Data Report: Buoy-Deployed ADCP
Gulf of Mexico and East Coast Carbon Cruise (GOMECC)
R/V Ronald Brown, 10 July – 4 Aug, 2007

Personnel

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Summary

A buoy-mounted ADCP was deployed for 3 - 5 minute sampling periods at alternate CTD stations, a last-minute solution required because the ADCP in the R/V Brown's hull was damaged. The standard error based on observed variability in velocity measurements during an averaging period is 3.1 cm s^{-1}. **Figures 1a and 2b** show resulting maps of velocity and shear vectors, with the most prominent feature being the Gulf Stream velocities of 1-2 m s^{-1}. A consistency check on velocity data is to compare the buoy velocity computed from bottom-track pings to the buoy velocity computed from GPS coordinates. Results of this check were also consistent with errors generally being below 5 cm s^{-1}.

Data Acquisition

A 300 kHz Acoustic Doppler Current Profiler (ADCP) was mounted in a buoy, aimed downward (**Fig. 2**), with the first depth cell centered at 4.5 m and a range of up to 110 m. Water velocity ensemble averages were computed from 25 measurements (pings) spaced evenly over 20 seconds, with 2 m depth resolution. At times, 7 additional seabed velocity measurements (bottom tracking) were interspersed with the water pings to measure the velocity of the buoy. A waterproof GPS was mounted on top of the buoy, logging position to 2 m resolution at all times, also measuring buoy velocity.

ADCP data were typically only collected at every other station, due to time constraints – it took about 30 minutes per station for the entire deployment process. Also, average velocity profiles are not being presented for Stations 1-16 because data are of lower quality. This is primarily because a lower number of velocity measurements were collected per 20-second ensemble (7) – the lower number of samples was an attempt to conserve battery power, but it was later determined that it would save an equal amount of power if bottom tracking were typically turned off. Email communication between the onboard crew and the lead technician on the mainland was essential in diagnosing and solving this problem.

Data Processing and Uncertainty

Data from each station were carefully examined, and the typical set of plots used for quality control are shown in **Figures 3-6**. Velocity data were edited to remove data below the seabed, and conservative editing was used to remove low-quality data. At each station, data from depths where 20% or more of the time series had bad data (low ping-to-ping correlation) were omitted.

It was possible to detect the water column depth directly from the ADCP data when it was within the measurement range using two methods: (1) bottom tracking pings, when available, or (2) from the strong acoustic backscatter signal from the seabed. For the latter approach, we used each ensemble average of ADCP acoustic backscatter data from each beam separately to obtain a time series of depth (Visbeck and Fischer, 1995). The single beam estimates and ensembles were averaged to give a single depth estimate for each station.

The observed standard deviation for velocity data utilized in a station average is typically 7-15 cm s^{-1}, with a full-cruise average of 10 cm s^{-1}. Combining this with sample sizes and the assumption of normally distributed data, the standard error for mean velocity estimates is 3.1 cm s^{-1}. This uncertainty is due to a combination of all noise sources, including sensor noise, GPS data uncertainty, noise caused by buoy tilt variability, and environmental variability. Velocity data are grand averages of several ensemble averages, including data covering a minimum of 160 seconds (but more typically about 240 seconds). Thus, the number of actual velocity measurements is at least 200, for which the manufacturer estimate of standard error arising from sensor noise alone is 0.4 cm s^{-1}. Uncertainty that arises in a grand average due to GPS resolution (2 m) is 0.8 cm s^{-1}.

A critical assumption in the short deployments of the ADCP buoy was that averages of only a few minutes should be equivalent to much longer averages. This is generally true in the coastal ocean, because the longest-duration turbulence has a timescale below 1 minute, and the tidal timescale is several hours. Exceptions would be rare periods when large Langmuir cells, internal waves or density fronts are present. The assumption was validated using a separate coastal ocean dataset (R. Chant, unpublished data, 2004) from a bottom-moored upward-looking ADCP in 23 m deep water. These data show that differences between 160 second and 15 minute averages are very small (rms difference of 0.9 cm s^{-1}; **Fig. 7**).

The ADCP uses an internal compass, and corrections were applied for the spatially varying effect of magnetic declination on the velocity direction estimates. Also, by comparing bottom-tracked and GPS-tracked estimates of buoy velocity, it was verified that the compass was not being biased by the steel-hulled ship (**Fig. 8**). Results of this check were also consistent with errors generally being below 5 cm s^{-1}.

