A Towed 75 kHz ADCP for Operational Deepwater Current Surveys

Steven P. Anderson
Horizon Marine, Inc.
15 Creek Road
Marion, MA 02738 USA
www.horizonmarine.com

Patrick Matthews
Oceaneering International, Inc.
11911 FM 529
Houston, TX 70041 USA
www.oceaneering.com

***Abstract* –This paper describes the development of a towed acoustic Doppler current profiler (ADCP) system that is used to support operational monitoring of deepwater currents. The towed body configuration provides a quiet and stable sensor platform that can be readily relocated and deployed from different vessels. High-frequency ADCPs are used in towed bodies for several shallow water applications.**

This towfish system is unique because it employs a 75 kHz RDI Long Ranger ADCP packaged in a large Endeco/YSI type 850 V-Fin. The towfish is 1.3 x 1.4 x 0.7 meters and weighs 185 kg in air. The towfish, winch and electronics are housed in a customized container that allows for a single point lift for loading and a 2.5 by 3.5 meter footprint on deck. In 2004, the towfish was used operationally in the Gulf of Mexico to survey upper ocean currents. The surveys were successful with only minor setbacks. The system calibrations were found to be very robust and stable. The towfish was deployed at nominally 20 meters depth with tow speeds of 1 to 3 m/s. The ADCP provided continuous along-track profiles with good data down to the instrument's maximum range of 500 meters. Raw data were telemetered to shore for processing and integration with satellite imagery and other in situ observations to provide a real-time synoptic analysis.

I. INTRODUCTION

Strong ocean currents can disrupt various deepwater activities and cause downtime for hydrocarbon exploration and production activities. Thus, accurate and timely observations can help with planning and assuring safe operations. Remote sensing cannot always be counted on to provide timely observations of the sea surface and is not a direct measurement of ocean currents. Drifting buoys have proven to be a cost effective means of collecting ocean current observations; however, drifters report only near surface currents and the Lagrangian technique does not provide a means of activity targeting and monitoring a specific site or area. Acoustic Doppler current profilers (ADCP) mounted on moorings and platforms can provide real-time current information but are not always optimally located. ADCPs deployed on ships provide the most viable way to survey ocean current profiles.

Only a shipboard ADCP can be used to collect ocean profiles while underway and thus provide surveys of synoptic ocean features. Deepwater current profiling requires a low-frequency ADCP operating at 38 or 75 kHz. Traditionally these large systems have been hull mounted systems mostly deployed on research vessels. When care is taken, the hull mounted system operates in a low-noise, bubble free environment and provides optimal performance. However, the system is tied to a single vessel.

In this paper, we report on the development and performance of a towed body with a 75 kHz ADCP. This application provides a system that can be easily relocated and deployed for various vessels, yet provides a very quiet, stable platform for the ADCP.

II. SYSTEM DESIGN

The system design started with two basic criteria. It had to profile currents to at least 400m and it had to be easily relocated and deployed from a range of vessels. The first criterion mandated a 75 kHz ADCP. To meet the second criterion, the system had to be deployed over the side or towed.

Deploying a large ADCP over the side would require a large mounting system to be welded to the vessel to withstand structural loading while underway. Thus it requires modification to the deployment vessel hull. In addition, it would be difficult to design a mount that would position the transducer head deep enough and isolated enough to assure a quiet, bubble free environment.

ADCPs operating at 300 kHz to 1.5 mHz have been successfully used in towed bodies for some time now and have performed quite well. Although a 75 kHz has not been deployed in this way, we knew it to be a reasonable approach.

The next step was to identify an acceptable towed body. The Endeco/YSI 850 V-Fin is a large towed body with a proven functional design (Fig. 1). Similar systems have been used to deploy acoustic equipment for bathymetric and biological survey.

A 75 kHz RDI Long Ranger ADCP was fitted into the V-Fin so that the first beam was aligned with the nose of the towed body (Fig. 1). The ADCP has an embedded compass to detect the system orientation, along with pressure and tilt sensors. An electro-mechanical tow cable provides both data and power.

Fig. 1. Endeco/YSI type 850 V-Fin with 75 kHz RDI Long Ranger ADCP. The V-Fin is approximately 1.3 x 1.4 x 0.7 meters.

A disadvantage to the towed body approach was that the ADCP would be deployed deeper than a hull or side mounted system and as a result, a single down-looking ADCP would not be able to sample the very near surface. Placing a second ADCP configured in an up-looking direction into the v-fin would allow profiling to the surface.

Before investing in a second ADCP, we first had to decide if our operational needs required the near-surface observations. Typically, we are working in the Gulf of Mexico tracking strong currents associated with the Loop Current and Loop Current eddies (LCE), mesoscale features in near geostrophic balance. LCE currents usually extend to 400m or deeper and are well correlated in depth. We knew intuitively that currents at the surface are well correlated with subsurface currents, and we would be able to track LCE's without the very near-surface observations. Current differences at the surface would likely be due to mixed layer response to wind forcing. But what is the typical shear at about 50 m and how different are the near surface currents from the upper thermocline?

