**MARCOOS SEMI-ANNUAL REPORT:** 9/30/2010 – 04/01/2011

NOAA Award Number NA01NOS4730014 (October 2010 – September 2012)

## 1) PROJECT SUMMARY

The *Middle Atlantic Coastal Ocean Observing Regional Association (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 in the 5 user prioritized theme areas of: 1) Maritime Safety, 2) Ecological Decision Support, 3) Water Quality, 4) Coastal Inundation, and 5) Offshore Energy. MARCOOS (a) *collaborates* with NOAA WFOs linking existing regional coastal weather networks to evolving NOAA WRF regional forecasting capabilities – *to provide* an improved ensemble of weather forecasts, (b) *operates* the existing Mid-Atlantic HF Radar Network and leverages Coast Guard drifters that are linked to statistical and dynamical models - *to provide* an ensemble of regional nowcasts and forecasts of 2-D surface currents, and (c) *operates* existing satellite receivers and leverages the Navy investment in a regional glider capability linked to the dynamical models - *to provide* an ensemble of 3-D circulation, temperature and salinity nowcasts and forecasts. The MARCOOS data management team facilitates implementation of an end-to-end system consistent with DMAC standards. Education & Outreach (EO) teams engage additional users and provide frequent and timely feedback, while an economic impact team assesses benefits of MARCOOS information. A management structure that establishes and monitors performance metrics ensures quality.

## 2) PROGRESS AND ACCOMPLISHMENTS

Year 4 of MARCOOS continues the sustained implementation of the original 10 major tasks.

**A) Atmospheric Data Integration:** WeatherFlow runs its mesoscale model operationally 4 times daily. In addition, 3 forecast offices within the MARCOOS domain contribute output from the WRF mesoscale model to form a multiple model averaged product. Since none of the models are run in a fully operational mode, a full suite of 4 mesoscale models was not available for sufficiently long to gather the proper statistics. When all models ran, no clear winner emerged. Neither the ensemble, nor any of the individual models consistently outperformed the other. Changes are being made to the evaluation process to deliver more conclusive and useful results, including working with the NWS offices to generate a more reliable datasets, adding more models to the ensemble, and assembling more expertise within the MARCOOS members via a workshop tentatively scheduled for early 2012.

A formidable result from the ongoing analysis is that marine meteorological observations play an important role in verifying the ensemble as well as its individual models. For example, verification statistics are kept for various regions within the MARCOOS domain including the lower Chesapeake Bay, where the ensemble has the largest common domain. The current set of verification sites in this region include 10 NWS sites, 11 WeatherFlow sites, 5 NOAA PORTS sites and 1 NOAA C-MAN. When examining forecast performance via statistics such as Wind Vector Difference, it is common to generate numbers such as those for July in which all models, including the ensemble, exhibit lower error rankings from all 10 NWS sites before data from any of the WeatherFlow, PORTS, and C-MAN combined are used. The conclusion here is that without these observations, one may falsely conclude that the models are performing well in the littoral zone. Currently unknowns such as thermal and latent heat variability between land, air, and sea, along with other unparameterized air/sea interactions, need model improvement.

