

MARACOOS SEMI-ANNUAL REPORT: 6/1/2015 – 11/30/2015
NOAA Award Number NA11NOS0120038 (June 2011 – May 2016)

1) PROJECT SUMMARY

The Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) continues to implement its partnership-based strategy to support stakeholder needs through sustained regional ocean observation and forecasting in the Mid-Atlantic Bight (MAB) from Cape Hatteras to Cape Cod. Over the 5-year project duration, MARACOOS has (1) united and integrated the organizational activities of MACOORA (established in 2004) and the operational activities of MARCOOS (established in 2007) into the single entity known as MARACOOS; (2) maintained and expanded the existing observing, data management and forecasting subsystems focused on the transition from data-generated to model-generated ensemble ocean forecast products that target multiple users; and (3) expanded end-to-end operations across all five regional themes through (a) enhanced education and engagement activities, (b) the leveraging of resources beyond IOOS through expanded Users and Advisory Councils, and (c) the application of IOOS Association-endorsed metrics to measure and demonstrate success. During this period, MARACOOS has begun compiling relevant procedures and documenting other requirements toward certification as per 15 CFR Part 997.

2) PROGRESS AND ACCOMPLISHMENTS

MARACOOS has exploited both successes and lessons learned in moving forward toward its 5-year goals. Chief among these goals are the aim to expand from observation to forecasts and the aim to expand the suite of valued information products across the 5 MARACOOS themes. In order to achieve these goals and thereby realize the potential envisioned in the 5-year plan, we see increasing user engagement and expanding leveraging of new and existing partnerships as crucial. Simultaneously, traditional performance metrics are being refined to gauge the spatial coverage and temporal reliability of the MARACOOS observations, and new metrics are being developed to assess the accuracy of these observations and our forecast products. Our milestone schedule is found on page 13, Section E of the MARACOOS proposal. In this report, progress towards milestones and metrics for each of the 5 subsystems are outlined first, followed by highlights of significant meetings and events. In sections A-K, the work accomplished during this reporting period to fulfill those milestones is discussed in greater detail.

Milestones and Metrics: Management Subsystem: During this reporting period, bi-weekly board meetings and operations meetings were held via conference call. The bi-weekly operations meetings included discussions on the Weather Forecast Ensemble Validation, Satellites, HF-Radar, Gliders, DMAC, Education & Outreach, Ocean Forecasts, Fisheries, CBIBS, and QARTOD. Observing Subsystems: a) The MARACOOS weather ensemble operations continue to run four times per day at 00, 06, 12 and 18 UTC out to 36 hours. WeatherFlow currently utilizes up to 11 forecast models in the ensemble. b) *Satellites:* There were 0 days of data acquisition gaps for the University of Delaware L-band dish, University of Delaware Geo-Stationary Dish, and the Rutgers University L-band dish. The Geo-Stationary satellite receiving dish at the University of Delaware (UDel) receives 40-80 measurements of sea surface temperature (4km resolution) in the MARACOOS region. As the data volume of this feed is enormous, MARACOOS held a week-long experiment in late November to collect and store Geo-Stationary SST to determine its usefulness for MARACOOS supported activities. The data is now available for use here: (<http://thredds.demac.udel.edu/thredds/catalog.html?dataset=GOESSSTAggregate>). Both the Rutgers and University of Delaware X-Band dishes are non-operational and expensive repairs are needed. The data stream is updated through our and processing of raw data from NASA. c) *HF-Radar:* The MARACOOS metric for long range data coverage and availability has surpassed the 80/80 metric goal (80% coverage 80% of the time) again during this period. d) *Gliders:* MARACOOS glider operators deployed 14 gliders in the MARACOOS region during 2015 totaling 367 days and 7443 kilometers sampled. DMAC Subsystem: The uptime for observations and model data in the MARACOOS Data Center continues to be >99% and the auto-monitoring system provides feedback on most of the data feeds. Modeling Subsystem: The delays in accessing the REMSS Level-4 blended GHRSSST data set that were noted in the previous semi-annual report prompted a change in September in the ESPreSSO system to assimilate the MUR L4 GHRSSST product from JPL PO-DAAC. Interruptions to the ESPreSSO altimeter data stream occurred in Nov due to changes in the RADS service at TU-Delft that were incorrectly implemented at Rutgers – changes have been made internally at Rutgers to better monitor RADS

release notes to avoid future disruptions. All analysis cycles were re-run when the missing data were restored. Two interruptions to ESPreSSO forecasts occurred on Oct 2 and Oct 18 due to internal Rutgers IT issues - the missing forecast cycles were completed and restored to the Rutgers THREDDS catalog within 36 hours. The deterministic NYHOPS model had the following metrics: a) up-to-3-days forecast horizon (FH): 100% operational, b) New125-member NYHOPS hydrodynamic ensemble; 78hrs FH: 100% operational, c) New 125-member SNAP-Ex extended ensemble; 105hrs FH: 100% operational, and d) New 125-member Stevens Hydrologic ensemble for NYH contributing watersheds; 78hrs FH: 100%. The SMAST-HOPS model continued to make weekly nowcasts/forecasts (on Wednesdays) and was available during 100% of the reporting period (June-December 2015).

Meetings/Engagement Activity Highlights: During the reporting period, MARACOOS was engaged in regionally based meetings and efforts that reached several thousand individuals in the areas of fisheries, water quality, coastal inundation primarily, with efforts also aimed at maritime safety and offshore wind. Several thousand more individuals were reached through MARACOOS’ electronic outreach. MARACOOS and its partners have engaged with national and international organizations to represent MARACOOS and IOOS capabilities, as well as to proactively search for opportunities to partner and leverage existing funding streams. Additionally, MARACOOS held one, in-person Board meeting (November) and conducted a Board meeting call every two weeks and an Operations meeting call every two weeks. During the MTS Oceans 2015 conference, MARACOOS supported an exhibit booth and a variety of theme-focused discussions with existing and potential new partners.

