The Mid-Atlantic Regional Coastal Ocean Observing System: Serving Coast Guard and Fisheries Needs in the Mid-Atlantic Bight

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***Abstract*- High Frequency (HF) Radar is an established central component of Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS). The HF Radar network currently consists of 26-sites with multistatic and nested coverage from Cape Hatteras to Cape Cod with high-resolution coverage of the four major estuaries in the region. This network provides regional surface current maps to improve United States Coast Guard search and rescue operations, mitigate hazardous material spills as well as improve rip current forecasting. The radial current files are aggregated into the national data archival system. Specific applications include assimilation into a statistical model and three dynamical models with the goal of improving surface current forecasts for search and rescue. Test bed activities will routinely compare these forecasts with drifters released into the coverage area to determine the parameters necessary for inclusion into the Coast Guard search-planning tool, SAROPS. The MARCOOS HF Radar network has moved from small isolated systems to a single integrated regional system, a model that is being scaled around the world.**

I. Introduction

High Frequency (HF) Radar derived real-time surface current maps are envisioned to be an integral component of the Integrated Ocean Observing System (IOOS). A national committee on surface current mapping, supported by OCEAN.US, has already outlined a structural plan to implement a national HF Surface Current Mapping (SCM) network. This plan separates the national network into regional centers responsible for the operation and maintenance of the systems. Recently MACOORA, the Mid-Atlantic Coastal Ocean Observing Regional Association, identified HF radar as an important integrating component of their envisioned Regional Coastal Ocean Observing System (R-COOS). A Mid-Atlantic HF Radar network is now capable of providing high resolution nested coverage within the five sub-regions (Chesapeake Bay, Delaware Bay, New York Bight, Long Island Sound and Massachusetts and Rhode Island Bays) while simultaneously linking the sub-regions together in one coastal network that covers the full range of the Mid-Atlantic coastal ecosystem (Figure 1).

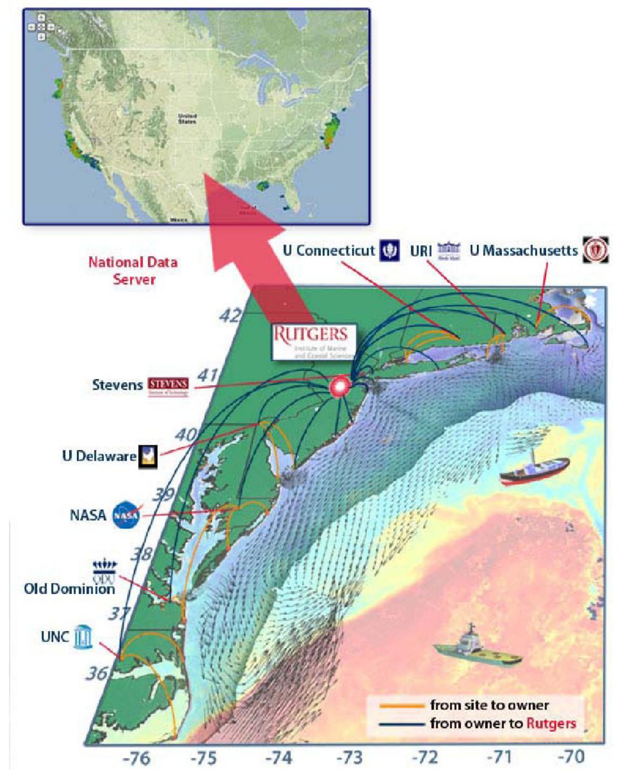

Figure 1: Map of MARCOOS HF Radar Network. The data flow is demonstrated as the movement of the radial data file from the radar site to node (orange line) and from node to central hub (blue). The radials are combined at the central hub and then displayed on the National Network.

MACOORA formed the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS) to generate quality controlled and sustained ocean observation and forecast products that fulfill user needs. MARCOOS products will support the two priority regional themes and provide critical regional-scale input to MACOORA's nested sub regional efforts on Coastal Inundation and on Water Quality. MARCOOS will accomplish this by coordinating an extensive array of existing observational, data management, and modeling assets to generate and disseminate real-time

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data, nowcasts and forecasts of the ocean extending from Cape Cod to Cape Hatteras.