Velocity Observations

Water velocity was generally 0.5 m s^{-1} or below, except in isolated cases (**Fig. 1a**). The Gulf Stream had velocities of 1-2 m s^{-1}, fairly uniform over the observed depth range (4-110 m). The offshore station on the West Florida shelf displayed strong velocities of ~0.8 m s^{-1}. Generally, weak currents were observed elsewhere, likely reflecting the relatively weak atmospheric forcing during the cruise.

Near-surface (5-10 m) shear was typically below 0.005 m s^{-1} per meter, and stations with high velocity did not necessarily have high near-surface shear (Fig. 1b). An inshore station in the Gulf of Maine had the strongest shear, at ~0.01 m s^{-1} per meter. Moderate shear was observed along the entire line that headed SSE from Martha's Vineyard.

References

Visbeck M. and Fischer, J., 1995. Sea surface conditions remotely sensed by upward-looking ADCPs. Journal of Atmospheric and Oceanic Technology 12, 141–149.

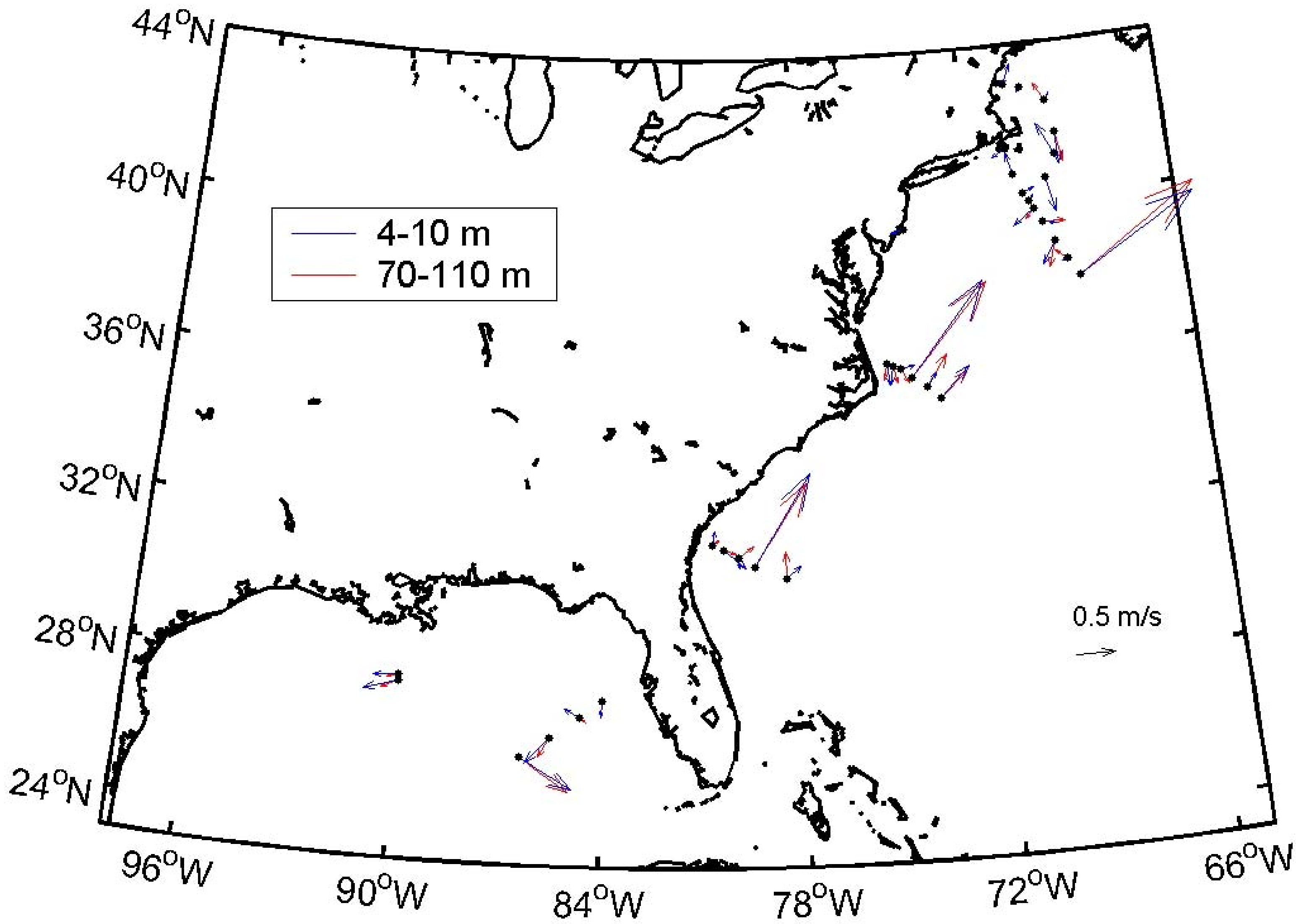

Figure 1a: Velocity vector averages for two depth ranges. Averages comprise any available data from those depths (after data quality control has omitted poor quality data); if there is only data between 70 and 75m, velocities will be averaged over those depths.