A) Atmospheric Data Integration: For the MARACOOS domain (36 to 43 N, and 78 to 69.5 W), WeatherFlow generates a gridded ensemble of surface meteorological fields from a variety of available high-resolution mesoscale numerical weather prediction (NWP) forecasts (ensemble members). The ensemble products, which include the gridded data, production imagery, proprietary WeatherFlow observational data used in production and the statistics, are available to the MARACOOS community.

The MARACOOS weather ensemble operations continue to run four times per day at 00, 06, 12 and 18UTC out to 36 hours. WeatherFlow currently utilizes up to 11 forecast models in the ensemble. WeatherFlow is taking advantage of available high-resolution (spatial resolution of 4km or better) NWP forecasts generated by government, academic, and private sectors that cover all or significant portions of the MARACOOS domain. The current list of models used in producing the ensemble is itemized in Table 1. As mentioned in previous reports, GRIB2 files are generated and available for anyone who may need atmospheric data to be used for forcing fields.

Table 1. Current atmospheric models used in the MARACOOS weather forecasting ensemble

Institution / Model	Runs Used (UTC)	Resolution (km)	West Lon	South Lat	East Lon	North Lat
Rutgers University WRF	00	3	-78.934	34.470	-69.189	42.391
Sterling VA WFO WRF	06,18	4	-82.942	35.391	-73.057	41.818
WF RAMS Chesapeake Bay	00,06,12,18	2	-77.700	36.200	-74.910	39.890
WF RAMS Cape Cod	00,06,12,18	2	-71.600	40.800	-69.404	42.996
WF RAMS Atlantic Coast (New)	00,06,12,18	2	-78.900	34.200	-73.356	40.752
WF WRF Atlantic Coast (New)	00,06,12,18	2	-78.900	34.200	-69.000	42.760
WF WRF Atlantic Coast B (New)	00,06,12,18	2	-78.900	34.200	-73.356	40.752
NOAA/OAR HRRR	00,06,12,18	3	CONUS			
NOAA/NCEP NAM	00,06,12,18	4	CONUS			
NOAA/NCEP WRF-ARW	00,12	4	CONUS			
NOAA/NCEP WRF-NMMB	00,12	4	CONUS			

The new information in this report relates to interesting verification statistics performed on the ensemble and each of the individual members. The Wind Vector Difference (WVD) is calculated on 6 groupings of observation locations with the MARACOOS domain.

The WVD is a popular numerical verification statistic used for winds as it essentially measures how well both wind speed and direction are modeled. Winds are broken into both U and V wind vectors, then the sum of square

root of both the U and V differences between observed and modeled values. These calculations were performed for an entire year on over 50 observation sites that include WeatherFlow, National Weather Service, NOAA Ocean Service, and Chesapeake Bay Interpretive Buoy System.

The 6 grouping are represented from RIGHT to LEFT bar chart (Figure 1) and are as follows:

- 1) Inland with little to no influence by sea breezes or any other littoral process,
- 2) Still inland, but some influence, by littoral processes;
- 3) Site located with a mile of navigable water;
- 4) Site located but within feet of navigable water;
- 5) Site located on water's edge (piers);
- 6) Site located over water, but land is within sight;
- 7) Site located over water, generally away from the influences of land.

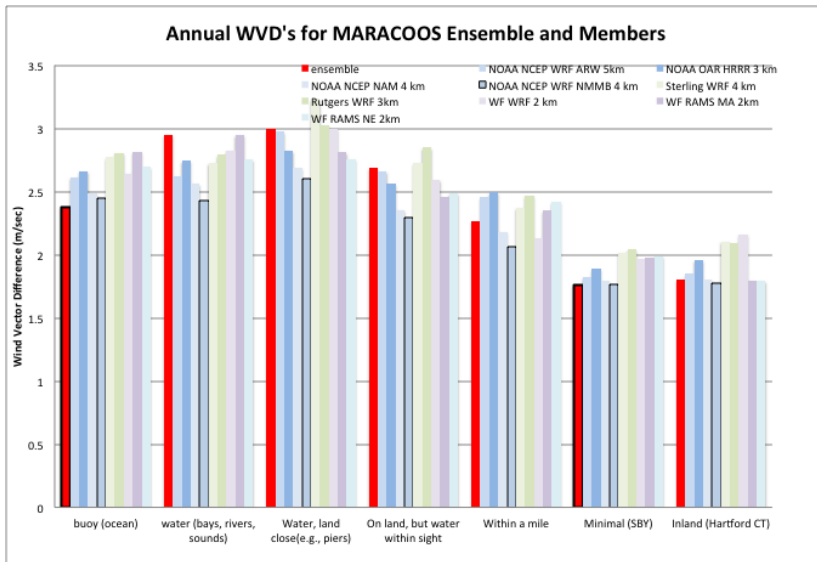


Figure 1. Annual WVD's for MARACOOS Ensemble and Members

All members, including the ensemble itself perform best inland (bar clusters 6 and 7, far right), followed by further offshore (bar cluster 1, far left). The poorest performance occurs within the coastal zone (From left, bar clusters 2 through 4 below). The high errors are generally due to vagrancies in model resolution and lack of properly resolved and accurate physical forcing fields, such as shelf water surface temperature.

The red bars represent the ensemble performance for each geographical region. The ensemble

performs best in 2 of the 7 regions (black bordered bars), and struggles in the same areas 2 through 4. Only the NCEP WRF NMMB member outperforms the ensemble (black bordered bars) and, in fact, it performs best in all 7 regions.

