

# Methods of Associating CODAR SeaSonde Vessel Detection Data Into Unique Tracks

## Abstract

Since 2011, Rutgers has been operating an over the-horizon vessel detection software called 'PeakPicker' at two 13 MHz CODAR SeaSonde sites located in Sea Bright, NJ and Belmar, NJ. The challenge of vessel detection using High Frequency (HF) radar is dealing with false detection peaks and then associating multiple peaks derived from different coherent integration times and background filters at a single time step into one peak representing the best estimate. Association of peaks occurs in two distinct phases. Level 1 Association associates multiple detection peaks derived from different coherent integration times (FFT) and background filters at a single time step into one 'best' peak while Level 2 Association will combine data from multiple sites representing different viewing angles. A Matlab script, plot\_all\_matches, matches target data in range and range rate (radial velocity) with AIS data (Figure 1) providing a ground truth of our ship detection progress. Utilizing the output of the matching data, we present techniques that increase the accuracy and decrease the error of detections.

## Vessel Tracking

Vessel tracking with HF radar takes place in three different steps: (1) detection, (2) association, and (3) tracking. Detection uses different data processing algorithms to define peaks in the radar returns above a highly variable background of noise and clutter. The vessel detection software utilizes two background filters and 6 combinations of FFT times and threshold level to produce detections. The first background filter is the median type, which averages both in Doppler and range space. The second background filter is the Infinite Impulse Response (IIR) filter, which averages only in time. Any signal above the background by a certain signal-to-noise ratio (SNR) threshold is counted as a potential detection. This is known as the classical constant false alarm rate (CFAR) detection. The result produces a time-series of all the observed peaks (real or not) identified by their range, range-rate towards or away from the radar, and bearing (Figure 2).

