Testing and Evaluation of a Dual-Frequency Six-Beam Acoustic Doppler Current Profiler

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***Abstract* - Observations of current velocity in near-surface and near-bottom boundary layers are critically important for many scientific, operational, and engineering applications. NOAA's National Data Buoy Center (NDBC) presently maintains approximately 110 weather and oceanographic buoys. Of these, some are tasked to measure full current profiles , including near-surface currents, in an operational real-time system. Nortek developed a dual-frequency, six-beam acoustic Doppler current profiler to meet the needs of observing the complete water column velocity profile, including the near-surface or near-bottom currents (depending on the mounting orientation). Three acoustic beams point upward or downward in the traditional current profiler mode. The other three acoustic beams are directed horizontally and spaced equally around the circumference of the profiler with 120 deg spacing between the beams. These beams measure the two-component horizontal currents at the level of the instrument. This geometry allows the observation of current velocity near the surface for buoy-mounted profilers and near the bottom for bottom-mounted profilers. Near-surface and water column current velocity profile observations from a 6-beam Nortek profiler mounted on an NDBC 3 m discus buoy are compared with current velocity profile measurements from a bottom mounted 1 MHz Nortek AWAC acoustic Doppler wave and current profiler located within 100 m of the buoy location.**

I. INTRODUCTION

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; as well as useful for search and rescue operations and to corroborate HF radar maps of current velocity. Ekman turning in the thin bottom boundary layer tends to cause across-isobath flow and represent a major mode of material flux, particularly of suspended sediments, from on-shore to off-shore. Many engineering projects require a current velocity measurement to be made within 1.0 m of the bottom. However, near-surface and near-bottom current velocity has always been intrinsically difficult to measure with acoustic Doppler current profilers due to blanking distance and/or side-lobe inference.

Acoustic Doppler current profilers have been used for over two decades to measure profiles of current velocity. Typically, Doppler profilers are deployed in either bottom frames on the ocean floor pointed upwards or deployed on surface buoys pointed downwards. Both methods work well to measure the current profile in the middle portion of the water column, but have limitations of how close to the surface and bottom they can observe.

Upward looking profilers mounted on bottom frames cannot measure accurate velocities in the top ~10% of the water column because of side-lobe errors. Further, due to the size of most bottom frames, the acoustic transducers are typically about 1.0 m above the bottom and the necessary blanking distance (typically greater than 1.0 m, depending on acoustic frequency) positions the first measurement cell at least 2.0 m above the bottom. Therefore, a profiler mounted on the 20 m isobath will not be able to accurately observe the top 2.0 m and the bottom 2.0 m of the water column.

Similarly, downward looking buoy mounted profilers cannot observe the near-surface or near-bottom currents accurately. Buoy mounted downward looking 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 1.0 m 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

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Doppler instrument. With a mounting depth of about 1.0 m and necessary blanking distance of typically at least 1.0 m, the first sampling location is often greater than 2.0 m below the surface. Side-lobe errors near the bottom interfere with observing the bottom ~10% of the water column.

II. EQUIPMENT

Nortek developed a dual-frequency, six-beam acoustic Doppler current profiler to meet the needs of observing the complete water column velocity profile, including the near-surface or near-bottom currents (depending on the mounting orientation). Three acoustic beams point upward or downward in the traditional current profiler mode (25 deg head angle), and are available in a range of acoustic frequencies to meet the required profiling range (from 10 to 100 m range). The other three acoustic beams are directed horizontally and spaced equally around the circumference of the profiler with 120 deg spacing between the beams. These beams measure the two-component horizontal currents at the level of the instrument. 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 2 MHz 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 1” and the rest of the water column profile begins with “cell 2”.

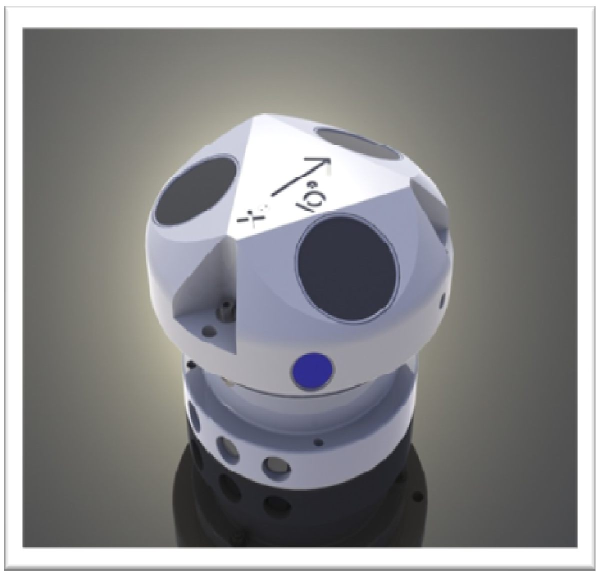

Fig. 1 Prototype drawing of six-beam acoustic Doppler current profiler used to measure water column profiles and near-boundary currents. Small transducers (blue), used to measure near-boundary currents, are oriented horizontally and operate at 2 MHz. Large transducers (black), used to measure the water column profile of currents, operate at 1 MHz. The size and frequency of the large transducers are modular to allow up to a profiling range of about 100 m at 400 kHz.

