U.S. Coastal Observatories Evolve to Serve EEZ Needs

CODAR's SeaSondes Provide Real – Time Dynamics of the Sea Surface

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Regional Coastal Ocean Observing Systems (RCOOS) in the U.S. have been swiftly linking up to combine ocean surface environmental data mapped with SeaSonde coastal radars, forming for example NEOS (North East Observing System) that covers Canada to the Carolinas. Hourly current observations allow understanding of flow on and beyond the continental shelf, as shown in the figure here. As these RCOOS join together, their real-time combined data products and planned forecasts are being absorbed by a host of government and private groups, while underway planning for a total coastal network at the federal level is moving ahead.

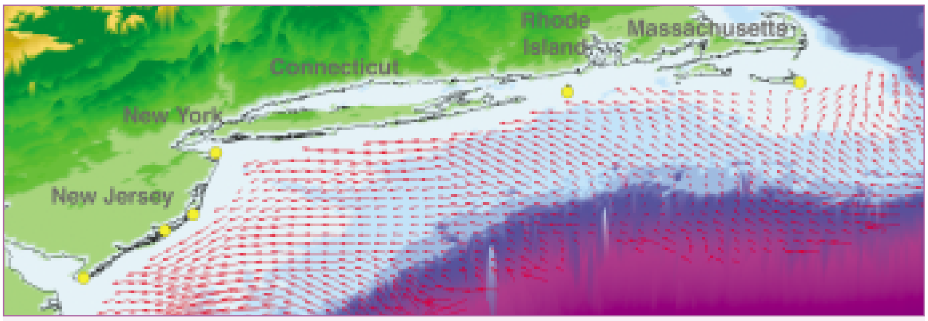

Figure 1. Surface currents under Hurricane Isabel, September 2003 over 3-hour period from six Long-Range SeaSondes shown as yellow dots on figure.

Figure 2. Photo of "COOL" (coastal ocean observation laboratory) room – the Rutgers command and control center, and inputs from three essential sensor suites.

U.S. Coastal Observatory Beginnings

One multi-faceted coastal observatory grew from humble beginnings at Rutgers University, starting with a single S4 current meter in the early 1990s. Their highly instrumented 30km x 30 km 'LEO' (Long-term Ecosystem Observatory) research area that evolved off the coast of central New Jersey in the late 1990s addressed the goal of better understanding physical processes that lead to recurrent coastal upwelling centers. The original measurement suite included: conventional in situ instruments; available satellite remotely sensed surface maps; CODAR SeaSonde HF surface-wave radars that map currents within this modest research area; cruises with shipboard adaptive sampling gear; autonomous underwater vehicles; aircraft flights; and a top-of-the-line command, control, and outreach center called the COOL room.

During the last five years, its focus has turned to new sustainable technologies that could provide more frequent coverage of the coastal zone over larger spatial scales, and for longer time scales on a real time basis. Three specific technologies were targeted:

- The newest lower-frequency Long-Range SeaSonde and multi-static radars that produce current maps over the entire shelf region;
- Acquisition of ocean color imagery from the full international constellation of satellites to reduce the revisit intervals;
- A fleet of long-duration underwater gliders with payload bays to provide subsurface physical/bio-optical data over larger areas.

This article highlights the SeaSonde radar role in this and expanding RCOOS such as NEOS.

Web-Based Data Serves Many Constituents

From the start of LEO, Rutgers posted all of their real-time raw and processed coastal ocean data on the web (www.marine.rutgers.edu). It didn't take long before word got around, and the number of web hits for these data grew exponentially. Not surprisingly, many groups integrated these data into their operations and came to depend on them.

From this paradigm, a new group of academic operational oceanography centers emerged. Operational oceanography refers to sustained collection or modeling efforts that include real-time distribution of useful data products to a larger community, scientific and otherwise. The evolution of LEO and other observing systems into regional groups like NEOS is an example of this unique U.S. process. Perhaps Walter Munk's observation that the first century of oceanographic measurements – characterised by very sparse sampling – has indeed given way to the era of serving up time and space-rich data sets in real time – the underpinnings of operational oceanography.

These Constituents Serve Vital Roles in EEZ Support – Examples follow overleaf.

