Surface Current Mapping Offshore of North Carolina with High-Frequency Radar

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Sites and History – the Outer Banks (OBX) high-frequency radar system was first established in 2003 with funding from the Office of Naval Research (the SEACOOS project). Two SeaSonde 5 MHz systems were installed that employ a direction-finding technique for determining the radial currents relative to the deployment site. A third site was added in 2013 with funding from the state. The map below (Figure 1) shows the locations of the three sites:
DUCK – in Duck, NC at the Field Research Facility operated by the U.S. Army Corp of Engineers
HATY – in Buxton, NC on what is now the Cape Hatteras National Seashore operated by the National Park Service
CORE – at the Great Island fish camp in the Cape Lookout National Seashore operated by the National Park Service.

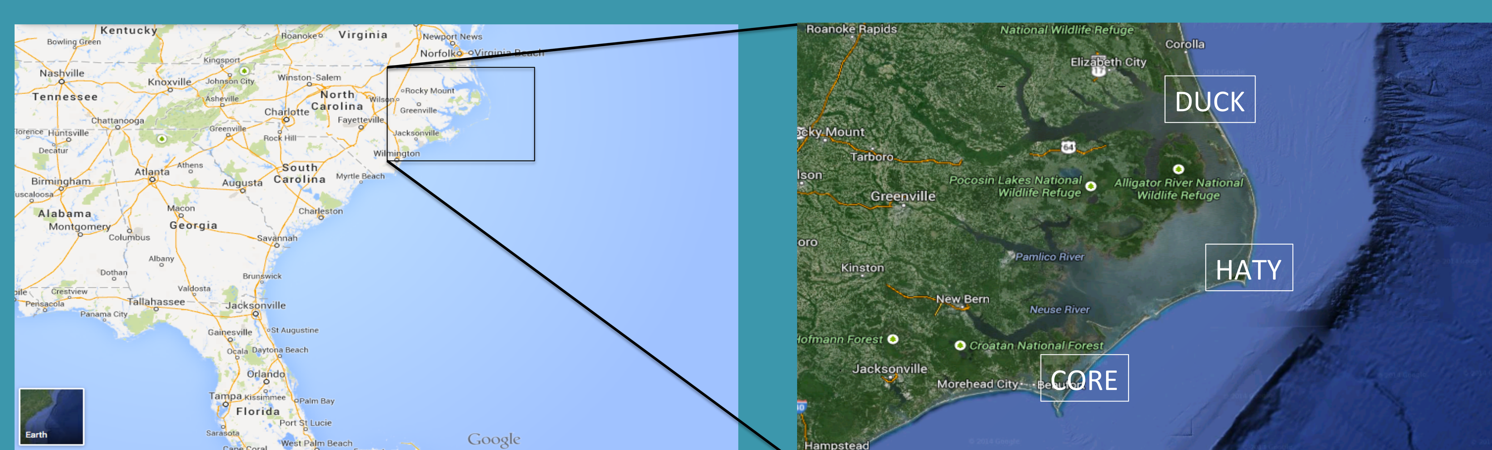

Figure 1 – map of the southeast (left) and map showing the locations of the high-frequency radar installations along the North Carolina coastline.

Since the initial installation the system has run nearly continuously, suffering only one prolonged outage at HATY over fall 2010/winter 2011 associated with a lightning strike. The emphasis since installation has been to maximize uptime and spatial coverage. Steps to harden power and communications were taken early on. Erosion has necessitated moving the HATY system several times, and lightning has proven to be the most persistent cause of downtime. Hurricane damage has also been an issue. Unlike the earlier installations that were positioned near power and communications infrastructure, the CORE site is in a remote location that requires its own power system and wireless communications. A stand-alone power system was installed during summer 2014 that allowed the system to operate over the 2014-2015 winter.