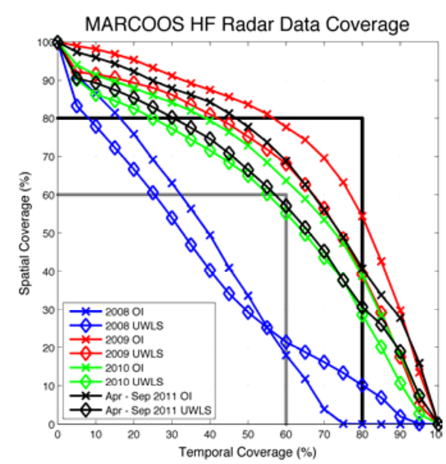


**Figure 1:** Temporal and spatial data coverage metric for the High Frequency radar network.

**B) HF-RADAR Equipment:** The operators in the network were able to maintain 80% radial coverage of the long range network, 94% for the new medium range network and 57% coverage of the standard range system, reflecting the regions priority to maintain the long range network and provide maintenance to the medium and short range network when available. The total coverage during this reporting period is shown as the black lines (OI combining method is the x and the UWLS is the diamond) in Figure 1. This metric indicates that 60% spatial/temporal coverage can be achieved with the Phase 3 level of funding as suggested in the Mid Atlantic HF Radar Consortium document authored in 2006. The 80% coverage could be achieved with Phase 4 funding consistent with the recommendation of the National HF Radar Network.

An event of interest was the passage of Hurricane Irene in August 27-28, 2011. Thirteen systems were able to maintain operation during the storm. The service at sixteen of the sites was interrupted due to power or communication outages. Power outages accounted for twelve of these outages so if there is no power, maintaining communication becomes a moot point. Most of the stations in the network are equipped with a small battery backup to condition power and maintain operation during quick power outages. The average power outage resulting from the storm was 84 hours. This will require a large battery bank and/or backup generator to maintain coverage during these types of storms.

**C) HF Radar QA/QC:** Quality assurance of the HF radar operations during this reporting period were summarized in two posters presented at the Radiowave Operators Working Group (ROWG) in Santa Barbara, CA. We completed the report comparing the Unweighted Least Squares and Optimal Interpolation combining method as part of the National plan to produce operational surface current vectors for use in Coast Guard SAROPS. Settings recommendations for the OI method were made. Data from MARCOOS servers consistently flows smoothly to the Coast Guard. There have been some inconsistencies in data availability and collection from the National HF-Radar Network.

**D) Underwater Gliders:** The MARCOOS team has conducted 5 glider missions spanning the entire MARCOOS domain. The surveys spanned 2225 kilometers representing 107 days at sea. These surveys, as opportunity allowed, were coordinated with the NOAA NMFS surveys conducted out of the Woods Hole and Sandy Hook Labs. Of particular note were two events that became the focus of the glider operations. These represented joint efforts of NOAA IOOS with the New Jersey Department of Environmental Protection/U.S. Environmental Protection Agency, Office of Naval Research, and the National Science Foundation. Efforts were focused on documenting 1) a mammoth summer phytoplankton bloom on the MAB and 2) atmosphere/ocean interactions during Hurricane Irene. Glider surveys during the summer bloom documented the subsurface spatial extent of the phytoplankton bloom (Figure 2A) that drove declines bottom water oxygen through the export of organic material from the euphotic zone (maracoos.org/summerbloom/). This event was followed by the passage of Hurricane Irene (Figure 2B). MARCOOS kept two gliders operating throughout the storm capturing rapid declines in surface temperatures in the upper mixed layer during Irene (Figure 2C). This data is providing the unprecedented opportunity to assess the impact of having realistic upper mixed layer temperatures to input to Hurricane forecast models. This unique data set is the focus of a science Tiger team.

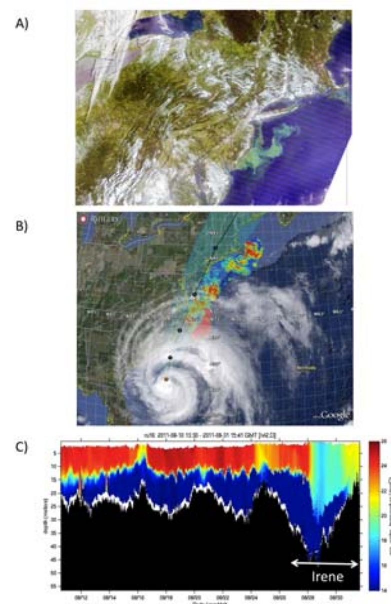


**Figure 2.** A) A visible satellite image of the 2011 phytoplankton bloom off the coast of New Jersey. B) The arrival of Hurricane Irene and the associated CODAR surface current maps from the CODAR array. C) Glider temperature data showing the impact of the passage of Hurricane Irene.

