1.3 MULTIPLE HF-RADAR SYSTEM DEVELOPMENT FOR A REGIONAL LONGTERM ECOSYSTEM OBSERVATORY IN THE NEW YORK BIGHT

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1. INTRODUCTION

The Rutgers University Longterm Ecosystem Observatory in 15 m of water (LEO-15) is located approximately 4 miles off the coast of Tuckerton, New Jersey. The purpose of this observatory is to monitor long-term trends and capture episodic events. Using an array of instrumentation, LEO-15 continuously samples the physical, biological and chemical properties of the shallow waters off the New Jersey coast. Multiple platforms including satellites, aircraft, ships and Underwater Autonomous Vehicles (AUVs) sample the underwater weather of the coastal ocean. Therefore, LEO-15 combines spatial remote sensing surface data with subsurface point measurements providing a well-sampled three-dimensional environment for coastal ocean research.

2. BACKGROUND

An integral part of this observation network is an expanding High Frequency (HF) radar system that provides continuous real-time surface current data in a spatial array. The Coastal Ocean Dynamics Application Radar (CODAR) system at LEO-15 includes two remote sites separated by 26 km in Brant Beach, New Jersey and Brigantine, New Jersey and a central data processing site at the Rutgers University Marine Field Station in Tuckerton, New Jersey. Each of the remote systems uses radio waves and Doppler theory to measure the component of the surface velocity moving toward or away from the antenna (Lipa 1983). The central site geometrically combines information from each site to give a spatial array of surface current measurements. To date there have been two separate system deployments. The first began in May of 1998 and was cut short in the middle of August 1998 by hurricane Bonnie. The second deployment began nine months later in May of 1999 and is continuing to sample in real-time, despite the passing of hurricane Floyd and several nor'easters. The present configuration provides hourly surface current maps stretching about 40 km offshore and 50 km alongshore with a spatial resolution of 1.5 km. The surface data is used as a real-time observation tool and results are displayed in near real-time on the World Wide Web (WWW). Existing products include raw, tidal, detided and filtered surface velocity fields as well as filtered velocity fields combined with surface divergence, surface vorticity, sea-surface temperature (AVHRR) and ocean color (SeaWiFS). These have proven to be very useful in adaptive sampling during intensified in situ research at LEO-15 (Kohut 1999). While the present system offers local users information for adaptive sampling and numerical model assimilation, a larger network of HF Radar systems is being implemented along the New Jersey coast. This extended network of radars will exhibit improved accuracy through information learned from existing system validation studies. These studies have examined the influence of antenna pattern distortions on both the accuracy and coverage of the surface current maps. Additionally, the introduction of long-range CODAR systems will extend the present data footprint out to the shelf break, 160 km offshore. This coupled network of CODAR systems will form the backbone of a larger regional observation network, the NorthEast Ocean Observing System (NEOOS).

3. ANTENNA PATTERN DISTORTIONS

LEO-15 provides an excellent testbed for HF-Radar validation studies. An important aspect of this validation has been the role of antenna pattern distortions in both the accuracy and coverage of the measurements. In contrast to a phased array HF-Radar system that uses antenna arrays to direct the signal in known directions, CODAR continually transmits the radio signal equally in all directions. Therefore, the system uses a direction finding algorithm that relies on the directional dependence of two cross-looped antennas to determine the incident angle of a backscattered signal (Barrick 1997). Figure 1a illustrates the angular dependence of the two loops. The loop 1 ideal pattern is shown as two dash-dot circles and the ideal loop 2 pattern is shown as two dashed circles. The heavy black line indicates the angle of the coast with respect to true north. The two loops are oriented perpendicular to each other so that independent signal measurements from each loop can be used to locate an incoming signal. For example, a signal coming from 160º is felt stronger by loop 1 than by loop 2 and a signal coming from 70º is felt stronger by loop 2 than by loop 1. Previous work has shown that system accuracy and radial coverage increase when a remote site has a near ideal measured antenna pattern. Therefore, work is now being done to identify the causes of antenna pattern distortions so that remote systems can be optimized for more accurate and more complete surface current data.