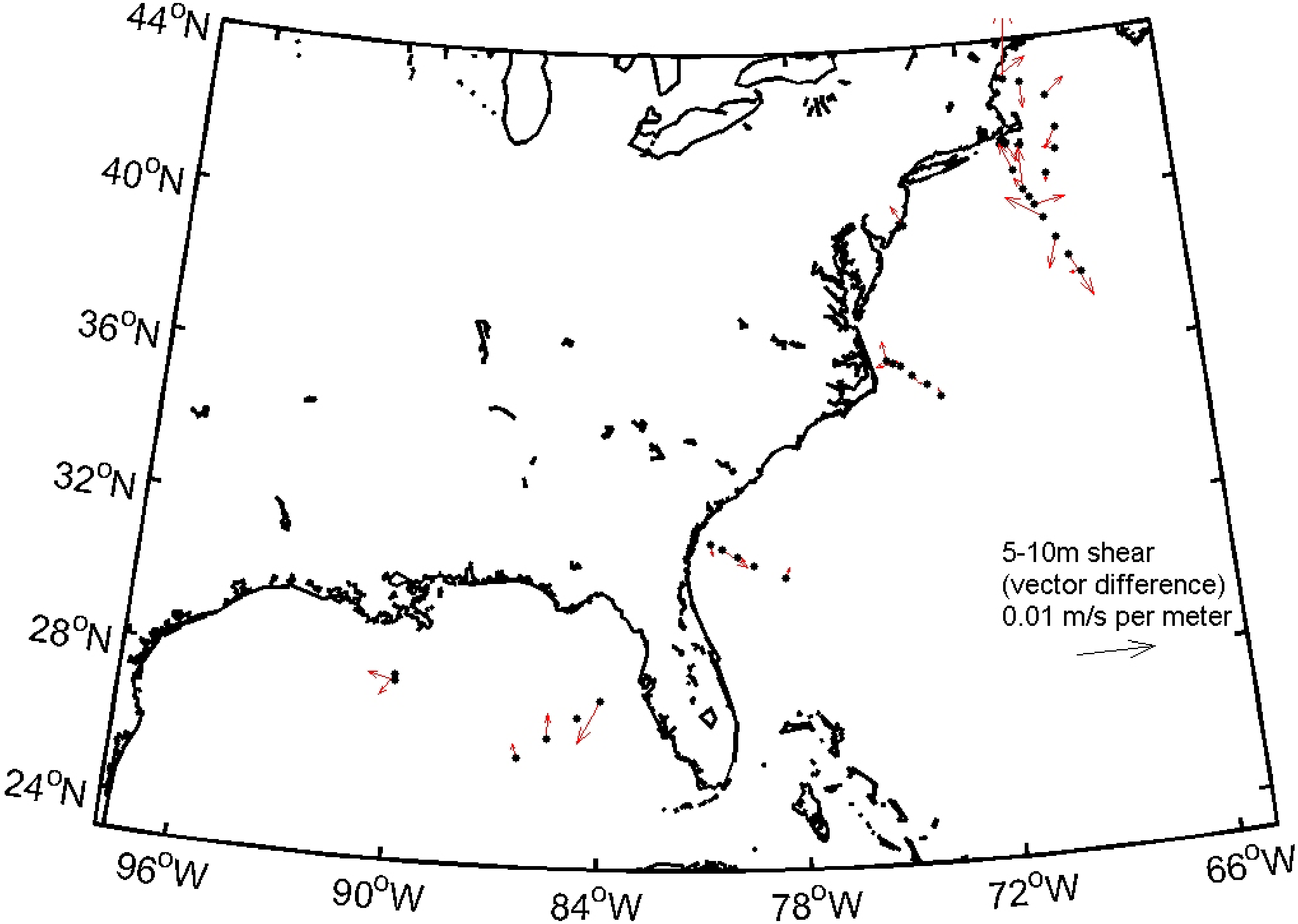

Figure 1b: Velocity shear for 5-10m depth is shown, computed as the vector difference between the velocity at each depth. Some additional averaging is used prior to computing the shear – the 5 m estimate is the 3-5 minute average of two neighboring depth cells, and the 10 m estimate is an average of three cells.

Figure 2: Photos showing the ADCP transducers (top), buoy, and GPS (lower picture, just right of center).