MARCOOS has established two new Glider Centers to complement Glider Central at Rutgers University. Glider Center North is located at UMASS Dartmouth, and Glider Center South is located at the University of Maryland CES (UMCES) Horn Point Laboratory in Cambridge, MD. The UMassD IOOS Slocum G-2 glider was delivered by Teledyne-Webb in July and will be deployed for a round-trip mission to the shelf break south of Martha's Vineyard before Thanksgiving. The University of Maryland, while continuing to develop Glider Center South, handles the operational MARCOOS glider program in the MAB. Most glider work has been to coordinate and carry out retrievals of gliders in the MAB region between Wallops Island, VA and the northern Outer Banks of NC. MARCOOS Glider Center South is expanding as a regional Glider/AUV center. UMCES is acquiring a Hydroid REMUS 600 AUV through a new National Science Foundation award. This AUV will be available for both research and operational monitoring of the southern MAB and its estuaries. The plan for the GLIDER/AUV Center is for the new REMUS 600 acquisition to anchor a cooperative fleet of 7 AUV's operated by 5 institutions in the region. The Center will, in conjunction with Glider Central at Rutgers, coordinate both glider and AUV operations in the southern MAB.

**E) Satellites:** We continue to support expanded satellite coverage efforts, which started during the 2010 Gulf Oil Spill. Google Earth is used to visually disseminate displays of cloud-filtered Sea Surface Temperature and chlorophyll from Cuba to Newfoundland. We are converting our file format to netCDF4 to decrease data size and increase ease of data access. We have also released a new near-shore salinity product (out to 50km offshore). Real-time implementation of coastal salinity is ongoing. We are also working on real-time applications of water mass products and have implemented the Navy Research Labs Advanced Processing System (APS). We are converting their output to netCDF4 for our THREDDS catalogs. We have started three fisheries projects that focus on using satellite products to describe the habitats of squid and butterfish (both commercially harvested), sturgeon in Delaware Bay (protected) and tiger sharks near Bermuda (protected). We will be using the APS output from our satellite dishes to run real-time forecasts of butterfish locations for commercial fishermen in December. Also, we have had more than 2500 people (k-12 to US Senators) this year visit our visualization lab, where they have learned about IOOS and the data streams that support the Mid-Atlantic region.

**F) Short Term Prediction System (STPS):** For the STPS system there were four major results/outcomes of operations during the last six months. First, we discovered that the 6km-Optimal Interpolation augmentations do not affect the errors. Second, there were no significant improvements in the performance of the STPS by incorporating wind data and in fact, made it worse in a substantial area of the MAB domain. Third, the impact of station outages were severe, though the stations at the edges of the domain affect larger areas than those toward the center of the research area. In particular, the areas close to shore near the mouth of the Chesapeake Bay, at the eastern boundary of the domain off Cape Hatteras, and to the south and east of Cape Cod the errors reach or exceed 20 cm/s. Lastly, the University of Connecticut set up a backup forecast system and implemented the option of acquiring data from the national server at NDBC.

**G) Dynamic Models:** The MARCOOS/HOPS Real-Time Forecast System has been operational since March 9, 2009. The model simulates the non-tidal dynamics of the WNA and GOMGB, forced by atmospheric fields (surface momentum flux, surface heat flux, surface water flux and shortwave radiation) from the Global Forecast System (GFS) at 1/2 degree resolution, which provides 7-day forecast fields. The horizontal structure of the model domain consists of 131 by 83 grid points with 15-km resolution, extending from Cape Hatteras to Grand Banks (30.5°N to 47.93°N in the meridional and from 80.54° W to 54.23° W in the zonal direction). There are 16 double-sigma vertical levels. The HOPS forecast system is presently assimilating blended SST (5-day composite) data from NOAA CoastWatch. The 5-day long forecasts are issued generally by Wednesday morning; Monday zero-hour is a typical model initialization state, with SST assimilation carried out on Monday afternoon and Tuesday noontime. Real-time Glider data is being assimilated when available. The forecast fields (Temperature, Salinity, Currents and Divergence) are available at www.smast.umassd.edu/modeling/RTF/. The CF-compliant model forecast data are available from the thredds server http://aqua.smast.umassd.edu:8080/catalog.hml.