We did a desk study of historical current profiles from the Gulf of Mexico collected with the 300 kHz hull-mounted ADCP on the R/V Pelican. This system was configured to profile from 9 m to 169 m depth with 4 m bins. We used data from six surveys conducted in and around Loop Current eddies. The surveys were typically two to three days each and included both winter and summer observations.

We directly compared the currents at 13 m to currents at 45 m from all six cruises (Fig. 2). The correlation between the current speeds is 0.96 and, as linear fit revealed, the 13 m currents were on average 0.05 m s^{-1} higher. After accounting for the very small bias, the currents at 13 m were equally likely to be larger or smaller than currents at 45 m; 90% of the 13 m current speeds were within $\pm$0.22 m s^{-1} of the 45 m current speed, independent of currents speeds.

After performing this review, we decided not to include an up-looking ADCP in the initial system configuration. Although we will miss some of the variability in mixed layer currents, we will still be able to track the mesoscale features. There is room on the v-fin to add a small uplooking ADCP in the future if required.

A 15 x 8 foot skid holding an 8-foot work van carries all the components of the towed system. The winch is installed next to the work van on the open side of the skid. The work van houses he computers, navigation and communications systems. In addition, the v-fin can be stored inside the work van while not in use or in transit. This makes loading and off loading the system a "single-pick" operation.

III. SYSTEM PERFORMANCE

The ADCP is configured to collect 40 16-m depth bins and 2. 5-minute ensemble averages. The v-fin depth is typically deployed at 20 m and the first bin is centered near a depth of 44 m. The ADCP routinely returns good data to 500 m depth and often to the extent of the 600m maximum range. However, the range performance is linked to the pitch of the v-fin.

The towed ADCP system was first deployed on 21 August 2004 from the Ocean Inspector in the northern Gulf of Mexico. The v-fin was towed at a nominal depth of 18 to 20 m. The tow cable was deployed through a sheave on the A-frame. The ship cruised at around 3 m s^{-1} with the v-fin deployed. Approximately 20 hours of data were collected.

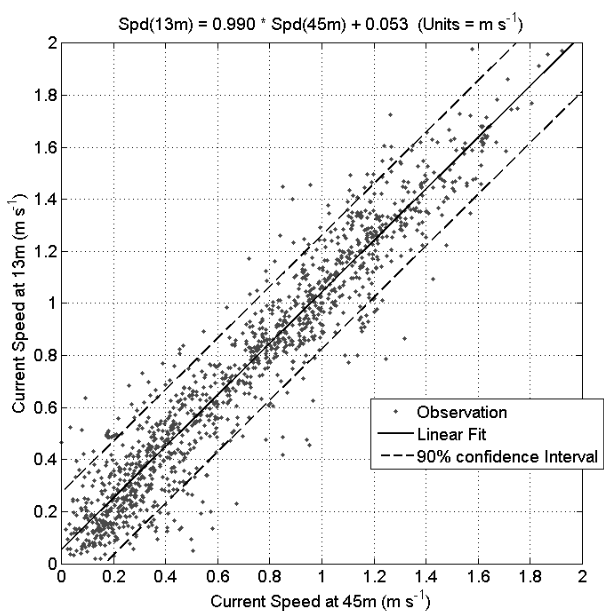

Fig. 2. Comparison of current speeds at 13 m and 45 m. Data collected from R/V Pelican's hull-mounted 300 kHz ADCP during six surveys conducted in and around LCE's in the Gulf of Mexico.

