A Chromophoric Dissolved Organic Matter (CDOM) Observatory

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LONG-TERM GOALS

The long-term goal of this project is to develop an understanding of coastal systems such that optical properties of complex coastal waters can be retrieved and predicted from remote sensing and modeling efforts.

OBJECTIVES

This project focuses on establishing a moderate-scale observatory (Neponset) to develop watershed and coastal ocean models and remote sensing algorithms and extending this knowledge to a larger system (Hudson).

Specific Objectives:

1) Design and deploy CDOM observatory components in the Neponset Estuary and Boston Harbor.
2) Refine remote sensing algorithms for CDOM in the Neponset Estuary, Boston Harbor, and Massachusetts Bay based on high resolution and/or hyperspectral satellite imagery ground-truthed within the CDOM Observatory.
3) Refine a predictive watershed model for CDOM sources based on a Soil Water Assessment Tool (SWAT) and Geographical Information Systems to predict sources of CDOM to the estuary.
4) Refine the existing Boston Harbor physical/biogeochemical model to provide a 3-day forecast of CDOM distributions in Boston Harbor.

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5) Observe CDOM distributions and processes in the Neponset Watershed and Estuary and Boston Harbor for at least 12 months and refine observation protocols and predictive modeling capabilities.

6) Develop “smart” network to respond to episodic events.

7) Extend and deploy CDOM observatory in the Hudson Estuary for a 2-week period to show general applicability of the observation and prediction capabilities. This has been done while using the CDOM distribution model developed by Alan Blumberg at the Stevens Institute of Technology.

APPROACH

The CDOM Observatory is composed of five major components: continuous monitoring stations, targeted sampling, remote sensing, watershed and coastal modeling, and cyberinfrastructure. Initial focus for all monitoring, sampling, and remote sensing will be the Neponset Watershed, Neponset Estuary, and Boston Harbor, but occasionally, cruises will extend throughout Boston Harbor out into Massachusetts Bay to follow the fate of terrestrial CDOM into coastal ocean waters. Towards the end of Year 2, the CDOM Observatory will be redeployed in the Hudson Watershed and Estuary to determine the transferability of the Observatory.

Bernie Gardner and Francesco Peri will be responsible for development, deployment, and maintenance of the CDOM observatory—the continuous monitoring stations in the estuary and watershed, and integration of the AUV. Watershed modeling and remote sensing will be carried out by Yong Tian who has developed remote sensing algorithms for CDOM based on hyperspectral radiometric measurements in the Gulf of Mexico and Hudson Estuary. Estuarine/coastal modeling will be carried out by Mingshun Jiang who maintains a Boston Harbor/Massachusetts Bay predictive model. Francesco Peri will be responsible for cyberinfrastructure development.

WORK COMPLETED

Five low-cost (<$10k) buoys were designed, constructed and deployed in the Neponset Estuary/Boston Harbor area. CDOM, water temperature, and chlorophyll fluorescence, as well as current direction, wind speed and direction, barometric pressure, relative humidity, and PAR are being measured. Real-time data is available at <http://www.cesn.org/livedata.php>

These buoys have been deployed in summer and fall, but were damaged in the winter due to freezing and thawing affecting the integrity of the housings. We have recovered them, fitted them with salinty sensors, and redeployed them. An additional redesign is now required due to the higher current demand of the salinity sesnsors.

An AUV (YSI EcoMapper) has been purchased. Autosampling units for watershed samples have been purchased, are ready for deployment in the case of a large rain event, and are being fitted with wireless telemetry (cell phone) so that they may be remotely programmed. 30 stations throughout the Neponset Watershed are continuing to be sampled monthly and analyzed for dissolved organic carbon (DOC) and chromophoric dissolved organic matter (CDOM) in the form of fluorescence and absoprtion spectra. Monthly cruises up the Neponset Estuary been interupted due to the loss of our orginal MiniShuttle (when it caught on mooring line, broke off, and has not been recovered), but have been reestablished. EO-1 satellite imagery has been procured. Our hyperspectral radiometer mounted on the bow of our research vessel has been useful in correlating the surface reflection with in situ CDOM measurements. The Boston Harbor model has been refined to increase the resolution to a 30 meter grid size in the Neponset Estuary portion of the Boston Harbor.

We deployed our small boat with a tow-yo package in the Hudson, Hackensack, Passaic, and Raritan estuaries during our deployment of assets in the Hudson Estuary in August, 2010. Additonally, 20 Hudson watershed samples and 4 continuous monitoring stations (YSI sonde based) were deployed at the four freshwater endmembers for the duration of the field work. Finally, the RV Sharp was used for 5 days with the ECOShuttle to obtain 3 dimensional CDOM distrbutions throughout the Hudson Estuary complex. Over 500 discrete water samples and samples for incubation experiments have been collected and are awaiting analysis.