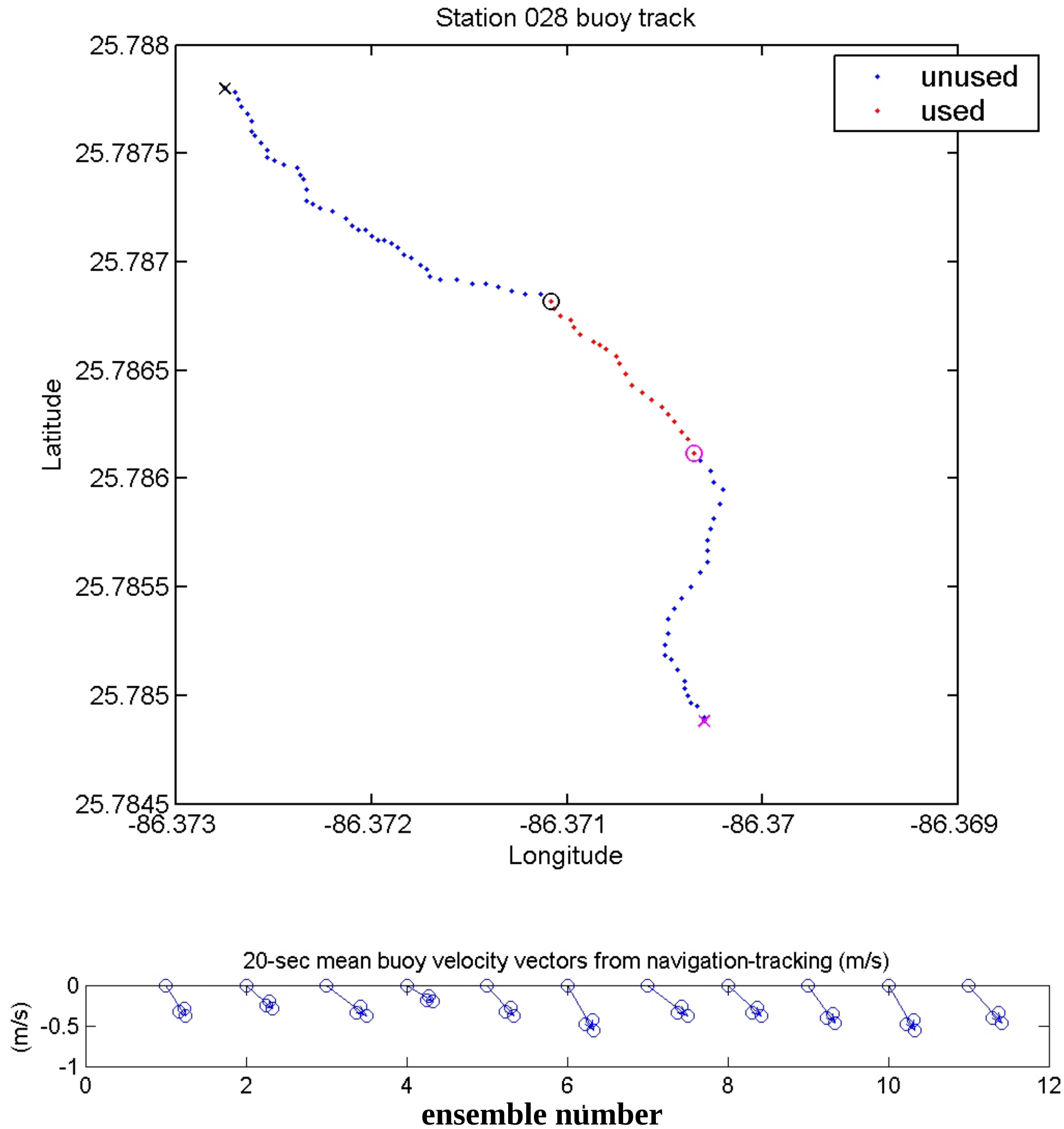

Figure 3: GPS data from Station 28 – (top) buoy location, (bottom) buoy velocity vectors for each ADCP ensemble (the three neighboring circles form the arrow at the end of the vector, and the vectors emanate from 0 m s^{-1}). In the top panel, the black x marks the first GPS data point, when the buoy was onboard the vessel. The black circle marks the beginning of good data, the red dots