NOAA’s National Data Buoy Center (NDBC) presently maintains approximately 110 weather and oceanographic buoys. Of these, some are tasked to measure full current profiles , including near-surface currents, in an operational real-time system. Under a NOAA Cooperative Research & Development Agreement (CRADA) with NortekUSA, NDBC began a systematic evaluation of the performance of the prototype six-beam profiler on an NDBC 3 m discus buoy (station number 42007). This buoy is located approximately 35 km south-southeast of Biloxi, Mississippi in a nominal water depth of 15 m. The acoustic frequency of 1 MHz was selected to provide the optimum profiling range and resolution for the water depth. The profiler is mounted within the triangular shaped bridal below the buoy hull. The three acoustic beams split well around the triangular bridal. The profiler is located 1.4 m below the water surface when the buoy is deployed. This location can be considered the depth of the near-surface current observation. The next cell of the depth profile begins 0.5 m below the near-surface velocity observation. Data are recorded every 1 hour with a 5 min average interval. Compass and tilt data are logged every 1 sec over the 5 min average interval and are used to vector average the velocity measurements.

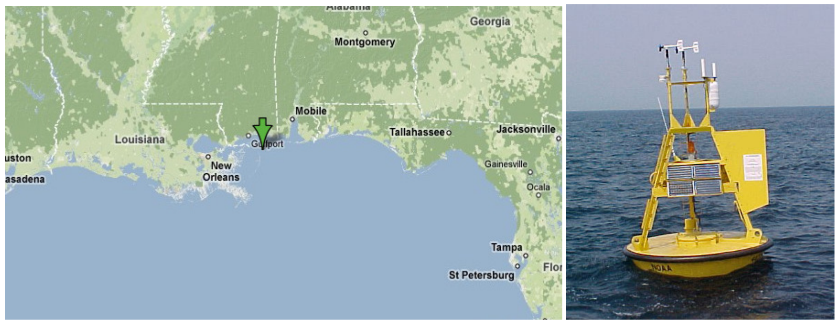

Fig.2 Map of NDBC Station 42007 buoy location (green arrow) in Gulf of Mexico and photo of 3 m discus buoy.

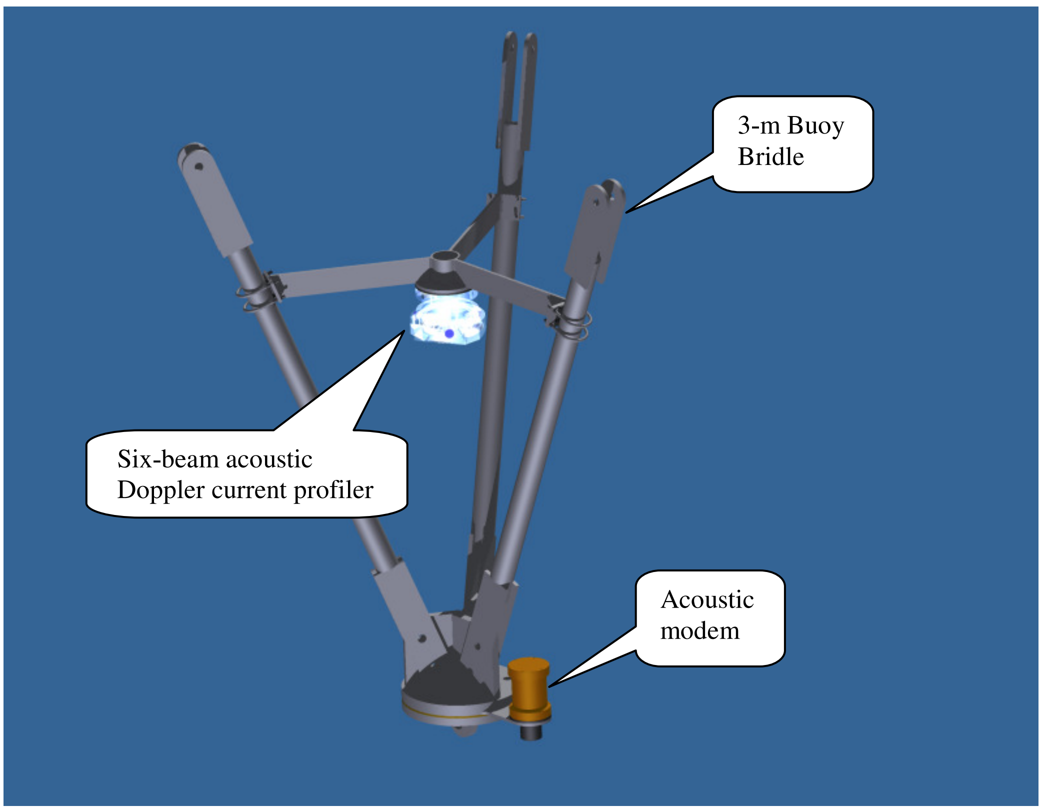

Fig 3. 3-m buoy bridle configuration showing six-beam acoustic Doppler current profiler and acoustic modem.

III. Experiment

Near-surface and water column current velocity profile observations from the 6-beam profiler mounted on the NDBC buoy are compared with current velocity profile measurements from a bottom mounted 1 MHz Nortek AWAC acoustic Doppler wave and current profiler located within 100 m of the buoy location. The bottom mounted Nortek AWAC provides processed, real-time current profile and directional wave data wirelessly to the NDBC buoy through a pair of underwater acoustic modems. Following the analysis of Siegel et al. (2008) rotary auto spectra and cross spectra analyses are used to examine the velocity gain and veering angle at different frequencies as a function of water depth.

[1] E. Siegel, D. Mayer and R. Weisberg, "A comparison of near-surface current measurement methods," *IEEE/OES/CMTC Ninth Working Conference on Current Measurement Technology*, pp. 44-49, 2008.