Conclusions: Weather model output is used extensively as input into numerous oceanographic models ranging from estuary to drift in Coast Guard search and rescue. High resolution atmospheric model output looks great but must be properly verified in order to a) reveal weak performance, b) understand why, c) build the proper improvements (higher resolution input fields, better parameterization schemes, improved ocean/atmosphere coupling schemes), and attach uncertainty to output. This MARACOOS work can provide the necessary understanding for improvement.

B) HF-Radar Equipment: The Mid Atlantic High Frequency Radar Network performed well during this progress period. The uptimes of the individual sites in the network are provided in Table 2. The long-range average is on par with previous periods. The 13 MHz radar station at Belmar has been replaced with the station at Bradley Beach. The station at Nauset, MA (NAUS) was finally repaired and is operating well now and a walking antenna pattern was performed. University of Delaware lost permission for the station at SLTR and the equipment was removed on July 14, 2015. They have received permission for a new station one mile south of the old location and plan on installing in the next progress period. The property for the SUNS station was sold so power is not available. Old Dominion is in conversation with the new property owners and they hope to restore operations in the next progress period. The WHOI stations METS and SQUB are still down. At least one will be installed on Nantucket, to the west of the existing long-range site to capture the mid shelf. WHOI thinks it should be online by early spring.

The spatial and temporal coverage of the 5 MHz long-range network is shown in Figure 2. The network again exceeded the 80/80 metric that was developed by MARACOOS and the US Coast Guard Office of Search and Rescue.

Table 2: Table of data availability for the progress period June 1, 2015 to November 30, 2015. The column to the right represents the percentage of data available on the National Network.

Data Availability to National Network
June 1, 2015 to November 30, 2015

5 MHz			25 MHz			13 MHz		
#	Site	%	#	Site	%	#	Site	%
1	NAUS	34	1	MISQ	77	1	SEAB	29
2	NANT	100	2	BISL	100	2	BRAD	95
3	MVCO	91	3	MNTK	100	3	SPRK	90
4	BLCK	96	4	GCAP	96	4	BRNT	65
5	MRCH	97	5	STLI	92	5	BRMR	100
6	HEMP	75	6	PORT	71	6	RATH	54
7	HOOK	94	7	SILD	87	7	WOOD	99
8	LOVE	65	8	CMPT	96			
9	BRIG	100	9	HLPN	75			
10	WILD	96	10	SLTR	0			
11	ASSA	99	11	VIEW	99			
12	CEDR	93	12	CPHN	100			
13	LISL	100	13	SUNS	86			
14	DUCK	95	14	LPWR	96			
15	HATY	98	15	METS	-			
16	CORE	71	16	SQUB	-			

Average: 88 84 76

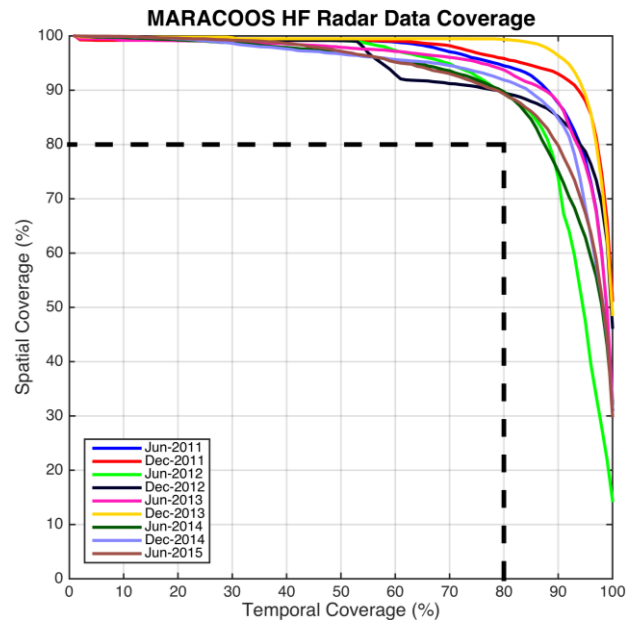


Figure 1. Spatial and temporal coverage of the 5 MHz network for each progress period of MARACOOS 2011-2015.

C) HF-Radar QA/QC: The MARACOOS HF radar operators have held twice monthly conference calls to exchange information and develop new procedures. The group maintains a status of site outages here: <http://www.radarops.comoj.com/wrocks/outagesummary.php>

Teresa Updyke, Anthony Kirincich, Sara Haines and Hugh Roarty are serving on the QARTOD HF radar Quality Control Committee.

Rutgers is coordinating with the University of North Carolina and Woods Hole on quality control methods. North Carolina and Woods Hole are focusing on the spectra to radial step and Rutgers is focusing on quality control of the radial files. Sara Haines presented results from their work at the ROWG meeting. Rutgers has been running the real time QC code since August 25, 2015. We will test the algorithm in the spring with a comparison to surface drifters provided by the Coast Guard Office of Search and Rescue.