Recent work tested two possible causes of antenna pattern distortions, remote site hardware and the influence of the local environment. To measure remote site antenna patterns, a transponder is mounted

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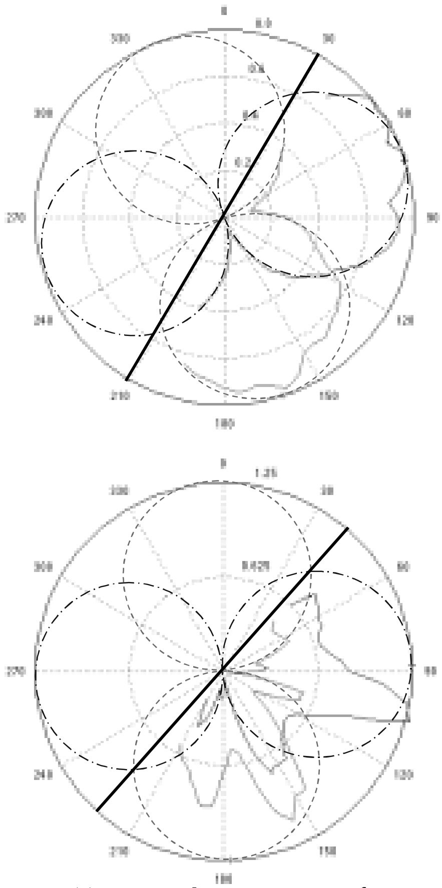

Figure 1. (a) Measured antenna pattern from run 1.
(b) Measured antenna pattern from run 2.

on a small research vessel. The vessel then tracks along a semi-circle around the receive antenna, maintaining a radius of 1 km. Since the frequency of the transponder is known, the magnitude of this signal as measured by each loop is recorded. Therefore, these data map out the directional dependence of the loops along the semi-circle.

Table 1. summarizes pattern runs that have been completed within the past year. One run at each environment, Brant Beach and Brigantine, was completed on October 27th 1999. In runs 1 and 2, each site was operating under normal hardware configurations. The Brant Beach pattern, shown in Figure 1a, is very close to the desired ideal pattern. While Figure 1b indicates that the pattern measured at Brigantine significantly differs from the ideal pattern.

Table 1. Summary of antenna measurement runs.

Run	Date	Environment	Antenna	Receiver	Figure
1	10/27/99	Brant Beach	A	A	1a
2	10/27/99	Brigantine	B	B	1b
3	09/14/00	Brant Beach	A	A	Not Shown
4	09/14/00	Brant Beach	B	A	2b
5	09/14/00	Brant Beach	B	B	Not Shown
6	09/14/00	Brant Beach	A	A	2a

These data prompted a second set of transponder runs designed to examine why these patterns differ between local environments and if these patterns change with time.

On September 14th 2000, four more pattern runs were completed to test the time dependence of the antenna patterns and the influence of both the antenna hardware and the surrounding environment. Run 3 was completed at Brant Beach with the normal hardware setup. Each of the remaining runs immediately followed a change in the hardware configuration. Run 4 measured the pattern of antenna B, normally setup in Brigantine, in the Brant Beach environment. Receiver B then replaced receiver A for run 5. After run 5 was completed, both antenna A and receiver A were returned to the normal operating configuration at the Brant Beach site for a final run.

Since runs 1 and 6 were completed in Brant Beach with the same hardware setup, the time dependence of measured antenna patterns is best illustrated by comparing these results. Figures 1a and 2a illustrate that the pattern did not significantly change over the 11 months between runs. The longevity of these patterns indicates that once a good remote site setup is attained it will not change over these time scales.

