Improvement of Surface Current Measurements with Spectra Reprocessing for 13 MHz SeaSonde Systems

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Abstract - **The demand for high-quality surface current measurements from High Frequency radar instrumentation is continuously increasing. To ensure that the CODAR (Coastal Ocean Dynamics Applications Radar) system is accurately mapping the surface current field, standards need to be met at the radial level. Limited radial coverage, flipped radial fields, and outlier vectors are a few signals indicating that there is a potential issue. This paper examines the results of the reprocessing methods for a 13 MHz SeaSonde located in Brant Beach, NJ (BRNT) between May 02, 2012 and May 09, 2012. After several test cases, it was determined that for that time period a signal above noise factor of 6.3 (~8 dB) and maximum radial velocity of 60 cm/s were the most ideal settings. Along with the altered radial configuration settings, a new batch application written by CODAR Ocean Sensors was utilized for reprocessing larger datasets at a quicker rate. The real time and reprocessed radial data was examined with neighboring CODAR sites operating at 13 MHz and the semi-diurnal (M2) tidal signal.**

Index terms—HF (High Frequency) radar, surface currents, reprocessing, radials, tides, SeaSonde.

I. Introduction

The importance of precise surface current measurements reflects in applications that include Coast Guard Search and Rescue (SAROPS) missions, input into weather models, and insight into understanding ocean physical processes. During 2012, seven 13 MHz radar systems were operated by Rutgers University Coastal Ocean Observation Laboratory (RUCOOL) between Sea Bright and North Wildwood, NJ. The higher resolution demands the task of ensuring that the radials from each site compliment each other in order to create a smooth, accurate representation of the surface current field.

The SeaSonde software creates radial files every hour on the hour as a result of spectral averaging. For a 13 MHz SeaSonde, Doppler spectra are averaged over 15 minutes and outputted every 10 minutes to produce radial current estimates [1]; seven spectra files cover a 15 minute period each, which means there is a 5 minute overlap between Doppler spectra computations. The short-term radials are created every 10 minutes from the individual spectra files and then averaged to create the hourly radial files utilized in total current estimates.

Ideally, analyzing every short-term radial would be beneficial for identifying whether first order line settings are suitable for the location and time of processing. However that can get extremely challenging when operating several High Frequency radars because it is time consuming to visually inspect each spectra file. So we rely on several quality control metrics for diagnosing radial accuracy. Average radial bearing between ideal and measured radials, spectra merged count, radial count, and data latency are a select few of the techniques that are applied for data inspection [2]. When one of the criteria for quality control is not met, spectra files need to be examined in order to determine whether the first order Bragg was properly processed.

This test case examines the week of May 02, 2012 for a 13 MHz SeaSonde in Brant Beach, NJ (BRNT) where interference was being processed as first order Bragg, leading to imprecise current measurements in that location. High noise or interference in the received signals is just one of the reasons for errors in the radial field. Other limitations for accurate radials include distortions in the measured antenna patterns and restrictions in the frequency resolution of the Doppler spectrum [3]. We present two considerations in the header settings when reprocessing the radials for this time period: 1) Max radial velocity limitation and 2) Noise factor (Signal above noise). The radial maps were then compared with two 13 MHz sites (Seaside Park, NJ and Brigantine, NJ), along with the semi-diurnal tidal constituent measurements from the NOAA gauge located in Atlantic City, NJ. We also present the description and results of a new batch processing application used during this case study.

II. Approach

Spectra files for the entire year of 2012 for the Rutgers University standard CODAR network were reprocessed with the new first order line settings. All of the header settings were replicated with the default settings with the exception of the noise factor and maximum radial velocity limit. The new settings were declared to be 6.3 (~8 dB) and 60 cm/s for the noise factor and maximum radial velocity limit, respectively. For the purposes of simplifying the analysis of the reprocessed data, we decided to focus on BRNT for the first week of May

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2012 since most of the test cases were performed on this site with the altered first order line settings. We compared the real time and reprocessed results from BRNT with the nearest High Frequency radar sites operating at 13 MHz. These sites include Seaside Park (SPRK) North of Brant Beach and Brigantine (BRMR), the closest site to the South. Figure 1 shows a map of the SeaSonde locations along with the overlapping radial coverage. We also compared average radial velocities with the tidal data from Atlantic City, NJ.

