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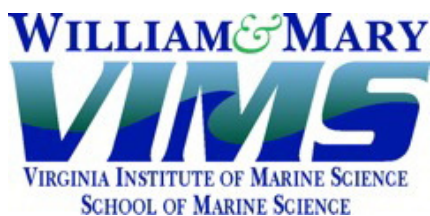
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## Evaluation of the Nortek Aquadopp Surface Current Meter In the York River, Chesapeake Bay, Virginia

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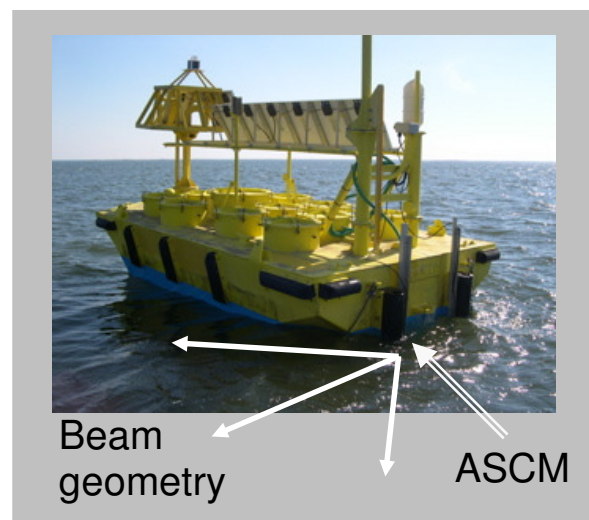
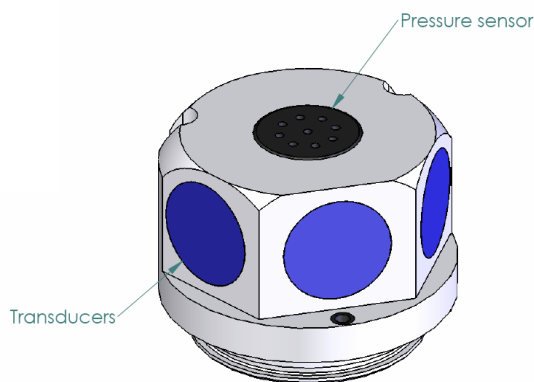


## Introduction

Surface currents within the top one-meter are very important to many physical and biogeochemical processes. Water contaminants such as oils and debris are constrained to the very near surface. Animal larvae and eggs can float to the surface for dispersal. Freshwater plumes can be very thin and are responsible for carrying large volumes of suspended-sediment and other terrigenous materials. Recent research suggests that near-surface dynamics may be responsible for the initiation and transport of harmful algal blooms. It has long been realized that most across-isobath transport occurs in the surface and bottom boundary layers. Surface currents are among the most important data for search and rescue operations and for recreational boaters. The surface layer is very susceptible to wind effects so that surface currents may show significant deviations from astronomical tidal predictions. Poorly resolving the near-surface layer can lead to incorrect transport calculations and make circulation model and HF RADAR calibration and validation difficult.

Despite the importance of surface processes, making accurate in-situ velocity measurements is inherently difficult. Upward looking acoustic Doppler current profilers typically cannot measure the top 10% of the water column due to acoustic side-lobe interference. Downward looking current profilers are typically mounted within a surface buoy and require some amount of blanking distance before the first valid measurement. Thus, for most of the coastal and open ocean, the top one-meter of the water column is not resolved.

We evaluate a new technique of making in-situ measurements of the near-surface layer by using a buoy-mounted acoustic Doppler current meter with horizontally oriented acoustic beams.



**Figure 1.** Aquadopp Surface Current Meter (ASCM) transducer configuration and location on NOMAD buoy.

The Nortek Aquadopp Surface Current Meter (ASCM) is designed to measure near-surface currents with three acoustic beams directed in a horizontal plane just below the surface. The three beams are arranged in one hemisphere directed away from the buoy or mounting platform. Each beam is angled 60 degrees from the neighbor beam (0 – 60 – 120). The horizontal blanking distance from the ASCM to the measurement volume is user-adjustable from 0.35 m to 5.0 m. This gives the ability to position the measurement volume away from flow disturbance of the buoy or mounting platform.