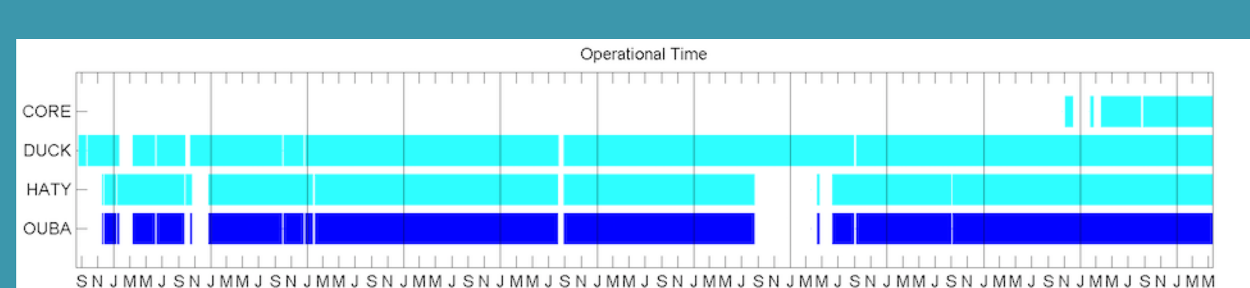

Figure 2 – timeline of individual station coverage (light blue) and total velocity vectors (dark blue) from the OBX installation.

Improvements in coverage have resulted from a better understanding of sources of interference (adjusting transmit frequency) and factors that impact system performance (antenna locations, beam patterns, cable size, corrosion prevention). Recent steps taken to improve coverage are given in the table below. The change in coverage due to the addition of CORE can be seen in Figure 3.

