High Frequency Radar Observations of Tidal Current Variability in the Lower Chesapeake Bay

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Background

A tidal analysis of a multi-year record of high frequency radar (HFR) surface current observations in the lower Chesapeake Bay characterizes the spatial and temporal variability of the tidal component of the surface circulation. The Bay radar observation network includes three 25 MHz CODAR SeaSonde systems, which provide radial data used to generate hourly velocity maps on a 2 kilometer spaced grid (Figure 1). Tidal analysis results are compared with wind, water level and salinity data collected by NOAA's Physical Oceanographic Real-Time System (PORTS). Harmonic analysis of NOAA PORTS Acoustic Doppler Current Profiler (ADCP) data is also examined.

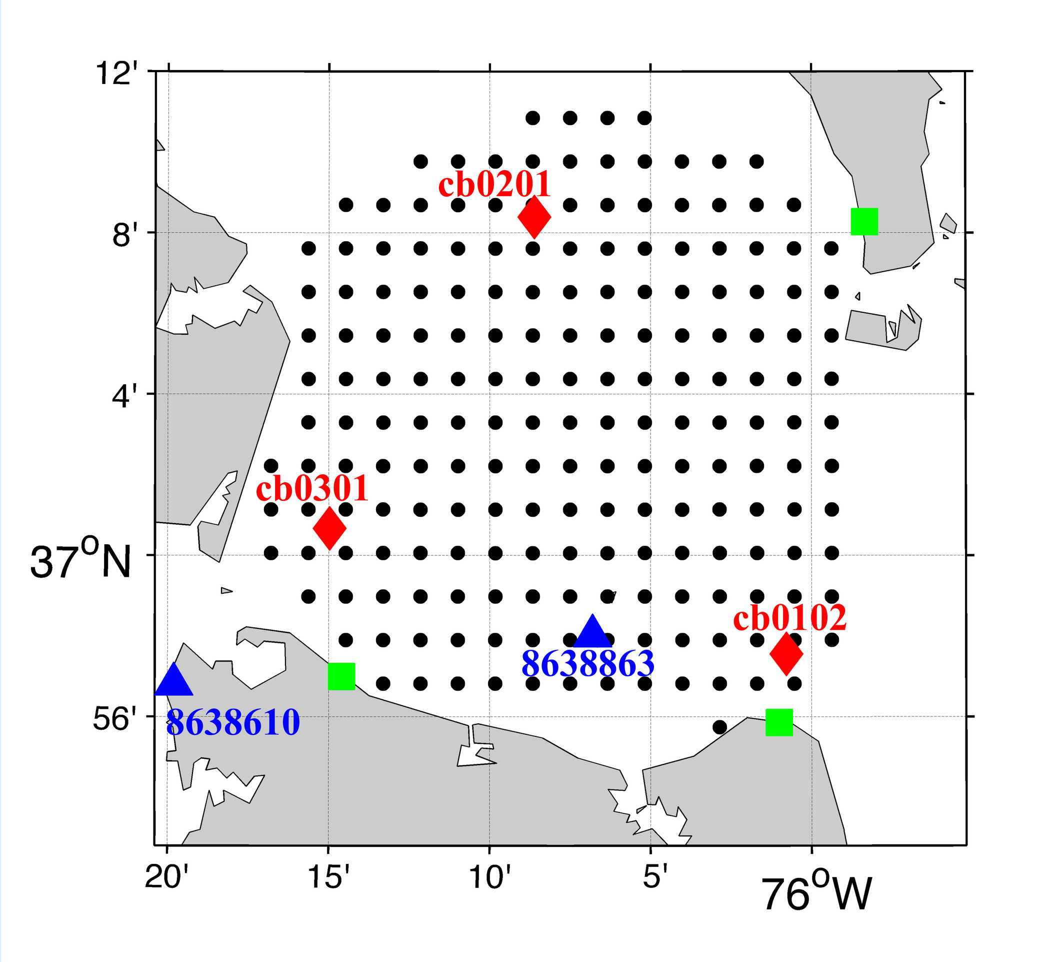


Figure 1. Chesapeake Bay radar site locations (green) and grid points for total velocity maps (black). NOAA ADCP stations (red) and water level/met stations (blue).