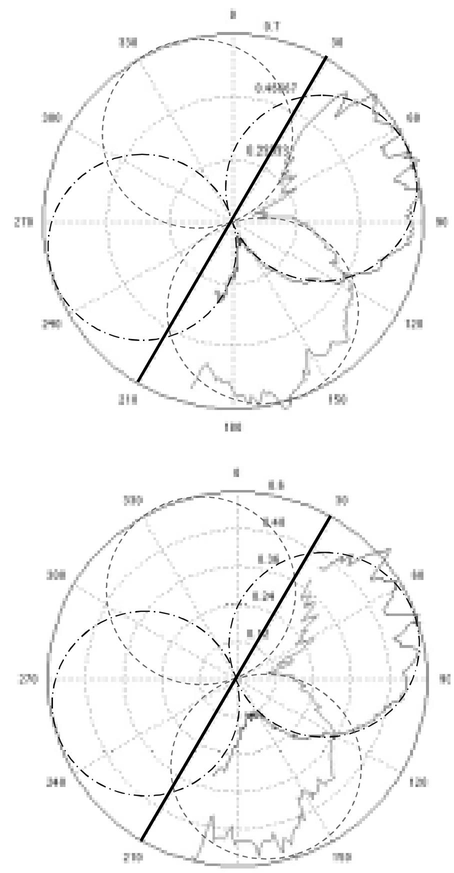

Figure 2. (a) Measured antenna pattern from run 6.
(b) Measured antenna pattern from run 4.

The receiver and receive antenna are the two pieces of hardware most likely to distort the patterns. Since antenna A and B were setup in Brant Beach during runs 5 and 6, comparisons between these data will identify the influence of the antenna on measured pattern changes. Figures 2a and 2b indicate that the pattern of loop 2 does not significantly change between runs. However, a closer examination of loop 1 reveals greater distortion in the patterns when antenna B was setup in Brant Beach. The measured patterns of runs 4 and 5, in which two different receivers were set up in the same environment did not significantly change. Therefore, the receiver does not influence the antenna patterns.

The environment proved to be a much larger contributor to measured antenna pattern distortions. Since runs 2 and 4 measured antenna B in each local environment, comparisons between these patterns illustrate the influence of the local environment on the distortions. Figures 1b and 2a show that the patterns improve dramatically when antenna B is moved from Brigantine to Brant Beach. Consequently, the Brigantine environment is distorting the antenna pattern significantly more than the Brant Beach environment. These tests have identified the environment as the major source of antenna pattern distortions. Future work must now attempt to identify the characteristics of these environments that differentiate the two. Through the understanding of antenna pattern distortions better remote site locations can be selected to ensure more accurate and more complete surface current data.

4. LONG RANGE CODAR

The long-range CODAR system operates at a lower frequency than the existing standard sites, allowing the signal to propagate further offshore. In June of 2000, the first long-range CODAR site on the eastern coast of the United States was deployed in Loveladies, New Jersey. Figure 3 is an example of a daytime radial current map measured by this system. Initial radial data indicates a range of about 190 km with a grid resolution of 6 km during the day and a decrease in that range at night. Since the lower operating frequency allows the signal to propagate further offshore, interference will also be felt from further away. In addition, lower frequency signals are subject to reflections off the ionosphere, dramatically increasing the range of possible interference sources at night. Preliminary tests using a radio receiver identified increased noise at the operating frequency during the nighttime hours. Since the CODAR signal strength decreases with range, the increased noise levels at night limit the distance a signal can travel and still maintain a high signal to noise ratio necessary for accurate measurements. Currently a test is being run at several approved operating frequencies to determine if the increased noise levels are frequency dependent.