**Figure 2.** ASCM with 3 horizontal transducers and mounted on bracket with transducer head 1.0 m below the surface. A pressure sensor is housed below the black plastic cover on the top of the transducer head. A cable connects from the end-cap of the ASCM to the real-time telemetry system on the NOMAD buoy.

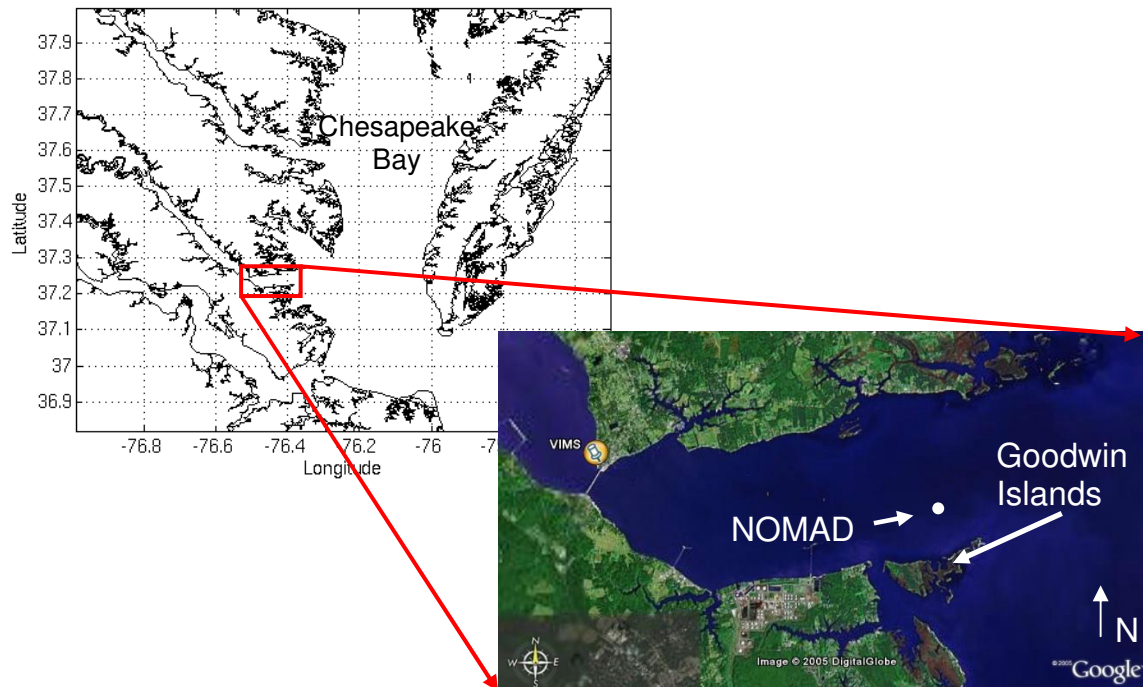
To remove the effects of buoy motion, the ASCM is programmed to sample rapidly and to average over a certain period of time; typically 1-5 minutes. The ASCM can also log “diagnostic” data (a 1 Hz time-series of engineering data including: pressure, tilt, roll, heading, velocity, and voltage). These “diagnostic” data will indicate buoy performance.

Because the ASCM uses three acoustic beams to measure two components of velocity (U, V), there is some extra information available. It is possible to use data from the third beam to calculate a “consistency check” also know as an “error velocity.” The third beam also helps to reduce noise in the velocity measurements.

## Evaluation

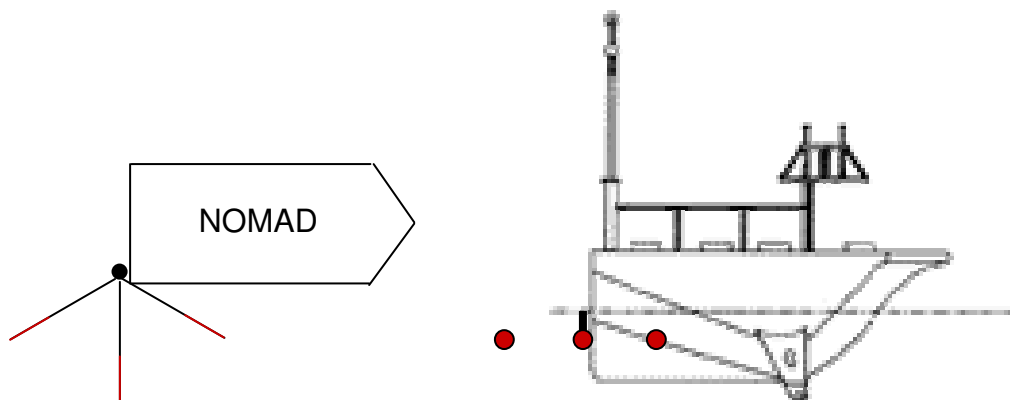
To evaluate the performance of the Aquadopp Surface Current Meter (ASCM), it was mounted on a Virginia Institute of Marine Science (VIMS) NOMAD buoy as part of the Chesapeake Bay Observing System (CBOS). Comparison data are