Methods

The radar current maps were processed with standard least squares techniques employed by the HFR community using the MATLAB HFR-Progs toolbox. Velocity vectors with a Geometric Dilution of Precision (GDOP) error estimate above 1.25 cm/s were removed from each map and replaced with spatially interpolated values. A temporal interpolation was then used to fill short (≤3 hour) gaps in the record. Tidal analysis was not performed unless data were present at least 70 percent of the time.

At each grid location, data were rotated to the major axis prior to harmonic analysis with the MATLAB UTide toolbox using an ordinary least squares approach. In order to examine seasonal variability, the record was divided into overlapping bi-monthly segments of time centered on the middle of each month. Consistency of major axis direction through time was used as a quality check on the data and ultimately led to the decision to analyze a subset of data collected from April 2009 to November 2015.

Multi-year Record Results

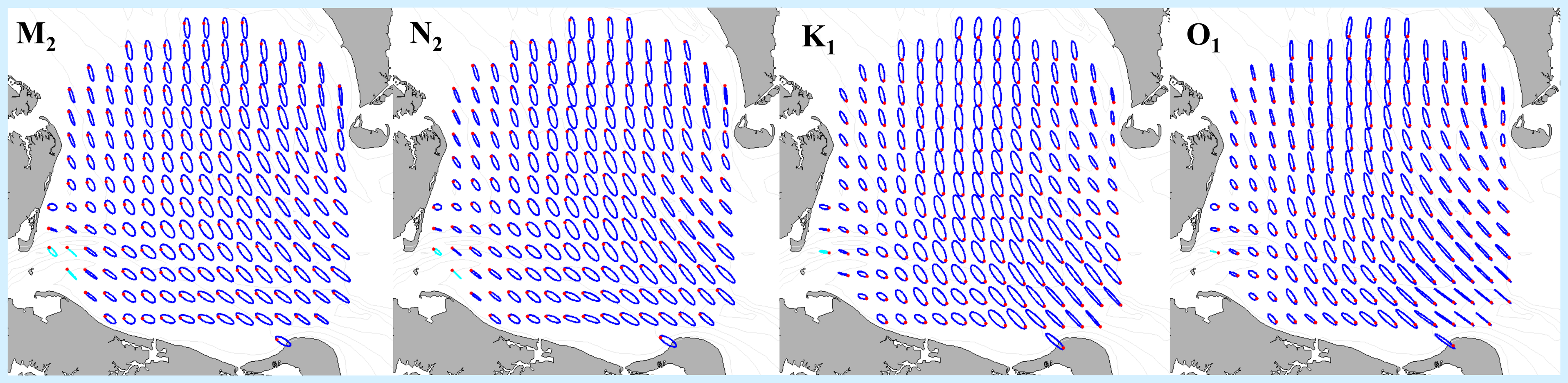


Figure 2. Tidal current constituent ellipses for the entire record (April 1, 2009 to Nov 30, 2015). Phase values are shown by the red dots. Dark blue ellipses indicate counter-clockwise rotation and light blue are clockwise.