mark all the locations of good ADCP data, and the magenta circle marks the last good ensemble. The magenta x marks the location of the buoy when the GPS was turned off.

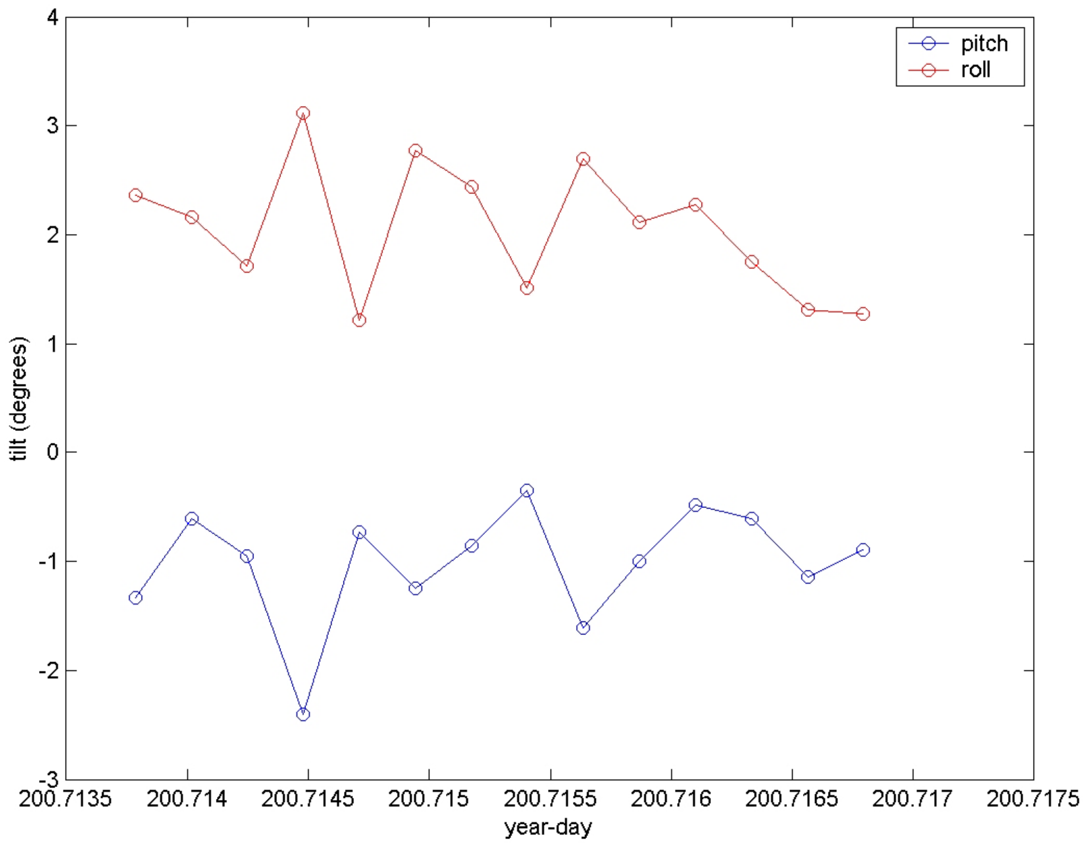

Figure 4: ADCP tilt data such as this were examined to help omit data from periods when the buoy was pulled by the line, or for other reasons. This figure shows tilt data after bad data were removed, so tilts are small.