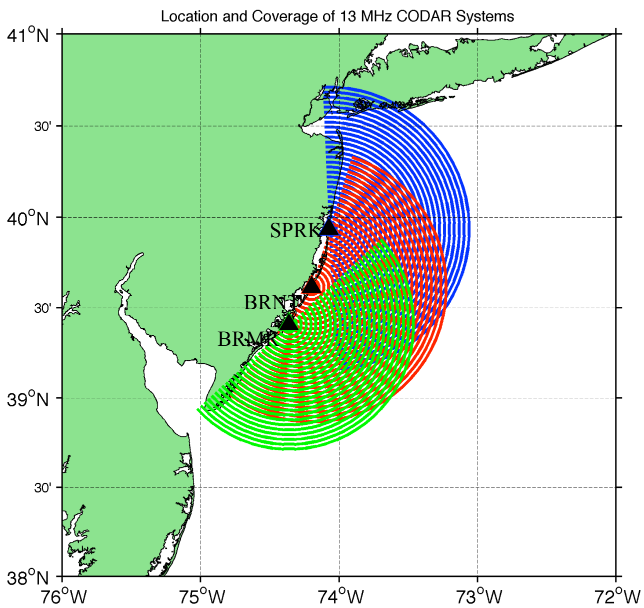

Figure 1. Map of study area. Seaside Park (SPRK), Brant Beach (BRNT), and Brigantine (BRMR) coverage areas shown in blue, red, and green, respectively.

A. Batch Reprocessing Application

A recently developed application written by CODAR Ocean Sensors allows for a very efficient method of reprocessing large datasets. In the past, and still in practice, spectra files had to manually be transferred to a specific directory with the new changes implemented in the radial configuration files. This approach became complicated when attempting to reprocess spectra files over the course of months to a year.

The new batch reprocessing function eliminated the need to transfer files, which makes working with an extensive amount of spectra files simpler. The application allows the user to input the following as variables: 1) Directory of spectra files to be reprocessed. 2) Time range. 3) Path of the radial configuration folder to be used. 4) Final reprocessed directory where a new folder is created with the new radials, spectra files, and radial configuration folder.

Another supportive feature includes the use of the console application, which displays messages as radials are being processed. If reprocessing discontinues at any point, console will present a log showing the spectra files processed and will be automatically saved in the new output folder. The new batch interface also allowed for performing several test cases with various first order line settings at an efficient rate.

B. SeaSonde Release 7 Software

We used CODAR'S Release 7 SeaSonde software during the examination with the first order lines. In order for this software to work, a SeaSonde radial or elliptical suite USB key is needed. This allows the SeaSonde Acquisition application to run which creates the cross spectra series files, time series files, and range series files. The CSPro application then averages and removes ship signals [4].

We had four available computers to reprocess all of the seven stations for 2012, all of which had Release 7 downloaded. Each computer was dedicated to reprocessing one of the four BPU (Board of Public Utilities) sites to limit confusion. Over time a log has been kept of APM dates, phase correction changes, hardware changes, antenna bearing alterations. All of this information was used to make the necessary changes to create the most accurate radials.

As opposed to Release 6, Release 7 allows the user to create AngSeg_SITE.txt files, which acts like a filter. This configuration file notifies the software to flag vectors that are over land and not within the site's coastal boundaries. The default AngSeg is 360 degrees, but we used a custom AngSeg for each site location, which is located within the radial configurations folder. Release 6 gives the user the option to specify how to mark vectors out of bounds in the Header.txt file. A custom AngSeg_SITE.txt file is only possible with the Release 7 software.

