Coastal Ocean Observing Systems Going Wireless

Evolving Technology Begins to Eliminate Cabling of Ocean Instrumentation in the Coastal Ocean Environment

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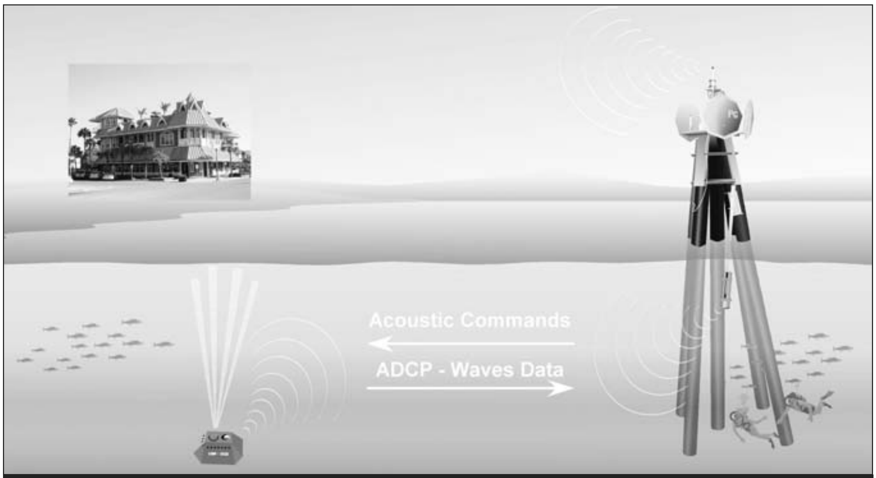

Wireless waves configuration: bottom mount, surface mount and repeater station on the beach.

The University of South Florida's (USF) Coastal Ocean Monitoring and Prediction System (COMPS)—a component of the Southeast Atlantic Coastal Ocean Observing System—is a collaborative university partnership that collects, manages and disseminates regional ocean observations and products for the coasts of the southeastern United States. COMPS, a regional association within the planned U.S. Integrated Ocean Observing System, utilizes acoustic Doppler current profilers (ADCPs) for measuring ocean velocity profiles. These are employed either surface mounted in buoy bridles, downward looking or bottom mounted in trawl-resistant racks along with other sensors. Profiling ranges on these west Florida shelf applications have varied between the 10-meter isobath and the shelf slope. Data acquisition may be accomplished by using a variety of methods, including internal recording; telemetry by radio, satellite or cables; and, most recently, by acoustics. These methods have advantages and disadvantages and, in certain applications, it is first necessary to transfer data from the seafloor to the surface before broadcasting to a home site. Cabling is straightforward, but subject to damage by trawling and anchoring. Acoustic modems alleviate this cabling issue, but are limited to the amount of data that can be transferred at a given time. Thus, while the acoustic transmission of ADCP velocity and other oceanographic data is well developed, the transmission of full wave directional spectra from an ADCP has proven difficult. USF's Ocean Circulation Group (OCG)—in collaboration with Teledyne RD Instruments Inc. (San Diego, California) and Teledyne Benthos Inc. (North Falmouth, Massachusetts)—tested an integrated telemetry system for the purpose of real-time acquisition and telemetry of velocity profile and directional wave data. Using an RD Instruments Workhorse ADCP (with Waves Technology) linked to a home station at USF (by a combination of Benthos Telesonar acoustic modems and FreeWave radios), an in-water test was initiated in February 2002. After solving a series of problems over the course of three deployments—including the recognition that wave data needed to be pre-processed prior to acoustic transmission—a successful systems design was achieved in a fourth deployment in August 2004.

Systems

Among the components that were integrated into the system was an RD Instruments Workhorse 600-kilohertz ADCP with patented Waves technology. Workhorse measurements included three independent calculations of wave height derived from orbital velocity, pressure and surface echo location. An RD Instruments NEMO real-time waves processing module was specifically designed for Waves users, and a self-contained device linked directly to the Waves-ADCP that processes real-time current and wave data at the source. This provides condensed data packets suitable for transmission to the surface or shore via an acoustic modem or hard wire

