Development and Demonstration of Bistatic and Long-Range CODAR SeaSonde HF-Radar Systems For Coastal Rapid Environmental Assessment Applications

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LONG-TERM GOALS

The long-term goal is to develop a nested grid of multi-static CODAR HF Radar systems and demonstrate their utility for mapping real-time surface currents on the New Jersey Shelf. The multi-static radar network, combined with real-time access to the international constellation of ocean color satellites and a growing fleet of autonomous underwater Gliders, will form the sustained component of the evolving New Jersey Shelf Observing System (NJSOS). NJSOS, along with similar regional observation efforts in Maine and North Carolina, will be linked within the NorthEast Observing System (NEOS) to eventually provide surface current maps for the entire northeast coast from Hatteras to Halifax.

OBJECTIVES

Immediate objectives are to: (a) evaluate and improve an emerging Long-range HF Radar capability; (b) develop and implement a proposed solar-powered buoy-based Bistatic HF Radar capability; (c) demonstrate the utility of a nested multi-static HF Radar network during the 2001 Coastal Predictive Skill Experiment (CPSE) at Rutgers Long-term Ecosystem Observatory (LEO) and in subsequent field efforts.

APPROACH

This project continues the successful partnership between Rutgers University (RU) and CODAR Ocean Sensors (COS) begun with NOPP funding in 1998. The existing standard CODAR systems at LEO serve as the test bed for expansion to the regional scale and the development of bistatic capabilities. Year 1 consisted of an evaluation of beam pattern measurements to improve CODAR system accuracy, the initial test of the first east coast long-range system, and the construction of the first bistatic system. Year 2 included installation of the long-range mono-static network to support the

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14. ABSTRACT
The long-term goal is to develop a nested grid of multi-static CODAR HF Radar systems and demonstrate their utility for mapping real-time surface currents on the New Jersey Shelf. The multi-static radar network, combined with real-time access to the international constellation of ocean color satellites and a growing fleet of autonomous underwater Gliders, will form the sustained component of the evolving New Jersey Shelf Observing System (NJSOS). NJSOS, along with similar regional observation efforts in Maine and North Carolina, will be linked within the NorthEast Observing System (NEOS) to eventually provide surface current maps for the entire northeast coast from Hatteras to Halifax.

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final CPSE at LEO, initial tests of the bistatic system on both the east and west coasts, and construction of the first standard-range bistatic buoy. Year 3 focused on the transition of the long-range systems to multi-static operation, the first test deployment of the standard-range bistatic buoy, and the design of a larger long-range bistatic buoy.

Key Individuals:

Scott Glenn, RU, Project Leader	Don Barrick, COS, HF Radar Development
Josh Kohut, RU, CODAR Operations	Belinda Lipa, COS, Algorithm Development
Chhaya Mudgal, RU, Java Software	Pete Lillabee, COS, Bistatic Construction

WORK COMPLETED

The final LEO CPSE was conducted during the summer of 2001 as reported last year. During the subsequent fall, summertime CODAR data from both the standard and long-range systems were reprocessed mainly to fill gaps due to the disruption of real-time communications. The final quality controlled current fields were provided to modelers supported by the ONR COMOP effort. The surface current data were assimilated by the ocean model run in hindcast mode to test the sensitivity to different assimilation schemes and the influence of adding the long-range currents.

The surface current datasets were also used to support the now completed thesis work of Dr. Josh Kohut. Chapters on the beam pattern calibration and validation, the long-term seasonal trends, and the observed shallow water response to a hurricane are being prepared for journal submission.

After the successful shipboard test of a standard (25 MHz) bistatic transmitter reported last year, a buoy-based transmitter was constructed and then deployed off the coast of New Jersey in December, 2001 during the final ONR-sponsored HyCODE cruise. The Brant Beach standard shore site was upgraded with GPS timing capabilities, and paired with the bistatic buoy, was simultaneously operated in both monostatic and bistatic modes through May 2002. The bistatic buoy was then recovered to inspect hardware and upgrade systems for a second test deployment planned for the fall of 2002.