This first implementation phase of MARCOOS will be an end-to-end regional ocean data acquisition, management, modeling and product-generation system in response to region-wide user needs in the thematic areas of Maritime Safety and Ecological Decision-Support. MARCOOS regional products will support the production of higher-resolution products that are being proposed by MACOORA sub-regional groups in response to the thematic areas of Coastal Inundation and Water Quality. MARCOOS will augment existing federal backbone products by leveraging its extensive existing assets. By coordinating, sustaining, and expanding ongoing ocean observing and forecasting activities, regional-scale data and products will be available in real time across the full Mid-Atlantic (MA) region and extending into the Bays and Sounds. The data will be assimilated into 2D statistical and 3D dynamical ocean forecast models, driven by NOAA NCEP (National Center for Environmental Prediction) standard atmospheric forecasts that include a dedicated NOAA-WRF (Weather Research and Forecasting) regional Sea breeze resolving forecast. Datasets and forecasts will be delivered into operational decision making systems, such as USCG Environmental Data Server (EDS) and Search and Rescue Optimal Planning System (SAROPS), through IOOS-compatible automated data servers for forecasting applications and a MARCOOS website. Outreach activities will extend products to support ongoing NWS rip current forecasting projects and refine products for the fishing community.

II. History of National SCM System

Ocean.US created the Surface Current Mapping Initiative (SCMI) in September 2003. A steering committee was established to identify the technical and managerial challenges associated with the creation of a national SCM network. The SCMI report recommends 2 technicians to maintain and operate every 5 HF radar stations. The committee also recommended a ratio of 5 sites per node where a node is used to designate the collection of sites operated by a group. The committee further recommended that pilot projects would be a good vehicle for the development of operational systems and standards. [1]

The Alliance for Coastal Technologies convened a national meeting in March 2004 to further discuss the application of SCMs to an Integrated Ocean Observing System. One recommendation of the workshop was to embark on a regional large-scale pilot study integrating existing HF radar systems to demonstrate the challenges involved in data exchange and reliability. [2]

In response to these national level meetings, and the resulting call for regional scale demonstration projects, the Mid-Atlantic High Frequency Radar Consortium (MAHFRC) was formed. As the initial coordinating body for the numerous independent HF Radar owners and operators in the Mid-Atlantic, a three-Phased plan was developed to implement a regional network that met SCMI standards. Phase 1 assumed that the many HF radars in the region would remain independent in their operation and funding, but that we would agree to share radial level data with a central facility to produce a regional-scale surface current product and provide it to users as available. Phase 2 assumed that an initial multi-year demonstration period could be funded to provide the equivalent of 1 full time regional coordinator, 3 full time field technicians supporting operations in the northern, central and southern portions of the region, provide $10,000 in annual support for each site to cover utilities, communications, and basic maintenance, and to maintain a regional spares fund to respond to outages such as the inevitable lightening strikes. After the initial demonstration period and the potential reevaluation of SCMI standards based on lessons learned, Phase 3 operations would be proposed at the regional level required for a sustained national network.

III. MARCOOS HF Radar Network Management

MACOORA was formed in 2005 as one of 11 Regional Associations making up the regional component of the U.S. Integrated Ocean Observing System. MACOORA initially identified over 20 independent and ongoing local or subregional ocean observing system efforts across their region. The MAHFRC plan to coordinate the HF Radar component of many of these individual programs and construct a regional-level system was presented to MACOORA and endorsed as having a high probability of successfully demonstrating the added-value of the regional approach, providing a pathfinder mechanism for more complicated regional coordination in the future. Numerous MACOORA user meeting break out sessions were used to identify potential end-to-end applications for future implementation with the regional-scale HF Radar network, including Coast Guard Search and Rescue, oil spill response, water quality, coastal flooding, and fisheries.

MARCOOS was MACOORA's response to the first national competitive merit-based call for the development of Regional Coastal Ocean Observing Systems (RCOOS). Funding of MARCOOS by NOAA IOOS in 2007 enabled MAHFRQ to jump from its Phase 1 voluntary level to the intermediate Phase 2 level of regional coordination (Figure 1). To produce regional scale products, the MARCOOS effort relies heavily on the existing infrastructure previously acquired and deployed at various times since 1996 as part of the subregional ocean observing systems.