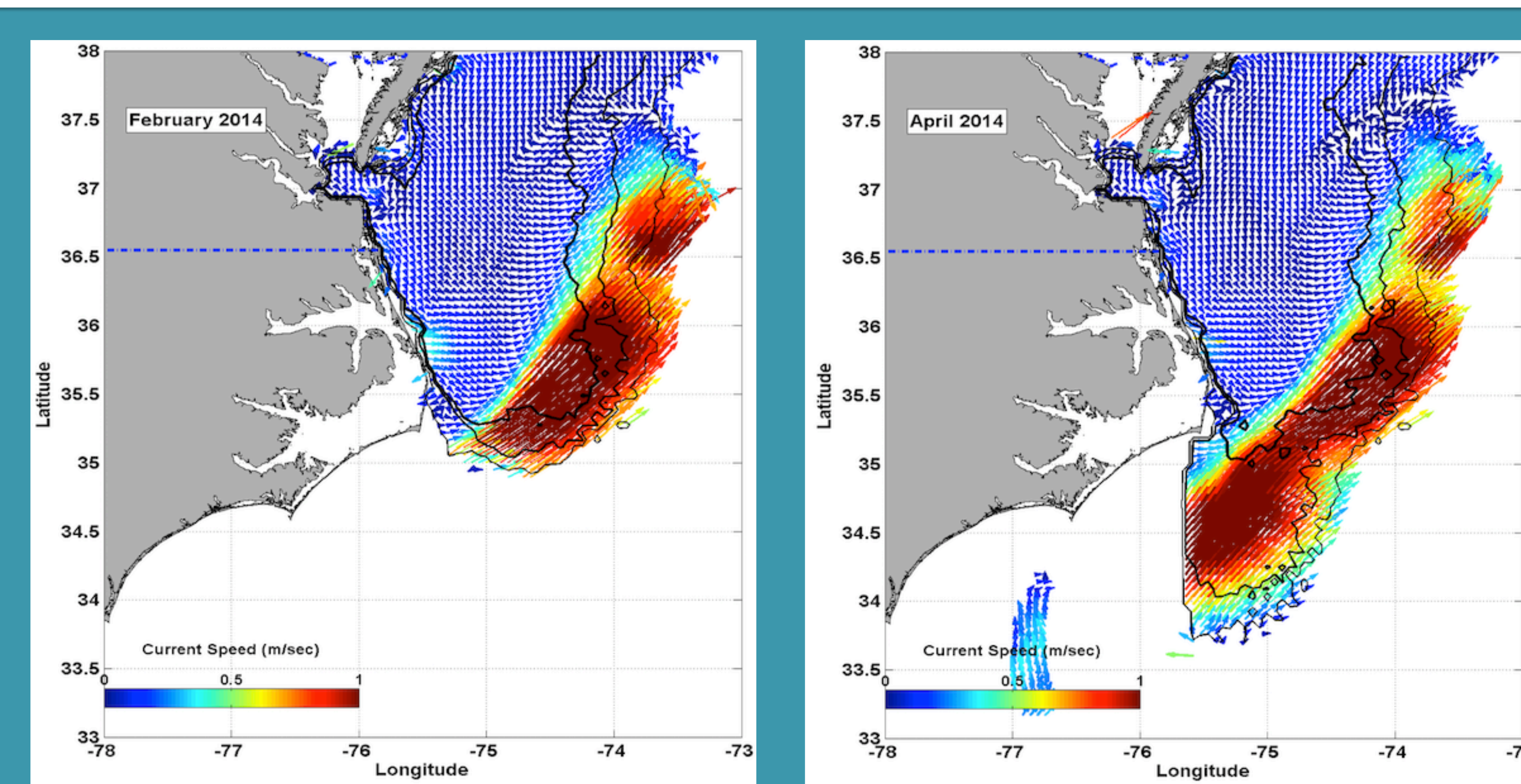

Figure 3 – month-averaged currents from February 2014 (left) and April 2014 (right) showing the increase in coverage from adding the CORE site. Black lines mark the 90%, 75% and 40% coverage regions.

Quality Control Efforts – each radar installation produces estimates of the current toward or away from the site, in a radial pattern. A particular issue with the OBX installations has been errant speed estimates. These sites are the only CODAR installations in the US overlooking the Gulf Stream and are challenged by the high currents (> 2 m/s) that occur. In an effort to improve the current estimates we are implementing recommendations made by Kirincich et a. 2012):
1. Utilize newly-available signal metrics to identify low quality speed estimates and exclude them from further processing. Two of the metrics relate to the algorithm used to define the direction of the current measurement and a third is related to the signal strength. Excluding estimates of low quality consistently leads to greater average speed estimates (Figure 4).
2. Employ a weighted averaging scheme to define the speed at a specific range and bearing. The CODAR system can produce multiple estimates of speed from a given location but the quality of the estimates can vary greatly. The standard processing fails to recognize the variability in quality of the estimates and simply averages all values. The weighting scheme appears to reduce the variability of speed estimates as seen in maps of the standard deviation of solutions (Fig. 5).