RESULTS

Our Neponset CDOM Observatory continues to be developed, but so far has yielded valuable results. Our data set of over 30 months of 30 samples distributed throughout the watershed has allowed us to understand the dependence of CDOM endmember values on land use, season and discharge. A simple model can use these parameters to predict the endmembers with an r^2 of 0.4 to 0.7 (Huang and Chen, 2009). This same simple model has been applied to the Hudson Watershed with approximately the same reliability (Huang et al., 2011). A more detailed model may increase this reliability to an r^2 of 0.7 to 0.8 (Wang et al., 2010).

The system of real-time buoys, shore stations, and watershed stations is still being developed and deployed (or redesigned and redeployed). So far, the design of the shore stations has been shown to be robust, and the buoys have worked well in non-winter months. Monthly Mini-Shuttle cruises suggest a strong “fall dump” of CDOM from fringing salt marshes. An increase from September through November, then a decrease to near zero in December is seen for the mid-estuary input contributed by salt marshes. This seasonality has been incorporated into your high resolution circulation model (60 meters resolution). A distributed source contributed at an ebbing tide yields the model results that best match our observations, although there are still some components of the model (e.g. changing land-water interface) that need to be developed.

The upwelling radiance data that we have gathered with our ASD hyperspectral radiometer in conjunction with in-water CDOM measurements, discrete CDOM absorption measurements and hyperpectral EO-1 satellite imagery has allowed us to develop algorithms to convert satellite data to surface water CDOM measurements.

Many of our assets (shore stations, remote sensing, Mini-Shuttle, ECOShuttle) were moved temporarily to the intensive study of the Hudson Estuary in August, 2010. The equipment all functioned remarkably well, and the observatory yielded the following preliminary results:

1) The Neponset watershed model is applicable to the Hudson watershed.
2) Tributary freshwater endmembers can be monitored and integrated into the circulation model to improve predictions of CDOM distributions in the Hudson Estuary.
3) CDOM endmembers are diluted during flood events (Huang et al., 2011b)

4) CDOM inputs from sewage can be detected and attributed to individual sewer outfalls, but mixes quickly (in about 1 day or less) to form a general sewage contribution in the Upper Hudson Bay.

5) 10-50% of the CDOM load is contributed within the estuary, primarily from salt marshes and sewage (Huang et al., 2011b).

6) Photochemical degradation dominates shorter time scales (1-2 weeks) while bacterial reworking (coupled degradation and concomitant production) of CDOM dominates over longer time scales (>2 weeks) in the Hudson River Plume, resulting in "marine" CDOM entering into the coastal ocean (Huang et al., 2001b).

IMPACT/APPLICATIONS

Our knowledge regarding CDOM source, transport, and fate in estuaies and coastal waters has been greatly expanded. We now have the ability to predict freshwater endmember CDOM based on land use, season, and discharge information. A simple watershed model has been applied to the Neposet and Hudson Watersheds and seems to give reasonable predictions so it may be that this model can be used more widely in many different watersheds. Physical circulation models (eg. Boston Harbor and Hudson Estuary) can use endmember CDOM values as inputs and produce 3-dimensional CDOM predictions for up to 3 days in advance. Rates determined by incubation allow the degradation of CDOM during mixing to be estimated. These predictive capabilities for CDOM appear to allow better prediction of optical water quality.

In addition, we have continued to develop our CDOM algorithms to allow high resolution (30 meter grid size) satellite imagery to be used to measure CDOM in coastal waters. This capabiltity could have a large impact on studying land-ocean transport of dissolved organic carbon as well as studying contaminant plumes, river plumes, or potentially in-water processes (Yu et al., 2010; Zhu et al., 2010).

Several technoloigcal advances have also been made. Inexpensive buoys have been designed, redesigned and deployed. Shore stations have been designed and deployed. A system for measuring hyperspectral water-leaving irradiance has been used on 3 different ships. An autosampler has been fitted for automatic sampling of rivers during episodic events. All of these technological advances will allow high resolution studies of coastal systems.

RELATED PROJECTS

The Boston Environmental Area Coastal Observation Network (BEACON) project is supported by the Department of Energy. This project within the UMassBoston Center for Coastal Environmental Sensing Networks (CESN) is aimed to provide a testbed sensor network system for testing new sensors, for facilitation collaborations with industry, for learning about the opportunities and barriers to maintaining a nearshore coastal sensor network, and to allow new research opportunities. The BEACON project is integral to allowing the ONR project to focus on CDOM and episodic releases of CDOM.