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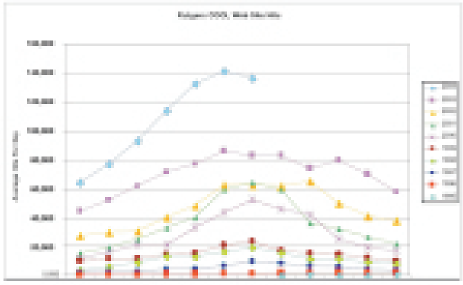

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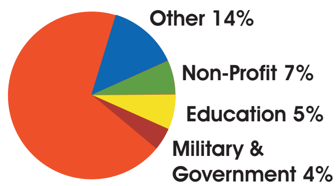

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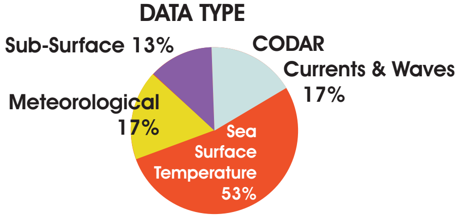

Search and Rescue: Coast Guard

As the Coast Guard checked out maps of surface currents on the Rutgers web site, they planned a series of tests to evaluate their utility in search and rescue operations. The first of these employed the standard SeaSondes near the mouth of Long Island Sound, with ranges to 45 km. A second set was just completed on the long range network that spans 200 km. In both cases, tracked drifters were deployed that resembled floating bodies. an example from the most recent tests over a 24-hour period is shown here.

These results were so encouraging that the Coastal Guard R & D Center Director officially endorsed CODAR technology for SAR thusley: 'R&D has completed an evaluation of Coastal Ocean Dynamics Applications Radar (CODAR) as a tool to improve search planning... CODAR surface currents were compared with the currents derived from NOAA sensors that are typically used by search planners. results showed that CODAR-derived surface current trajectories are nearly twice as good as trajectories produced from NOAA sources. This improvement in surface current quality translates into smaller search areas and potentially few resources needed to cover those areas. R&D is working with the sponsor to select a Group that will serve as a pilot site for integrating CODAR data into operational search plans'.

Storm Wave & Track Inputs: Weather Service

NOAA has been quick to pick up on the web data available at Rutgers. Hurricane eyes and the low-pressure centers of severe winter storms are difficult to establish and follow as they evolve. We show a figure of long-range SeaSonde surface currents whose cyclonic pattern follows the center of an October 2002 Nor'Easter storm that moves up the East coast of the U.S. these current maps have allowed NOAA to better define the geometry of the storm, which otherwise sparse data sampling doesn't afford.

Another example is wave spectra obtained from SeaSonde echoes and posted on the Rutgers web site. A January 2004 example shows the wave energy spectrum over three days as a storm passes through. Their NWS Mt. Holly office uses these CODAR wave data for broadcast marine weather forecasts and as input to surf zone models to forecast rip currents along the New Jersey and Delaware coasts.

Coastal Surveillance: Homeland Security

An important and unique application of the evolving coastal SeaSonde radar network is 'dual-use' for ship surveillance. Because conventional microwave radar coverage cuts off at the horizon, the Long-Range SeaSondes can pick up the coverage against vessels in regions that are otherwise missed. This has led the Dept. of Homeland Security and Navy to explore the expansion of this network for maritime security and drug interdiction purposes. This expansion includes both simultaneous bistatic and backscatter applications (with transmitters on offshore buoys), as well as superdirective receive antennas to increase system sensitivity with minimal cost. This contrast with the conventional, dedicated and costly backscatter systems offered by non-U.S. vendors. A discussion of CODAR's dual-use ship-surveillance technology was covered in an earlier EEZ International article [1]. Environmental data within the EEZ are necessary for effective operation of such a ship surveillance system. Knowledge of real-time surface currents and waves are critical for operation of surveillance radar; for example, they dictate the 'range of the day', i.e., how far a vessel of a given size can be expected to be seen. This information also allows anticipation of when and how any attack or incursion might be expected. A very recent detailed article on how SeaSondes can provide such data appeared in the Canadian Miliary Journal (CMJ) [2].

Fisheries: NOAA/NMFS

Upwelling center mapping - the original quest behind the Rutgers LEO network - has great impact on fish fates. Convergence and divergence obtainable from SeaSonde surface current maps determine where nutrients vital to fish growth can be found, and in turn, where the fish themselves are congregating. In addition, most fish larvae float on the surface, and their fate depends on the patterns of flow. Normally, larvae transported out to sea do not survive. An example showing the strong correlation between eddy/upwelling centers mapped by CODAr and bio-mass is shown here from the Santa Barbara Channel in California.