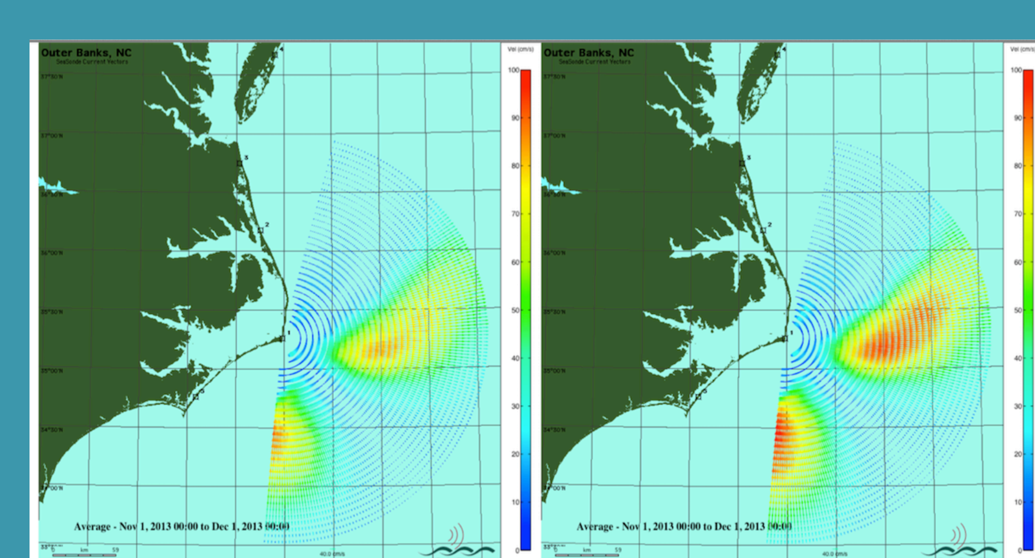

Figure 4 - Monthly averaged radial velocity estimates from HATY, with the vendor software measurements (left) and quality controlled measurements (right). Note the significant increase in speed of the radial velocity estimates in the Gulf Stream (hot colors) in the quality controlled averaged radial velocities.

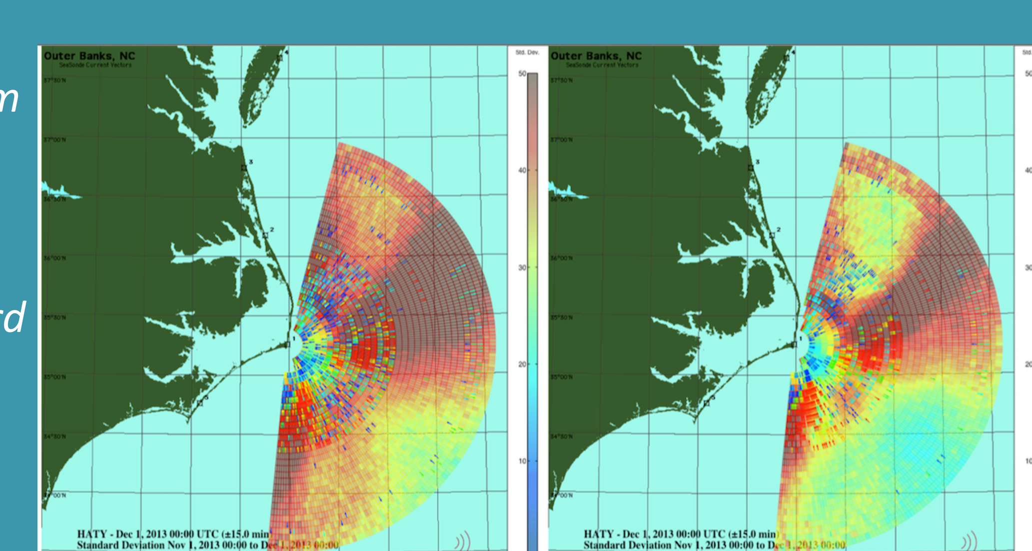

Figure 5 - Standard deviations in radial current measurements from HATY over one month using the vendors processing (left) and the new quality controls (right). Note the higher values of standard deviation (red) in quality controlled data are located along the GS front where high velocity variability is expected.

Gulf Stream Properties – To provide a simple characterization of the Gulf Stream and its variability we have been developing methods to extract position information. We have chosen to concentrate on analysis of radial velocities along bearings with strongest radial currents due to challenges faced when attempting to analyze the entire domain. Shown below are results from examining 2 months of data (Figure 6). Range-time plots clearly show the Gulf Stream (Figure 7). Time series of the position of the region of most rapid change in current with range and position of maximum speed (Figure 8) illustrate how the Gulf Stream moves on weekly periods. The average locations compare favorably with frontal locations derived from sea surface temperature (Figure 9).