C. *Spectra Files*

It is habitual to collect spectra and range data throughout the entire year for each CODAR site. We have external hard drives installed for each site to maximize disk space. Over time, operators swap the external hard drives to ensure limited data loss. The spectra and range files are then transferred to a terabyte(s) hard drive in the lab with Level X RAID to have backup copies of the data. All of the 2012 spectra files were located on one hard drive, providing access from any machine for reprocessing.

III. DEFAULT FIRST ORDER LINE SETTINGS

The default noise factor set by the 13 MHz SeaSonde is set to 4, which translates to ~6 dB. The default maximum radial velocity limit is set to 180 cm/s. When noise and high interference saturate the first order Bragg, it often leads to uncharacteristicly strong vectors. In addition to interference, antenna phase corrections from the sea-echo are important for the [5] MUSIC algorithm to properly extract the bearing measurements of a given signal.

Figure 2 displays a radial map for BRNT during which the default first order parameters were used and also when improper phase corrections were set. Interference from an external source, along with the default first order line settings, resulted in many solutions placed over land and a gap in coverage to the South.

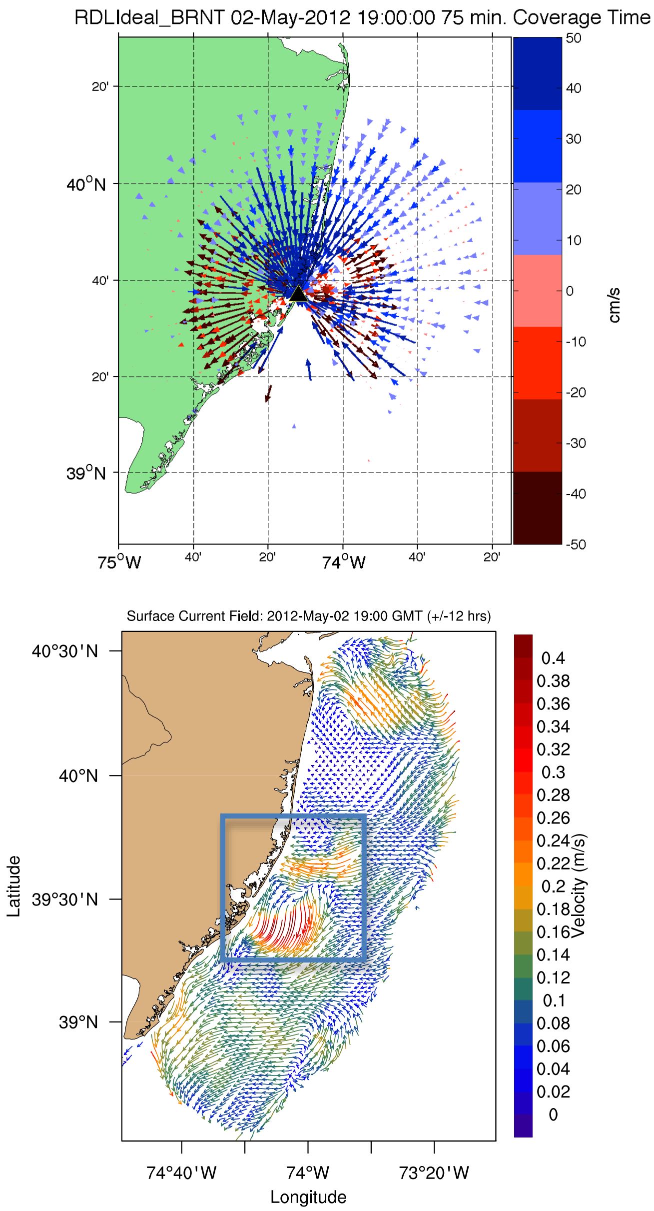

Figure 2. A radial map (top) for Brant Beach, NJ (BRNT) 13 MHz SeaSonde with default first order line settings. Blue vectors indicate a positive Doppler shift while red indicates a negative Doppler shift, or red shift. The bottom plot shows the 25 hour surface currents for that time period. The box highlights the large spatial variability in vector magnitudes due to interference.