from a bottom mounted Nortek AWAC (Acoustic Wave And Current profiler). The AWAC was located about 90 m due East of the ASCM.

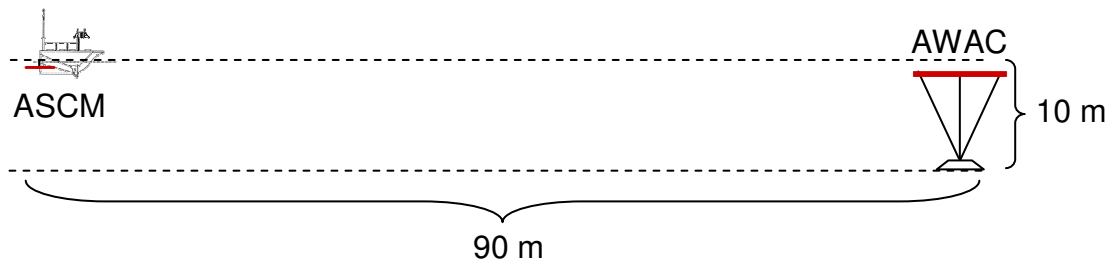


**Figure 3.** Location of the NOMAD buoy in the York River, Chesapeake Bay. Note the predominate channel geometry is East-West.

The transducer head of the ASCM was mounted about 1.0 m below the water surface, on the transom of the NOMAD buoy. The beams were directed to the side of the NOMAD buoy. The AWAC was mounted in about 10 m water depth and configured to profile ten 1.0 m velocity cells. In order to get AWAC velocity measurements as close to the surface as possible for this comparison, the surface-most velocity cell was actively selected with the changing tidal range. Typically, this 1.0 m cell was centered nominally 1.5 m below the surface.



**Figure 4.** Representative drawing of ASCM location on the NOMAD buoy with the red symbols showing the measurement volume of the three acoustic beams.

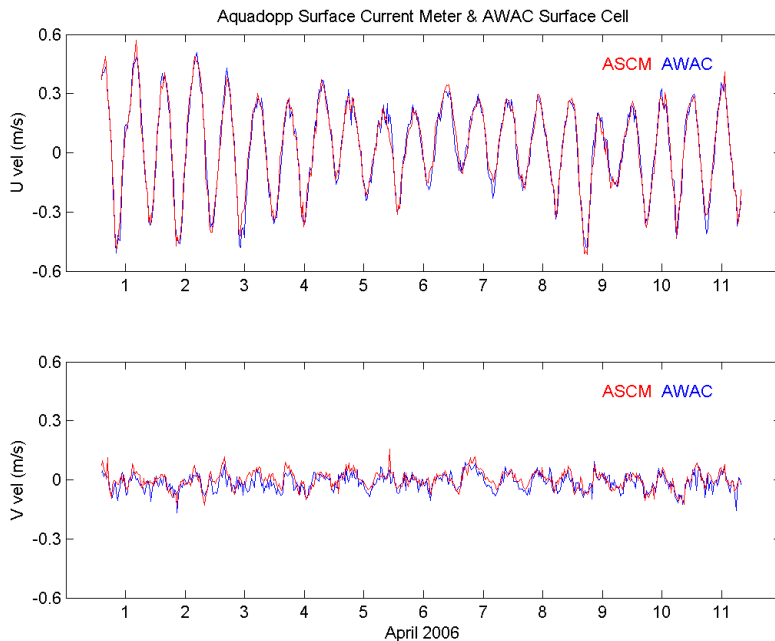


**Figure 5.** Scale drawing showing the horizontal distance between the ASCM and reference AWAC. The red symbols show the measurement volumes of both systems. Bathymetric features between the two locations are not represented, but are thought to be negligible.