We gave presentations and authored several papers using the surface current data during this progress period. They are:

1. Baskin, Roarty, Barrick, Whelan, Marxen, Gradone (2015) “High Frequency Radar Measurement Resiliency with Bistatics” OCEANS 2015, Washington DC, October 19-22, 2015
2. Forney, Roarty and Glenn (2015) “Measuring Waves with a Compact HF Radar” OCEANS 2015, Washington DC, October 19-22, 2015
3. Gradone, Roarty, Evans, Glenn, Handel, Baskin, Dusek, Paternostro “Assessing HF Radar Data in New York Harbor: Comparisons with Wind, Stream Gauge and Ocean Model Data Sources” OCEANS 2015, Washington DC, October 19-22, 2015
4. Updyke and Atkinson (2015) “Extreme and Non-Tidal Events in the Chesapeake Bay High Frequency Radar Surface Current Record” OCEANS 2015, Washington DC, October 19-22, 2015
5. Roarty (2015) “Repair and Hardening of Mid Atlantic Ocean Observing Assets After Hurricane Sandy, Mid Atlantic Bight Physical Oceanography and Meteorology (MABPOM) Meeting, October 28, 2015, Cape May, NJ

6. Roarty (2015) “Observations of the Surface Circulation over the Mid Atlantic Bight Continental Shelf”, Radiowave Oceanography Workshop (ROW), November 5, 2015, Woods Hole, MA.
7. Haines, Muglia and Seim (2015) “ New Radial QC Results” Radiowave Oceanography Working Group (ROWG), November 5, 2015, Woods Hole, MA

D) Underwater Gliders: The 2015 MARACOOS glider efforts were focused on the third annual Gliderpalooza. The overall goal of Gliderpalooza is to coordinate a range of ocean efforts, funded by disparate programs from a variety of agencies to demonstrate continental scale distributed ocean observing technologies to sample ecologically relevant scales. The integrated data is being used to serve a range of science goals while providing a regional data set for hindcast studies that can be used to improve physical, optical and ecological modeling/sampling efforts in the future.

The main goals of the Gliderpalooza efforts have been to 1) provide a unique data set the modelers can use for years to come; 2) provide a standardized dataset over ecological scales and information on fish/mammal migrations; 3) provide a 3-D snapshot of the Mid-Atlantic Bight (MAB) cold pool; 4) provide an extensive distributed instrumented network through the peak period of fall storms including hurricanes, demonstrating a community "surge" capacity; 5) provide a demonstration of the potential U.S. national glider network; 6) provide seamless flow of real-time glider data into the Global Telecommunications System (GTS) via DMAC and into the regional ocean models; 7) demonstrate an initial capacity for real-time evaluation of a distributed ensemble of ocean model forecasts using spatially distributed datasets; and 8) engage undergraduates in ocean observing efforts.

The 2015 Gliderpalooza included a total of 19 partners with 13 institutions in the US, 2 in Canada, 1 private company (Teledyne-Webb), and the U.S. Navy. From these 19 partners there were 22 individual gliders that performed 27 deployments between May and December. While this is lower than the 2014 deployments this is partly reflective of the lack of storm activity in the summer of 2015 as 4 CINAR Tempests gliders were not deployed in rapid response to tropical cyclones and are currently held in reserve for summer 2016. Additionally, this is also due to the increased use of long-duration lithium batteries in Slocum Gliders resulting in less total deployments but equal or more time at sea. Collectively we have had at least 593 data days in the water and 14 of these deployments were submitted to the IOOS DAC.

In addition to increasing datasets submitted to the IOOS DAC, we have also continued to develop QAQC guidelines for glider platforms. We have developed software to assign quality control flags to data being received from gliders in real-time for five QARTOD tests: gross range, climatological, spike, rate of change, and flat line. Thresholds for the gross range test are defined by the operational ranges of the sensors on the glider, and for the flat line test are either defined by the sensor’s resolution or assumed to be exactly zero. Thresholds for the climatological, spike, and rate of change tests were estimated based on past glider data for both the MAB summer and the MAB fall – we currently have thresholds for (where applicable) temperature, conductivity, pressure, salinity, density, and dissolved oxygen (currently only for summer). We are in the process of further developing the software to make it generalizable to other regions and seasons, and are looking at other non-glider data to verify and/or adjust our defined thresholds. We have also developed software to shift dissolved oxygen measurements in time to correct for the delay in sensor measurements, and software to correct spikes in derived salinity and density due to thermal lag issues.

One research highlight occurred between 27 June and 17 July 2015 when Glider Blue successfully measured the eastern end of the early season Mid-Atlantic Bight (MAB) Cold Pool. During the mission, Blue required piloting inshore out of the Leg-2 adverse currents due to a warm core ring (Figure 3). These measurements show that by late June-early July the Cold Pool is established. However, the exceptionally warm upper

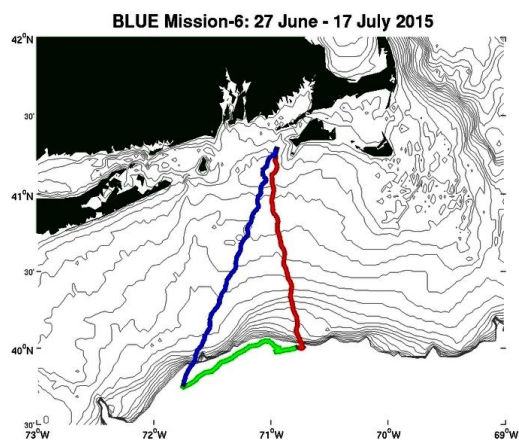


Figure 3. 27 June -17 July 2015 glider Blue trajectory with Legs -1 (red), -2 (green), and -3 (blue).

layer temperatures indicate that the Cold Pool is either being eroded or displaced by a warm core ring (Figure 4). The high salinities associated with the warm core ring appear to be infiltrating both the pycnocline and bottom boundary layer on the shelf proper. Maxima in the backscatter are seen in the bottom boundary layer on the shelf, while the chlorophyll maxima are seen both in the pycnocline and bottom boundary layer.

