

Repair and Hardening of Mid-Atlantic Ocean Observing Assets After Hurricane Sandy

NOAA Award No. NA14NOS4830003

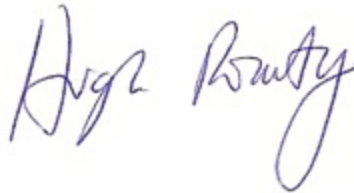
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A handwritten signature in blue ink, reading "Hugh Roarty".

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INTRODUCTION

Seventeen High Frequency radars were damaged within the Mid Atlantic Regional Association Coastal Ocean Observing System when Hurricane Sandy passed through the region in October 2012. The objective of this work is to repair and harden these observing system assets as well as some computer and ADCP assets lost during Sandy. The benefits of this work will increase the coverage and data quality of the surface current measurements in the region. The US Coast Guard uses the surface currents operationally for search and rescue, and the NOAA Office of Response and Restoration uses them for oil spill response. Other users of the data include New Jersey and Massachusetts Department of Environmental Protection offices, county health offices and Mid Atlantic Fishery Management Council. The technical networks that will be leveraged are the Mid-Atlantic Regional Association Coastal Ocean Observing System, NOAA National High Frequency Radar Network, DHS National Center for Secure and Resilient Maritime Commerce and the NJ Board of Public Utilities Radar Network.

Dr. Hugh Roarty and Mr. Colin Evans prepared the report.

1. PROGRAM INFORMATION AND HIGHLIGHTS

During the 3rd quarter of 2014, the following progress was made:

A. Procurement

All of the equipment delivered by CODAR arrived before the end of the 2nd quarter. During the 3rd quarter, focus shifted towards resiliency and equipment needed to better maintain the radars with the following purchases: 1. UPS systems that can handle 2200 W of load capacity were purchased for the dual transmit sites and also for locations that have two sites running out of one enclosure. 2. A Rutgers technician attended a one-day grounding class for communication systems in Reading, PA to improve knowledge in properly grounding coastal radar electronics. 3. A one day CODAR retreat took place on September 15th, 2014 to discuss future resiliency and improvement plans for Sandy affected sites. Much progress has been made with installing the new equipment and also planning resiliency practices for the future to harden the network.

B. Site Installations

The equipment delivered in batches two and three has been installed at six sites during the three-month period between July and September 2014. Two full sites were installed in Seaside Park, NJ and Port Monmouth, NJ. Three combined antennas/cables were installed in Brigantine, NJ, Brant Beach, NJ, and Staten Island, NY. One dual transmit system upgrade is nearly finished in Loveladies, NJ. During the third quarter of 2014 the following progress was achieved:

1. Installation of full 13 MHz system in Seaside Park, NJ (SPRK)
2. Installation of full 25 MHz system in Port Monmouth, NJ (PORT)
3. Installation of 13 MHz combined transmit/receive antenna in Brant Beach, NJ (BRNT) and Brigantine, NJ (BRMR).
4. Installation of 25 MHz combined transmit/receive antenna in Staten Island, NY (SILD).
5. Continued efforts in dual transmit upgrade at LOVE.
6. AIS-pattern generation software installed on sites: SPRK, BRNT, BRMR, SILD, HOOK, and HOMR.
7. Data analysis and QA/QC checks of SPRK, PORT, BRNT, BRMR, and SILD.
8. Different methods of antenna calibrations.

Included in the following sections on the next page are photos of the new site installations and upgrades. Each site shows the new hardware (SeaSonde antenna, AIS antenna, or SeaSonde chassis), :

1. Seaside Park, NJ (SPRK)



2. Port Monmouth, NJ (PORT)



3. Brant Beach, NJ (BRNT)



4. Brigantine, NJ (BRMR)



5. Staten Island, NY (SILD)



6. Loveladies, NJ (LOVE)



B. Site Inventory

As a way of keeping a record of all of the serial numbers located at each site, Rutgers created a spreadsheet as a method of organization. Every month has an inventory tab to assist in tracking when equipment was swapped and also when a piece of equipment gets sent back to CODAR for repairs.

The next page shows the inventory list of equipment and software keys installed up to the end of September where the third quarter ends. The highlighted rows indicate the sites being repaired due to the damage from Sandy. On the bottom of the sheet is a list of spare equipment, along with current RMAs that are in the process of being repaired by CODAR. There were some equipment malfunctions that halted progress with the dual transmit system at LOVE and also the site installation at SPRK. The RMAs included the LOVE dual transmit receiver that suffered a problem with the module that communicates with the second transmitter, a receiver front panel board issue at SPRK, and a resistance problem with the SPRK dome antenna on loop two. While new equipment was being repaired by CODAR, available spare equipment was installed to keep the sites running.

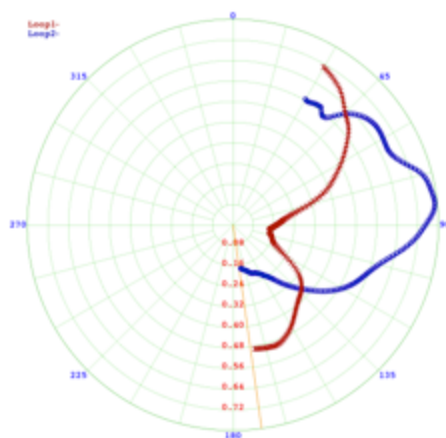
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C. Antenna Calibrations

Antenna pattern calibrations were performed at seven of the sites to correct for bearing errors at the radial level. Walking, boat, and AIS-generated patterns will be compared in the following sections. Loop 1 is depicted as the red line and loop 2 is shown as the blue line.

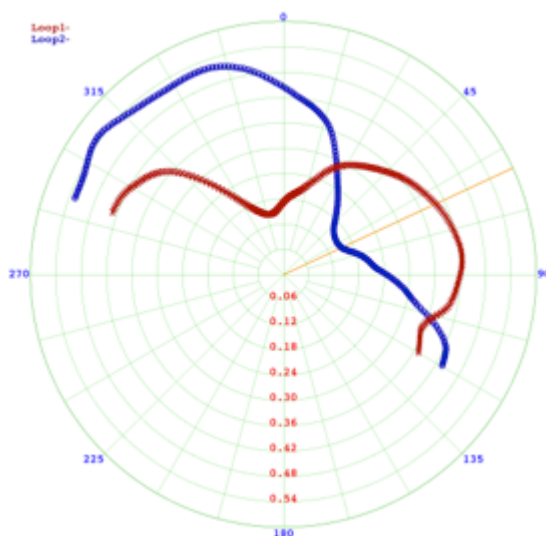
1. SPRK

a. This beach is a popular spot for the summer so we relied on the AIS equipment to assist in an antenna pattern measurement. After more than a week of vessel hits, we generated this pattern:

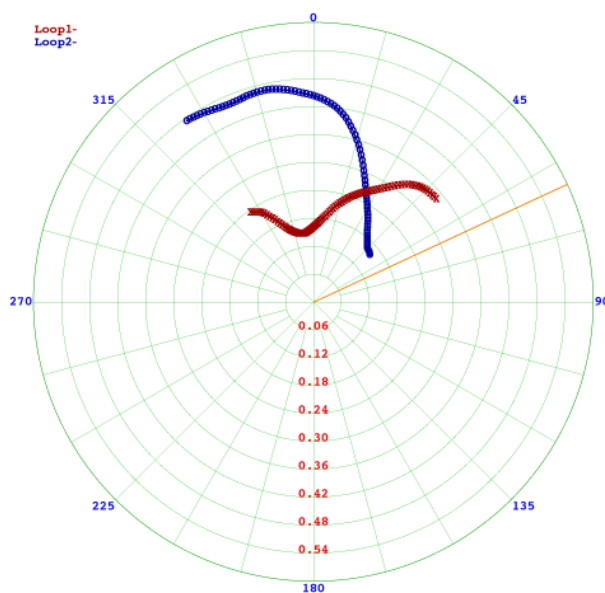


2. PORT

a. A walking antenna pattern measurement was performed with the new site equipment on August 19th, 2014. Below is the measured pattern:



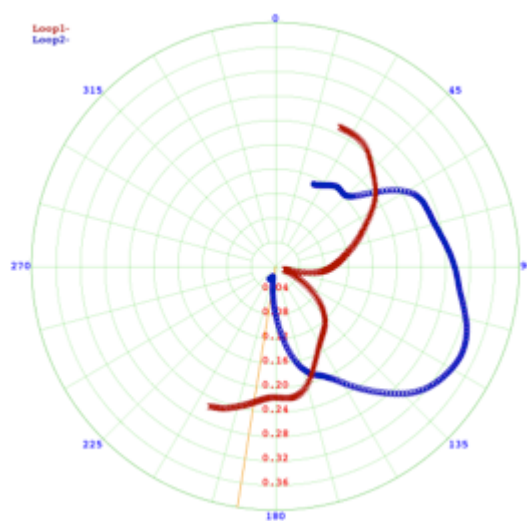
b. A boat calibration was also performed on August 28th, 2014. Below is the measured pattern:



The boat pattern measurement was difficult to perform because the boat was not able to move the transponder close to shore with the shallow bathymetry. This is seen as the measurement for loop 1 stops at 45 degree bearing while the walking pattern extends to 120 degree bearing.

3. BRNT

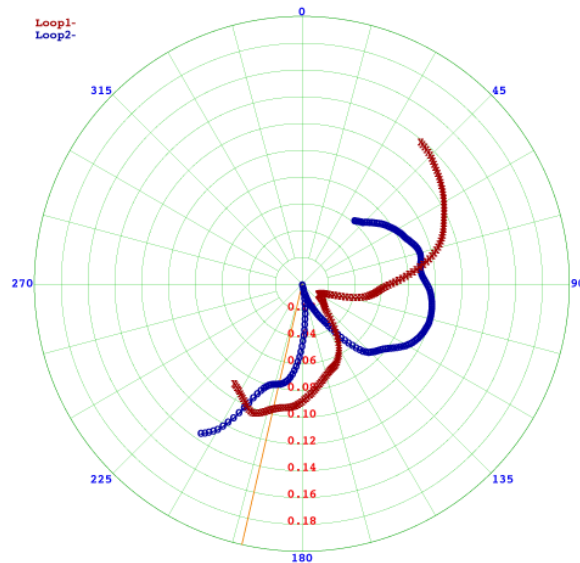
a. A walking antenna pattern measurement was performed on October 1st, 2014. The measured pattern is displayed below:



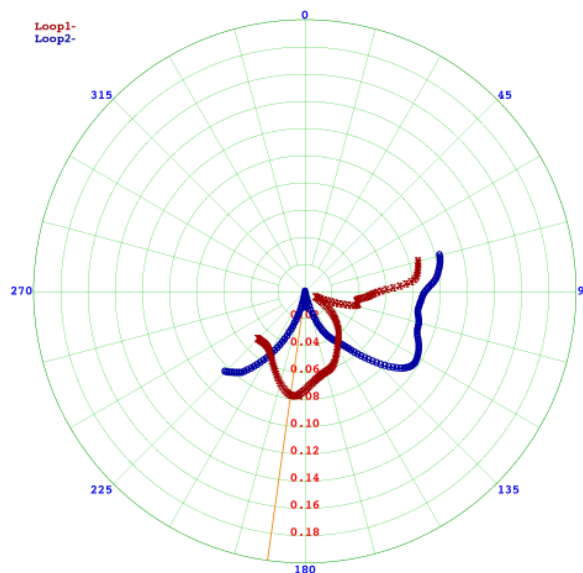
A new AIS with APM-generation software was recently installed at this site and a pattern will be processed once enough loop files are created.

4. BRMR

a. A walking antenna pattern calibration was performed on August 26th, 2014 and is displayed below:



b. Another pattern was measured using the AIS software package and is currently installed in the configurations folder on site:



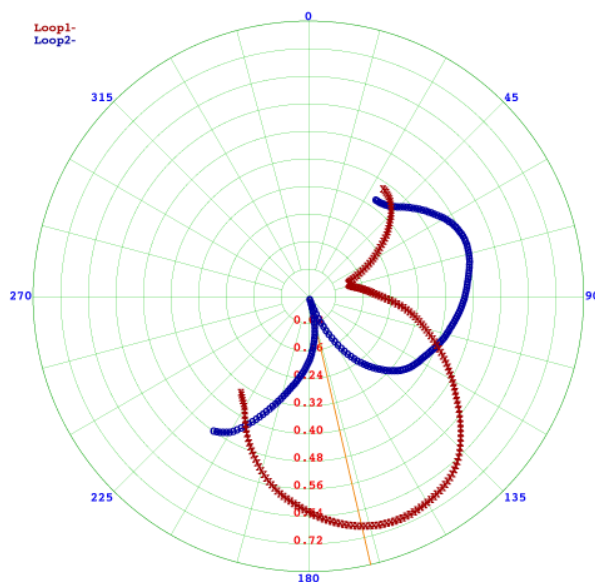
For a period of time, the AIS pattern-generation software was not working properly and this problem was reported to CODAR via phone call on September 19th, 2014. There was an issue with the webserver agent starting up on the daily computer

reboot. The fix has since been implemented on this site (as well as all other sites running AIS pattern-generation software).

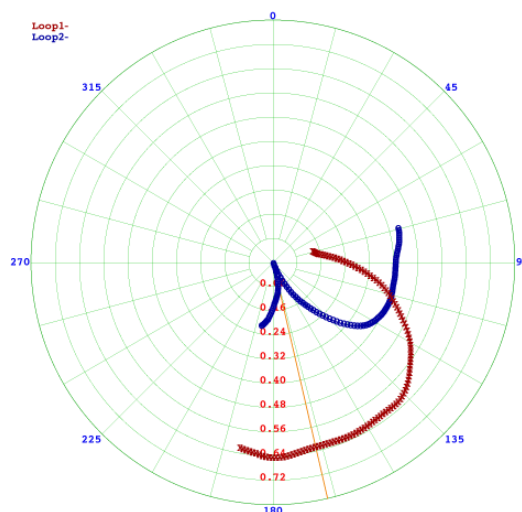
5. SILD

We were able to perform all three types of calibration methods for this site and future work consists of analyzing the patterns and data quality.