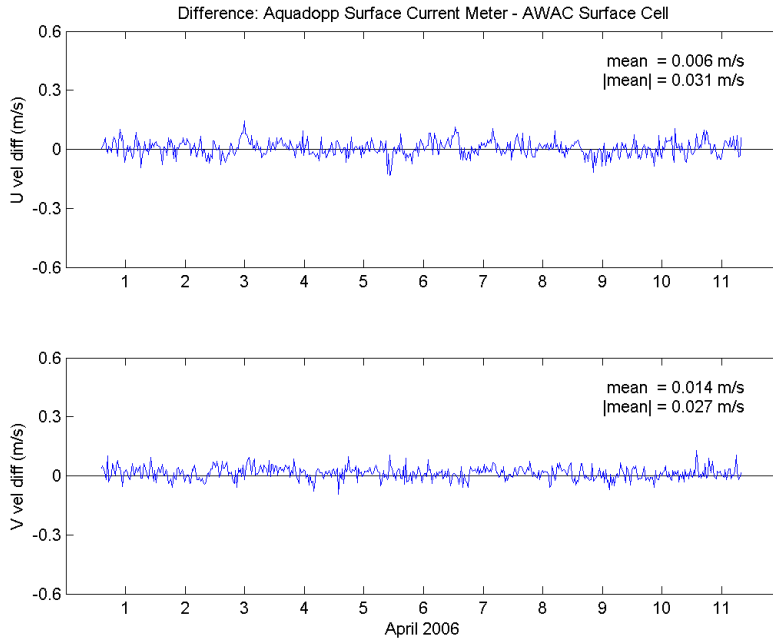
The ASCM was configured to average velocities over 90 seconds. The AWAC was configured to average velocities over 60 seconds. The instruments had not been configured to necessarily measure velocity at the same exact times. Comparable velocity estimates are within 1-15 minutes of each other.

## Summary

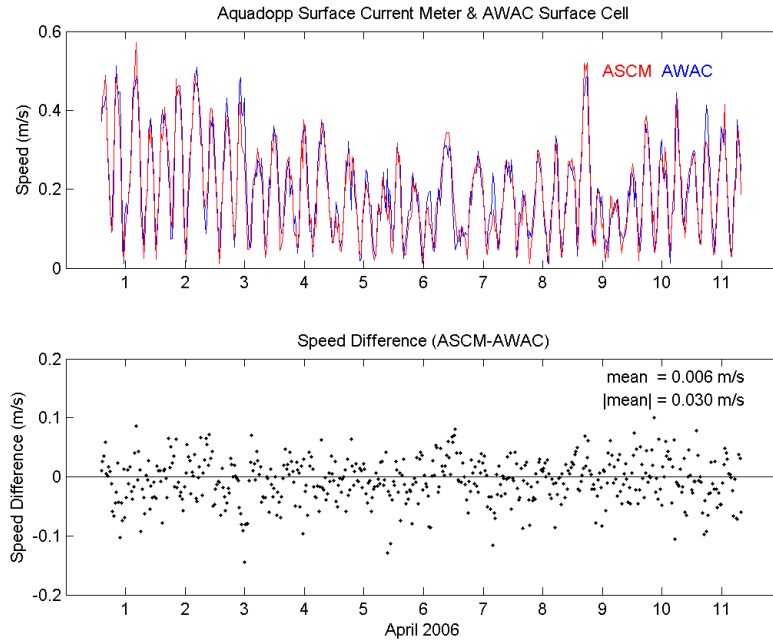
The agreement between the surface current measurements of the ASCM and AWAC was very encouraging. Despite the lateral separation of the instruments and the different shapes of the measurement volume, the data were quite similar.



**Figure 6.** The U component (East/West) and V component (North/South) of velocity for both the ASCM and AWAC during 11 days of overlapping record. Note that the U component has higher velocities due to the orientation of the tidal currents in the channel.