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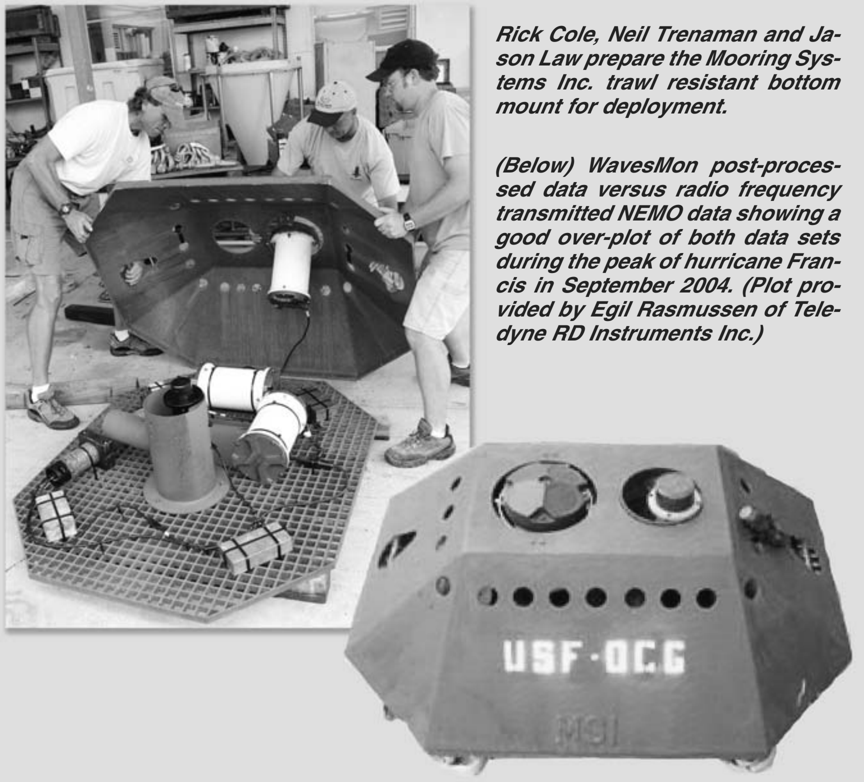


Rick Cole, Neil Trenaman and Jason Law prepare the Mooring Systems Inc. trawl resistant bottom mount for deployment.

(Below) WavesMon post-processed data versus radio frequency transmitted NEMO data showing a good over-plot of both data sets during the peak of hurricane Francis in September 2004. (Plot provided by Egil Rasmussen of Teledyne RD Instruments Inc.)

link. Benthos Telesonar acoustic modems—an ATM-885 remote modem, with an AT-408 omni-directional transducer—served as the underwater component of the acoustic communication link that interfaced with the ADCP. This system acoustically transmits (or receives) data from a local ATM-880 surface modem using an AT-408 omni-directional dunking transducer located near the surface. Both modems required 21 volts of input power and operated at the middle frequency range of 16 to 21 kilohertz. A FreeWave wireless data transceiver was positioned at the surface. A line-of-site, multi-point radio network consisting of an offshore master broadcasting to a slave receiver (via a repeater station) was used to telemeter this data back to USF.

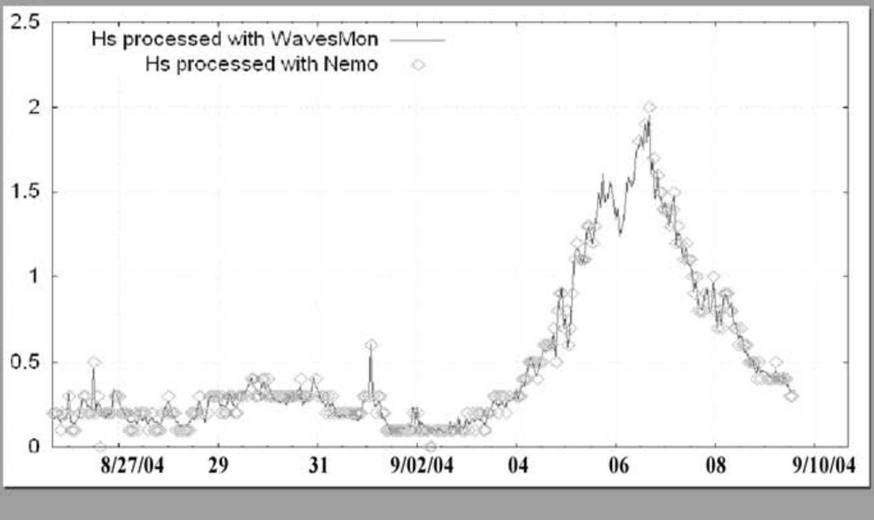
A laptop PC was configured to receive hourly data, which was then routed to the COMPS Web page for internal viewing over the 17-day deployment interval. The small boat deployable ADCP mount used to secure all sub-sea instrumentation was provided by Mooring Systems Inc. (Cataumet, Massachusetts).

Deployments

A total of four test deployments were made. In all cases, the out-of-water telemetry links were sent by radio frequency modems with a PC interface used to collect data in real time via the waves processing software Waves Monitor (WavesMon). This allows for the evaluation of waves and currents at a glance. The program also creates waves records (in a .wvs format) that can be displayed by the WavesView software that searches time series for interesting wave energy events. In three deployments, velocity data were received and processed, however, wave burst information was problematic. This led to the development of pre-processing wave data *in situ* at the ADCP location (NEMO), leading to a successful fourth deployment. The deployment site, located approximately one and a quarter miles west of the beach, consisted of two acoustically linked components: an instrument rack situated along the seven-meter isobath, 110 meters from a fixed channel marker where the radio master and surface dunking transducer were mounted. With the assistance of Neil Trenaman and Egil Rasmussen of RD Instruments and Adam Lipper from Benthos, all instrumentation was tested and prepared in the OCG laboratory and then deployed from USF's R/V *Subchaser*.