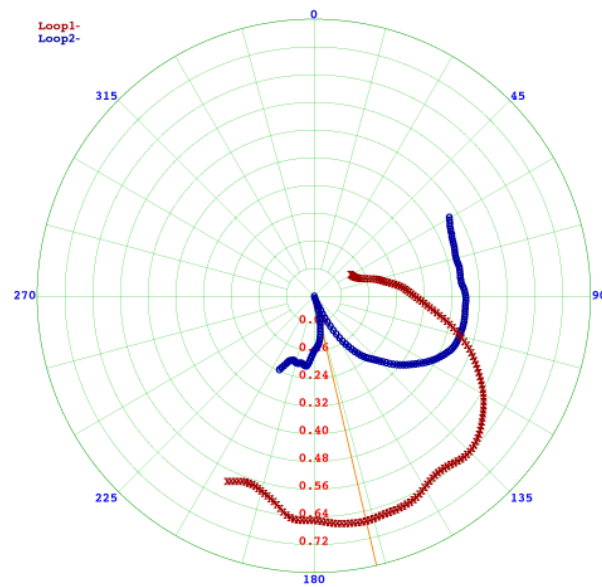
a. A walking antenna pattern measurement was performed on August 26th, 2014 after the new antenna installations. The pattern is displayed below:



b. Two days later (August 28th, 2014), a boat pattern measurement was performed:

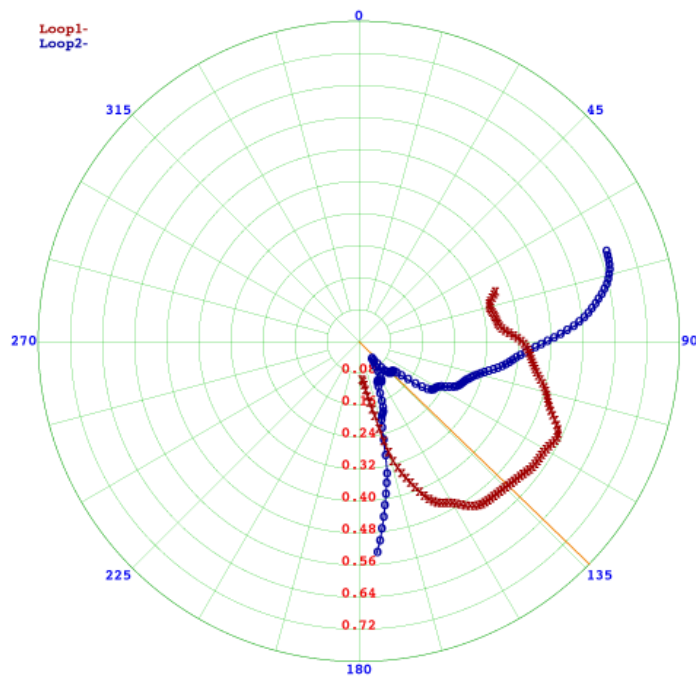


c. We also measured a pattern with the AIS software on August 20th, 2014.



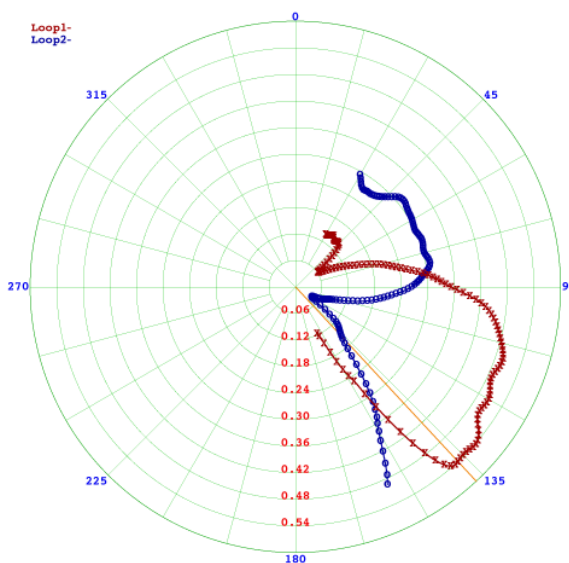
6. HOOK

An AIS-generated pattern was installed on September 2nd, 2014 after the installation of the new dual transmit equipment. Although the installation was completed in the previous quarter, an antenna pattern wasn't measured until this quarter. The following figure displays the current AIS-generated pattern installed on site:



7. HOMR

An AIS-generated pattern was measured for the 13 MHz site in Sandy Hook, NJ on August 12th, 2014. HOMR previously had a walking pattern measurement executed in a previous quarter and the AIS-generated pattern is currently installed on site. Below shows the pattern:



Below is a table that indicates the report that included that particular antenna pattern measurement type. For instance, the walking pattern for HOOK was published in report 3 and the AIS generated pattern was published in this current report. The entire table will be filled out by the end of the project.

Antenna Pattern Measurement Type

		Walk	AIS	Boat
1	MVCO			
2	HEMP	3	3	
3	HOOK	3	4	
4	LOVE			
5	SILD	4	4	4
6	BELM			
7	BRNT	4		
8	BRMR	4	4	
9	PORT	4		4
10	SEAB	3	4	
11	SPRK		4	

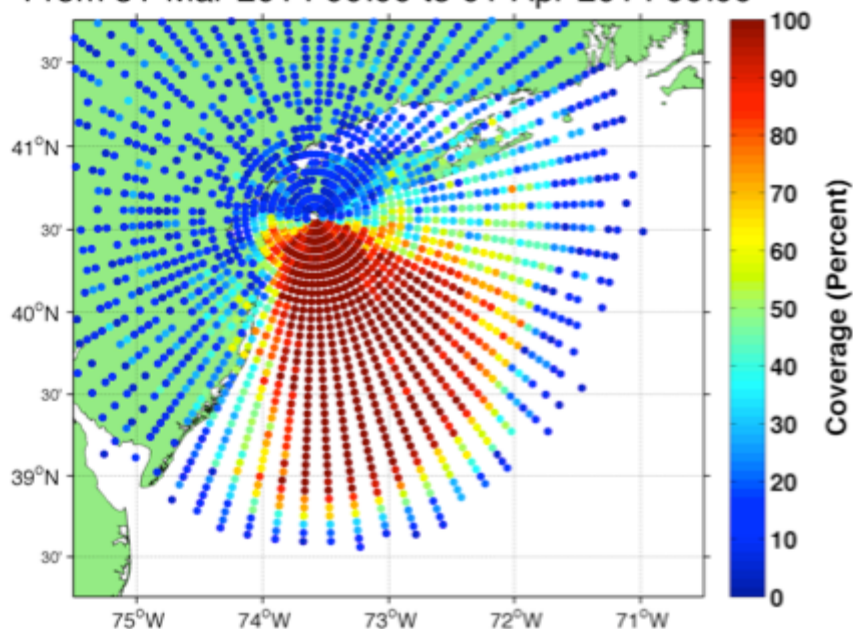
D. Data Quality

Several QA/QC methods are implemented to analyze the quality of the data reaching Rutgers and the National Network. Radial vector count, average radial velocities, radial coverage, and data latency are just a few qualities that are examined to determine how well a site is operating.

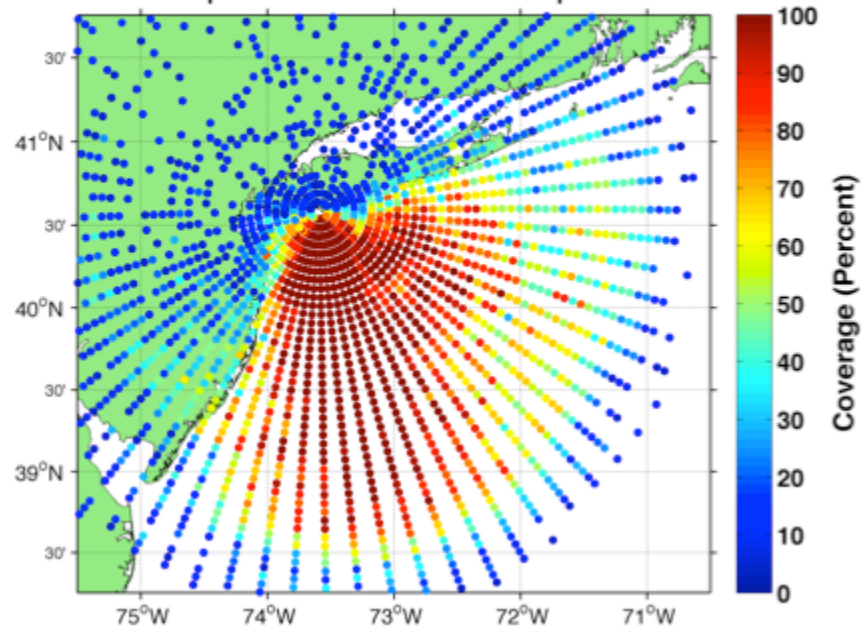
1. Dual Transmit Data Analysis

The purpose of the dual transmit upgrade at HEMP is to extend the range in coverage. The range extension improved from an average of 230 km to 250 km when the site is operating well. The site must be properly tuned in order to accurately measure the phase offset between the two transmit antennas in order to get the maximum range extension possible. The next page shows the comparison in coverage before and after (respectively) the dual transmit install and phase offset measurements were completed.