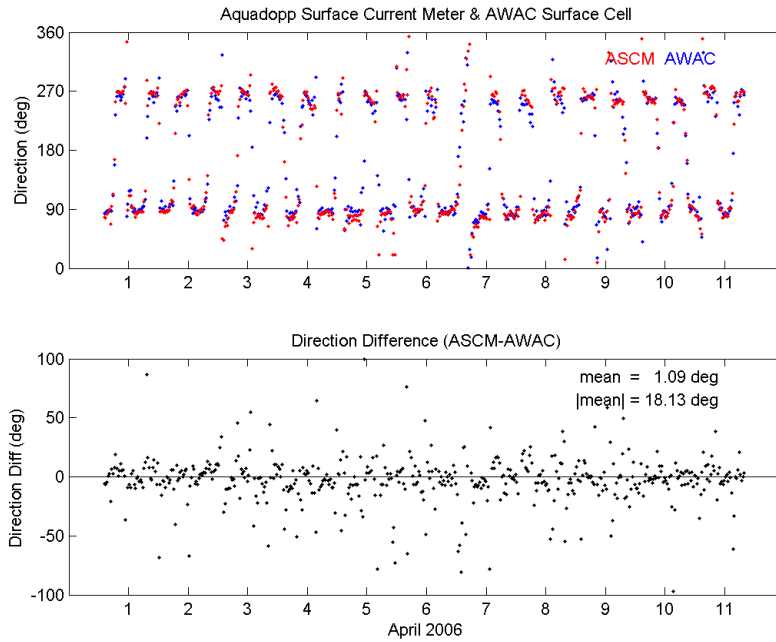


**Figure 7.** The mean difference and mean of the absolute value of the difference ( |mean| ) between the ASCM and AWAC (ASCM-AWAC) for the U component and V component of velocity.

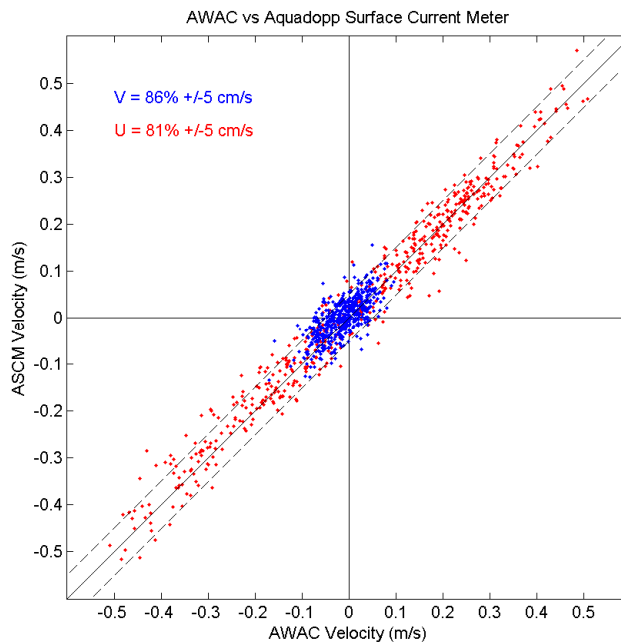


**Figure 8.** The current speed and speed difference (ASCM-AWAC) for both the ASCM and AWAC during 11 days of overlapping record.

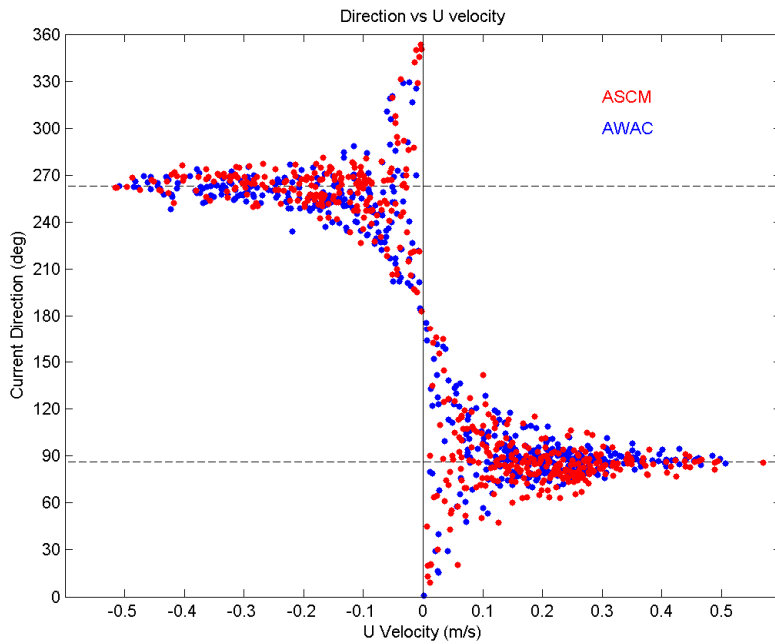
The absolute difference in current magnitude and direction averaged 3 cm/s and 18 degrees, respectively. The component velocities agreed within  $\pm 5$  cm/s 81% of the time for the along-channel component and 86% of the time for the across-channel component.



