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A Wireless Real-Time Coastal Observation Network

A new integrated coastal observation system is providing preliminary data from the North American Great Lakes. This system can be implemented in other coastal regions. To date, it has been successfully deployed on Lakes Michigan, Huron, and Erie to make seabed to sea-surface measurements of chemical, biological, and physical parameters, which are transmitted wirelessly through buoys and permanent stations. Called the Real-Time Coastal Observation Network (ReCON), the new system leverages existing networking technology to provide universal access to a wide variety of instrumentation through the use of an underwater Ethernet port server [*Austin*, 2002]. A team of NOAA engineers and scientists has completed the development and testing of this integrated coastal observation network.

Utility of the Network

An Ethernet-based coastal observation network design enables the creation of system components, such as sensor drivers, data transfer software, system control functions, database management, web display ,and archival functions, using standard web-design tools. The underwater, universal hub easily allows the attachment of sensors at any time during the deployment period. Portable buoys and permanent stations transferring data into network nodes distributed across broad coastal regions can be integrated at a central location using the Internet. This implementation of a coastal network providing real-time chemical, biological, and physical observations has already benefited ecosystem researchers, resource managers, forecasters, educational institutions, and public users. Further, regional observations downloaded at time intervals required to describe particular ecosystem features and events can be presented to managers and operational forecasters through ad hoc web displays or to students and researchers through searchable database management systems.

Using this approach, an observation network can be deployed in any coastal region with Internet availability. Buoys need only be placed within antenna range of the shore station. Deployment range, dependent on the height of the shore antenna, can be as much as 32 kilometers allowing buoy placement anywhere within an approximate 1400 square kilometer area. Additional buoys or fixed stations can be used to extend range through the use of the relay capability inherent in wireless network devices. The observation network supplies enough throughput capacity to simultaneously support continuous measurements from both standard oceanographic and meteorological instrumentation (such as wind and temperature measurements, current velocity profilers, and chemical sensors) and more advanced surface and underwater applications such as streaming imagery.

By leveraging existing internet technology for real-time data collection, NOAA's observation infrastructure can be significantly upgraded to provide forecasters, researchers, coastal resource managers, and the public with the data necessary to make informed decisions in response to ecosystem change [*Ocean.US*, 2002]. The transition of this research and development effort to an operational coastal implementation has the potential to improve forecasts and forecast verification, increase marine safety, and reduce public health risks while responding to established national goals [*Ocean.US*, 2006].

Network Specifications

The important aspects of the ReCON coastal internet-based network are the ability to wirelessly connect buoys to shore at distances up to 32 kilometers or to other buoys in an array, and to connect vessel-based data collection systems through offshore buoys or directly to the shore. The ReCON universal hub provides a standard instrumentation interface for the deployment of multi-sensor data collection platforms. Data archiving, data management, and system control are implemented through the Internet.

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Fig. 2. Lake Erie ice imagery, camera looking south at approximately 180°. (a) Image taken on 27 February 2007 showing snow ice with wind-rowed snow and areas of black ice (re-frozen leads or melt holes). (b) Image of 5 March 2007 showing pancake ice and open water.

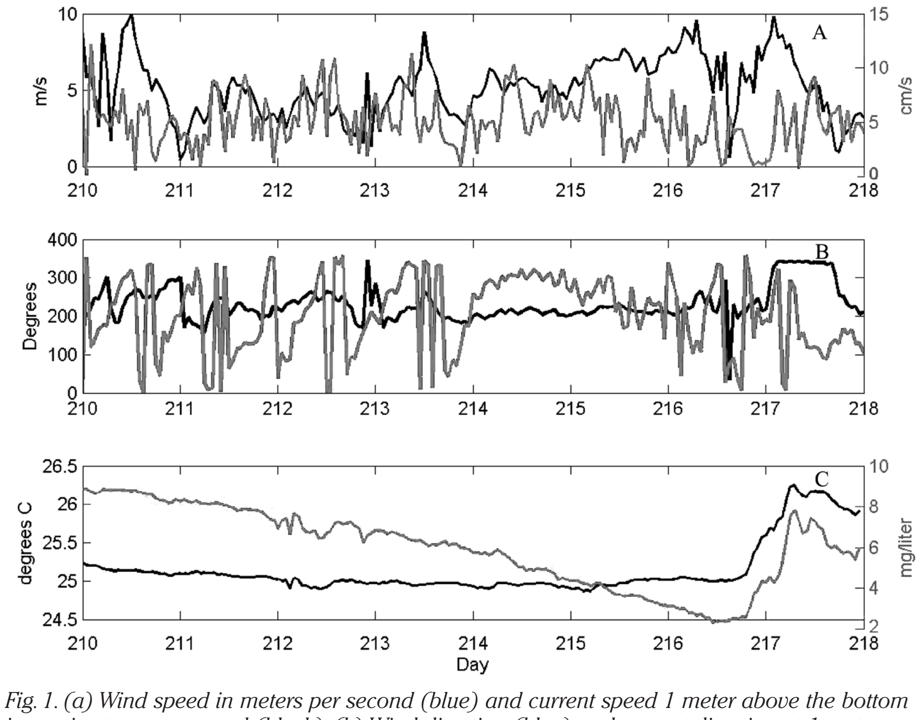

Fig. 1. (a) Wind speed in meters per second (blue) and current speed 1 meter above the bottom in centimeters per second (black). (b) Wind direction (blue) and current direction at 1 meter above bottom (black). The wind direction follows the meteorological convention, so the wind is from the direction indicated. The current direction follows the oceanographic convention so the flow is toward the direction shown. (C) Water temperature 1 meter above the bottom (black) and dissolved oxygen concentration in milligrams per liter 1 meter above the bottom.