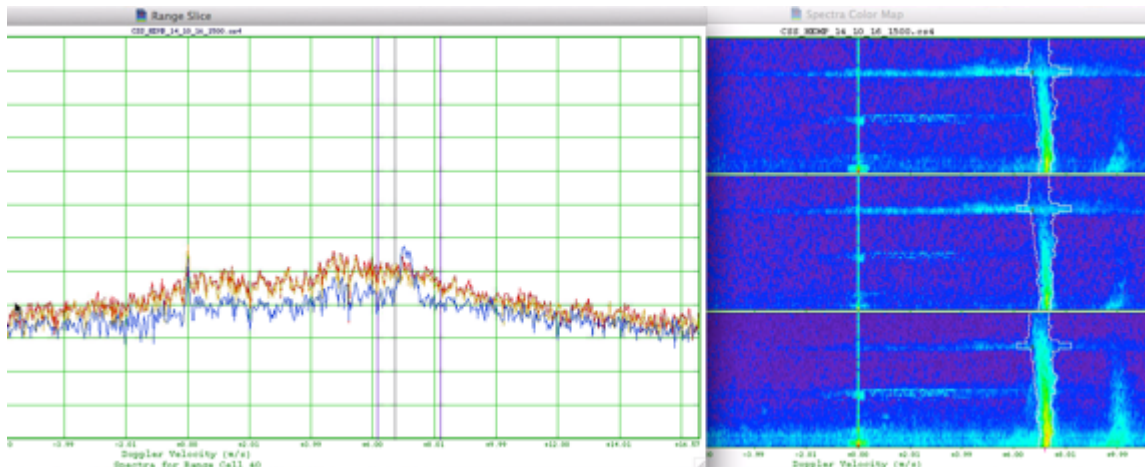
HEMP RDLi Coverage, 25 of 25 possible hourly maps
From 31-Mar-2014 00:00 to 01-Apr-2014 00:00



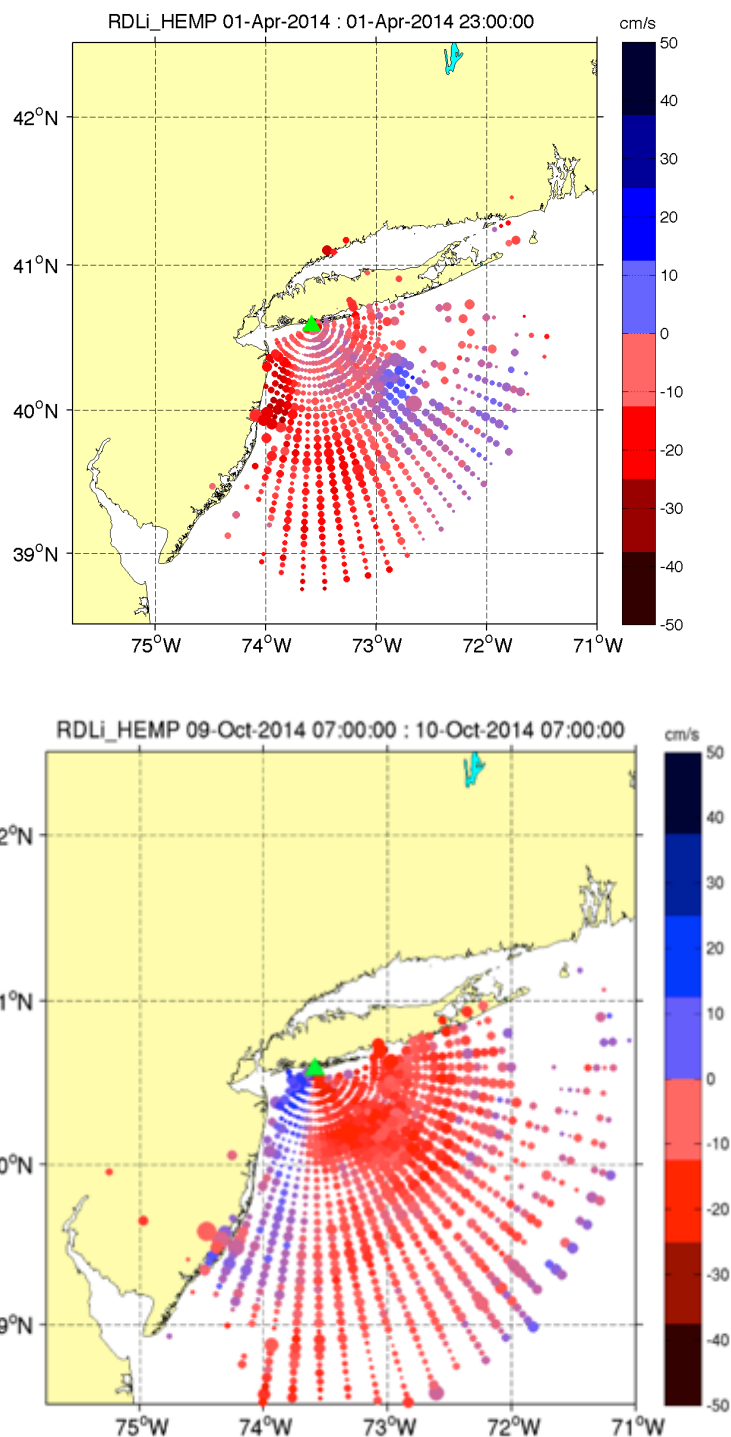
HEMP RDLi Coverage, 25 of 25 possible hourly maps
From 22-Sep-2014 00:00 to 23-Sep-2014 00:00



The one issue we've encountered with the dual transmit upgrade is the potential for more interference from other sites transmitting at the same frequency. When such bistatic interference occurs, it can potentially be processed as first order Bragg scatter (as shown in the figure below) and it is often evident with the appearance of strong, anomalous vectors. The bistatic interference seen at HEMP is commonly found in range cells 40 and 41 (shown below). We are working with CODAR to set the GPS alignments properly to improve timing and reduce the interference.