Pollution Monitoring: Local Governments, NOAA

Spills of oil, trash, and other floating pollutants are an inevitable consequence of EEZ operations. The local coastal environment is negatively impacted, while various local, state, and federal agencies have roles to play in preventing and migrating such disasters. An example occurred off the coast of New Jersey in July 2004. A floating trash spill 20 yards wide and 7 miles (13km) long was transported directly offshore on July 8 from Sea Bright Municipal Beach by surface currents. Fortunately in this case, the timely offshore frontal flow between the warm and cold water masses kept much of the pollution away from the beach. Nonetheless, the beach soiling caused considerable uproar in the local July 8 Asbury Park Press.

Naval Operations: Navy

The U.S. Navy - as do most other navies - maintains a number of coastal test facilities where training and exercises are conducted. Among the types of exercises that depend on surface current and wave data to plan operations are: amphibious operations; submarine operations; anti-submarine warfare; mine countermeasures; and for all naval vessels in coastal waters - navigation. Ship detection and surveillance, i.e., the dual-use mission described earlier, is also important. The article in CMJ cited above reviews these uses of environmental data by navies.

Coastal Erosion: Arm Corps of Engineers

The Army Corps of Engineers in the U.S. has responsibility for planning for and mitigating coastal erosion. The interaction of near-shore surface currents with the wavefield is the driving mechanism behind this erosion. Hence the use of data available from SeaSonde is an integral part of developing climatology to understand where and how such processes occur, and why such great geographical variations are encountered.

Regional Observing Systems Take Shape before National Network

Our discussion here began with LEO, leading on to NEOS that covers the Northern half of the Eastern seaboard. There are other RCOOSs that exist: SeaCOOS to cover the Southeast and Florida coasts; a network of eight medium and long-range SeaSondes covering the Texas coast; and a network of ten mid and long-range SeaSondes to cover the Oregon coast. these have all been funded by combinations of state, regional, and federal research grants, and are operated by university groups.

A somewhat different RCOOS is

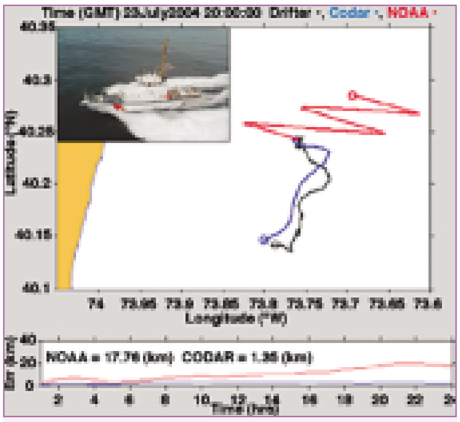

Figure 4. Coast Guard tests showing trajectories of: (1) actual drifter over 24-hour period (black); (2) estimated trajectory from SeaSonde data (blue); (3) estimated trajectory from NOAA data base (red). All trajectories started at same point at same time in center. Bottom shows divergence error among trajectory endpoints vs. time. Courtesy of Dr. James O'Donnell at University of Connecticut, and the US Coast Guard R&D Center.

underway in California. Although there are at least four existing regional groups that evolved over the past decade (Naval Postgraduate School, University of California branches at Santa Barbara, Davis, and San Diego), a new statewide initiative has just commenced. Funded by a voter-approved conservancy bond measure, this initiative begins procurement of approximately 40 radars in late 2004. These will cover the entire coastline, with continuous coverage to 200km and regional 'nested' coverages in zones of more intense maritime activity.

Meanwhile, a national surface current mapping initiative – under the auspices of OceanUS – has developed a plan to ring the U.S. coast with a network of HF radars. The plan calls for 100-200 long-range systems to be deployed around the entire U.S. coast.

But folks in the U.S are not waiting. RCOOS and their constituents want these continuous data sets now, that will allow them to understand and work in the coastal environment of the EEZ: they are going ahead on their own. The most exciting 'nut to crack' beyond posting of nowcasts is forecasts: both short and long range. Many groups in the U.S. are working on demonstrations of how SeaSonde surface-current data can be assimilated into numerical models. And subsequently, how model outputs – when operated in a forecast mode – offer significant improvement beyond existing knowledge for operations within the EEZ.

As these new operational oceanography centers continue to evolve in the U.S., we look forward to collaborations with similar operational centers now forming in other parts of the world, including the Mohn-Sverdrup Center for Global Ocean Studies and Operational Oceanography in Bergen, Norway.