Portable buoys [*Frye et al.*, 2000] and permanent stations are connected to shore through wireless internet radios capable of providing up to 1.5 megabytes per second of system bandwidth. Connections to underwater instrumentation are implemented through a marine-grade Ethernet network cable. This connection allows buoy computer access to data or imagery from multiple devices plugged into an underwater network hub using standard marine connectors. Data and imagery are first transferred to and stored on the buoy computer, then transferred at a scheduled time (typically hourly) to the shore computer over the wireless internet connection.

System Implementations in the Great Lakes

Permanent and buoy-based ReCON systems have been deployed at coastal locations around the Great Lakes, beginning in 2003. A network computer located at the Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, Mich., accesses the data from shore computers through the Internet. The buoy computer monitors the solar-battery power system allowing variable power cycling to conserve energy during periods of limited solar exposure. Underwater sensors can be re-programmed from the central computer in Ann Arbor in anticipation of rapidly changing ecosystem events. During such episodic events, specific system components can be placed in continuous operation to enable high resolution temporal sampling.

A ReCON system deployed on western Lake Erie on a U.S. Coast Guard navigation structure, in collaboration with the University of Toledo's Lake Erie Center (located in Oregon, Ohio), supported preliminary investigations into conditions contributing to episodic hypoxia events and subsequent effects on benthic organisms. Figure 1 shows data collected from this station during 2006. Water depth at the station was 8 meters. Sensors at the station included a bottom-mounted acoustic Doppler current profiler, a YSI 6600EDS multiprobe

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(that included temperature and oxygen sensors) located 1 meter above the bottom, and a meteorological station. The clockwise circulation observed through day 214 (August 1) is due to internal inertial waves. The data show that the oxygen concentration decreased steadily until about noon on day 216 (August 3). Both the water temperature and the oxygen concentration then increased for about the next 24 hours, before declining again.

The short duration of the hypoxic episode illustrates the value of using real-time data provided by the ReCON buoys to trigger field sampling, since more traditional monitoring methods (using a small boat to go out once a week to measure the oxygen concentration, for example) would likely have missed the event. Recent studies have suggested that even short term hypoxic events in western Lake Erie can have adverse effects on benthic organisms [*Bridgeman et al.*, 2006].

The same Lake Erie ReCON station is also used to transfer hourly imagery. The pan and tilt internet camera, located 12.5 meters above the water level, has a horizontal field of view (FOV) of 71.3° and a vertical FOV of 53.1°. The camera is capable of providing image resolution up to 1280 by 960 pixels. During winter, ice imagery (Figure 2) is used to develop ice cover estimates for use by Great Lakes shipping. GLERL and Jet Propulsion Laboratory scientists have also used this winter imagery to provide 'ground truth' information for the development and validation of algorithms for satellite synthetic aperture radar (SAR) and scatterometer ice cover classification and mapping. Great Lakes ice cover information—including spatial coverage, concentration, ice type, thickness, freezeup and breakup dates, and ice duration—is a necessary input for ice control and ice breaking operations and ice forecasting and modeling efforts. In addition, ReCON provides real-time estimates of local conditions during cloud cover.

A separate ReCON node located on Lake Huron at the Thunder Bay National Marine Sanctuary (TBNMS) in Alpena, Mich., provides buoy-based streaming imagery of underwater historic artifacts and conventional composite video from a remotely operated vehicle (ROV) operated from the deck of a research vessel. The webcam is plugged directly into the underwater network hub connected to a surface buoy located approximately 16 kilometers offshore providing shipwreck observations to TBNMS visitors.

The system is also used to transfer audio and video over the Internet to multiple classrooms across the country for use in real-time 'live dives' providing historic and scientific educational opportunities. The composite video and audio signal from the ROV and scientific narrators on deck is digitally reduced in size using a hardware compression device. The compressed information is transferred over the Internet to host computers where it is restored to original quality for use with any video display device. Students and teachers in the classroom are then able to interact with onsite researchers using internet audio and text messaging techniques in wide use today.

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G E O P H Y S I C I S T S

In Memoriam

George A. Guy, 92, 23 February 2007; Atmospheric Sciences, 1948
Takeo Kosugi, 57, 26 November 2006; Solar and Heliospheric Physics, 1994
Elizabeth Sulzman, 40, 10 June 2007; Biogeosciences, 2000