The standard deviation for each radial vector was calculated and plotted below before and after the dual transmit upgrade, respectively



The plots show the average radial velocities (color bar) associated with the standard deviation (size of dot) for each range and bearing. The color scheme indicates whether the vector is moving toward (blue) or away (red) from the radar. A smaller dot indicates a lower standard deviation and a higher standard deviation is represented by a larger dot. One of the advantages of having a dual transmit system is the consistent coverage in range cells 200-230 km offshore. These were once the very outer range

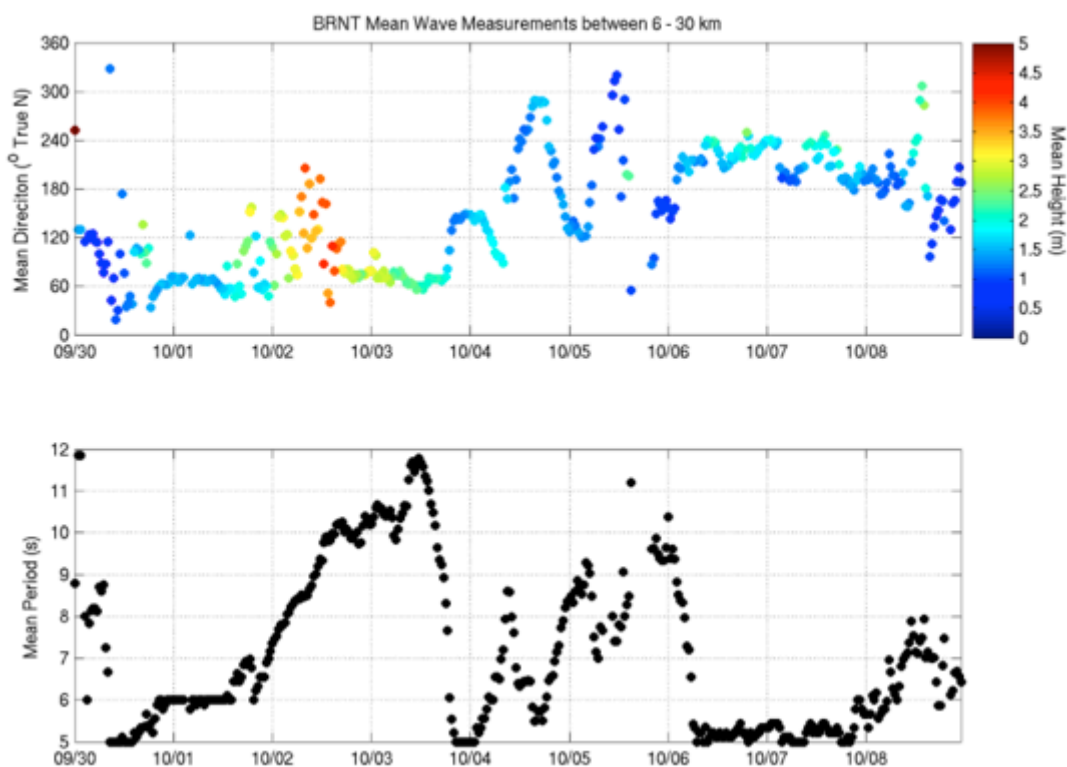
cells for the normal long-range HEMP site and, depending on the sea-state, would typically show high standard deviations. It is not uncommon to lost coverage in the last few range cells where the signal does not always propagate out that far, but with the installation of the second transmit unit there is consistent coverage because of the extended radar signal.

2. Wave Measurements

The radars have been setup to monitor wave energy as well. Rutgers has a page that updates everyday displaying a time-series of the last week of wave measurements. These plots can be seen here:

<http://marine.rutgers.edu/~cevans/MARACOOS/Waves/13MHz.php>

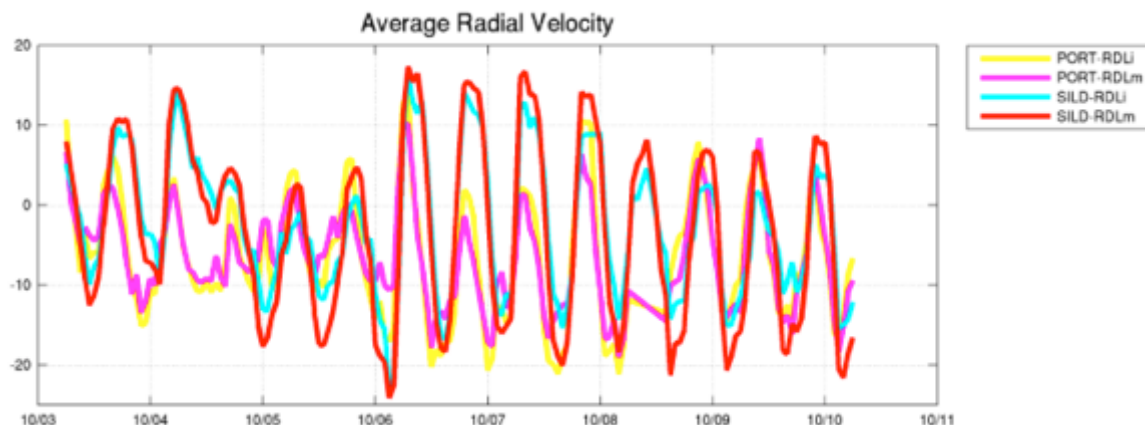
Wave height, direction, and period can be depicted from second order Bragg measured by the radar. Below is an example of a time series plot from a mid-range site located in Brant Beach, NJ (BRNT):



The range in wave measurements varies depending on how far the second order Bragg extends off shore. These plots will be improved in future analysis to clearly display if shallow water in the closer range cells is affecting the data. Rutgers is working on programming a 3D animation to display wave height measurements overlaid on top of a bathymetry map, along with improvement in the time series plots.

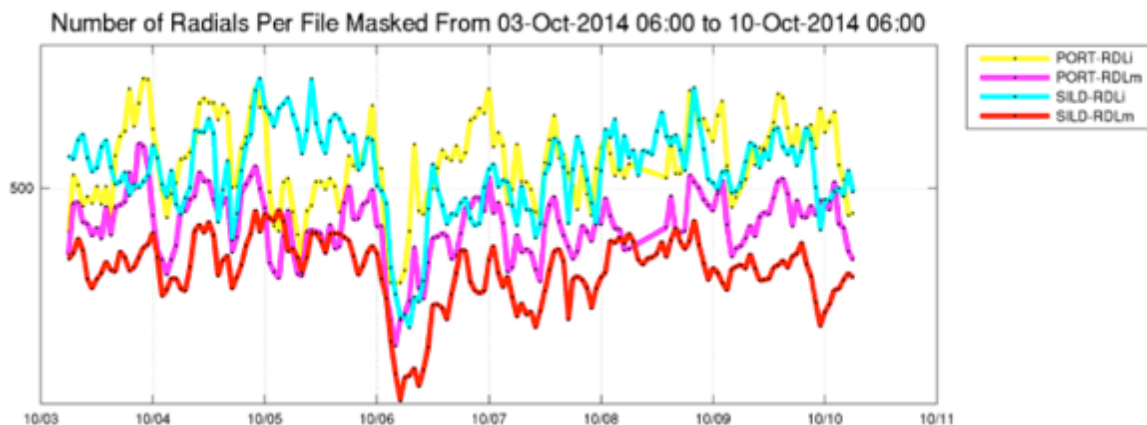
3. Radial Time Series QA/QC

Average radial velocity and radial vector count plots are generated hourly as a method of quality control. If the radar is operating efficiently, the M2 tide should be clearly represented by the semidiurnal peaks in the hourly-averaged radial velocities. Below shows the latest time series plot displaying the average radial velocity for each hour for the New York Harbor standard-range sites in Staten Island, NY (SILD) and Port Monmouth, NJ (PORT):