A larger long-range (5 MHz) bistatic transmitter was constructed and installed on the R/V Endeavor for the final HyCODE cruise. The Loveladies long-range shore site was upgraded with GPS timing so that it could be paired with the bistatic transmitter on the Endeavor. Simultaneous monostatic and bistatic operation of the paired system was demonstrated with the Endeavor stationkeeping at three locations offshore New Jersey. The successful test led to the design and the ongoing construction of the first long-range bistatic buoy, now scheduled for a late fall or early spring deployment. To further prepare for this test, all four long-range systems deployed along the New Jersey coast have been upgraded with GPS timing systems acquired through an ONR DURIP grant. The enhanced system will be operated as a multi-static network during the long-range buoy test. Real-time software for calculating multi-static velocity components and combining them into a total vector product is approaching the beta-test stage and is expected to be ready for the upcoming test.

RESULTS

Dr. Kohut's thesis included results on the calibration and validation of CODAR surface current observations, on the seasonal variability of the observed current fields, and on the observed shallow-water response to a hurricane. During this time period, multi-static system development tasks continued.

Calibration. All monostatic HF radars estimate the radial current velocity component, its range and bearing. Velocity and range estimates are well established. Estimates of the bearing depend on antenna configurations and knowledge of the actual beam pattern formed by those antennas. It was found that the local environment plays a more significant role in beam pattern distortion than any of CODAR-specific hardware. Comparisons with in situ ADCP data indicate that bearing estimates were improved when the measured beam pattern was used, enabling the MUSIC algorithm to more consistently place the radial velocity vectors in the correct angular bin. He resulting RMS differences between the ADCP and CODAR-derived currents using the measured patterns were reduced below the values using ideal patterns for two different types of HF Radars.

Seasonal Variability. Annual mean flow is primarily along-isobath, but the response during the stratified season was found to be very different from the mixed season. During the stratified season, surface currents are highly correlated with the alongshore wind, tending to be to the right of the wind vector and rotating to the left with depth. The seasonal average current is weak due to a bimodal distribution between strong upwelling and downwelling responses primarily oriented alongshore. Current fields uncorrelated with the wind are generally weak and not aligned with topography. During the mixed season, strong variability with a cross-shore component is observed. Surface currents are less correlated with the wind. Currents tend to be to the left of the wind at the surface and rotate slightly to the left with depth. Surface current fields uncorrelated with the wind resemble the observed fields and tend to follow topography in regions were the gradient is maximum. The mixed response acts as a single frictional layer tightly linked to the underlying topography.

Storm Response. Tropical Storm Floyd passed directly over the CODAR array and LEO cabled observatory in September of 1999, providing a unique dataset to study the shallow water response to a hurricane. Before the storm, currents were in a cross-shore geostrophic balance, while in the along-shore direction, a small scale pressure gradient was balanced by bottom stress. During the storm, winds from directly offshore built up a cross-shore pressure gradient that accelerated the current offshore during the eye. The rectilinear response is driven by a propagating storm surge and balanced by bottom friction. Energy added to the system by the atmospheric forcing is quickly dissipated by bottom friction. After the storm, the single layer flow becomes stratified with freshwater inflow. The surface layer moves toward the north driven by an along-shore pressure gradient.

System Development Results. The first snapshot of results from the initial 5-month duration test of the 25 MHz bistatic CODAR buoy are displayed in Figure 1. Radial component currents derived from the Brandt Beach site operated as a monostatic system are displayed on the right, and hyperbolic component currents from the buoy/Brandt Beach bistatic pair are displayed on the right. Good agreement between radial and hyperbolic current components is noted where these components are in similar directions. The buoy operated from December through late April, with the system failure traced to a simple loose wire in the solar charging system. This first buoy deployment, designed for ease of access from the Rutgers field station in Tuckerton, will be followed by a second test deployment during the final segment of this project. The second test is designed to optimize comparisons with in situ ADCP data.