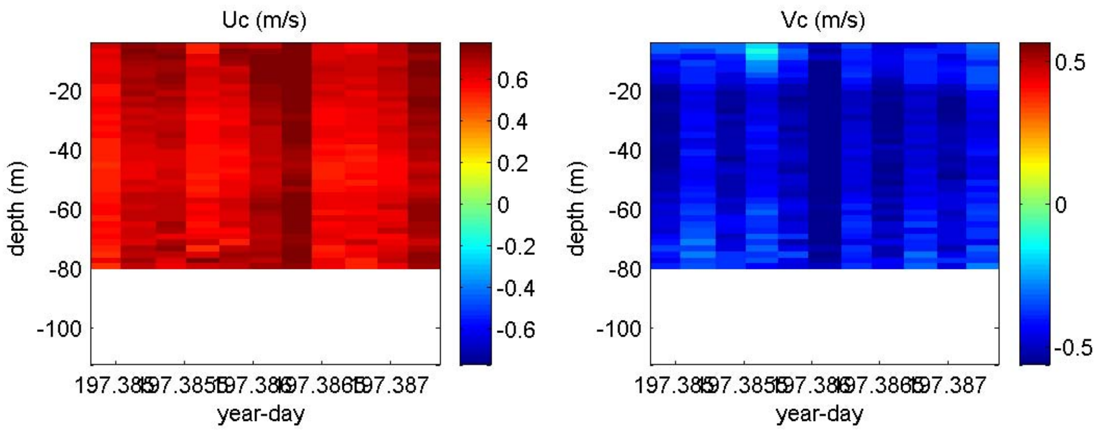

Figure 5: Time series showing all the available (after quality-control) velocity data utilized at Station 28. Each of the 11 20-second ensemble averages is averaged into one grand average for the station. Variability evident from one ensemble to the next is of the order 10 cm s^{-1}. The observed standard error for the resulting average velocity data is 3.1 cm s^{-1}.

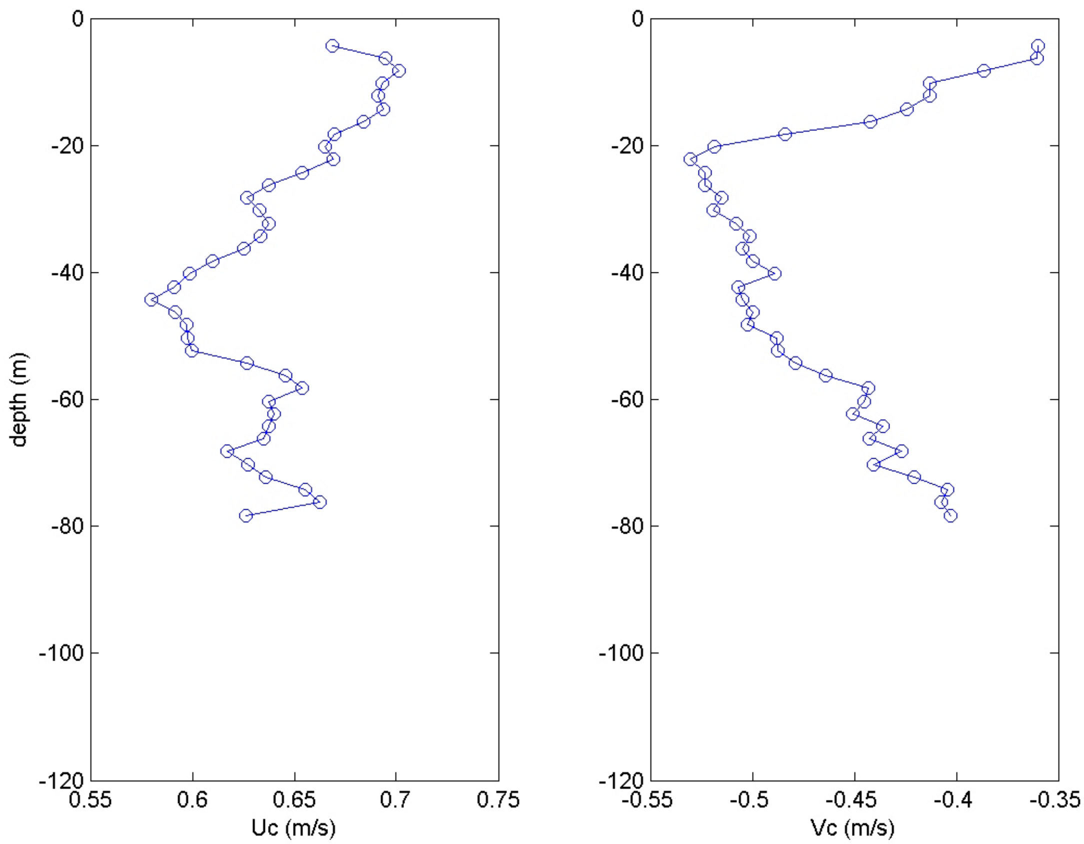

Figure 6: Resulting average velocity data for Station 28.