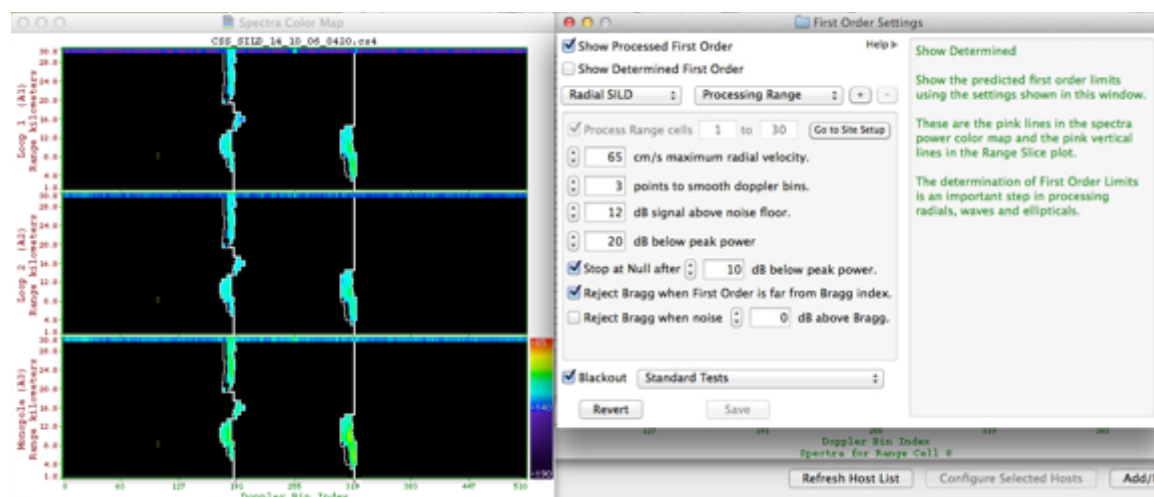


Here we see 12-hour peaks in the radial velocity hourly average but there are times where the peak is much lower in magnitude at PORT than SILD. There are also times where there is no clear, distinct peak. When this happens, it is necessary to analyze the data at the spectra level and examine the first order line settings.

Time series plots are generated for radial vector count at each hour. There are a few reasons these plots are helpful in QA/QC. If the radar is continuously generating radial files with low vector counts, the first check is to examine whether there is Bragg on all three antennas. If there is evidence of Bragg scattering, then the reason for the low radial vector count is most likely software related, notably the first order line settings in the configurations folder. The latest time series for the New York Harbor sites is displayed on the next page:



From the above plot, it is clear that the measured radial file size was at one point extremely low for the 25 MHz site SILD (Staten Island, NY) on October 6th, 2014. Spectra files for that time period were analyzed using the SpectraPlotterMap software application, written by CODAR Ocean Sensors. Below is a screenshot of a spectra file on October 6th, 2014 using the “blackout” option to clearly outline what was processed as first order Bragg.



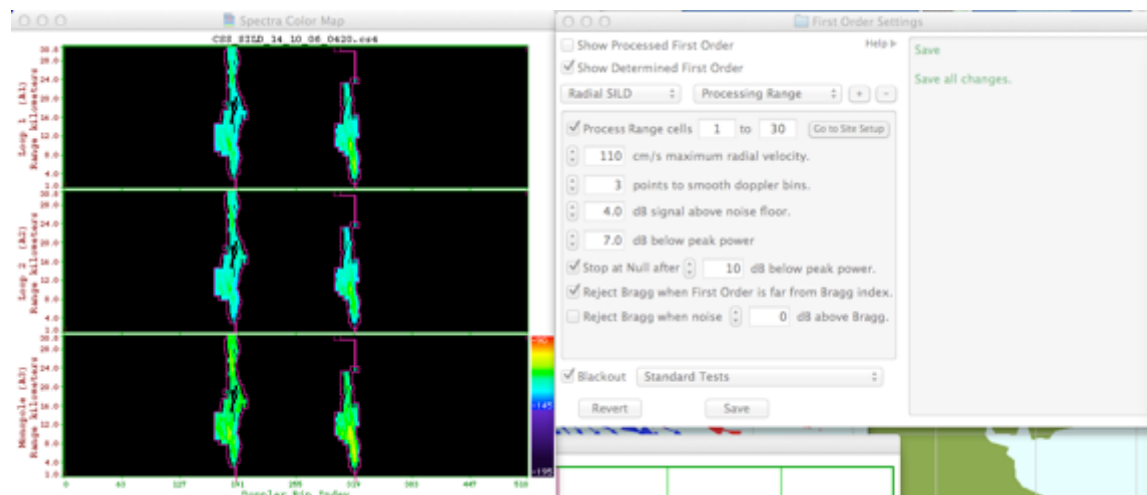
The first order lines were too constrictive for capturing the Bragg scattered signal reflected off of the surface gravity waves, which would explain the small radial file sizes for that time period.

The next step is to adjust the first order lines so that they are not too constrictive and not too wide for more accurate processing. In this particular case with SILD, it is a difficult environment to determine what constitutes as first order Bragg since there appears to be some evidence of second order saturation but nonetheless, much of the Bragg return is not getting processed. It was determined that three options in the first order configuration settings needed to be adjusted: maximum radial velocity, signal

above noise floor, and peak power drop-off. The changes made in the settings are displayed in the table below:

SILD	Max. Radial Velocity	Signal to Noise	Peak Power Drop-off
Before FOL changes	65 cm/s	12 dB	20 dB
After FOL changes	110 cm/s	4 dB	7 dB

The changes implemented in the FOL configuration at SILD improved the radial coverage in the New York Harbor. The same spectra from October 6th, 2014 shown above is displayed on the next page with the FOL changes:



Again, SILD is an interesting site when it comes to first order processing because of the unique environment. CODAR and Rutgers have discussed FOL changes since there seems to be “split” Bragg peaks past range cell 12. The new first order processing settings do a better job capturing the Bragg peaks, which increased the radial vector count in the reprocessed radial files.

2. ISSUES/RISKS & MITIGATION

Based on almost two decades of previous experience with CODAR HF-Radar site installations, high level potential risks to the success of this project include:

1. If the municipality, park or land owner of the potential installation site location refuses to allow installation of a site, then there could be delays in site installation or it could force us to move the site location to a less than optimal location.
 - a. Mitigation: As these are replacement sites with previous approvals, this risk should not come to fruition.
2. If CODAR delays the delivery of sites due to a backlog of orders or lack of personnel, site installations could be delayed.
 - a. Mitigation: There are two mitigation strategies here: The first strategy was to discuss and plan the orders with CODAR in August with a goal to insert these into the CODAR construction process; The second strategy was to build an additional 1-2 weeks of slack in the schedule based on delivery dates estimated by CODAR in August, and then again in late December.
3. If CODAR delivers faulty equipment, then we would be forced to ship the equipment back to CODAR for repair, thereby delaying potential installations of the systems by several weeks.
 - a. Mitigation: The CODAR equipment will be delivered in four batches of 3 to 6 sites at a time. If some of the equipment is faulty, it can be shipped back to CODAR to be fixed while technicians, test, install, calibrate and retest another system in the batch.
4. If there is severe weather such as winter snows, frozen ground, or a hurricane/nor'easter causing beach destruction, then installations could be delayed.
 - a. Slack has been built into the schedule for these events which will occur over the 2 years of the project at one or more of the site locations.
5. If a technician departs Rutgers or UConn, then the team will lose technical proficiency and some of our capability to install the sites in a timely manner.
 - a. There are now additional technicians at Rutgers not currently funded through this project that could replace funded team members should they depart for another job.

3. SCHEDULING

The baseline schedule for this project is shown below in figure 1. As mentioned in the previous report, the exact dates and install sites were subject to change based on logistical challenges including but not limited to weather, municipality support/approval and strategic need. Original installation date details are shown in figure 2.