IV. REPROCESSED FIRST ORDER LINE SETTINGS

After several small test cases with the BRNT radial configuration settings, it was decided that the most suitable factors for this time period were a noise factor of 6.3 and a maximum radial velocity of 60 cm/s. Switching the maximum velocity threshold significantly improved the radial qulaity by eliminating strong interference in the first order Bragg processing. Raising the noise factor by 2.3 dB also improved the boundary lines for first order processing in capturing very little noise without removing valid radial measurements. Figure 3 shows the reprocessed radial map with very few vector solutions over land and with no outlier radials due to interference; the bottom figure shows the 25 hour average currents for that time period. The reprocessed totals show much less spatial variability compared to the real time data, seen in Figure 2.

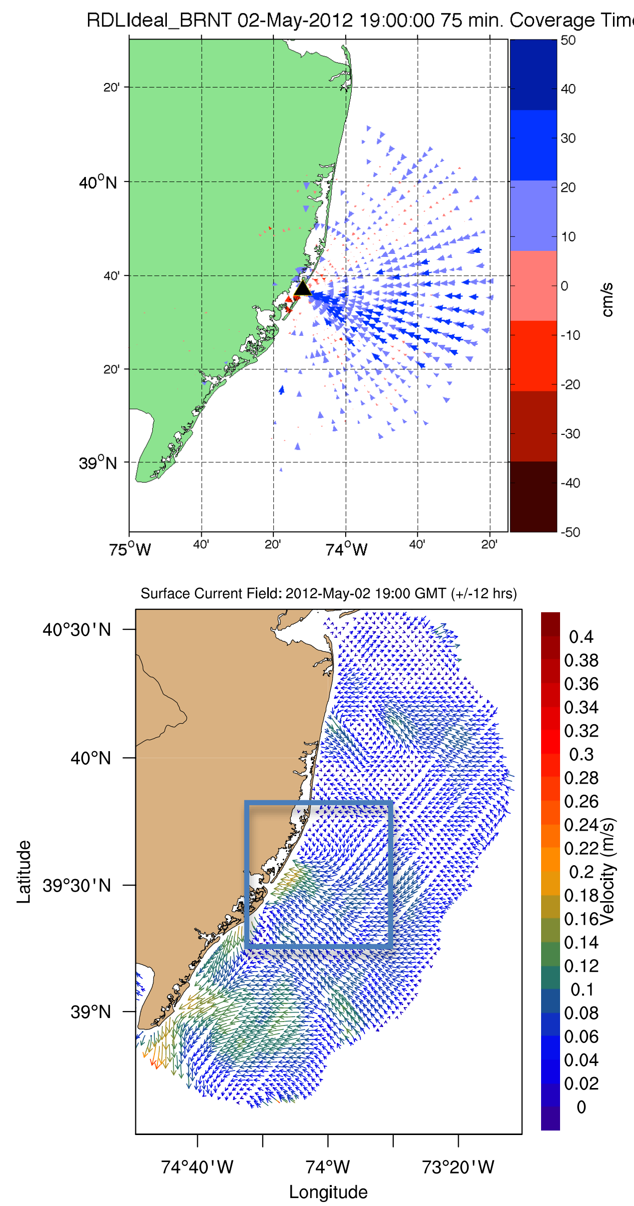

Figure 3. Reprocessed BRNT radial map (top) with the new first order line settings and phase corrections. On the bottom is a total map of the reprocessed surface currents for the 13 MHz CODAR network. Notice the difference in spatial variability in the box.

IV. ANALYSIS

Visually, the reprocessed radials and surface currents appear to be more realistic than the data processed in real time during the first week of May 2012. In this section, we relate the averaged radial velocities with the M2 tide measurements and also compare metric data to SPRK and BRMR.