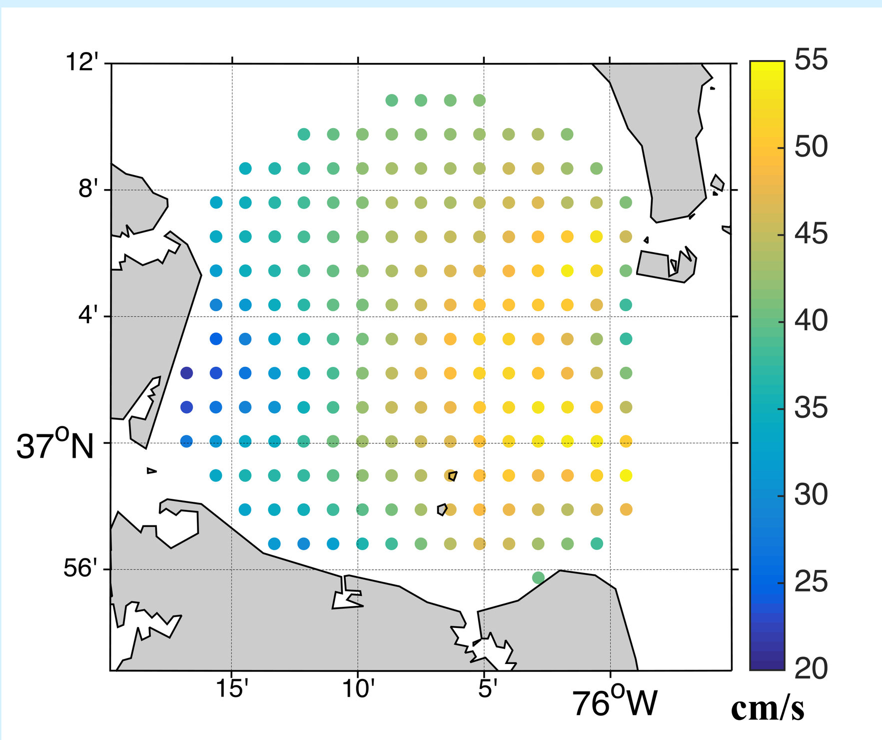


Figure 3. M_2 major axis amplitudes for the entire record.

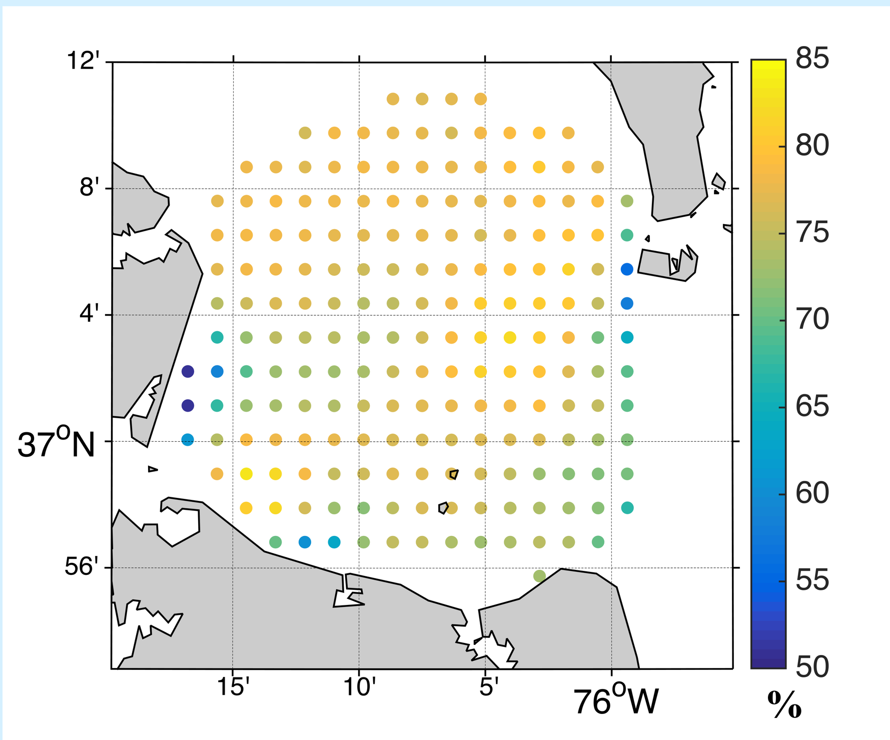


Figure 4. Percentage of variance explained by the tidal component.