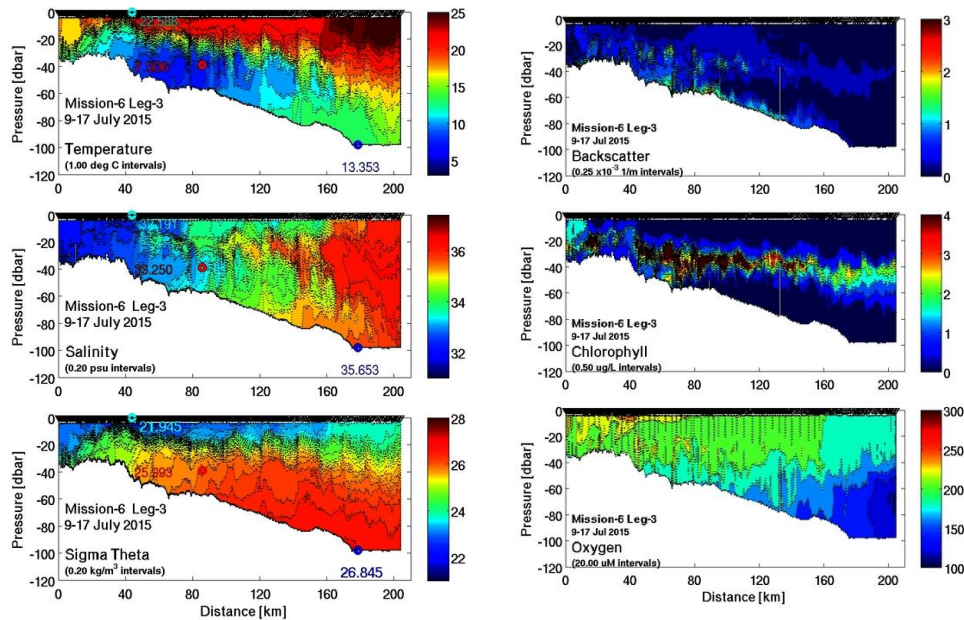


Figure 4. (LEFT panels) UMassD glider Blue’s Leg-3 (9-17 July 2015 - blue in Fig.3) color-coded water property sections with color-coded legends of the indicated units; (Top) Temperature section, in which the section-minimum temperature (T - red dot) and the temperature at both maximum (blue) and minimum density anomaly (cyan) are located; (Middle) Salinity section, in which the salinity associated with (a) minimum temperature (red); (b) maximum density anomaly (blue); and (c) minimum density anomaly (cyan) are indicated. (Bottom) Density anomaly (sigma-theta) section, in which the (a) maximum density anomaly (blue); (b) minimum density anomaly (cyan); and (c) density anomaly at minimum temperature (red) are presented. (RIGHT panels) Contoured (top) backscatter; (middle) chlorophyll; and (bottom) oxygen.

E) Satellites: Public Data Feeds and Infrastructure Updates:

MARACOOS continues to support expanded satellite coverage from the Gulf of Mexico, to Cuba to Newfoundland. We utilize de-clouded sea surface temperatures (SST’s) from the Rutgers University L-Band dish and post the data to a publicly available THREDDS server in a Climate Forecast (CF) netCDF format. The MARACOOS CF-compliant SST data feed, which began in 2005, is updated in near-real time (<http://tds.maracoos.org/thredds/SST.html>). These can now be accessed at greater speed due to computer infrastructure updates on the THREDDS server. This real-time SST data is also visualized via the MARACOOS Asset Map (<http://assets.maracoos.org>), in Google Earth (http://modata.ceoe.udel.edu/web_kmzs/), and via browser-based map services (<http://www.ceoe.udel.edu/our-people/profiles/moliver/orb-lab/real-time-sea-surface-temperatures>). MARACOOS is also deploying the JPL MUR SST product to our users. It is a gap-filled, 1km product but has

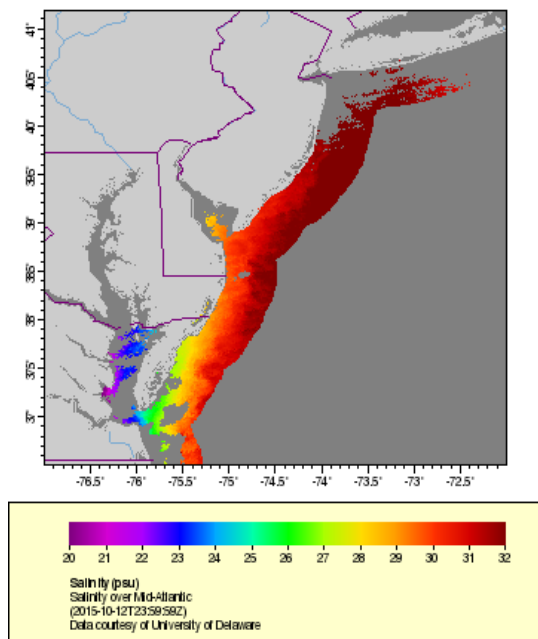


Figure 5. Test Ocean Color salinity product

a latency of 1-2 days. (<http://tds.maracoos.org/thredds/SST.html?dataset=MURSST-Agg>). The UDel ocean color processing creates a real-time CF-compliant netCDF4 ocean color data feed, which is being updated in near-real time (<http://tds.maracoos.org/thredds/MODIS.html>). Ocean color data is now processed with NASA SeaDAS instead of the NRL APS system. The ocean color THREDDS feed includes 39 ocean color-related products, including estimates of the inherent optical properties, which are critical for understanding the coastal ocean. The ocean color record covers 2002-present. We have also deployed a provisional coastal salinity product based on ocean color data (Figure 5) on a test ERDDAP server (<http://128.175.28.250:8080/erddap/griddap/MidATLsalinity2.graph>), and expect this to be deployed on the MARACOOS THREDDS server soon.