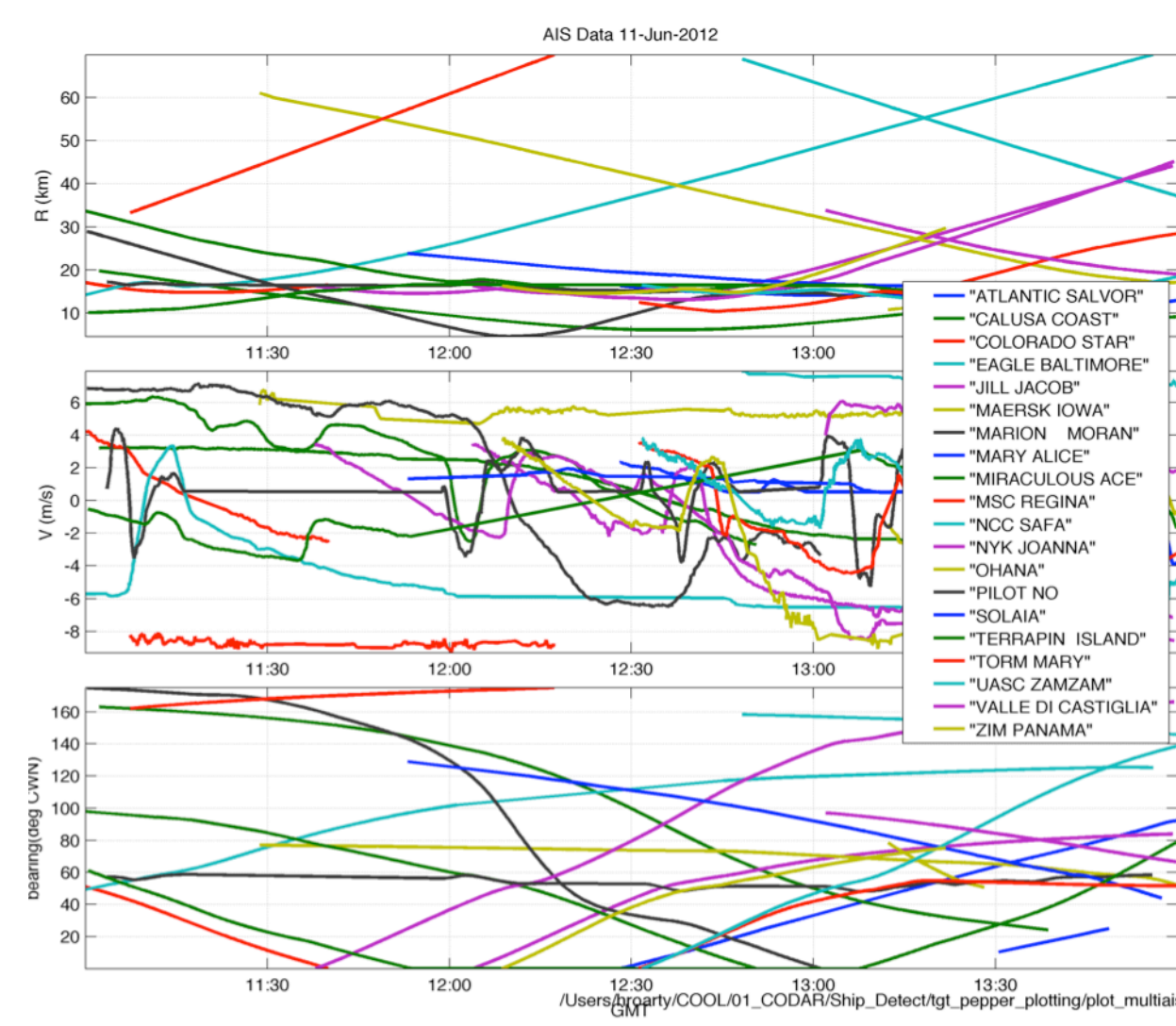


Figure 1:

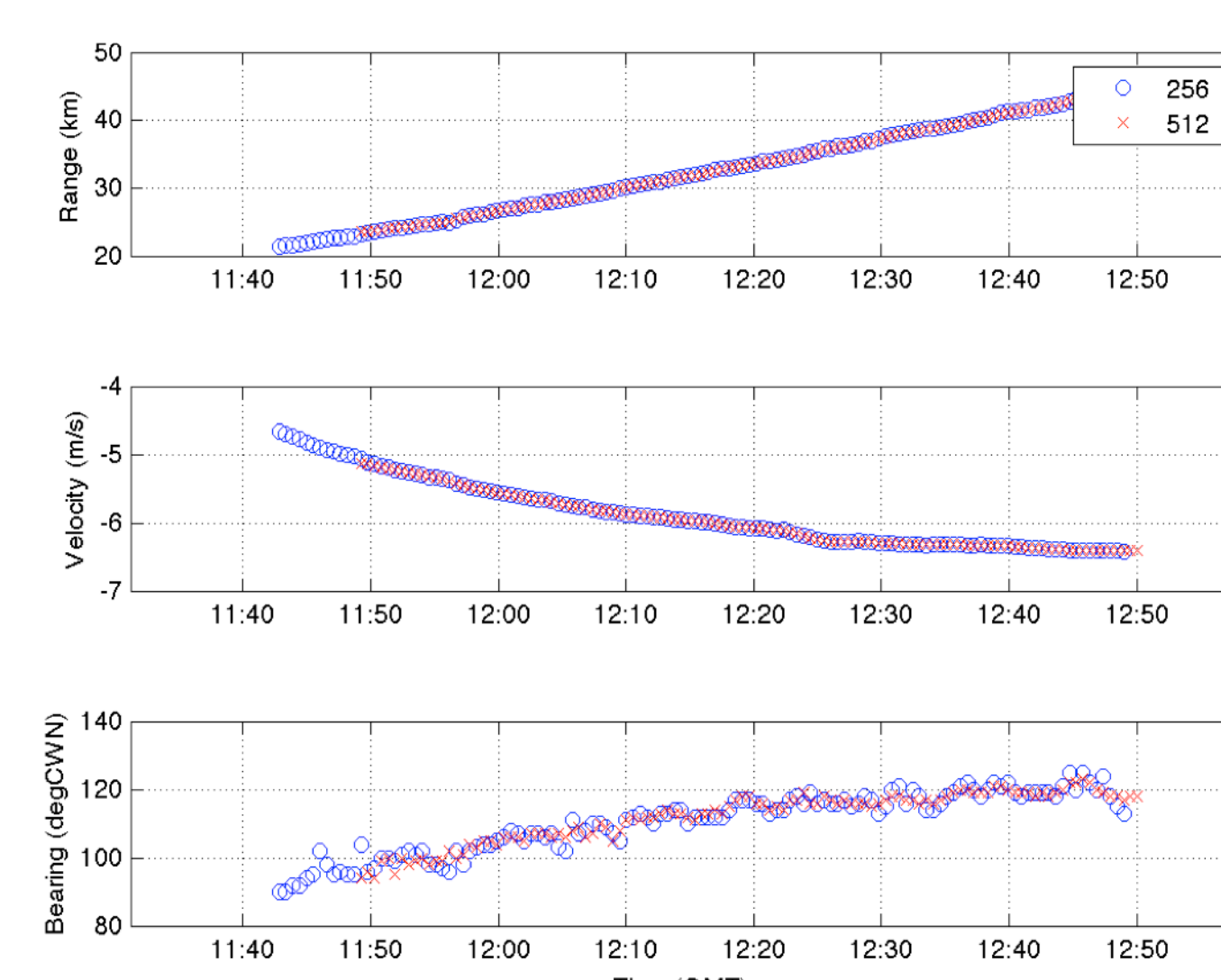


Figure 2:

## Level 1 Association Algorithm

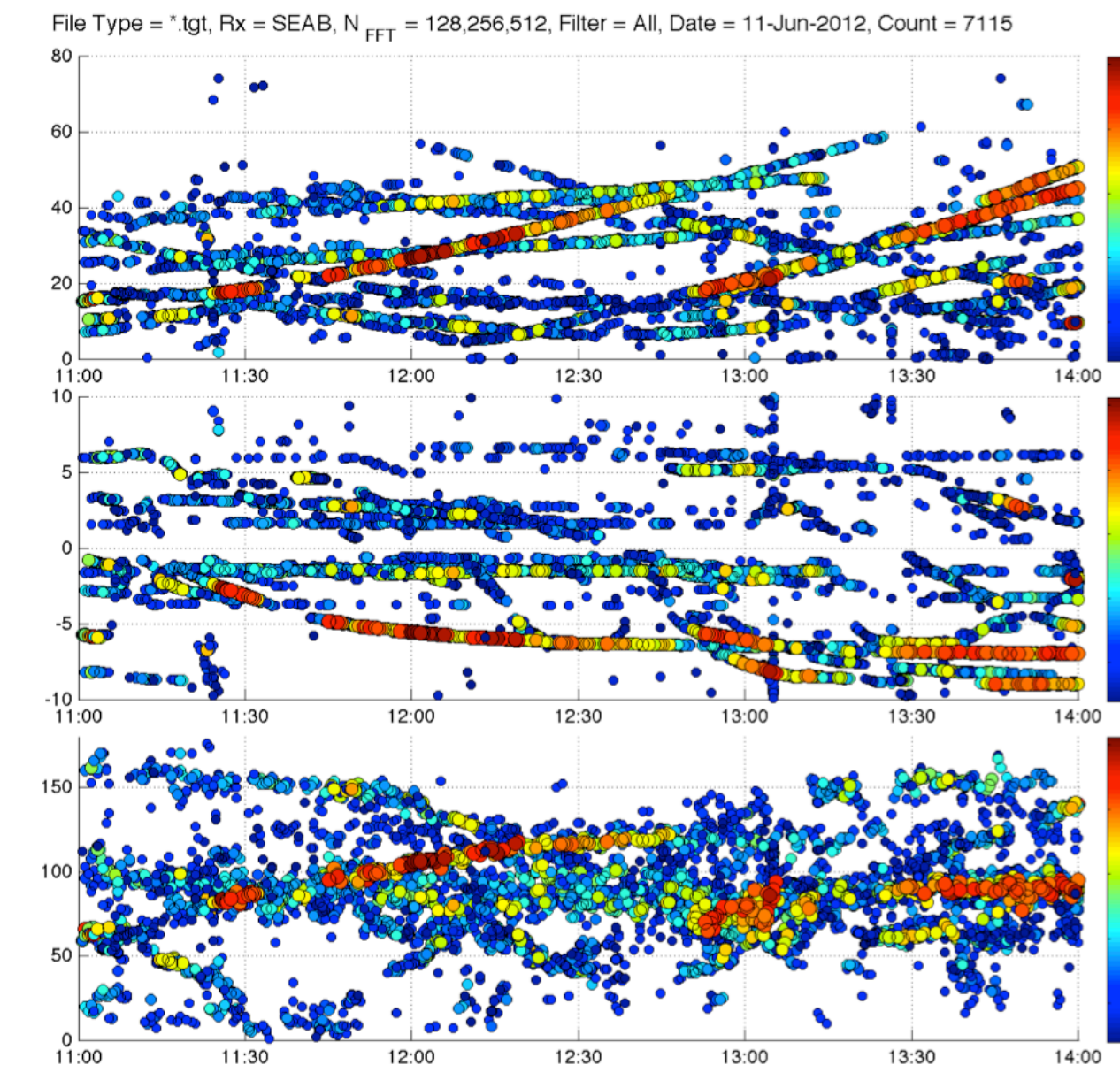


Figure 3:

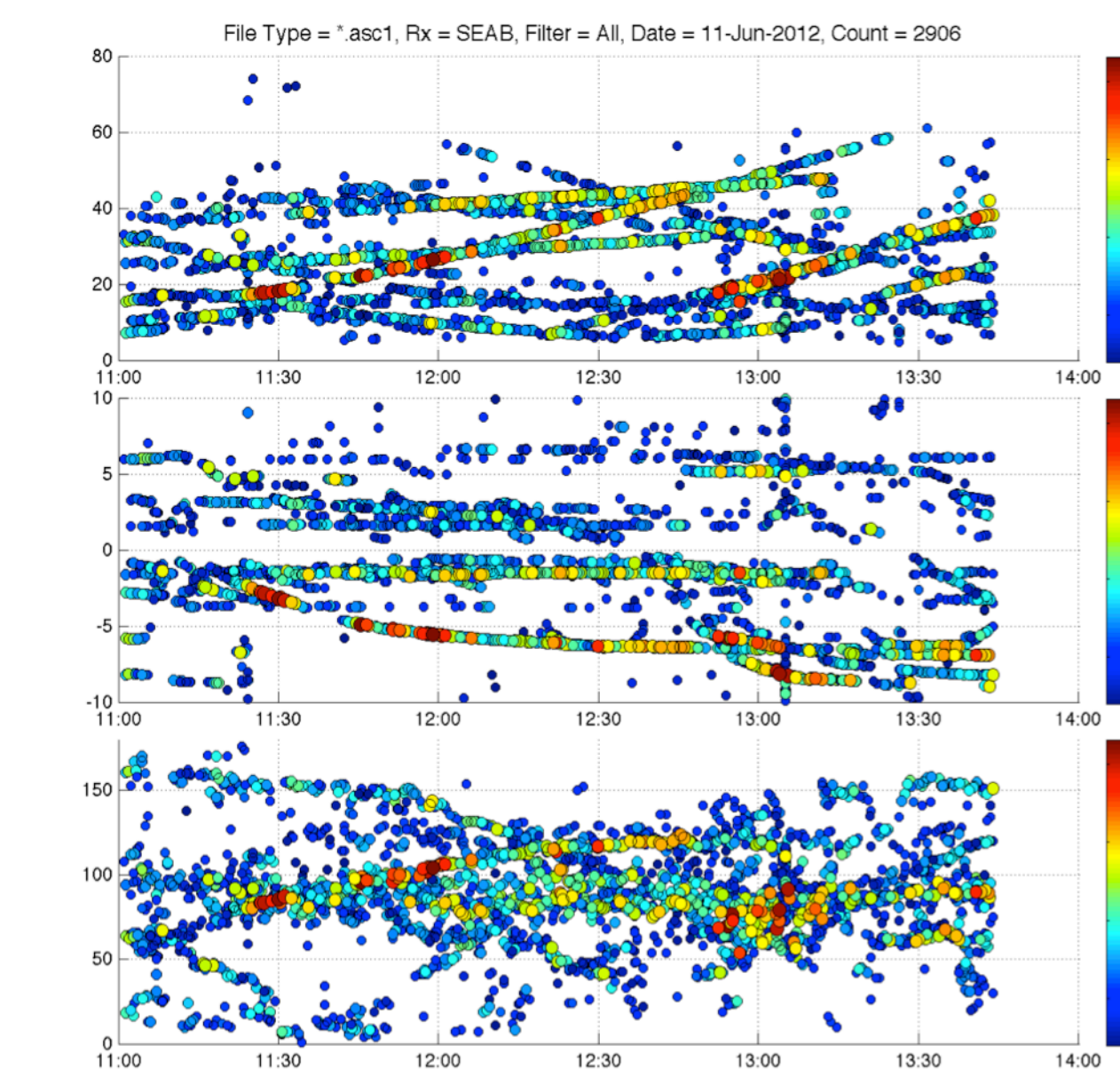


Figure 4:

Level 1 Association takes PeakPicker data (Figure 3) and combines multiple looks at the same target into a single "best estimate" and reduces the number of false alarms, providing more accurate target information and lower uncertainties (Figure 4). Search windows are defined in range/velocity space around high SNR peaks for all combinations of FFT, threshold, and background. Peaks appearing in this search window are assumed to be the same target.

## Level 2 Association Algorithm

The Level 1 Associated ASCII files for each field site are sent to a central processing site, where Level 2 Association occurs. Level 2 Association combines multiple field sites, both backscatter and multi-static, to give Latitude/Longitude and x-y target velocity of the same targets as seen by multiple looks geometrically (Figure 8).