Bi-monthly Time Series Results

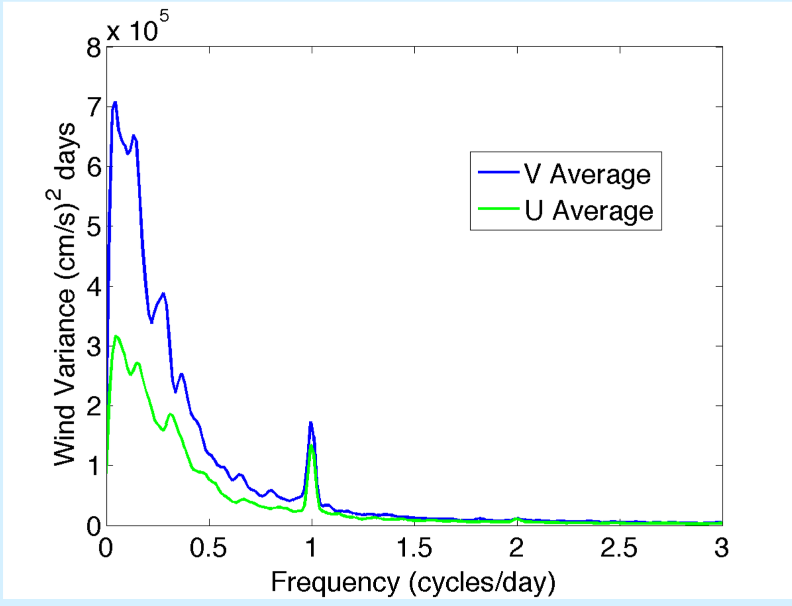


Figure 5. Average of bi-monthly wind spectra for winds observed at station 8638863. A peak at 1 cycle/day shows the diurnal land-sea breeze cycle while peak variances at less than 0.5 cycles/day indicate longer period weather driven events.

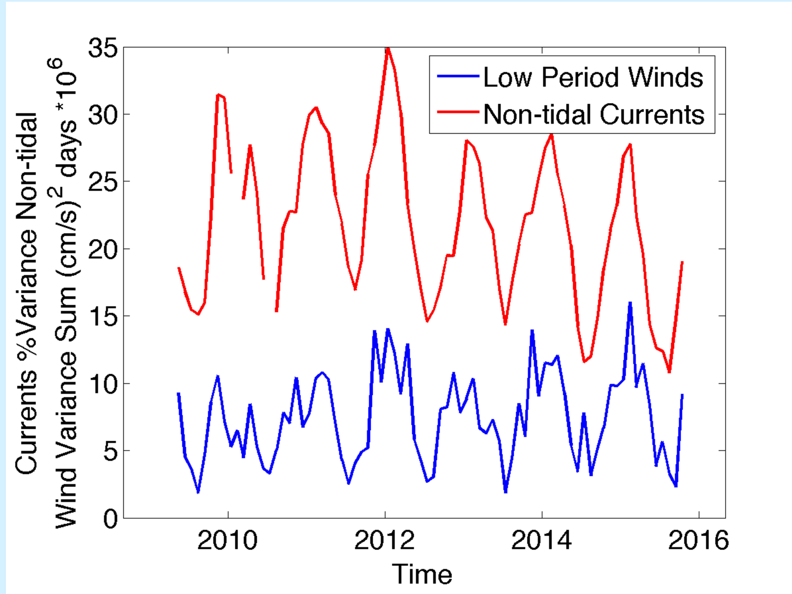


Figure 8. The percent of the total current velocity variance not explained by the tide is correlated with the cumulative wind variance in low periods (2-7 days) at station 8638863. The velocity variance is based on a spatial average over the radar grid.