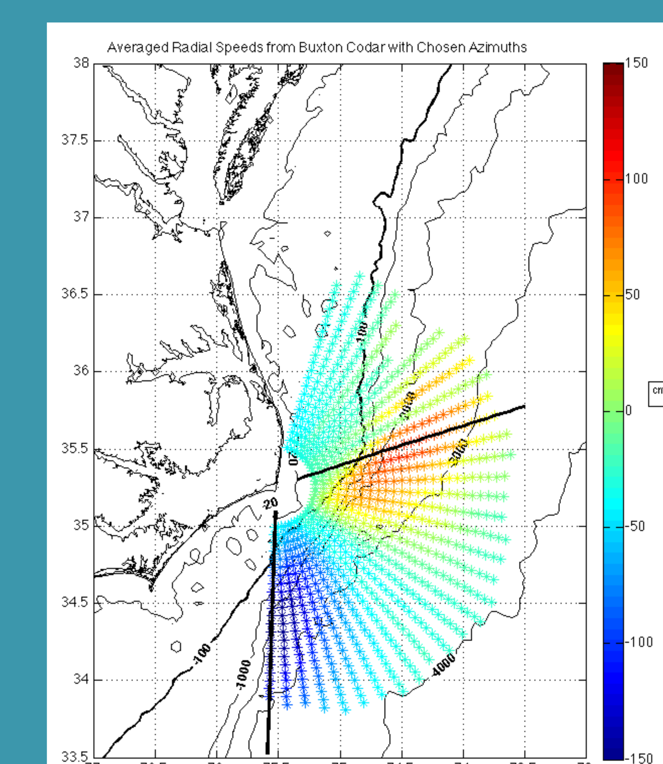

Figure 6 – mean radial over 2 months; positive is away from the site by convention. Black lines mark bearings used in subsequent analysis.

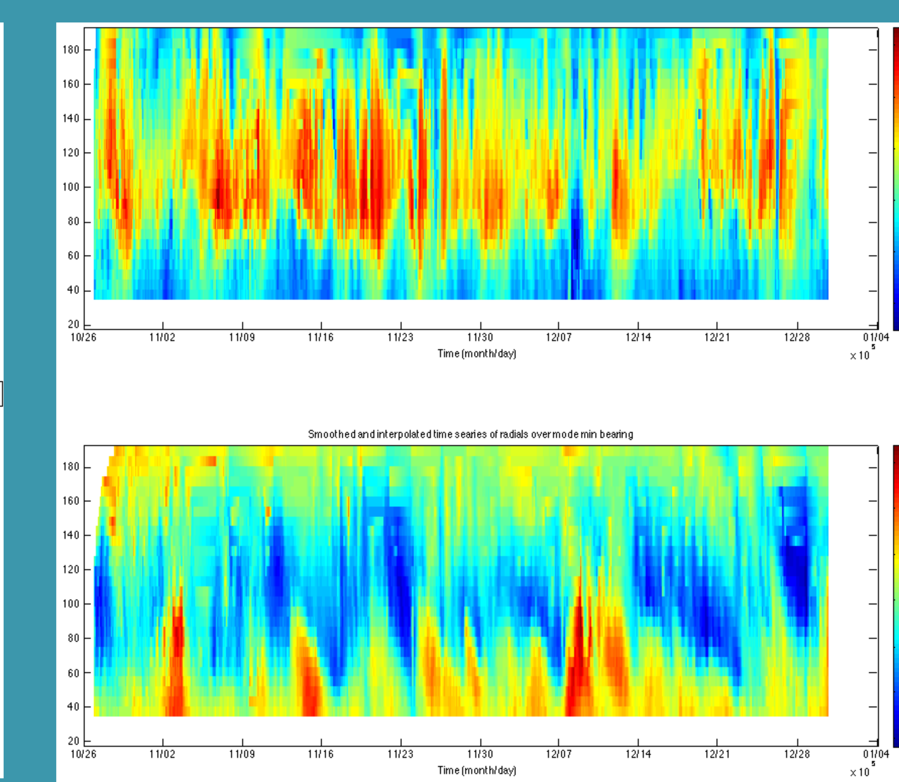

Figure 7 – current as a function of time and range along the NE (top) and S (bottom) bearing in Figure 6.