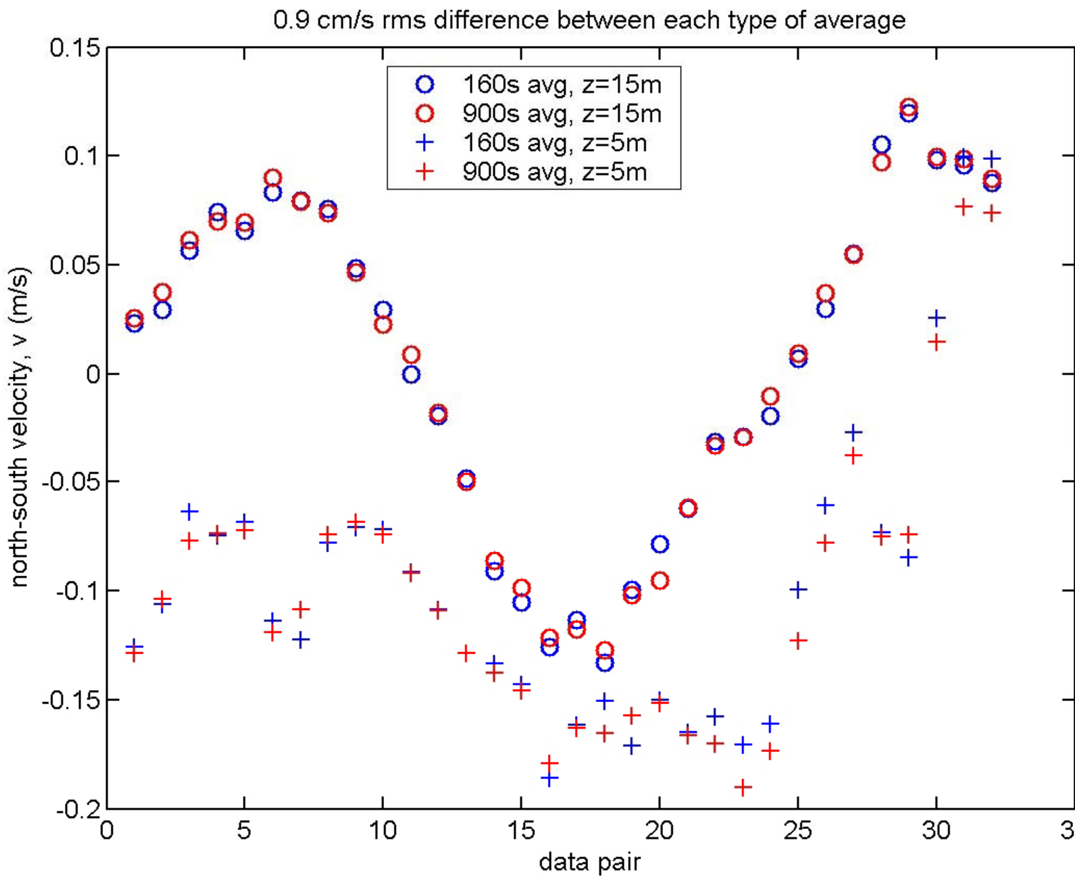

Figure 7: Comparison of 900-second averages with 160-second averages, using time series data from an ADCP moored at a 23 m deep site with strong tides in water off the northern New Jersey coast. Depths in the comparison are z = 5, 15 m. The rms difference between 160 s averages and 900 s averages is only 0.009 m s^{-1}, indicating that 160 s averages are interchangeable with longer-term velocity means of 5, 10 or 15 minutes that are commonly collected aboard moving vessels with hull-mounted ADCPs.