Data streams from VIIRS are currently being evaluated. The data processing stream has been ported to the University of Delaware Mills Super Cluster for satellite data processing. This has significantly increased the speed of data delivery. Data from the UDel Geo-Stationary satellite receiving dish is available on the web, and is now on an experimental THREDDS server hosted at UDel:

(<http://thredds.demac.udel.edu/thredds/catalog.html?dataset=GOESSSTAggregate>).

Rutgers is continuing to acquire a 28 year AVHRR data set from the NOAA CLASS website. Rutgers is downloading the five channel level-1 data in order to enable reprocessing of SST data using a coldest pixel algorithm. This new algorithm maintains accurate upwelling center temperatures during summer as compared to current standard SST products such as SPORT composites which eliminate the daily localized cold centers of east coast upwellings. This data set will also serve numerous studies including but not limited to long term climate studies and hindcasting for physical and ecological models. Real-time acquisition and coldest pixel composites are continually being generated in near-real-time for use in atmospheric modeling.

F) Dynamic Models: Rutgers continues development of an expanded Gulf of Maine and MAB ROMS model to succeed the present ESPreSSO system. The prototype system – termed “DOPPIO” – has encountered difficulty assimilating coastal corrected altimeter data from AltiKa in the Gulf of Maine. Approaches are being sought to QC these data aggressively for use in the real-time system. Jason-2 altimeter data remain reliable, but the inclusion of data from AltiKa and CryoSat is highly desirable. In addition to AVHRR SST, the DOPPIO system was assimilating microwave SST from WindSat until the instrument became unreliable in September. It has been dropped from the assimilation data stream and replaced with AMSR-2 SST, which became accessible from PO-DAAC. With each change in assimilation data sets experimentation is required to develop a robust acquisition and QC system, and to characterize observational errors in the context of ROMS 4DVAR assimilation. The schedule for replacing ESPreSSO with DOPPIO as the ROMS MARACOOS real-time system has been pushed back to June 2016 at the earliest.

The multiscale operational forecasts with SMAST-HOPS model continued with SST assimilation during June 2015 through December 2015. During this period, Mr. M. Monim, a new graduate student has been running the forecast system by himself with occasional support from Dr. Andre Schmidt, who has transitioned into his new position of System Administrator at SMAST. Monim’s research will utilize the assimilative forecasts (and hindcasts) to understand the seasonal impact of Warm Core Rings on the shelf. Monim has successfully implemented a process of assimilating ARGO observations in real time, which is now operational from October 2015 for the SMAST-HOPS. Scientific analysis of impact of Argo assimilation on the forecasts has just begun. During the next six months, we plan on incorporating the new WOA13 climatology as the background for the FORMS system.

In a related effort, past six years (2009-2015) of Gulf Stream north wall (GSNW) and eddy locations are being used to develop an automated method of identifying the GSNW and Rings. This automated methodology (based on utilizing AVISO SSH anomaly fields) has been tested to identify the GSNW and used for couple of forecasts during October 2015. UMass Dartmouth presented preliminary results from this work in the Oceans’15 meeting in DC. Finally, a quantitative skill assessment for the model after recent improvements with regional climatology and Argo assimilation will be carried out. This assessment will utilize the recently developed MARACOOS DMAC framework, which provides a suite of archived, near-real time and real-time observational information from multiple sensors including Buoys, Drifters, HF Radar fields, Gliders and fixed platforms.

As a prelude to the 2016-2018 efforts, a WCR census effort has been started while initiating the metadata creation of the 40 years of Gulf Stream charts donated by Jenifer Clark to the Ocean Modeling and Analysis Laboratory at UMass Dartmouth. This effort will be expanded to include CCR, GS axis and water mass characteristics of the MAB, GOM waters so that it can be utilized for validating multiple model simulations and understanding past changes in these regions.

A significant milestone was reached in the large ensemble modeling effort underway at the Davidson Laboratory of Stevens Institute of Technology (SIT) to predict combined overland flooding from inland rain and coastal tide and surge – as well as other parameters such as waves, river discharge, currents, water temperature, and salinity – with increased accuracy. Three new ensemble forecast systems were developed and deployed operationally in late 2015; two hydrodynamic ensembles based on the sECOM 3D model, and one hydrologic ensemble based on the HEC-HMS model, all running 125 members per ensemble, four cycles a day; including forcing from GEFS, SREF, Rutgers WRF, CMC, NAM, and ECMWF. Communications on NOS' ability to host and disseminate the NYHOPS output on the CO-OPS' Tides and Currents website are reaching conclusion. Encouraging preliminary results from branching (event-specific) ensembling techniques and the validation of the ensemble predictions will be presented at the next AMS meeting in New Orleans in early January 2016. The first operational transition to the new ensembles was for the well-known SSWS, henceforth called the Stevens Flood Advisory System (www.stevens.edu/SFAS; more details in http://hudson.dl.stevens-tech.edu/sfas/SFAS_Latest_News.pdf).

A heretofore undocumented example of the benefit of our forecasts to stakeholders is the use of the NYHOPS model by the Hudson River Fisheries Unit of NYSDEC. The NYHOPS 3D hydrodynamic model includes local river discharges and stream flows, tides, and atmospheric conditions, predicting the mixing of the oceanic and fresh water masses within mid-Atlantic estuaries. Thus, not only is the model used to safely plan boat surveys during model-predicted calm wave conditions and appropriate tidal stages, but NYSDEC Fisheries uses NYHOPS to track the day-to-day placement of the Hudson River's salt front, which is an important input into NYSDEC's relative abundance modeling for the endangered juvenile Atlantic Sturgeon in the spring. Based on field-sampled salinities since 2011, NYSDEC has determined that the NYHOPS model has been 95% accurate in predicting whether their sample points are within the salt wedge or not. The outstanding NYHOPS model's skill in salt wedge placement at the bottom of the Hudson is underscored by it being overall 13% more accurate than a real-time-data-based USGS regression model during the last two spring sampling periods (Robert Adams, NYSDEC, personal comm.).

