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Eliminating the Blanking Distance For Acoustic Doppler Current Profilers

The Nortek Aquadopp “Z-Cell” Profiler Introduces a New Paradigm For Buoy and Bottom-Mounted Applications

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Observations of current velocity in near-surface and near-bottom boundary layers are critically important for many scientific, operational and engineering applications. Accurate measurements of near-surface currents are required for studying the dynamics of surface features such as freshwater plumes, harmful algal blooms and surface contaminants and useful for search-and-rescue operations and corroborating high-frequency radar maps of current velocity. Similarly, processes in the near-bottom boundary layer, such as Ekman turning that causes across-isobath flow, represent a major mode of material flux that needs to be measured in order to help understand sediment transport and nutrient dynamics.

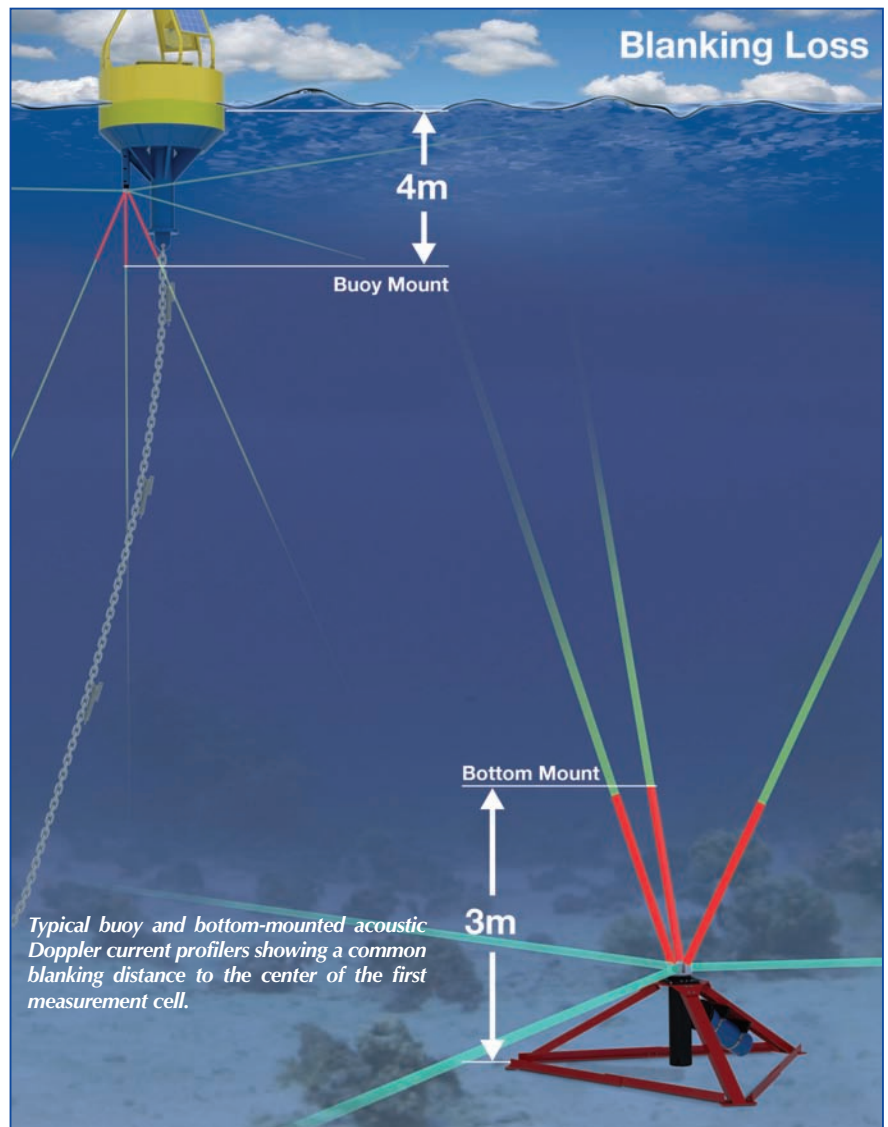
Many engineering and environmental assessment projects require a current velocity observation within one meter of the boundary. However, near-surface and near-bottom current velocity measurements have always been difficult to measure with acoustic Doppler current profilers due to the blanking distance between the instrument and the first measurement position.