ROMS ESPreSSO covers a domain from Cape Hatteras to Cape Cod out to the Gulf Stream. Air-sea fluxes are from bulk formulae using rain, long- and short-wave radiation, 2-m air temperature, pressure, and humidity, and 10-m winds from the NCEP NAM forecast. Global HyCOM with NCODA provides open boundary data, plus 7 tidal harmonics for velocity and sea level. River flows are daily average USGS gauge data. Resolution is 5 km horizontal and 36 vertical layers. Vertical turbulence closure is the k-kl option of the Generalized Length Scale method. Data assimilation is by the Incremental 4-Dimensional Variational (I4DVar) method applied to a 3-day window of data to adjust initial conditions to each analysis window, and generates a daily 72-hour forecast. Data assimilated are CODAR currents, infrared and microwave satellite SST, sea level, and a regional high-resolution hydrographic climatology to constrain biases introduced by the boundary conditions.

NYHOPS v3 is an extensively validated, fully three dimensional, estuarine circulation model that provides real –time 48-hour marine forecasts of the ocean, estuarine, and freshwater coastal zone. The model is based on the sECOM version of the POM family of models. This forecast model is operationally used for flooding alert guidance by the NWS, spill guidance by NOAA OR&R, search and rescue by USCG, transit planning by the Hudson River Pilots, and identifying shoreline energy regimes in the Hudson estuary. The grid size is variable with the current horizontal resolution averages 360 m in the Hudson, down to 25 m in some tributaries. This is being refined with current funding from a different project to an average of 85m. NYHOPS has 48 hour forecasts and 24 hour hindcasts initialized every 6 hrs. Data inputs include real time data from NOS, USGS, HRECOS, AHPS, NCDC, historic power plants and water treatment facilities, Coast Guard Ice data (proposed). Outputs/Products include 3D currents, 3D water temperature, 3D salinity, total water level, wave fields, wind fields, surface air temperature and other surface meteorology and localized air-sea heat fluxes as well as Real time web application, downloadable datasets and GIS files for shoreline energy regime classification work. The model is operationally linked to a water quality model forecasting CDOM.

**H) DMAC:** The DMAC team has been focused on the integration of MARCOOS data sets in a new "asset map" that leverages IOOS data standards – TDS/OPeNDAP, WMS, and SOS. The system leverages distributed servers within the MARCOOS group, as well as the Amazon Cloud and the U.S Coast Guard EDS. The Asset Map is now being used as a template for custom outreach programs, the first being a new web product to meet the needs of fishermen following a recent fisheries meeting. The team is also building a version of the Asset Map that will focus solely on Gilder data management as a prototype for national and international glider management. Additional work has been completed through the contract to enhance the connection to SAROPS EDS from the National HF Radar network (SCRIPPS server) and the derived STPS forecast generated by UConn. Kyle Wilcox was invited to be on the THREDDS Steering Team, a group set up to "help guide Unidata in their development of the NetCDF-Java/Common Data Model/THREDDS Data Server family of technologies." As part of the SOS Working Group, the DMAC team has started putting together NetCDF templates based on the CF-adopted discrete sampling geometries. These templates will serve as a reference to other RAs when creating NetCDF files from many non-gridded data feeds (profilers, gliders, buoys, etc.)