Acoustics

Many factors must be taken into consideration before deploying an acoustic telemetry system. Operating depth, required communication range,



multi-path, ambient noise and environmental conditions are all critical. Multi-path, the most restricting affect—both on baud rate and reliability—is the result of sea-surface and seafloor reflections, reflections from objects near the receiving modem, thermal gradients and water turbulence. The waves deployments for this project were of prototype designs and corrected on a trial and error basis. Subsequent to the initial three attempts, RD Instruments redesigned the wave data processing and data transfer, while Benthos incorporated software and hardware modem modifications. The modems began with the user's binary digital data, which can be representative of any type of information that can be digitally encoded. For example, any data that can be passed through the Internet can be handled by the modems. Whereas typical computers use copper wires (or radio signals) as the data transmission medium, acoustic modems use water. This greatly reduces the effective data transfer rates and distances. The original digital data is sent through the water in packets and subpackets. The ocean environment is often a noisy place, and signal interference can occur from the effects of wind-driven waves, passing ships and snapping shrimp (to name but a few). If the modem receives a large data packet with a small amount of missing data (due to noise interference), the modem will ask the distant modem to resend the subpacket which contained the error. Using these techniques, all data being sent from the distant modem are able to make the journey through the water unchanged, and be ready for delivery from a standard computer serial port to the end user.

> ***"Data acquisition may be accomplished by using a variety of methods, including internal recording; telemetry by radio, satellite or cables; and, most recently, by acoustics."***

Instrument Set-Up

The waves set-up calls for 20-minute, five-bin data sets. Three bins are required, with the extra two used for redundancy. A 20-minute sample interval provides sufficient record length for wind wave burst analysis. At two hertz, this results in 2,400 samples per burst. A higher sampling rate and duration increases power consumption. Along with the waves bursts velocity, profiles are sampled every 10 minutes with 60 pings.

NEMO Waves Module

Options for real-time telemetry of oceanographic data are often limited by the available bandwidth of the telemetry technology or the cost of the service. In some instances, they are limited by both. Since real-time ADCP waves processing requires the wave data to be sampled continuously at two hertz for 20 minutes, if data are lost during this interval, the processing is compromised. The NEMO allows ADCP waves and currents data to be buffered over the sample interval and then quickly processed and condensed for outputting a real-time wave and current profiling data packet. The effect of the NEMO is to condense the data from an original 150,000 bytes to a 150-byte data string suitable for acoustic transmission in report-ready format.

Results

Along with the successful deployment of this real-time system, the Florida peninsula experienced a very active hurricane season in 2004, with the second of four major hurricanes (Francis) passing just to the north of the site. Both the survival of the system and the associated data added to the project's success. A comparison of the real-time transmitted data from NEMO versus the data processed using WavesMon (after the recovery of the instrument) provided an excellent over-plot.

During the height of the storm, telemetry was lost for over 12 hours. The most probable causes for this loss are high levels of suspended sediment and/or entrained air bubbles throughout the water column. Contour plots and corresponding profile plots indicated that the acoustic intensity signal was fully saturated. Data did return acoustically and in real time after the storm passed.

Data Dissemination

Once data was received from the field, it was archived in the USF-COMPS base station computer. This data was then processed using decoder scripts written in Perl programming language.

The wave observations of significant wave height, peak period, direction, water level and time series graphics were made available via the Internet internally (not publicly) for testing purposes. The graphics scripts were written in Interactive Data Language programming. Once this system is permanently installed, it will become an added product on the COMPS Web page.

Conclusions

This USF-OCG/RD Instruments/Benthos test demonstrated that waves data can be successfully transmitted acoustically through the water column and then to shore for post-processing. Benthos modems integrated to the RD Instruments Waves ADCP and NEMO very well. Not only was the system test a success, but the data set also proved beneficial in checking the three methods RD Instruments uses to record waves. Along with the temporary acoustic telemetry failure (due to saturation by bubbles and sediments), the ability of the ADCP to utilize surface tracking as the primary method for calculating the wave height was compromised. This strengthens the argument for the need for more than one sampling technique to ascertain wave height when using ADCPs.

Spectral plots in post-processing (showing the three independent sampling techniques), revealed that the surface tracking beam technique does not work during storm conditions. However, having both the orbital velocity and the pressure sensor options allow the ADCP to continue to measure the wave field even under extreme conditions. The surface tracking technique works well during calmer conditions. Experimenting with various telemetry options will continue with the hopes of moving COMPS buoys farther offshore into deeper waters.

Acknowledgements

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Dr. Robert Weisberg works as an experimental physical oceanographer engaged in ocean circulation and ocean-atmosphere interaction studies in the tropics, on continental shelves and in estuaries. His research presently emphasizes in-situ *measurements, analyses and models of the west Florida shelf circulation and the interactions between the shelf and the estuaries.*