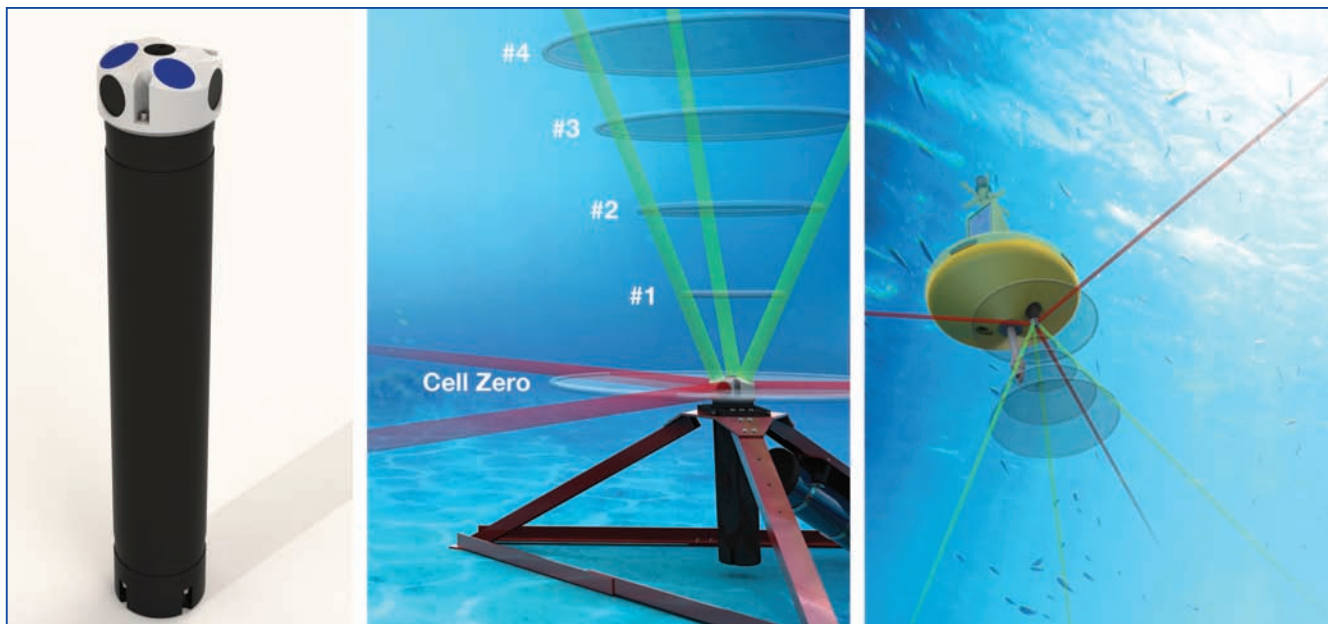
Current Profiling Challenges

Acoustic Doppler current profilers have been used for more than two

decades to measure profiles of current velocity. Typically, Doppler profilers are deployed in either bottom frames on the ocean floor pointed upward or deployed on surface buoys pointed downward.

Both methods work well to measure the current profile in the middle portion of the water column, but they have limitations of how close to the instrument they can measure due to the blanking distance.





Due to the size of most bottom frames, the acoustic transducers are typically at least one meter above the bottom, and the necessary blanking distance (typically greater than one meter, depending on acoustic frequency) positions the beginning of the first measurement cell at least two meters above the bottom. The center of the first measurement volume is even farther away from the bottom.