G) DMAC: Please see the supplemental report for the DMAC update.

H) Education and Outreach: With additional support from NSF, the Education and Public Engagement (EPE) team continues to focus is on the integration of time series data into undergraduate teaching. We are organizing an intensive hands-on workshop focused on developing effective teaching with data practices using MARCOOS data assets and OOI data visualizations tools. We will engage diverse institutions, including community colleges, Primarily Undergraduate Institutions (PUIs), Minority-Serving Institutions (MSIs), research laboratories, and larger research universities, as well as a team of pedagogical experts to review a series of sample lessons developed by the RU team, on biological productivity and energy transfer. We are currently working on developing learning objectives and activity outlines of five data investigations that could be developed with OOI & MARCOOS data.

The Rutgers Education and Outreach team just completed a crosswalk of the presence of OOI and MARCOOS science themes presented in popular introductory textbooks used in oceanography courses. We propose to compare IOOS themes and concepts and popular published textbooks to triangulate where MARCOOS data investigations/activities can be woven into existing courses.

Finally, we have been working with the Lawrence Hall of Science and Western Washington University to develop a college course using data to teach climate change. We expect to roll out the course in the fall 2016. It is currently being piloted in four pre-college programs in LA and CA.

D) Economic Benefits: **MARITIME SAFETY:** Navy Fleet Weather Center Norfolk: MARACOOS in a coordinated effort with SECOORA, supported Fleet Weather Center Norfolk at Naval Station Norfolk with an updated website during this hurricane season, providing additional Navy-identified information to support weather-related decision making for the fleet that can contribute to protection of property and cost-saving efforts.

NOAA COOPS PORTS: MARACOOS has worked with NOAA COOPS to include surface current data into NOAA PORTS as a product to serve the maritime pilots and navigation community in New York / New Jersey Harbor and the Chesapeake Bay approaches. Although the specific economic benefit is difficult to assess, it is reasonable to assume a risk reduction and complementary advantage to mariners in their efficiency, reduction of loss, and bottom line operating expenses, resulting in an economic advantage to the transportation and commerce sectors operating in those port areas. The Port of NY/NJ supported \$207 billion in cargo value in 2014, while the ports of VA/MD supported \$119 Billion of total cargo value.

NOAA NWS AWIPS 2: MARACOOS surface current data are flowing into NWS AWIPS II to support WFOs in their forecast products. While it may be difficult at this stage to assess specific economic benefits, it is reasonable to assume that enhanced weather forecast products provide a reduced risk profile for a positive impact on weather-dependent industries and the corresponding economic performance.

ECOLOGICAL DECISION SUPPORT: NOAA NMFS: The partnership between MARACOOS, NOAA NMFS, and the fishing community resulted in a multi-million dollar net economic gain to the industry as a result of the newly instituted butterfish directed fishery. The successes in the butterfish fishery resulted in new conversations in the area of mackerel during this reporting period. A clear economic benefit is on the horizon for this fishery, which previously landed approximately 60,000 tons annually.

WATER QUALITY / ECOLOGICAL DECISION SUPPORT: NOAA NMFS: MARACOOS is supporting the multi-million dollar shellfish industry in the Long Island Sound region, leveraging its relationships with the shellfish industry and state and federal sanitation regulators (NESSA and FDA) and resource managers to assist in identification of a suite of low-cost sensor network deployments, with the data to be managed and served by MARACOOS. Initial effort in LI Sound is to support development of a Water Quality monitoring network to inform the *Vibrio parahaemolyticus* (Vp) predictive model developed by NOAA NCCOS and FDA. This is in collaboration with UCONN, State of CT Bureau of Aquaculture, CT Sea Grant and the local shellfish industry—an industry of approximately \$30 million annually and 300 employees. Next steps include collaborating with NERACOOS to identify existing WQ monitoring capabilities and data streams that can be ingested into a serving system and to understand the process used to stand up NECAN, as a possible model of the region-wide *Vibrio* forecasting and monitoring network.

COASTAL INUNDATION: NOAA NOS: MARACOOS has been engaged by partners, Old Dominion University and Virginia Institute of Marine Science to serve as a data integrating agent in support of the Hampton Roads Sea Level Rise Intergovernmental Pilot Project. The projected economic benefits associated with a reduction in loss can only be partially attributed to the data collection and integration efforts of MARACOOS. While the system is not yet up and running, collaboration discussions continue, with strong involvement from NOAA NOS, especially COOPS, and involvement from Sea Grant, State and local agencies, and other federal partners.

NOAA NOS: MARACOOS partner, SIT has leveraged MARACOOS investments to secure significant additional resources from the Port of New York and New Jersey to advance its storm surge model and predictions, which will greatly benefit the safety and economic security of the region. Further, an agreement was reached between COOPS and Stevens for COOPS to ingest NYHOPS model outputs into COOPS products, which would further enhance NOAA products and the economic benefits they provide to the maritime transportation sector.

OFFSHORE ENERGY: NOAA NMFS / DOI BOEM: MARACOOS is leading the development of a Mid-Atlantic Animal Telemetry Observing System (MATOS) in collaboration with partners in the Mid-Atlantic, including NOAA NMFS Chesapeake Bay Office and BOEM. BOEM is interested to identify species in support of assessments for industry wind farm siting. Reducing uncertainty in the management process will allow enhance economic opportunities for the emerging wind energy industry in the Mid-Atlantic.

