., Aerosolized Red Tide Toxins (Brevetoxins) and Asthma. *Chest* 131: 2007, 187-194.

[5] Stumpf, R, et al., T. Skill Assessment for an Operational Algal Bloom Forecast System. *J. Mar. Sys*., 76: 2009, 51-161.