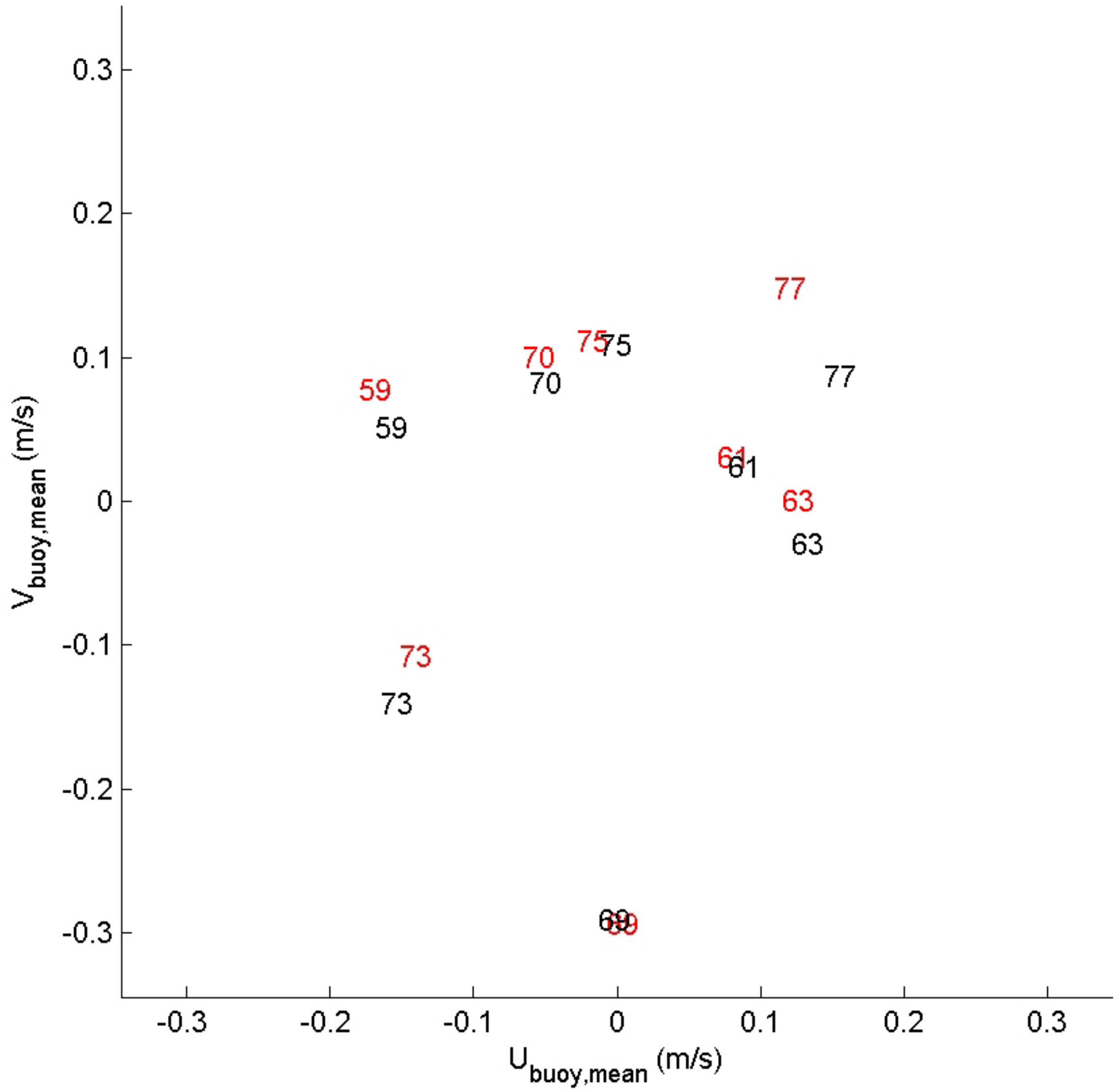

Figure 8: Comparison of buoy velocity averages for various numbered stations, from (black) bottom tracking and (red) navigation (GPS) tracking. The center of the figure (0, 0) is the beginning of the velocity vector, and the location of the number gives the arrow head point. Bottom tracking velocities generally match navigation tracking velocities, with a mean difference of 2.6 cm s^{-1}. Similar results were found when data were omitted if the buoy was 10-20 m from the vessel – these results suggest that the ADCP's internal compass is unbiased by the ship's metal.