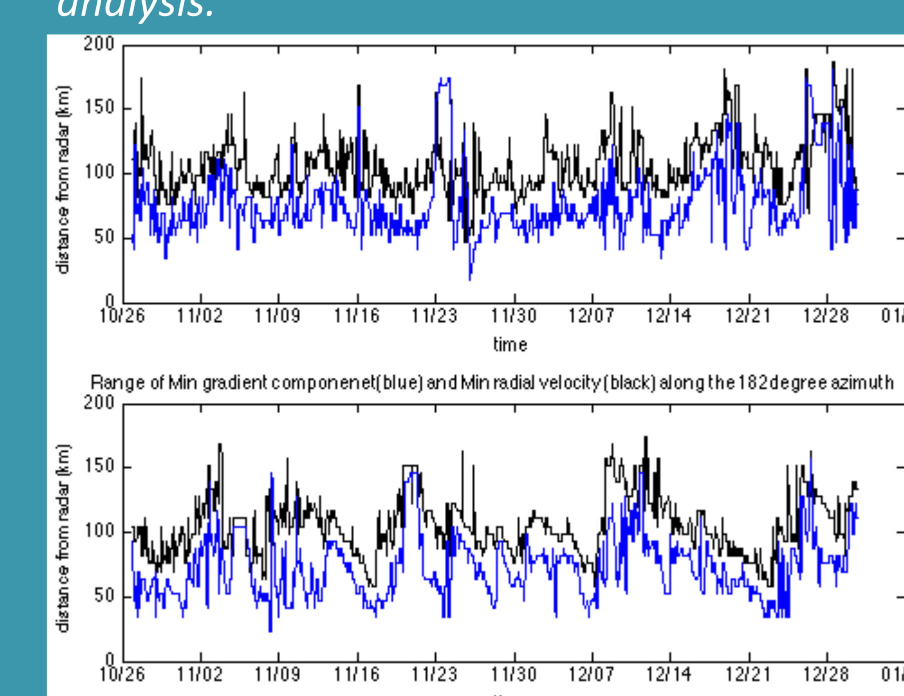

Figure 8 – time series of the distance to the maximum radial velocity gradient and maximum velocity along the NE (top) and S (bottom) bearing.

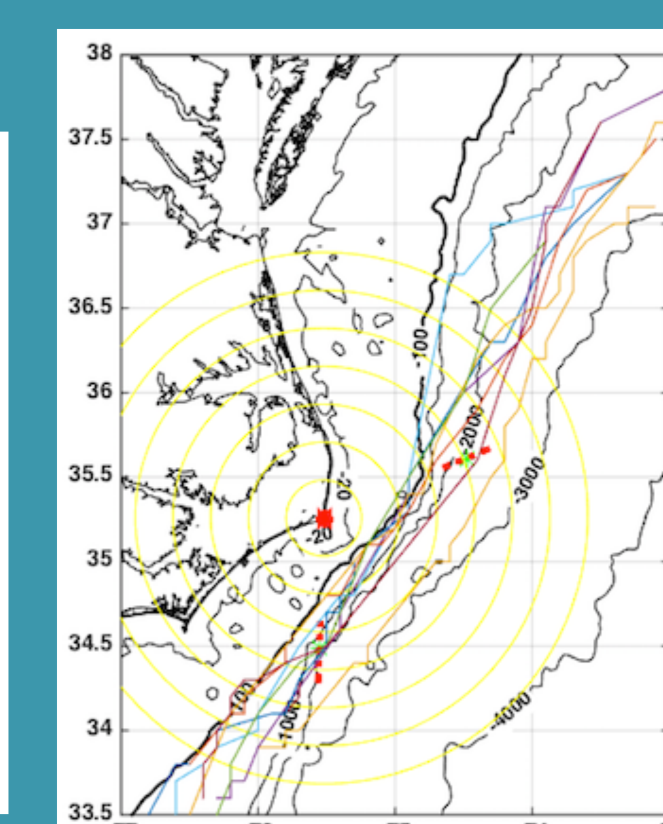

Figure 9 – mean (green) and standard deviation (red dash) of maximum velocity location relative to bathymetry and Naval frontal positions derived from SST.

Reference: Kirincich, A., T. De Paolo, and E. Terrill (2012), Improving HF radar estimates of surface currents using signal quality metrics, with application to the MVCO high-resolution radar system, *J. Atmos. and Ocean. Tech.*, 29.9: 1377-1390.

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