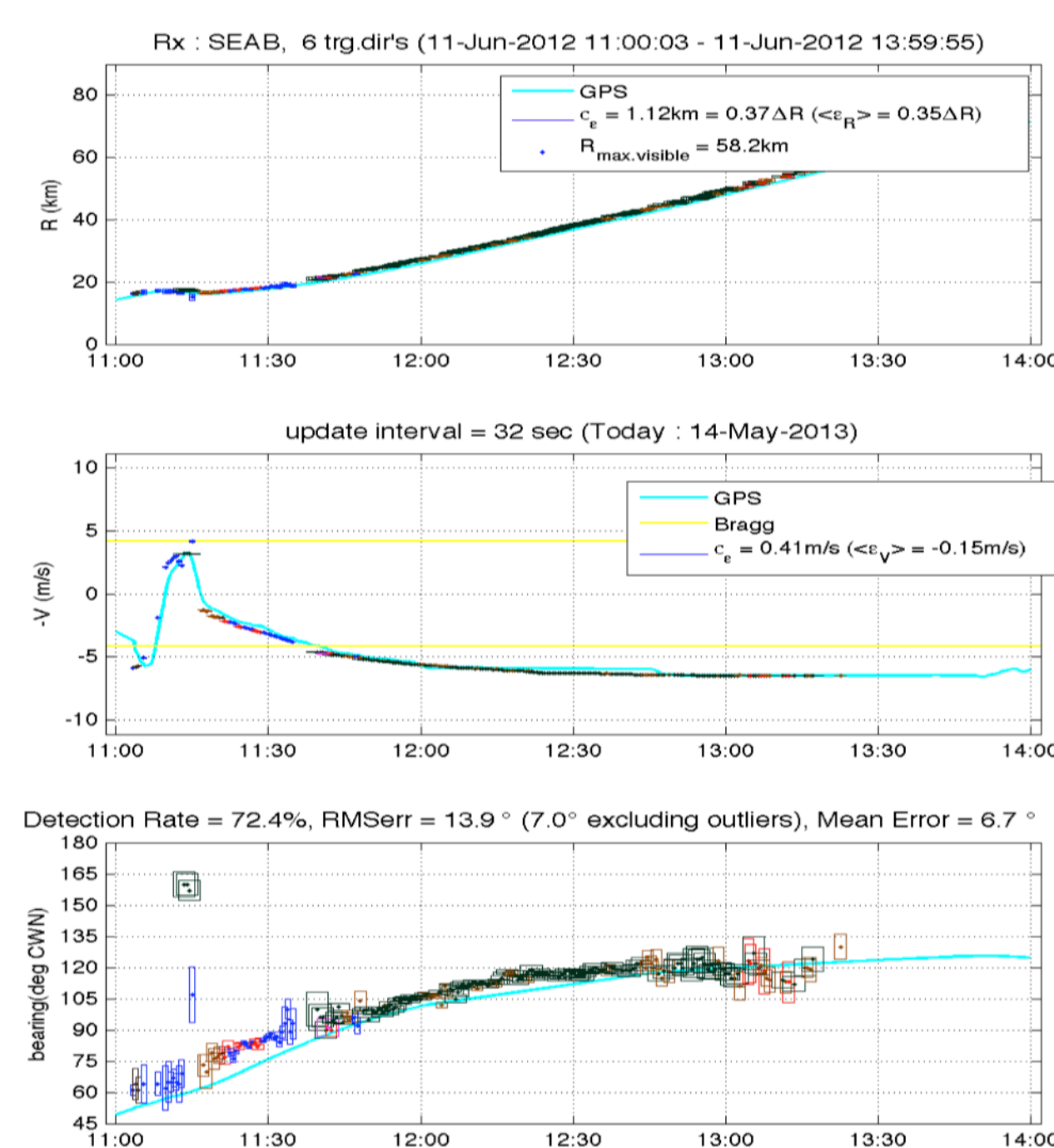


Figure 5:

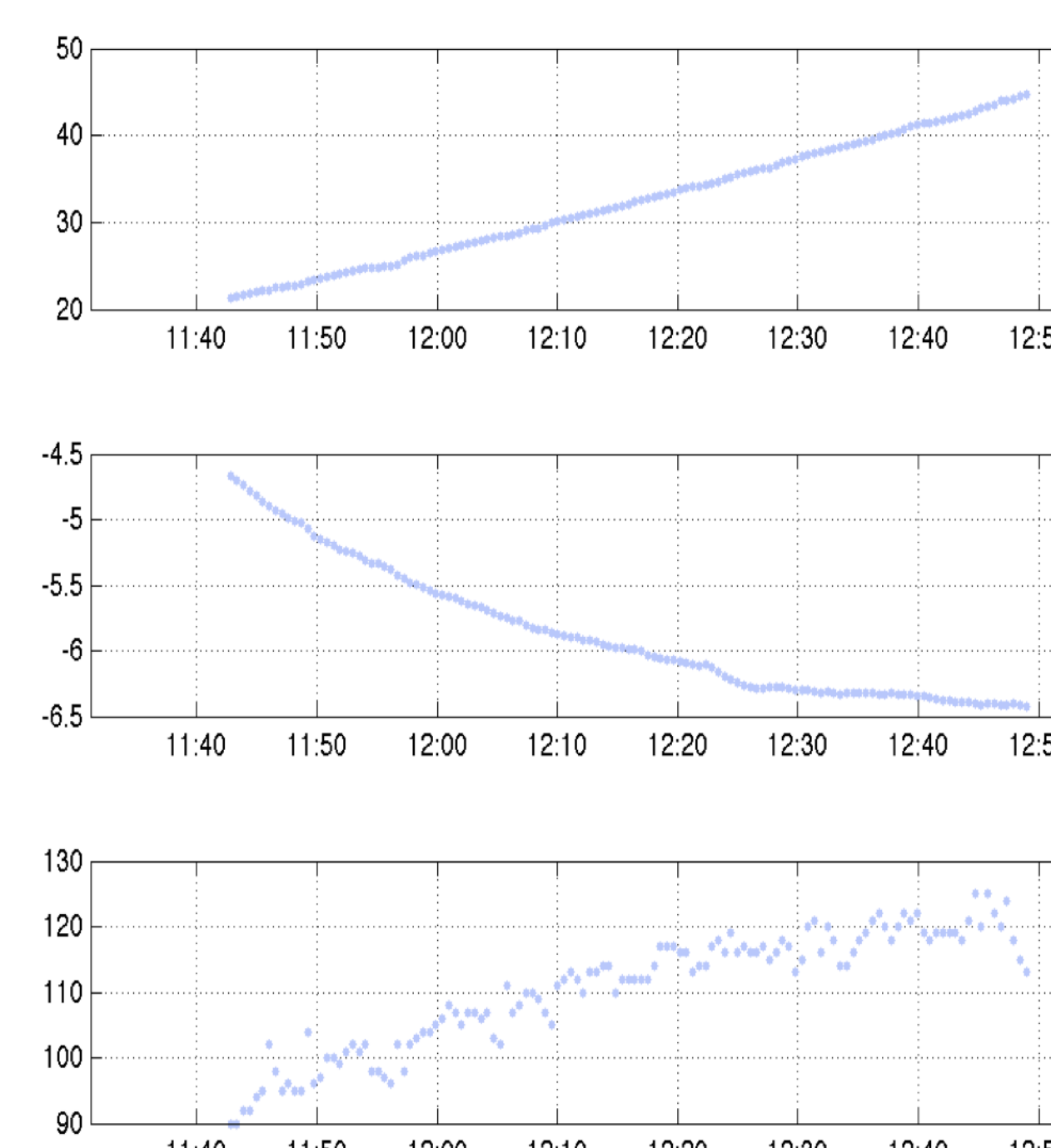


Figure 6:

PeakPicker detection data and AIS data are correlated based on range and range rate to assist in our development of the Level 2 association algorithm (Figures 5 and 6). As a result, the approximate percentage of time that PeakPicker detected a given ship can be calculated. This data is output into ASCII text files for further examination.

## Results



Figure 7:

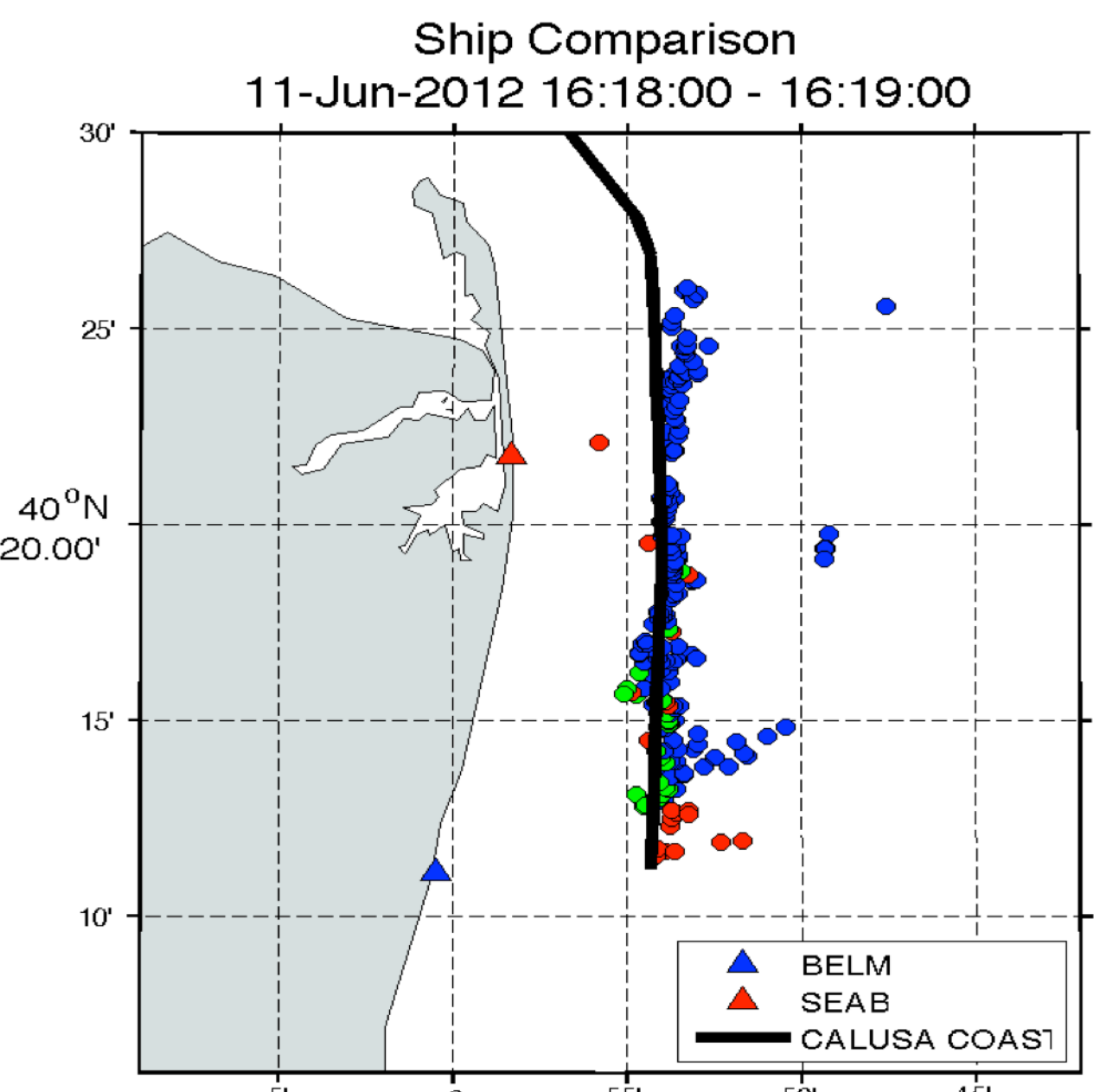


Figure 8:

When multiple HF radar sites are able to detect the same ship, Calusa Coast (Figure 7), from different angles, we are able to estimate a third "overlap" location, shown as the green detection in Figure 8. Compared to each separate site, this overlap point is typically closer to the actual location of the vessel at a given point in time. In Figure 9, the mean error for the overlap points (+/- 0.64 km) is very low, showing that these points correlate well with GPS locations.

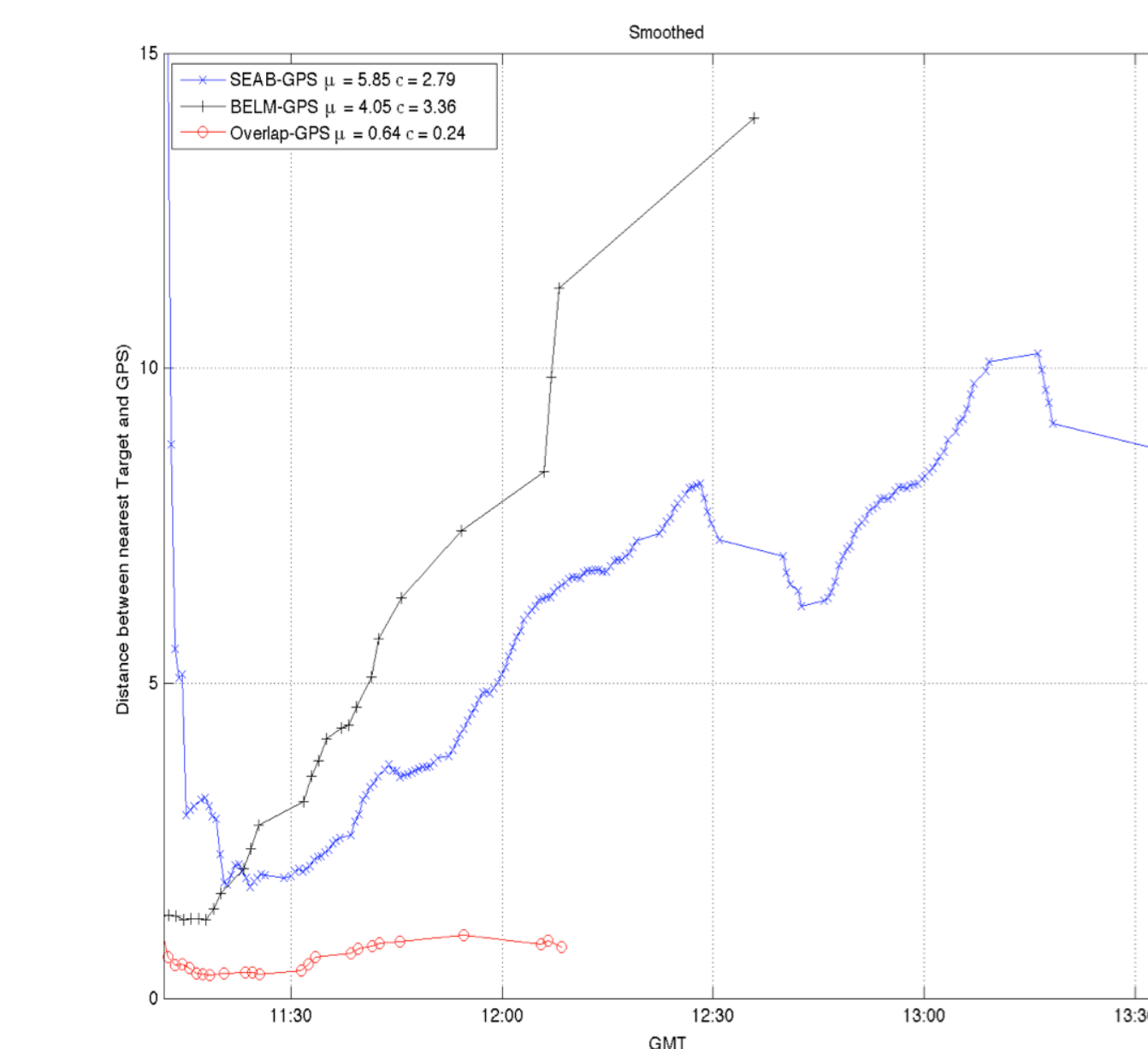


Figure 9:

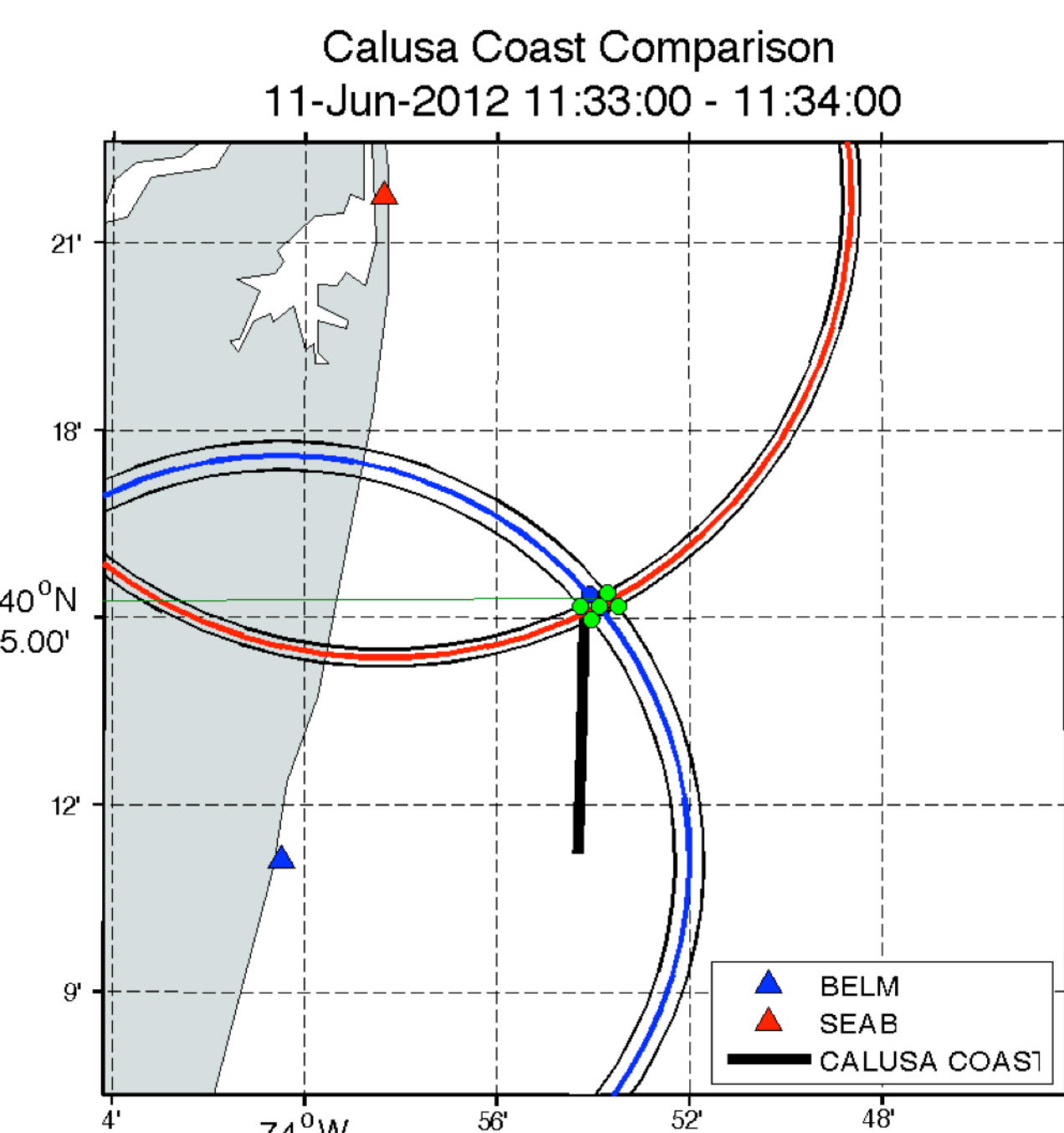


Figure 10:

Using the mean range error, four points are calculated from the initial detection (Figure 10). These points create a quadrilateral box around the center of detection, giving us an area of detections rather than a specific location for a detection. The size of this quadrilateral changes based on the increase/decrease in range error. The quadrilateral is advantageous due the antenna pattern of the radars being frequently affected by the local environment around the radar. Bad antenna patterns result in data with large bearing inaccuracies.

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