For the first three-year increment of IOOS funding MARCOOS has sectioned the Mid-Atlantic HF Radar Network into 3 regions a northern, central and southern region. There is one fully funded operator responsible for the sites in their respective region. The operators are geographically separated. How can this separation be overcome? Several tools have been implemented to bridge this geographic divide. A monthly conference call has been set for operators to communicate and share pressing issues. A collaborative development web site was created for the sharing of documents and as an archive of communications during the project. An advanced HF radar operator training course was conducted by Codar Ocean Sensors from February 18-22, 2008. The agenda was user driven developed in collaboration with the manufacturer of the HF radar. A database was created where critical information on each site was centrally accessible and stored for a unified regional system. Best practices documents on radar antenna patterns and quality assurance and quality control of radial data were created to be shared among the HF radar operators.

IV. MARCOOS HF Radar Data Aggregation and Products Development

At present 26 radar sites are operating in the MARCOOS region. Radial current data from each site is first collected at the local central computer sites for each of the 9 operators. The radial data is then aggregated at Rutgers as part of the National HF Radar data server supplied by NOAA. Locally, the radial data is used to produce a regional scale product that covers coastal waters from Cape Cod to Cape Hatteras, and to produce local high resolution products in each of the bays (Figure 2). This data is currently displayed on the Rutgers Coastal Ocean Observation Lab website (http://marine.rutgers.edu/cool) to provide users a quick look at the datasets. The total vector fields are then made available for assimilation by the University of Connecticut's Short Term Prediction System (STPS) and via OPeNDAP servers for assimilation into an ensemble of 3 dynamical forecast models run by Rutgers, Stevens Institute of Technology, and U. Massachusetts – Dartmouth. Statistical and dynamical forecasts also can be viewed on the originator's websites, but more importantly are then transferred to the US Coast Guards Environmental Data Server (EDS) by Applied Science Associates. Once in EDS, the data and forecasts undergo a year test phase within the Coast Guard's new Search and Rescue Optimal Planning System (SAROPS). After the demonstration period at the Coast Guard office of Search and Rescue, the accepted data and model forecasts are available in the field offices that have access to SAROPS.

V. Success Stories

The ACT workshop [2] listed 13 different applications of SCMs. MARCOOS has utilized the existing HF radar network for 6 of those 13, Search and Rescue, Sewage

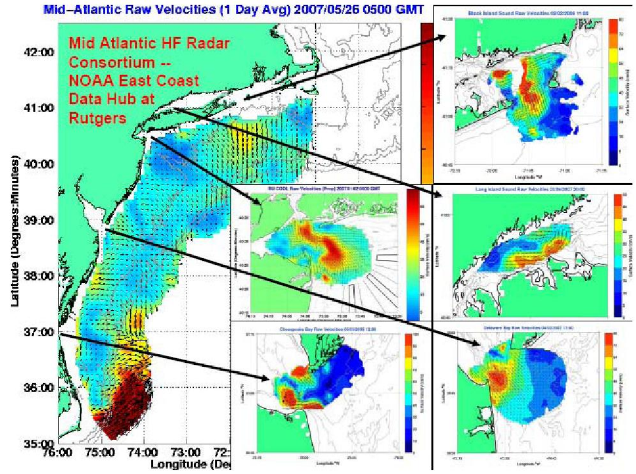

Figure 2: Initial data products from the MARCOOS HF Radar Network. Aggregated radial data is assembled into total vector products on a low resolution 6 km regional grid covering the full continental shelf between Cape Hatteras and Cape Cod. Total vector products on high resolution 1 km grids are produced in 5 nested subdomains.

Spills, River Discharge Plumes, Rip Currents, Fish Survival Recovery and Larval Invasive Species. Two stories of these applications are shared here.