Similarly, downward-looking buoy-mounted profilers cannot observe near-surface currents. Buoy-mounted profilers miss the top portion of the water column because of the required mounting depth and blanking distance. Most coastal and offshore buoys purposely mount the downward-looking profiler at least one meter below the surface to keep the transducer head below any bubbles formed by breaking waves, as bubbles attenuate the acoustic energy and can greatly reduce the total profiling range of the Doppler instrument. With a mounting depth of about one meter and necessary blanking distance of typically at least one meter, the center of the first sampling location is often several meters below the surface.

Z-Cell Development

Nortek developed the Aquadopp “Z-Cell” profiler, a dual-frequency, six-beam acoustic Doppler current profiler, to meet the needs of observing more of the water column velocity profile, particularly the near-surface or near-bottom currents, depending on the mounting orientation. Three acoustic beams point upward or downward in the tradi-

tional current profiler mode.

The extra three acoustic beams are directed horizontally and spaced equally around the circumference of the profiler, with 120° spacing between the beams. These horizontal beams measure the two-component horizontal currents at the exact physical level of the instrument, thereby eliminating blanking distance. This geometry allows the observation of current velocity near the surface for buoy-mounted profilers and near the bottom for bottom-mounted profilers. The horizontal beams use a two-megahertz acoustic frequency for high accuracy and narrow beam width. Operationally, the system functions as a single acoustic Doppler current profiler. The near-boundary velocity is located as Cell 0 in the data stream and the rest of the water column profile begins with Cell 1. The Z-Cell is available as either a one-megahertz profiler (with a nominal 20-meter profile range) or 600-kilohertz profiler (with a nominal 50-meter profiling range).

Testing and Validation

The Z-Cell concept of horizontal acoustic beams for near-surface velocity observations has evolved over several years of testing and validation on several buoy platforms. The first operational real-time Aquadopp Z-Cell profiler was deployed on NOAA’s National Data Buoy Center’s three-meter Discus Buoy 42007, located approximately 35 kilometers southeast of Biloxi, Mississippi, in a nominal water depth of 15 meters.

The Z-Cell was mounted within the

Drawing of Aquadopp Z-Cell profiler and example bottom-mounted and buoy-mounted applications. Velocity is measured at Cell 0 using horizontally directed acoustic beams.

triangular-shaped three-leg bridal below the buoy hull. The transducer head was positioned 1.5 meters below the water surface. This location can be considered the depth of the near-surface current observation (referred to as Cell 0). The next cell of the depth profile (Cell 1) is centered 1.5 meters below the near-surface velocity observation.

Data were recorded every hour with an average interval of five minutes. Compass and tilt data were logged every second over the five-minute average interval and were used to vector average the velocity measurements. A bottom-mounted Nortek acoustic wave and current profiler (AWAC) was positioned within 50 meters of the buoy to corroborate velocity profiles from the buoy-mounted Z-Cell.

A tidal analysis using the semimajor ellipse orientation of the two primary tidal constituents at this location (O1 and S2) was used to verify accuracy of the near-surface velocity observations from Cell 0 compared to the current profiles from the Z-Cell and AWAC. The direction of the semimajor ellipses from Cell 0 match the ellipse orientations in the velocity measurements made lower in the water column for both the Z-Cell and AWAC. This is consistent with tidal theory, which suggests little rotation in

the water column from the barotropic forcing.

The currents in this study region (northern Gulf of Mexico) are complex and controlled by several factors, including tidal forcing, bathymetry, wind and thermocline depth. On several occasions, the near-surface currents observed in Cell 0 exhibited strong shear compared to the velocities observed in Cell 1 and deeper, just 1.5 meters below.

Ekman theory indicates that near-surface currents should be 45° to the right of the wind direction in the Northern Hemisphere, and the currents should continue to rotate to the right with increased depth. On many occasions, the large rotation in the upper portion of the

water column (perhaps related to a shallow thermocline) provides a situation in which the near-surface currents observed in Cell 0 have a sign reversal (other direction) compared with the velocity measured in Cell 1 and below. The near-surface currents are oriented to the right of the wind direction, typically about 90° to 120°.