**I) Education and Outreach:** We have engaged the commercial fishing industry in a series of workshops to get their input on specific product development. A fisheries workshop held in Providence Rhode Island brought together MARCOOS and industry partners to develop an ocean observatory/ fisheries community interactive partnership. A working group composed of 3-5 industry and 3-5 MARCOOS representatives has formed with the specific purpose to identify future product needs and development. The two other workshops were designed with the specific purpose of engaging the industry in the development of a 2$^{nd}$ generation IOOS informed butterfish habitat model focused on mitigating bycatch in the loligo squid fishery. Late this fall we will operationalize this 2$^{nd}$ generation model to produce near real time regional scale habitat "nowcasts" which we will evaluate in the field with commercial fisherman. We believe this will be the first attempt to operationalize a regional scale fishery habitat model within IOOS.

Tony MacDonald continued coordination with the Mid-Atlantic Regional Council on the Ocean (MARCO) and the MARCO CMSP Action Team to assist in identifying observing derived data into the Mid-Atlantic Mapping and Planning Portal in collaboration with The Nature Conservancy, including regular conference calls and participation in the MARCO Management Board Meeting on September 14, 2011. Mr. MacDonald also assisted in planning the Fisheries Workshop held on September 26, 2011, attended the meeting and prepared draft meeting report. J. McDonnell, S. Lichtenwalner, and C. Ferraro all attended monthly NFRA education calls. They facilitated the formation of a subcommittee of members to specifically discuss education and online tools development related to the Ocean Observatory Initiative Education and Public Engagement (EPE) tasks. Additionally, Rutgers conducted a webinar overview of the OOI EPE project to the NFRA education committee on September 13, 2011 to brief them on future education tools.

**J) Economic Benefits:** Tony MacDonald coordinated efforts with Dennis King in identifying areas of focus for further analysis of economic benefits including potential benefits from Josh Kohut and John Manderson fisheries ecosystem by-catch research, and MARCOOS support for offshore wind energy activities. In addition, Mr. MacDonald included support for development of protocols for integration of ocean observation data into the MARCO Mapping and Planning Portal as part of the MARCO Regional Ocean Partnership grant in partnership with the Center for Remote Sensing and Spatial Analysis at Rutgers and TNC. On August 9, an IOOS Regional Member Site Visit meeting was hosted at Rutgers to present the economic benefits of IOOS to the Assistant Secretary of Commerce. Attendees included NOAA (including Dr. Sullivan), Rutgers, Stevens Institute of Technology**,** Monmouth University, Industry Representatives (Fishing, Industry, NJ BPU offshore energy, Teledyne Webb Research). Additionally leadership from NERACOOS, SECOORA, and MARACOOS attended.

**K) Statistics: New Regional Products:** Continuing the extension of the HF-RADAR network into the estuaries and implementation of the new satellite based salinity product for the estuaries is proceeding. Offshore a