A Webb Slocum Electric Glider was deployed as part of the NSF funded Lagrangian Transport and Transformation Experiment in 2004. While the glider was on the surface a software malfunction disabled the glider causing it to drift on the surface with no means of communicating and no ARGOS broadcasts of its location. The Civil Air Patrol offered to donate one tank of gas to a Glider search for use as a training mission. The days following the last glider communication, the wind and currents oscillated between upwelling and downwelling conditions. One hundred simulated drifters were released at the last known position of the glider in the surface current fields as measured by the high resolution HF radar network. A random ±5cm/s current was overlaid on the measured current field to predict the glider's drift (Figure 3). A 220 mi^2 search area was defined for the glider's probable location 10 days after communication was lost. Using this search area the Civil Air Patrol was able to locate the glider after their seventh pass through the search area, resulting in the successful recovery of the $100,000 robot by a rescue vessel that was standing by.

Tropical Storm Ernesto had weakened to a tropical depression after it made land fall in North Carolina. However a large high pressure system to the north combined with Ernesto's transition to an extratropical frontal structure to produce gale force winds over much of the coast from Virginia to New York. The strong winds from offshore caused significant transport of water towards the coast as Ernesto's newly developed extratopical front and rain bands propagated northward along the coast. Figure 4 illustrates Ernesto's forecast frontal structure just before (4a) and just after (4c) the front passed New York Harbor. The ocean response before the frontal passage (4b) shows the final hours of shoreward transport into New York Harbor, followed by rapid flushing of the system (4d) after the storm front passed. The model wind fields and observed surface currents are now providing a test case for coastal inundation models for MACOORA. The wind fields provide surface forcing for coastal inundation models, and the surface currents assimilated into regional forecast models provide offshore boundary conditions.

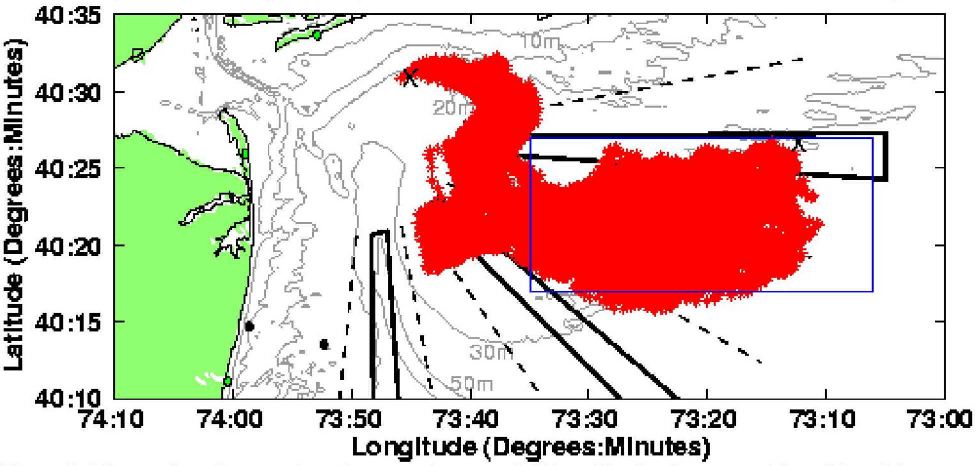

Figure 3: Map used to plan search and rescue of wayward glider. The last known position of the glider was at 40:30 N and 73:45 W. The search area was defined as the blue box. The glider was recovered at 40:25 N and 73:10 W.