Applications

Emergency Response. The measurements where Cell 0 recorded substantially different current magnitude and/or direction compared with observations lower in the water column are of particular interest from the perspective of search-and-rescue, hazardous materials control and numerical modeling. If a program manager or researcher were trying to predict the location of a water parcel based only on information from Cell 1 velocity, the net location of the parcel, after some time, could be substantially different compared to a more accurate prediction of the location based on Cell 0 velocity.

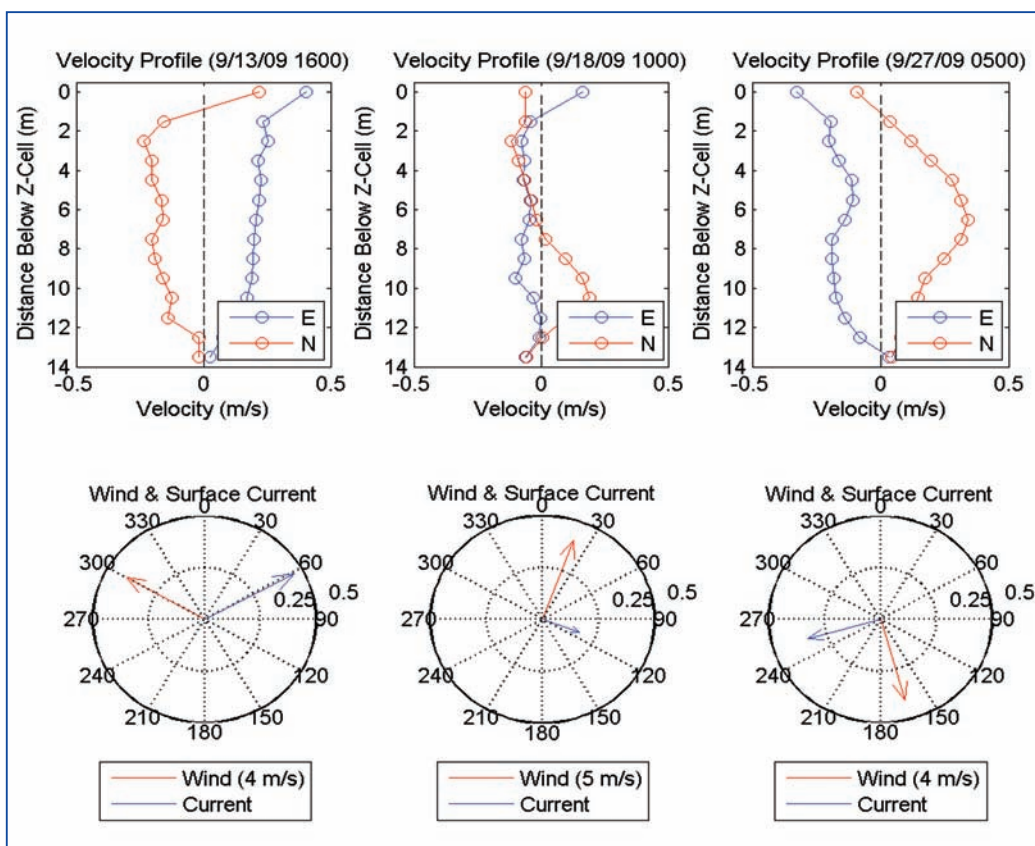
An analysis was performed to estimate the difference in position of a water parcel after 24 hours (assumed to have constant velocity) using velocity from Cell 0 and Cell 2 of the Z-Cell. The mean current magnitude difference was 0.06 meters per second, but frequently

ranged from 0.10 to 0.20 meters per second.