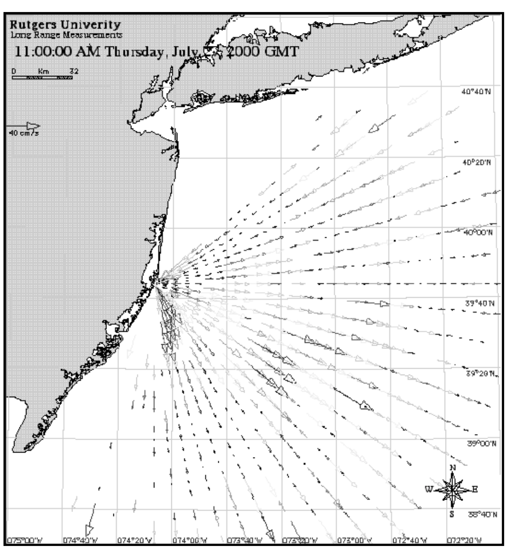

Figure 3. Long-range radial field, July 27 2000.

Initial single site validation of the long-range radial fields has used the standard systems already in place. Current maps generated by combining radial fields from the two standard sites are compared to maps generated using radials from the long-range site

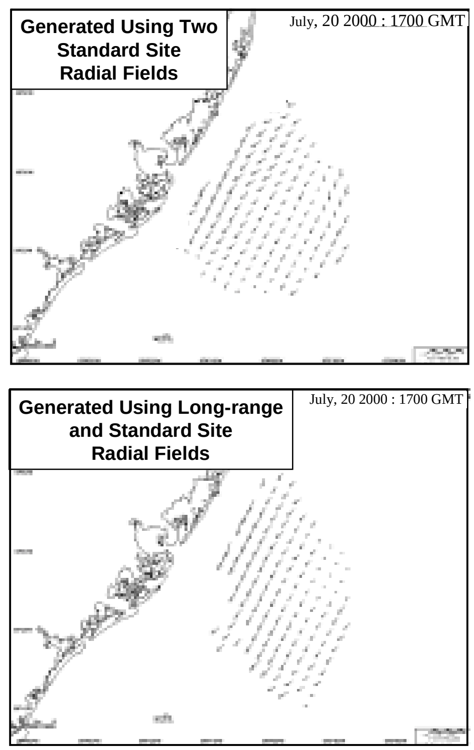

Figure 4. Total velocity fields generated from (a) two standard sites (top) and (b) from a single standard and long range site (bottom).

and a single standard site. Figure 4a is a total vector map generated by combining the radial fields from the two standard sites. The flow is moving alongshore to the south with currents increasing nearshore. Figure 4b is a total vector map generated by combining the radial fields from the long-range site and the southern standard site located in Brigantine. Notice how the same features are depicted in this plot with the flow moving alongshore to the south and stronger nearshore. This is the first of four sites to be deployed along the New Jersey coast. Once fully operational, this network of long-range CODAR systems will provide continuous maps of surface current fields extending 170 km offshore with a grid resolution of 3 to 6 km.

5. CONCLUSIONS

The existing CODAR sites, both long range and standard, represent the beginning of a larger network of radars to be deployed along the New Jersey coast. This network is integral to a regional observation network for the entire New York Bight (LEO-NYB) that will be linked to other regional observatories to form the NorthEast Ocean Observing System. The existing systems provide an excellent testbed for future sites. Future validation work will look closer at the environmental influences on the measured antenna patterns. With this information, better remote site environments will be selected for future CODAR deployments. By deploying these new and improved systems, the benefits of an observatory like LEO-15 will be extended to include the entire continental shelf off the coast of New Jersey.

6. REFERENCES

Barrick, D.E. and B. J. Lipa. 1997. Evolution of bearing determination in HF current mapping radars. *Oceanography*., **10**(2), 72-75.

Kohut et al. 1999. SeaSonde is integral to coastal model flow development. *Hydro International*., **3**(3), 32-35.

Lipa, B.J. and D.E. Barrick. 1983. Least-squares method for the extraction of surface currents from CODAR cross-loop data: application at ARSLOE. *IEEE J. Ocean Engr*., **OE-8**, 226-253.