Figure 1. High level schedule for the CODAR installations.

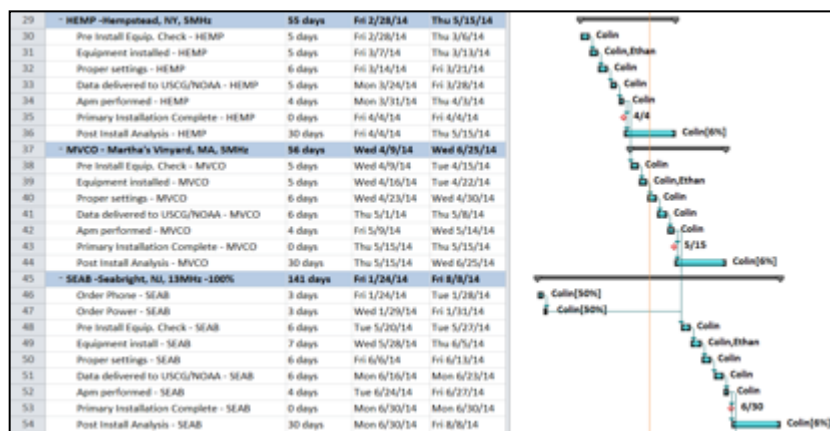


Figure 2. Detailed installation schedule of the first three installation sites.

There are 21 major milestones over the course of this project which include delivery of the four batches of CODAR systems to Rutgers and the University of Connecticut, and primary installation completion of each of the 17 sites. Table 2 lists the scheduled dates of the installations as well as current progress towards every milestone. It should be noted that we expect to maintain site installations for each date in the Milestone Table, however, the exact site installation may vary based on availability/permission of local authorities, communication installations, power installations, etc.

	Milestone Name	Date	Complete
1	Deliver Batch 1: of SEAB, MVCO, HEMP	2/28/2014	Yes
2	Deliver Batch 2: SPRK, PORT, HOOK, LOVE	5/2/2014	Yes
3	Deliver Batch 3: of, SILD, BELM, BRNT, BRMR	8/8/2014	Yes
4	Deliver Batch 4: of GCAP, BISL, MNTK, MISQ, SLTR, STLI	9/26/2014	Yes
5	Primary Installation Complete - HEMP	4/4/2014	Yes
6	Primary Installation Complete - MVCO	2/15/2015	
7	Primary Installation Complete - SEAB	6/30/2014	Yes
8	Primary Installation Complete - PORT	8/13/2014	Yes
9	Primary Installation Complete - GCAP	9/23/2014	In Progress
10	Primary Installation Complete - SPRK	10/13/2014	In Progress
11	Primary Installation Complete - BISL	11/11/2014	In Progress
12	Primary Installation Complete - HOOK	11/26/2014	Yes
13	Primary Installation Complete - MNTK	12/18/2014	In Progress
14	Primary Installation Complete - LOVE	1/12/2015	In Progress
15	Primary Installation Complete - MISQ	1/27/2015	In Progress
16	Primary Installation Complete - SILD	2/26/2015	In Progress
17	Primary Installation Complete - STLI	3/10/2015	In Progress
18	Primary Installation Complete - SLTR	4/9/2015	
19	Primary Installation Complete - BELM	5/26/2015	
20	Primary Installation Complete - BRNT	7/6/2015	Yes
21	Primary Installation Complete - BRMR	8/14/2015	Yes

Table 2. The 21 Major project milestones include deliveries of the four batches of CODAR systems as well as primary installation of each of the 17 sites.

4. BUDGET AND EXPENDITURES

Table 3 highlights the budget by line item, expenses, commitments (largely CODAR hardware) and the remaining balance of the account. Subcontractors are listed as single line items.

Description	Budget	Expenses	Commitments	Adjustments	Balance
Salaries Regular Employee	\$132,600.00	\$50,593.47	\$0.00	\$0.00	\$82,006.53
Other Compensation	\$0.00	\$640.00	\$0.00	\$0.00	-\$640.00
Fringe Benefits Manual Adj	\$58,477.00	\$0.00	\$0.00	\$0.00	\$58,477.00
Fringe Benefits - FICA	\$0.00	\$2,978.28	\$0.00	\$0.00	-\$2,978.28
Fringe Benefits - Medicare	\$0.00	\$696.57	\$0.00	\$0.00	-\$696.57
Fringe Benefits 12000	\$0.00	\$19,073.74	\$0.00	\$0.00	-\$19,073.74
Project Supplies DCGA	\$4,324.00	\$13,367.91	\$223.11	\$0.00	-\$9,267.02
PERM EQP-DCGA < \$5,000	\$18,000.00	\$1,249.55	\$0.00	\$0.00	\$16,750.45
Mobile Phone Charges	\$0.00	\$124.13	\$0.00	\$0.00	-\$124.13
Telephone Toll Chrg	\$3,600.00	\$0.00	\$0.00	\$0.00	\$3,600.00
Conference Exp DGCA	\$0.00	\$474.75	\$0.00	\$0.00	-\$474.75
Postage	\$0.00	\$349.48	\$0.00	\$0.00	-\$349.48
Other Services	\$185,600.00	\$0.00	\$0.00	\$0.00	\$185,600.00
PERM EQP-DCGA > \$5,000	\$1,145,095.00	\$1,105,594.95	\$9,650.00	\$0.00	\$29,850.05
Travel Domestic DGCA	\$20,000.00	\$3,692.70	\$0.00	\$0.00	\$16,307.30
Facility & Admin Costs	\$99,520.00	\$28,648.11	\$5,430.21	\$0.00	\$65,441.68
Repair & Maint Equipment	\$0.00	\$16,170.00	\$1,910.00	\$0.00	-\$18,080.00
Repair & Maint Vehicles	\$0.00	\$898.56	\$0.00	\$0.00	-\$898.56
Subcontract	\$401,714.00	\$249,267.18	\$25,000.00	\$0.00	\$127,446.82
Subcontract	\$48,408.00	\$0.00	\$0.00	\$0.00	\$48,408.00
Subcontract	\$203,170.00	\$52,266.20	\$326,759.62	\$0.00	-\$175,855.82
Rent Equipment DGCA	\$10,002.00	\$0.00	\$1,200.00	\$0.00	\$8,802.00
	\$2,330,510.00	\$1,546,085.58	\$370,172.94	\$0.00	\$414,251.48

Table 3. Sandy Supplemental budget by line item with subcontractors listed at the bottom of the table.