J) CBIBS Buoys: The Chesapeake Bay Interpretive Buoy System is being used as a development tool for MARACOOS support of fixed platform time series data, including Web Services (SOS), QARTOD QA/QC

recommendations, and provision of data to Federal agencies. The CBIBS Data Acquisition software is now running on the Applied Science Associates cloud, and a new CBIBS database with Web Services has been constructed, populated with historical data, and being updated in real time.

NOAA, MARACOOS, and ASA are jointly participating in IOOS DMAC QARTOD conference calls, and are seen as the lead RA in implementing QARTOD standards. Data are served via IOOS-standard SOS web services, and QARTOD QA/QC is being applied in real time. Through MARACOOS, ASA has been tasked with developing a complete end-to-end system for collecting, quality checking, archiving, and delivering CBIBS data, as well as documenting the system for IOOS certification purposes. CBIBS Buoy data now appear in full on the MARACOOS

Asset Map directly from the QC¹d database (as opposed to coming through NDBC), making access more timely, accurate, and complete. Discussions proceed with NCEI on ways to archive QARTOD flags, again leading RA activities in this field. In addition to CBIBS physical data, the database will support collection of Acoustic Tag data from the CBIBS system in support of the Mid-Atlantic Acoustic Tagging Observation System (MATOS), a component of the IOOS Animal Tracking Network.

MARACOOS continues to provide support for CBIBS long-term planning and operations and maintenance, as well as expanding operational and forecasting activities in the Chesapeake Bay. Discussions have been held with Chesapeake Bay Program, shellfish user groups, and ecological forecasters to integrate CBIBS data into their activities and to look at new observing assets and tactics to improve Chesapeake Bay management products. NOS CO-OPS routinely uses CBIBS real-time surface salinity observations to correct the CBOFS hydrodynamic model used for Chesapeake Bay PORTS.

K) QARTOD: MARACOOS continues to work toward implementation of QARTOD manuals as a replacement and/or enhancement of existing QA/QC processes, including in support of MARACOOS' certification application due next period.

The MARACOOS ASA CBIBS data management initiative is presently applying recommended tests from the following QARTOD manuals, and delivering quality controlled data with QARTOD-recommended (Manual for Oceanographic Quality Control Flags) flags: Wind Data, in situ Surface Wave Data, Ocean Optics Data, Temperature and Salinity Data, Dissolved Oxygen in Coastal Oceans, and in situ Current Observations. MARACOOS PI Doug Wilson serves on the IOOS DMAC QARTOD working group.

3) SCOPE OF FUTURE WORK

There is no expected change in the scope of future work until the new proposal is funded in June 2016.

4) LEADERSHIP PERSONNEL AND ORGANIZATIONAL STRUCTURE

The total Board complement is currently at 17 with the potential for up to 1 additional board-appointed member in the future. No changes to the Board make-up occurred during this period. However, a new position was created on staff, a program coordinator, and Kathryn Hickey was hired in the position to carry out administrative duties and communication activities. An intern associate (Katie Liming, a UDel Junior) carried out social media support activities. It was decided to transition Grace Saba (Acting Technical Director) in a new role supporting innovation strategies, and return Mike Crowley back into the role as Technical Director in the coming period.

5) BUDGET ANALYSIS

The total budget for years 1 through 5 is \$13,538,876. Year 5 subcontract totals for the 18 subcontracts and Rutgers, the prime, are shown in Table 3. Current balance remaining for the lead and all subcontracts as of December 2015, is shown in the right hand column. Note that many of the subcontractors billing lags

DISTRIBUTION	BUDGET	EXPENSES	REMAINING BALANCE
Rutgers	\$ 4,249,022.00	\$ 3,524,883.13	\$ 724,138.87
Applied Science Associates Inc	\$ 1,908,205.00	\$ 1,469,281.94	\$ 438,923.06
Caribbean Wind LLC	\$ 540,000.00	\$ 365,674.34	\$ 174,325.66
Center for Innovative Technolo	\$ 254,458.00	\$ 207,763.04	\$ 46,694.96
Old Dominion	\$ 58,641.00	\$ 57,770.22	\$ 870.78
Old Dominion Univ Research Fou	\$ 55,000.00	\$ 50,295.27	\$ 4,704.73
Old Dominion University	\$ 627,915.00	\$ 450,662.11	\$ 177,252.89
Stevens Institute of Technolog	\$ 415,012.00	\$ 300,775.84	\$ 114,236.16
University of Connecticut	\$ 425,254.00	\$ 304,944.52	\$ 120,309.48
University of Delaware	\$ 467,868.00	\$ 317,045.31	\$ 150,822.69
University of Delaware	\$ 114,099.00	\$ 67,390.97	\$ 46,708.03
University of Delaware	\$ 2,320,810.00	\$ 2,047,188.01	\$ 273,621.99
University of Maryland	\$ 283,719.00	\$ 245,124.58	\$ 38,594.42
University of Massachusetts Da	\$ 1,136,949.00	\$ 817,038.56	\$ 319,910.44
University of North Carolina C	\$ 17,783.00	\$ 1,136.91	\$ 16,646.09
University of Rhode Island	\$ 146,648.00	\$ 80,052.94	\$ 66,595.06
VIMS	\$ 12,000.00	\$ -	\$ 12,000.00
WeatherFlow Inc	\$ 415,493.00	\$ 355,217.70	\$ 60,275.30
Woods Hole Oceanographic Insti	\$ 90,000.00	\$ 47,032.01	\$ 42,967.99
Total	\$ 13,538,876.00	\$ 10,709,277.40	\$ 2,829,598.60

several months, so these totals are not indicative of the total spent to date.

Table 3. MARACOOS years 1-5 budget distribution with total and remaining budget listed for the prime and all subcontractors.