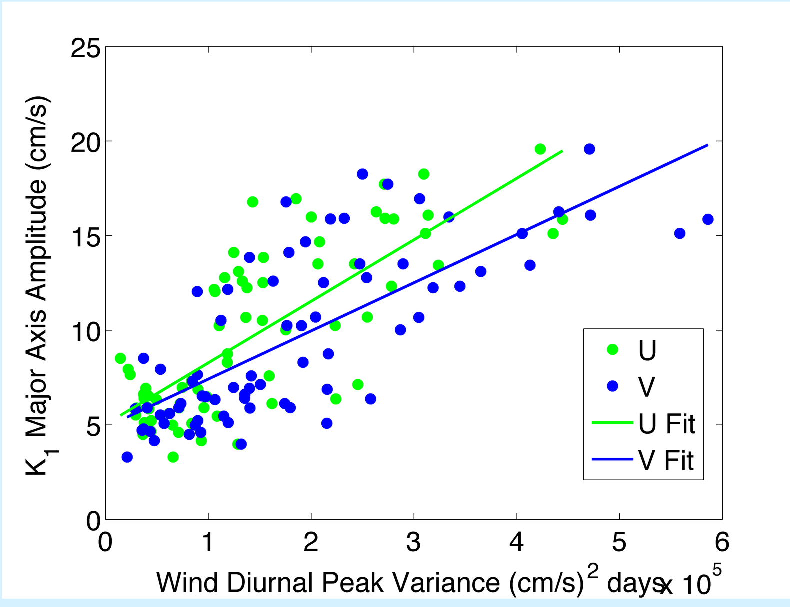


Figure 6. The diurnal peak variance in winds correlates with K_1 major axis amplitude averaged over the radar grid.

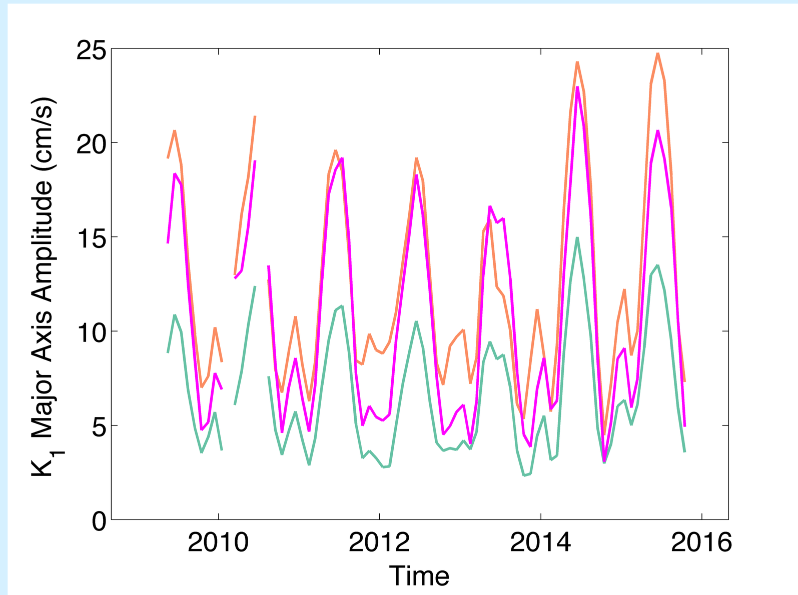
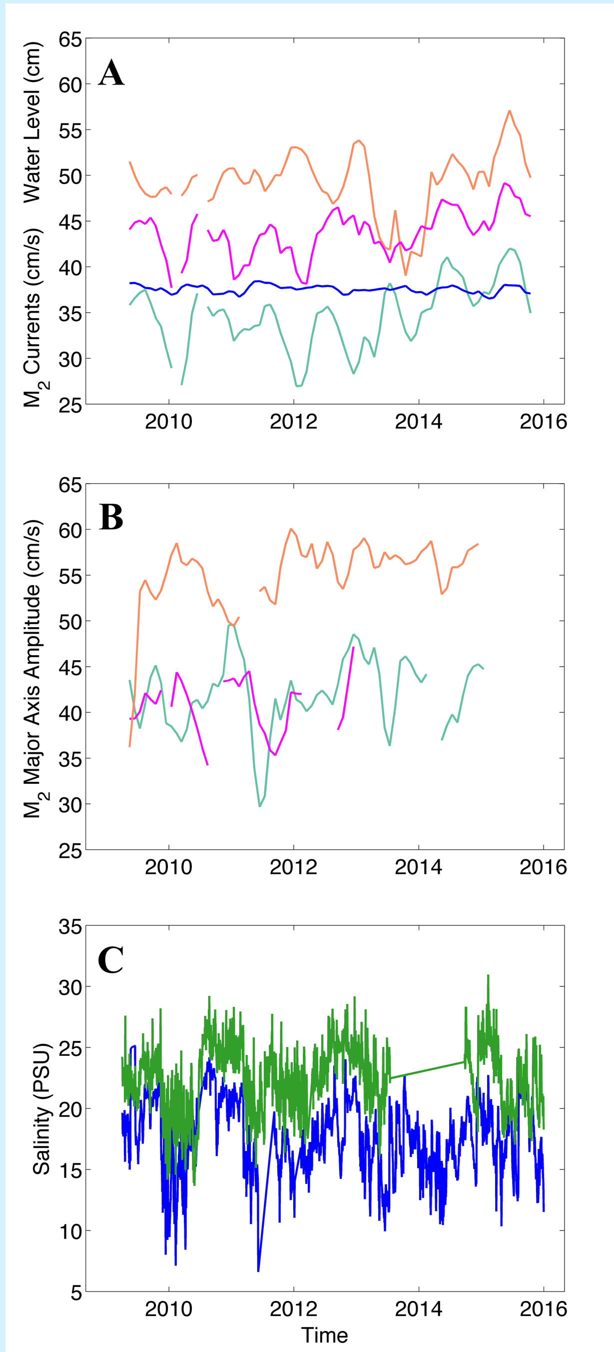
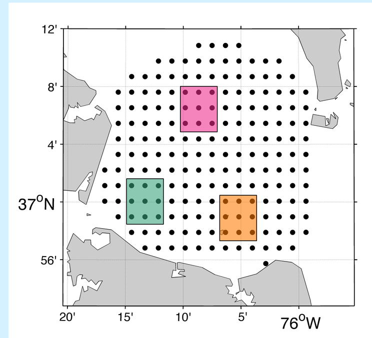