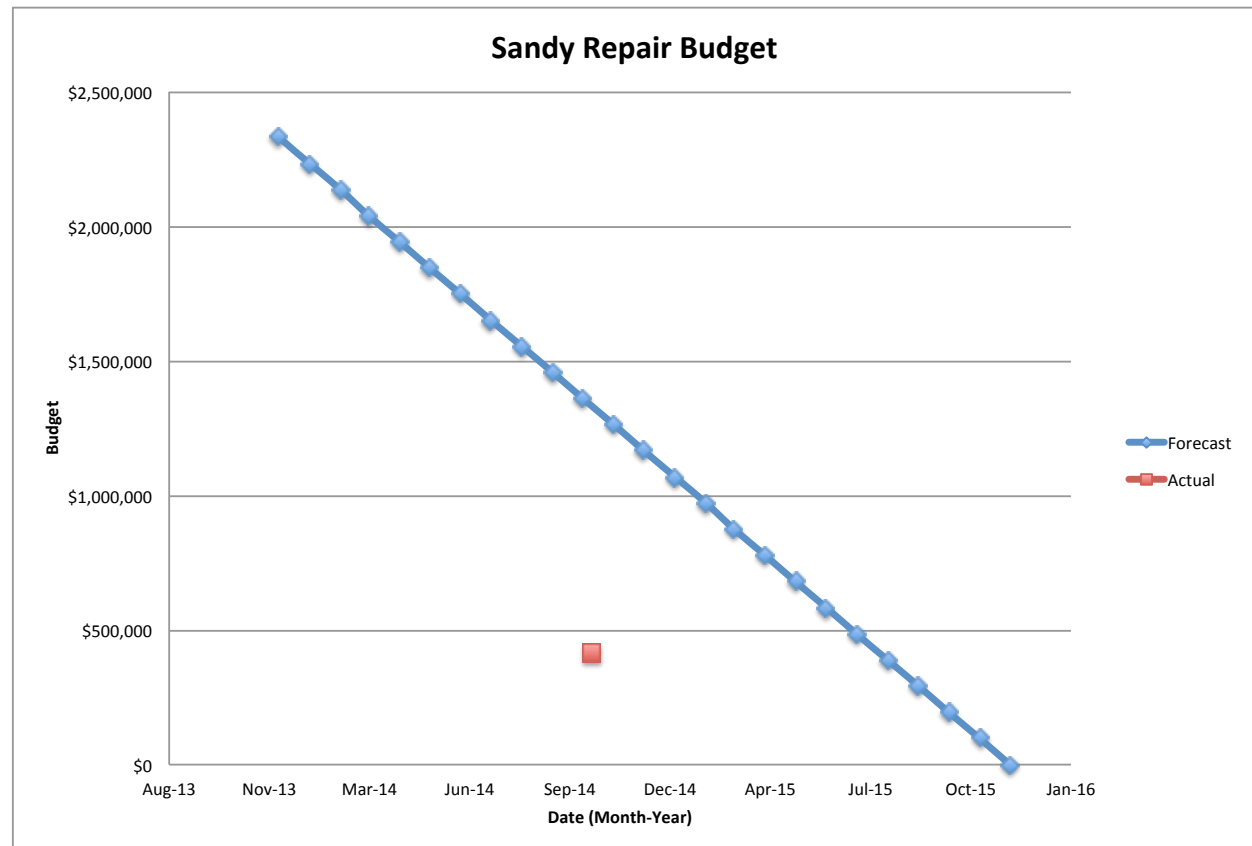


Figure 1: Budget spending chart showing the forecasted spending (blue) and actual (red).

6. Appendix 2:

University of Connecticut Progress Report

1. PROGRAM INFORMATION AND HIGHLIGHTS

During the 3rd quarter of 2014, the following progress was made:

A. Procurement

The upgraded transmitters and receivers for Misquamicut and Block Island were delivered late September to the University of Rhode Island.

B. Site Installations

Stehli Beach upgrades are almost complete. The machine shop is fabricating a new antenna mount that will be installed on a roof. Once this is complete the new antenna will be installed at Stehli beach. All other equipment installation has been done at Stehli. Great Captain will be installed soon. The Island caretaker needs to be available with his onsite equipment to transport the equipment from the dock over the beach to the building site of the current installation. Block Island and Misquamicut have all the new hardware installed. Block Island communications are currently down. A repair technician has fixed the issue as of 10/13/2014. A trip is being planned to configure the communications. Misquamicut communications are also down. A trip is being planned for 10/16/2014 to configure the communications there as well. Montauk will receive a new air conditioner to finalize the hardening at that site. The current installation of all 5 sites is detailed in the images below

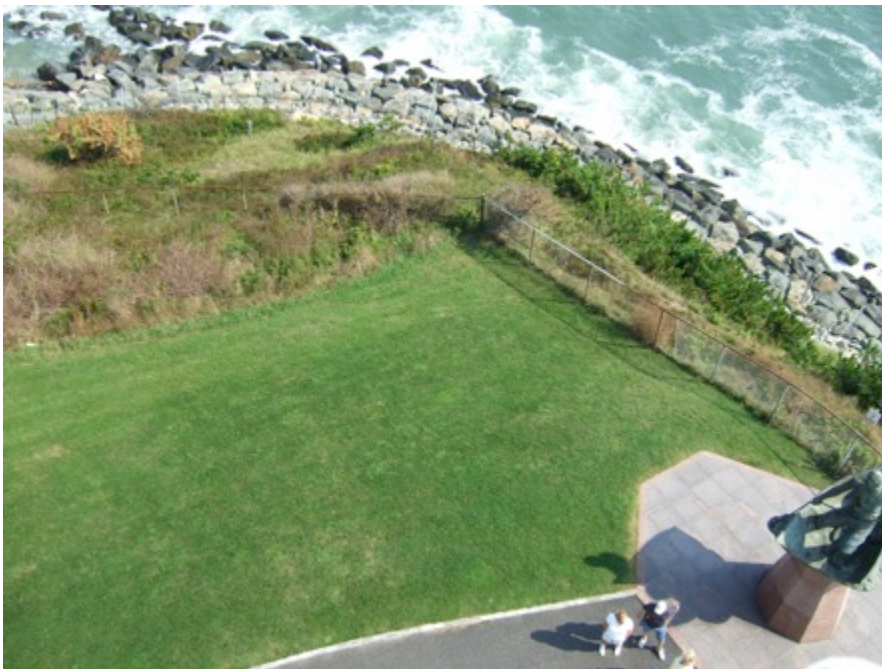
1. Block Island



2. Misquamicut, RI



3. Montauk, NY



4. Stehli Beach, NY



5. Great Captain Island, CT



The proposed timeline to complete repairs and harden the sites is below.

TASK	Timeline	Status
1. Repair		
a. Replace control computers at both sites (Mac Mini computers)	July 2014	Complete
b. Replace air conditioners at both sites	July 2014	Complete
a. Replace antennae and cables at both sites (from CODAR)	Oct –Nov 2014	In Progress
b. Replace transmitter and receiver at GCAP (from CODAR)	Oct –Nov 2014	Complete
c. Calibrate both sites	November 2014	In Progress
2. Hardening		
a. Install waterproof enclosures at GCAP	Oct –Nov 2014	Complete
b. Install lightening protection kit at GCAP (from CODAR)	Oct –Nov 2014	Complete
c. Install GPS timing at both sites at GCAP (from CODAR)	Oct –Nov 2014	Complete
d. Install multi-static processing software at both sites (from CODAR)	Oct –Nov 2014	In Progress
e. Install backup satellite communications for both sites		In Progress
f. Install power outage protection		In Progress
g. Acquire backup antennae and cables for use at GCAP, STLI, BISL, MNTK and MISQ		Complete
h. Acquire backup transmitter for use at GCAP, STLI, BISL, MNTK and MISQ		Complete
i. Acquire backup control computer for use at GCAP, STLI, BISL MNTK, and MISQ		Complete

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Purchases:

- 2 combined antennae.
- Upgrade of CODAR electronics from 2 sites to GPS share capability.
- 2 bistatic processing software licenses
- 3 lightning protection kits to provide protection for the CODAR electronics.
- 3 UPS units to replace aging ones in use.
- 3 web power switches to enable remote control of power to CODAR electronics.
- 3 routers (needed to facilitate use of web power switches).

Installations:

The installation of the replacement or upgraded equipment listed above has been completed at sites BISL and MISQ. The installation at site MNTK is planned during the next few weeks.

Expenditures:

Other Direct Costs:

Operating:	\$4291
Equipment:	\$106,800
Overhead (20% of operating):	\$858
Total	\$111,949