The mean difference in position from this analysis was 8.5 kilometers each day. However, frequently a horizontal separation of 20 kilometers per day could result from the difference in velocity observations between cells 0 and 2. To put this in some perspective, the edge of the horizon is located about 4.7 kilometers away from an observer standing up in a small boat. This difference in horizontal position can be significant to search-and-rescue operations, hazardous materials response and numerical models focused on predicting storm surge level or harmful algal bloom dynamics.

Engineering and Assessment. Elimination of the blanking zone provides expanded opportunities for current velocity measurements in the bottom one meter of the water column for engineering or environmental assessment projects. The Z-Cell can be deployed in a sturdy, trawl-resistant bottom frame and profile the full water column, as well as observe the velocity in the bottom one meter.

Under-Ice Measurements. There are many areas of environmental and commercial interest that are covered by ice for many months each winter. The Z-



Three Z-Cell velocity profiles showing high velocity shear between Cell 0 and Cell 1 (top). Compass plots of wind direction and surface current direction (bottom).

Cell form factor and acoustic beam geometry allow the user to easily observe velocity profiles below static ice cover. A narrow hole can be drilled through the ice and the Z-Cell positioned with the transducer head just below the lower boundary of the ice. The horizontal acoustic beams will measure the critical ice-boundary-layer flow just below the ice while the other acoustic beams profile the water column velocity.

Real-Time Observing Buoys. The Z-Cell solves several common problems associated with real-time velocity observations from surface buoys. Because the Z-Cell performs the job of a single-point current meter and a current profiler, only one instrument needs to be mounted to each buoy bridal to achieve both current profiles and near-surface measurements. This means only one data stream must be integrated with the real-time data-logging and telemetry system. Upgrading the telemetry infrastructure from a standard Aquadopp profiler to an Aquadopp Z-Cell profiler is seamless, as the data structures are identical; the only differ-

ence is that the data begin with Cell 0 instead of Cell 1. Finally, because only one instrument is required for current measurements, the overall power budget may be reduced. The Z-Cell uses approximately 15 percent more power than a standard Aquadopp profiler (nominally one watt).

Conclusions

The Aquadopp Z-Cell profiler offers a new paradigm for acoustic Doppler current profilers by using six acoustic beams to eliminate the blanking distance and offering current velocity observations immediately at the level of the transducer head. This concept widens the opportunities for measurements on bottom-mounted and buoy-mounted applications. The Z-Cell has been selected for deployment in real-time applications on NOAA buoys in the Gulf of Mexico and Chesapeake Bay, as well as in the Gulf of Maine and Puerto Rico ocean observing systems.



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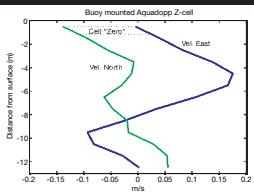
A NEW WORLD

NO MORE «BLANKING LOSS» WITH AQUADOPP Z-CELL

Z-Cell deployed on buoy



Measured "Cell Zero" data



The 1 MHz version of the Aquadopp Z-Cell



Data Loss

A current profiler cannot measure the complete profile from the bottom to the surface. Instead, it loses data close to the instrument and close to the far boundary. The boundary loss is due to sidelobe interference and nobody has found a way to solve this problem. The near-instrument loss comes from the combination of mounting height, the electro-acoustic blanking and the offset of the first measurement cell. In many applications this means that valuable and interesting information about the ocean current is lost.

The Nortek solution

In the new Aquadopp Z-Cell, Nortek has extended the profiling range by introducing a "Cell Zero". This new data is generated by an extra set of horizontal transducers. The transducers operate at a different frequency (2 MHz) and provide the 2D current velocity at the level of the instrument. This is to the benefit of anyone who is interested in the detailed current velocity in the boundary layer.

#4

#3

#2

#1

#0

Cell Zero

CURRENT AND WAVE MEASUREMENTS IN THE OCEAN, LAKE AND LABORATORY



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