Figure 7. Average K_1 major axis amplitude in different sections of the radar grid. Line colors correspond to areas of the grid indicated by shaded boxes in the map to the right.





Map Legend for Figures 7 & 9.

Figure 9A. An average of bi-monthly M_2 major axis amplitude in different areas of the radar grid indicated by the shaded boxes seen in the map legend above. The M_2 amplitude of water level at NOAA station 8638863 is shown in blue and is much less variable.

Figure 9B. Bi-monthly M_2 major axis amplitude at NOAA ADCP stations: cb0301 (green line), cb0201 (pink) and cb0102 (orange). These data are from analysis of bin 5 data at an approximate depth of 7.6 meters.

Figure 9C. Salinity calculated for NOAA stations: 8638610 (blue) and 8638863 (green).

Conclusions

The M_2 tidal contribution to surface flow varies spatially with higher major axis amplitudes near the mouth of the Bay and lower amplitudes near the mouth of the James River. The percentage of total current variance explained by the tidal component ranges from 70 to 85% over most of the grid. Harmonic analysis of bi-monthly time segments indicate the level to which the tidal current constituents vary over time. The variability of the K_1 component compared to diurnal variance in winds suggest that the value of this major axis tidal constituent is increased in summer months coincident with an increase in the diurnal land-sea breeze. Variations in M_2 amplitude are complicated by several factors and a correlation with salinity was not apparent.

References

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ODU HFR website: http://www.ccpo.odu.edu/currentmapping

National HFRADAR Network Gateway: http://cordc.ucsd.edu/projects/mapping