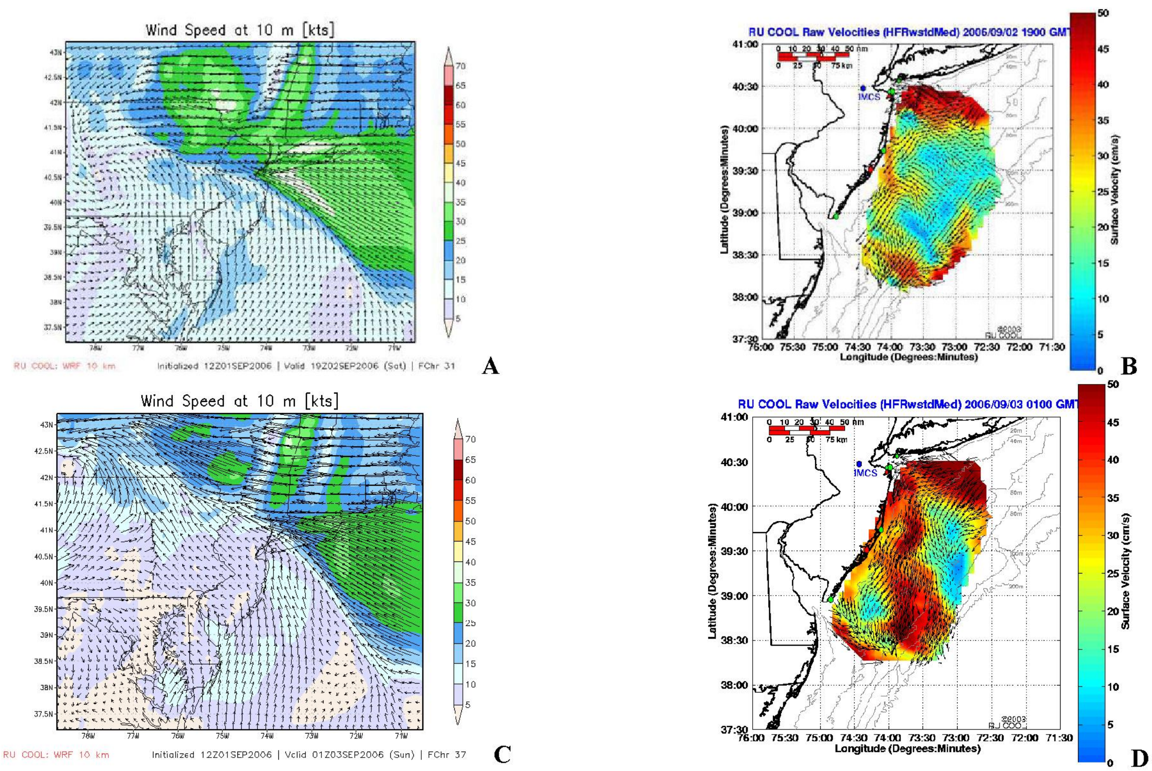

Figure 4: Slides showing the passage of Tropical Storm Ernesto. The top 2 panels are September 2, 2006 at 19:00 GMT. The bottom 2 panels show the conditions at September 3, 2006 at 01:00 GMT. The panels on the left are output from the Rutgers WRF model. The panels on the right are measured surface currents from the HF radar. The front of the storm can be seen progressing NE across the state of New Jersey. The storm surge that had accumulated at the NY Bight apex broke after the passage of the front and flowed south. This can be seen in panel D.

VI. Conclusions

MARCOOS has established an end-to-end system for operating a regional scale HF Radar network, aggregating the data in a central location, producing quality controlled total vector maps, distributing the maps to statistical and dynamical modelers for assimilation, bringing the data nowcasts and bringing the model forecasts into the USCG's Environmental Data Server so that it can be accessed through Search And Rescue decision-makers through SAROPS. The system is operating at the MAHFRC Phase 2 level during this initial three-year demonstration of MARCOOS.

One operational challenge for the Phase 2 level is that MARCOOS is currently using only 3 fully funded technicians and a regional coordinator to maintain 26 systems, well below the 2003 SCMI recommendation of 10 technicians for this level of network. Significant leveraging is still reducing costs. However, the present 3-year MARCOOS pilot project may ultimately result in an upward revision of the number of radar sites 2 technicians can cover. Advances in the reliability and speed of cell-phone communications, remotely controllable backup power systems, and larger computer disc storage over the last 5 years are extending the required revisit intervals at remote shore sites. The SCMI workforce numbers also were based on the operation of a long-range network, with one constraint being that a technician must be able to drive to a site, repair it, and drive home all in one day to be cost effective. The SCMI report did not anticipate that the actual network would evolve as a nested system of long range systems driven mainly by offshore Search and Rescue needs combined with an inner nest of high resolution systems driven mainly by water quality needs. The result is that many more than 5 sites are now expected to be located within a ½ day drive of each technician's home base. Ultimately new support technologies and revised designs of the national network may lead to a revision in the estimated workforce requirements.

VII. Acknowledgments

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References

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[2] Radar Technologies for Surface Current Mapping, Alliance for Coastal Technologies No. ACT-04-03