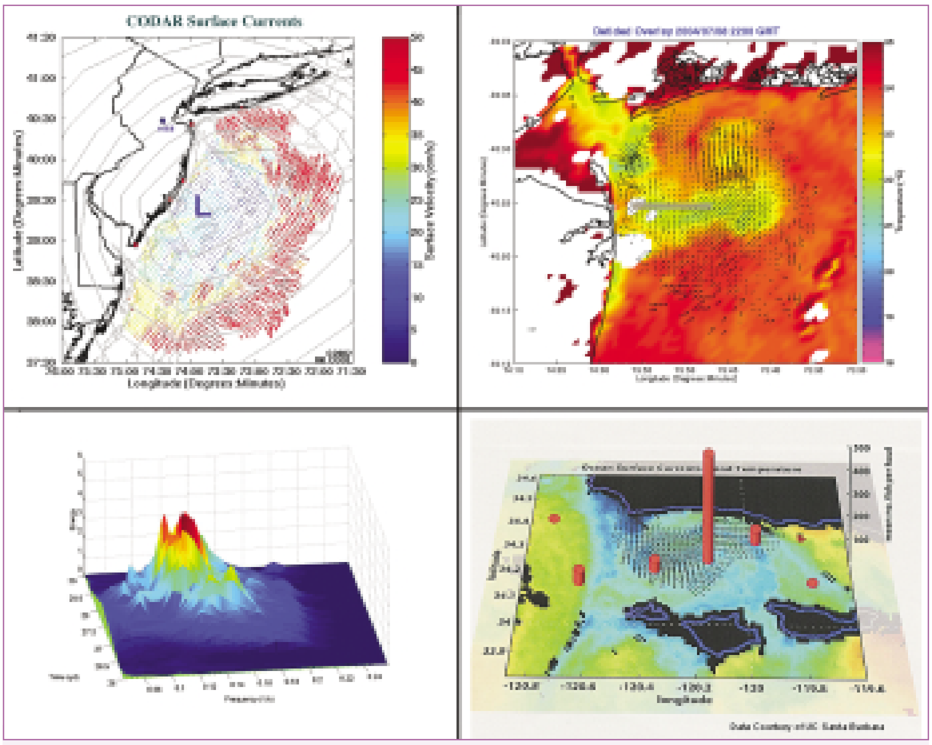

Figure 5. SeaSonde Output Examples. Upper left: surface currents seen under strong storm off East coast, overlain on pressure map. Lower left: wave energy spectrum during winter storm. Upper right: Trash spill (gray streak) off Sea Bright Municipal Beach, NJ being transported offshore by surface currents. Lower right: biomass productivity histogram from sampling overlain on map of surface current eddy.

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[1] Barrick, D. and L. Pederson, HF Surface-Wave Radar: Revisiting a solution for EEZ ship surveillance, EEZ International, Spring 2004, pp. 35-37.

[2] Whitehouse, B.G. and D. Hutt, Ocean Intelligence in the Maritime Battlespace: The role of spaceborne sensors and HF radar, Canadian Military Journal, Spring 2004, pp. 35-42.

ABOUT THE AUTHORS

Scott Glenn received his Sc.D. in Ocean Engineering from the Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution Joint Program in 1983. He has worked on the development of new ocean observation and forecasting systems at Shell Oil Company,at Harvard University for the U.S. Navy, and now at Rutgers University as a Professor of Marine and Coastal Sceince.

Josh Kohut received his Ph.D. in the Rutgers University Graduate Program in Oceanography in 2002. He develops and applies new robotic, radar and remote sensing technologies to real-time ocean monitoring. He currently is the Director of the Coastal Ocean Observation Lab (COOL), Rutgers' center for operational oceanography.

Donald Barrick received a B.E.E., M.Sc., and Ph.D. from the Ohio State U. in electrical engineering. From 1972-1983 he served as Chief of the Sea State Studies Division of the U.S. National Oceanic and Atmospheric Administration's Wave Propagation Laboratory in Boulder, CO; there he developed compact HF radar systems for real-time mapping of ocean currents and waves. In the mid 80s, he founded CODAR Ocean Sensors, Ltd., a company that has created and developed the SeaSonde® line of HF radars. His scientific interests include radar remote sensing, electromagnetics, antennas, signal processing, and applications to oceanography and marine operations.

Laura Pederson is the Director of Marketing for CODAR Ocean Sensors, Ltd. With a background in science television and education, Laura joined the company in 1996 to develop a broader market for the advanced SeaSonde® product line.

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