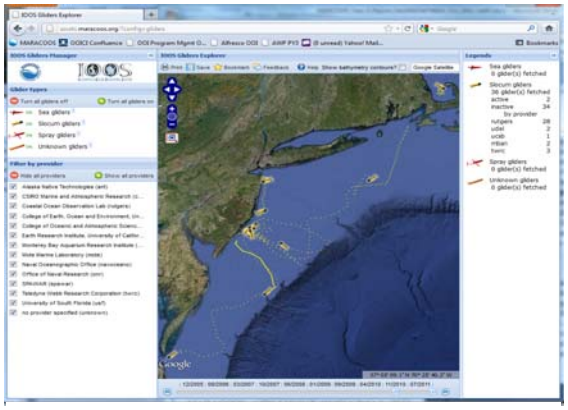

**Figure 3.** New Global Glider Asset Map zoomed into the MARACOOS domain.

new bottom temperature product is being developed based on glider bottom temperatures, the National Marine Fisheries Service records, and the dynamical model bottom temperature forecasts. The nearshore waves product validated off of New Jersey, and confirmed off Long Island Sound, is being propagated through the regional network. A new MARACOOS handheld device (eg. phone) application is being pilot tested. Specific additions include: **New National products:** MARCOOS is validating HF-RADAR data as part of the transition to a National HF-RADAR network product to be delivered to the USCG SAROPS. A new International Glider Asset Map was prototyped and delivered to IOOS headquarters for evaluation (Figure 3). **Deployed Assets:** Multiple MARCOOS gliders were deployed and recovered and 2 new satellite ground stations were installed at the University of Delaware. **Assets Removed:** None **Assets Maintained:** 4 Satellite Ground Stations, 30 CODAR sites, over 100 Weather Stations and 2 Glider flights every 6 months for 3 years. Over 100 weather sites contributed data to AWIPS and EDS. Real-time forecasts were produced by 1 statistical and 3 dynamical models. **Papers published:** 7 papers were published (http://maracoos.org/papers). **Presentations**: Over 30 presentations were made (http://maracoos.org/presentations). **Data Management:** The asset map was upgraded http://assets.maracoos.org.

## 3) SCOPE OF FUTURE WORK

MARCOOS Year 4 is now over, and we are in the no-cost extension year. Most operations are transferred to the MARACOOS project which will submit its first 6 month progress report on December 30, 2011. The main purpose of the MARCOOS Year 4 no-cost extension was to cover the fall glider deployment which is still ongoing at this time. Additional work is required by several technology groups during this flight. The real time glider data is being assimilated by the operational models, which also include CODAR and satellite data. The glider must be recovered, any damage must be repaired, and the full dataset must be archived. The results will be presented to fisheries groups by our outreach teams. The DMAC team will continue to upgrade the glider components of the Mid-Atlantic Asset Map and a few dedicated asset maps, including the newly envisioned Mid Atlantic fisheries asset map, and the IOOS international asset map.

## 4) LEADERSHIP PERSONELL AND ORGANIZATIONAL STRUCTURE

During this reporting period, the merger of MACOORA & MARCOOS into the single MARACOOS entity occurred, starting June 1, 2011. The two major changes for the new MARACOOS were the appointment of Michael Crowley as the Technical Director for the operational aspects of MARACOOS, and the appointment of Dr. Gerhard Kuska as the MARACOOS Executive Director for the organizational aspects of MARACOOS.

## 5) BUDGET ANALYSIS

The Year 4 MARCOOS budget includes Rutgers $606,000 plus $1,190,000 in subawards for a total of $1,796,000. This budget analysis covers the first year of funding of the Mid Atlantic Regional Coastal Ocean Observing System grant NA01NOS4730014. The remaining balance shown is based on invoices to date, not necessarily what has been spent to date as billing from subcontractors can lag.

| # | Distribution | Year 4 | Remaining Balance |
|---|---|---|---|
| | **LEAD**: Rutgers University | $606,000 | $5,195 |
| 1 | Applied Science | $207,000 | $52,815 |
| 2 | Center for Innovative Technology | $45,000 | $14,961 |
| 3 | Monmouth University | $25,000 | $10,849 |
| 4 | Old Dominion University | $100,000 | $42,772 |
| 5 | Stevens Institute of Technology | $114,000 | $0 |
| 6 | University of Connecticut | $148,000 | $49,653 |
| 7, 8 | University of Delaware (2) | $72,000 | $997 |
| 9 | University of Massachusetts | $229,000 | $71,064 |
| 10 | University of North Carolina | $18,000 | $7,898 |
| 11 | University of Rhode Island | $27,000 | $23,265 |
| 12 | Weatherflow | $90,000 | $0 |
| 13,14 | University of Maryland (2) | $115,000 | $25,101 |
| | TOTAL AWARDED | $1,796,000 | **$304,570** |

The base IOOS regional funding was $1,700,000. Additional NOAA funds included $10,000 to cover expenses for the RU27 glider exhibit at the Smithsonian, and $86,000 to support validation of the OI algorithm for the National HF-RADAR Network.