A. M2 Tidal Constituent

The M2 tide is a strong, semi-diurnal tidal constituent caused by gravitational pull of the moon and is considered by [6] to be the strongest in the Mid-Atlantic, responsible for over 80% of the tidal variance [2]. Water level height should coincide with the average radial velocity directional change. Radial velocities depend on the backscattered signal due to ocean waves half the radar wavelength traveling towards or away from the site [7]. A negative velocity measurements indicates the Bragg waves are traveling away from the radar while a positive Doppler shift suggests that the waves are moving towards the receive antenna.

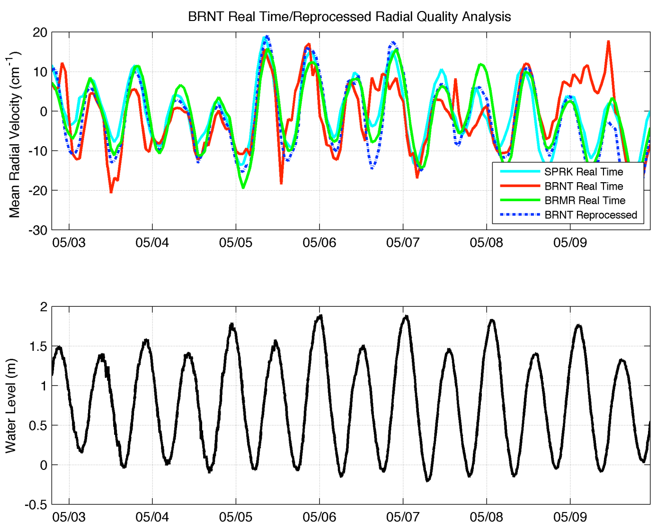

Figure 4. A subplot comparing the average radial velocities for 4 different datasets (top). The radial velocities are averaged every hour. The bottom plot shows the water level height from the NOAA Atlantic City tide gauge.

Figure 4 shows the comparison between the averaged radial velocities for each dataset with the water level at the nearest NOAA tide gauge. The datasets include the real time data during the study period from SPRK, BRNT, and BRMR along with the reprocessed data from BRNT with the altered first order line settings. There are multiple periods where the BRNT real time average radial velocity does not mirror the tidal peaks (May 9th for example), while the other datasets match up well with the water levels.

B. 13 MHz CODAR Data

Ideally, there should be a maximum peak in radial velocity every 12 hours. The default first order lines at SPRK and BRMR during that time period appear to capture the first order Bragg without any signs of interference. The BRNT real time data shows intermittent anomalies (Figure 4). The irregularities in the average velocity measurements are due to some source of interference that was processed as first order Bragg. Figure 5 displays the correlation between the average radial velocities for the BRNT real time and reprocessed datasets compared with the SPRK and BRMR real time average velocities.

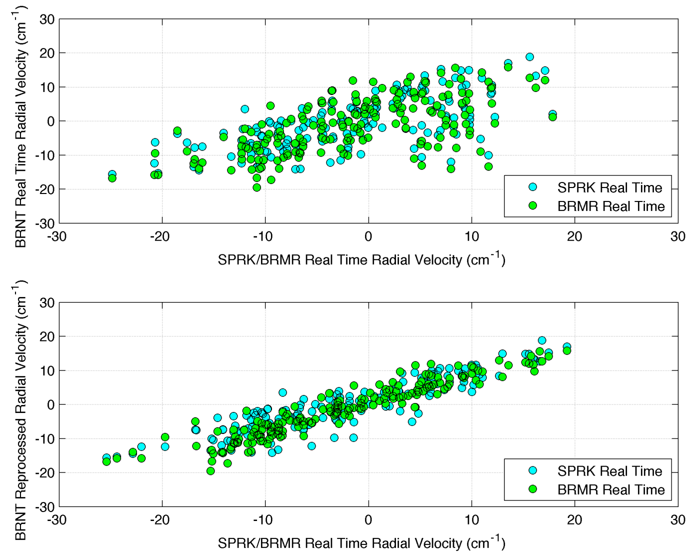

Figure 5. Scatter plot showing the comparison between BRNT real time radial velocities (y-axis) with SPRK and BRMR (x-axis) (top). The bottom plot shows the same comparisons with the BRNT reprocessed average velocities.