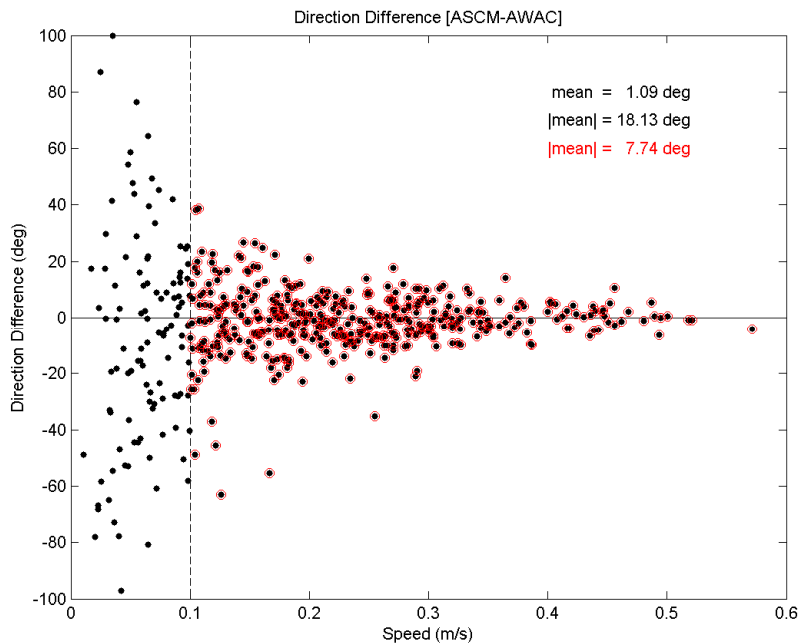
**Figure 9.** The current direction and direction difference (ASCM-AWAC) for both the ASCM and AWAC.



**Figure 10.** Scatter plot of U and V components of velocity between the ASCM and AWAC. The black line shows a 1:1 relation, and the dashed lines show  $\pm 5$  cm/s. The values in the graph give the percentage of data points that fall within the dashed lines ( $\pm 5$  cm/s of each other).



**Figure 11.** The current direction as a function of the U component of velocity for the ASCM and AWAC. The dashed lines show the principal tidal directions.



**Figure 12.** Scatter plot of the direction difference (ASCM-AWAC) as a function of current speed. As the current magnitude increases, so too does the directional accuracy, and the directional differences become smaller. The mean difference and mean of the absolute value of the differences are given. The red circles indicate speeds greater than 10 cm/s. As the speed increases, the current direction becomes more consistent, and the mean of the absolute value of the directional differences becomes smaller (red).

Directional uncertainty occurred most often during times of “weak and variable” currents, and improved to an absolute average of 8 degrees for magnitudes greater than 10 cm/s. As expected, times of weak currents correspond to the times of most rapid acceleration (and reversal) of tidal flow so that temporal and spatial disparity between measurements could accentuate differences in magnitude and direction.

All Doppler measurements have an inherent level of uncertainty. For properly performing instruments, the uncertainty has no bias and can be considered noise (which is easy to filter out in post-processing). As configured, the theoretical velocity uncertainty for the AWAC was 2.2 cm/s and 1.2 cm/s for the ASCM. This gives a combined uncertainty for comparison difference measurements of  $\pm 3.4$  cm/s. This suggests that most of the velocity differences (and thus magnitude and direction differences) is due to the inherent uncertainty of the individual Doppler measurements.

The results demonstrate the ability of the ASCM to make robust measurements of near-surface currents from a buoy-mounted configuration. The differences between the instruments were of the same order of magnitude as the uncertainty inherent in the Doppler measurement. The user-adjustable blanking distance allows the measurement to be made outside the region of flow disturbance, granting greater flexibility for measurements on buoys or near structures. This comparison highlights the benefits of observing system infrastructure that allows redundant measurements for comparison purposes and validation of new instrumentation.