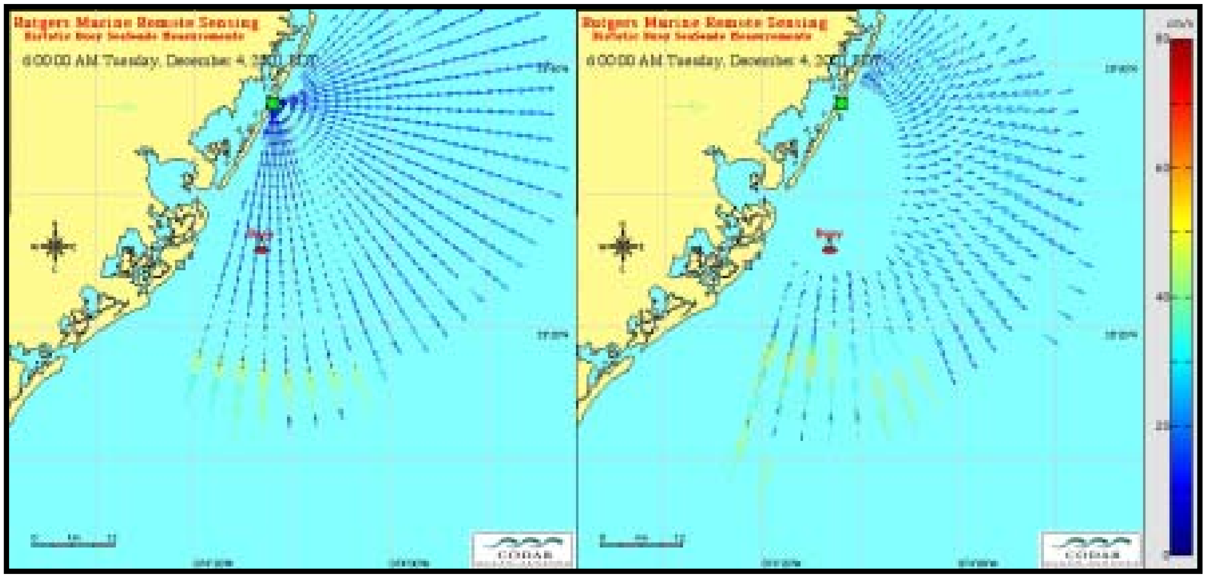

Figure 1: Radial and hyperbolic current components from the Brandt Beach shore site paired with a 25 MHz bistatic transmitter on a buoy moored offshore Tuckerton.

Following the same procedure used to develop the 25 MHz bistatic transmitter, a long-range 5 MHz bistatic transmitter was first tested from a ship. Figure 2 displays initial results from the December, 2001 test aboard the RV/Endeavor. Radial current components from the Loveladies monostatic system are again displayed on the right, and hyperbolic current components from the Loveladies/Endeavor bistatic pair are displayed on the right. The test indicates that the bistatic configuration extends the nominally 200 km range of the monostatic system to about 300 km or so.

IMPACT/APPLICATIONS

Lessons learned from the New Jersey CODAR network are regularly transitioned to CODAR users throughout the world. Rutgers CODAR personnel are currently assisting with ongoing CODAR installations in North Carolina, Florida, Alaska, and Norway. The success of this and other CODAR installations worldwide have led to the sale of over 100 CODAR-type HF Radars.

CODAR HF Radars are considered to be the primary backbone component of the NorthEast Observing System (NEOS). The objective is to provide CODAR current coverage of the entire northeast shelf from Hatteras to Halifax.

Ocean.US has designated HF Radars to be a high impact enabling technology that should be supported in a regional pilot study in preparation for deployment as a national HF Radar network that rings the nation.

TRANSITIONS

Real-time CODAR datasets are made available over the World Wide Web. Documented users include the Coast Guard for search and rescue, NOAA for oil-spill response, and the Navy for homeland defense purposes around New York Harbor.

The success of CODAR HF Radars has led the Coast Guard to begin a project to input CODAR surface current fields into their existing search and rescue software, which presently relies on the specification of a single (and often climatological) current speed and direction.

RELATED PROJECTS

The ONR-sponsored COMOP-II and HyCODE projects use CODAR surface currents as a primary dataset for assimilation. The ONR-Sponsored Terrain-following Ocean Modeling System (TOMS) project, led by Hernan Arango, is merging portions of the widely-used Princeton Ocean Model (POM) with ROMS to produce TOMS. An NSF project to develop a variety of data assimilation schemes for ROMS/TOMS will make similar use of the CODAR datasets.

Scientific results from the New Jersey CODAR systems are being submitted to the NOPP-sponsored Coastal Observatories special section of the Journal of Geophysical Research.

ONR-sponsored development of a Mission Control Center for a fleet of autonomous underwater Gliders uses CODAR-generated surface current maps to help guide operations of the New Jersey Glider fleet.

As part of new NSF and NOAA-sponsored Glider-based studies of red tides on the west Florida shelf, a new long-range CODAR system is being installed near Sarasota in collaboration with Mote Marine Lab to aid Glider operations.

A new ONR-sponsored project will examine the dual-use capabilities of a multi-static CODAR network for ship-tracking in the New York Bight.

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