NASA has recently funded a project on the "Geospatial Synthesis of Chromophoric Dissolved Organic Matter Distribution in the Gulf of Mexico for Water Clarity Decision Making" (Chris Osburn, PI; Eurico D'Sa, Paula Coble, Tom Bianchi, co-PIs). Data on CDOM export from terrestrial systems into the Gulf of Mexico and related remote sensing data will be useful to this ONR project's goal to better understand CDOM flow from terrestrial systems to marine systems and to use remote sensing to estimate in situ optical properties.

Another project supported by NSF-Chemical Oceanography entitled “DOC Outwelling from Salt Marshes” has been approved for funding. Robert Chen will act as PI along with Jennifer Cherrier (FAMU), Jaye Cable (LSU), and Christof Meile (UGA) as co-PIs. This focused study on DOC and CDOM produced in salt marshes will help refine our estuarine models of sources of CDOM to estuaries. Several of the buoy designs for our CDOM observatory may be used in this project, and alternatively, new buoy designs generated in the NSF project may be used in the ONR CDOM observatory.

MIT SeaGrant has provided support to establish the Consortium for Ocean Sensing In the Nearshore Environment (COSINE), a collaboration between CESN at UMassBoston, Tom Little at Boston University and Ferdi Hellweger at Northeastern University. This 6-year focused area research project will examine the use of wireless sensor networks in coastal areas with specific emphasis on coastal inundation, monitoring bacterial water quality, and episodic contaminant release.

PUBLICATIONS

Huang, W. and Chen, R.F., 2009. Sources and transformations of chromophoric dissolved organic matter (CDOM) in the Neponset River Watershed. J. Geophys. Research-Biogeosciences, 114, doi:10.1029/2009JG000976.

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Huang, W., Chen, R.F., and Gardner, G.B, 2011b. Chromophoric Dissolved Organic Matter (CDOM) Budgets in Hudson and Tributaries’ Estuaries. In preparation.

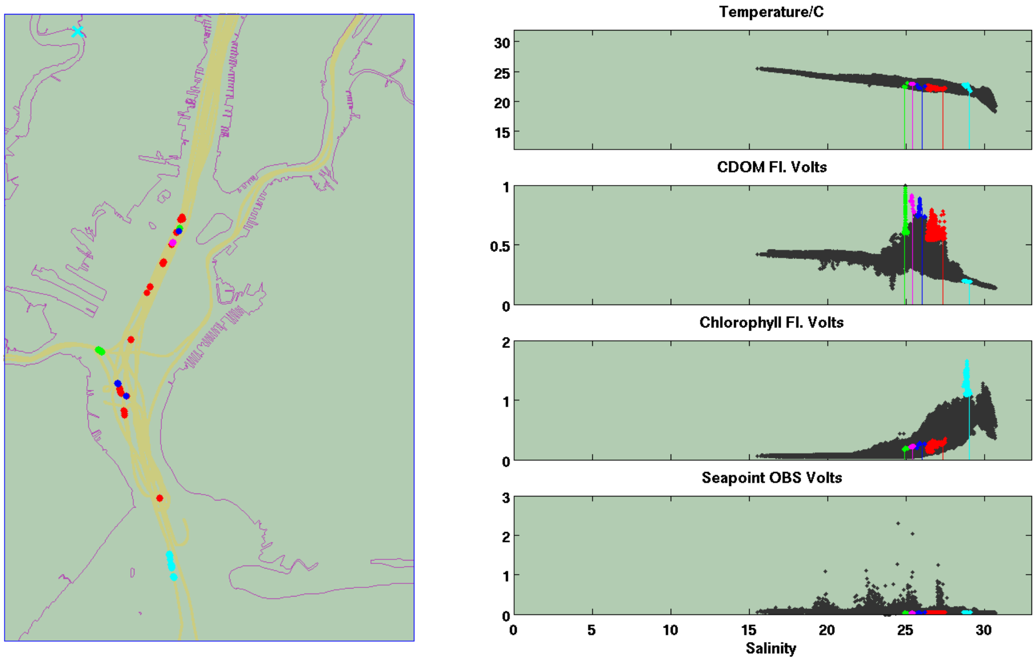

Figure 1: Temperature, CDOM fluorescence, chlorophyll fluorescence, and optical backscatter plotted against salinity for the upper Hudson Bay from the RV Sharp cruise in August, 2010. Data was collected using the ECOShuttle undulating vehicle. Color coded areas correspond to the ship track on the map to the left. Highlighed in green, blue, and red are contributions of CDOM (above the conservative mixing line) from subsurface sewage effluents that contribute to the overall CDOM export of the estuary.