The correlation values between the BRNT real time velocities with the SPRK and BRMR real time velocities were 0.68 and 0.63, respectively. For the reprocessed BRNT data correlation values were caluclated to be 0.91 and 0.95 when compared with the SPRK and BRMR real time velocities, respectively. There was a much improved comparison with the reprocessed data set.

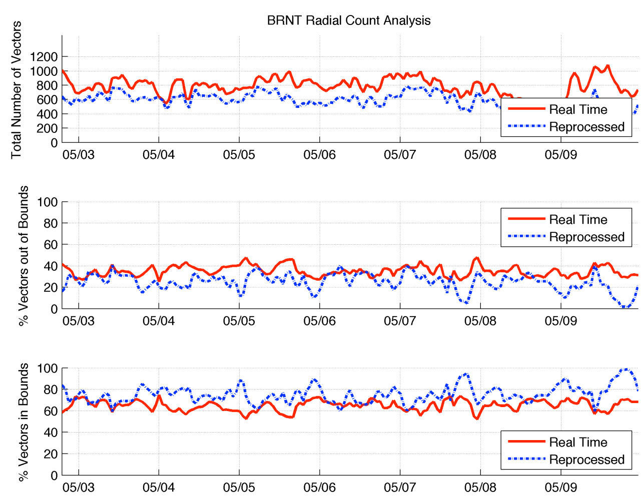

Figure 6. A subplot of the total amount of vectors for each radial file (top), the percentage of radials over land (middle), and the percentage of radials over water (bottom).

C. Radial Metrics

The quality of the reprocessed data correlates nicely with the other 13 MHz radar sites, as well as the M2 tidal signal. In this section we compare radial metric data. Figure 6 displays three plots showing the total amount of solutions witin the file, the percentage of vectors placed on land, and the percentage of vectors placed over water. The reprocessed BRNT files averaged approximately 600 vectors per file while the real time data recorded on average nearly 800 vectors per file. Though the real time files registered more vectors, the percentage of radials over land is much higher than the reprocessed, ultimately leading to less vectors MUSIC places over water with proper bearing measurements. Overall, radial metric analysis shows an improvement in radial coverage when reprocessing with a noise factor of 6.3 (~8 dB) and a maximum radial velocity threshold of 60 cm/s.

VI. CONCLUSIONS

First order line settings need to perform well during radial processing for any CODAR site. One of the major reasons they do not perform well is due to changing ionospheric conditions. The ionospheric conditions depend on solar radiation, leading to a day-night cyles, which attenuate and/or reflect the radio signals from the radar [8]. Other reasons for interference include other High Frequency radars operating within the same bandwidth, internal noise, and the environment (e.g. storms).

The default first order line settings are typically utilized within the Rutgers Univeristy CODAR network but there are occasions where the settings need to be changed. Often, the noise factor plays a role in eliminating contaminated spectra where first order processing becomes compromised. We saw strong interference contaminate the radial field in May 2012 for BRNT with the default settings. We found a 2.3 dB threshold increase in signal-to-noise and a lower maximum radial velocity allowed in the processing ensured the elimination of interference-induced radial velocities. These settings, or any first order line settings, will not always be suitable because there are too many factors that are constantly changing. For this reason, reprocessing is extremely important when it comes to operating high-frequency radars. The recently developed batch reprocessing application is a very efficient way to reprocess contaminated spectra to ensure the most accurate radial maps are being measured by the High Frequency radars.

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