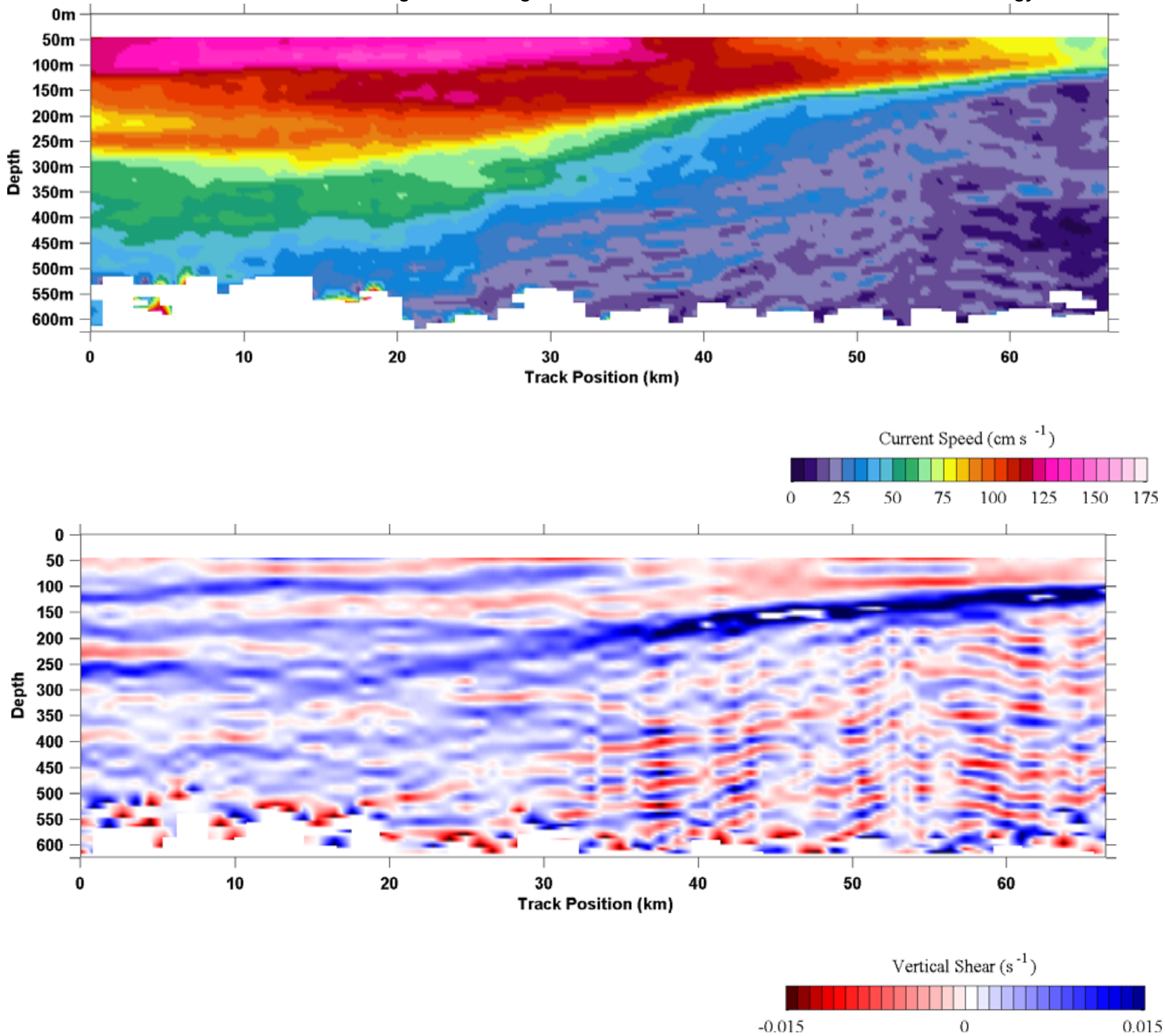

Fig. 3. Example data from towed 75kHz ADCP. Shown are transects of (top) current speed and (bottom) vertical shear for a 65 km survey line conducted in the Gulf of Mexico. The data include strong currents and are shear related to an anticyclonic eddy. The very stable v-fin allows for resolution of small vertical structure throughout the vertical range of the instrument.

An example of data collected is shown in Fig 3. The example includes strong currents from an anticyclonic eddy. In also shows layers of fine-scale shear that are particularly noticeable at the edge of the eddy between 35 and 65 km along the track. These layers are coherent for five or more kilometers and may indicate an enhancement of near-inertial internal wave active in the thermocline along the edge of the eddy. The system is able to resolve such fine scale variability because it is so stable.

At the start of each deployment, we conduct a “calibration run” to check for any offset errors in the navigation system. This consists of following a straight track in one direction for 3 miles, and then turning the ship and backtracking near the same line. These reciprocal current measurements should agree if the ship’s and v-fin’s navigation are in close alignment. So far we have not encountered any position offset errors. The likely reason is the ADCP’s short horizontal offset to the vessel’s navigation reference point.

The sea trial winds were at 4-6 m s-1 and the significant wave height was 0.5 m. The mean (and standard deviation) of the pitch and roll were -11.0 (1.1) and -2.5 (0.6) respectively. On a more recent deployment, sustained wind speeds reached 12.0 m, s-1 significant wave heights were 1.6 m. The mean (and standard deviation) of the ADCP pitch and roll were -6.0 (2.9) and -1.1 (0.6) respectively. The nose was again tilted slightly downward, with more motion in the pitch. The roll statistics were almost the same as under light wind conditions. Thus the platform was very stable but the ADCP system is tilted slightly with the nose down.

It is evident from the various deployments that the mean pitch varies with ship speed. We would expect improved performance if the v-fin were flown completely level. At this time, we do not have an operational procedure to fine tune and calibrate the pitch of the v-fin while underway.

III. RESULTS AND CONCLUSIONS

Raw data are sent to a shore based analysis office where it is quality controlled and integrated with remote sensing, model and other in situ data. The results are then transmitted to decision makers in the field to help with planning and maintaining safe operations. We have developed in house software tools to help with the data assembly. The time from data acquisition to integrated data reporting can be less than 30 minutes.

The system still lacks the capability of measuring currents at the very surface of the ocean. Although we have shown the strong correlation between surface currents and deeper currents, there are times when it would be advantageous to directly measure the surface. We may eventually add a second ADCP to the v-fin to directly measure surface current.

We were successful in building a system that met our goals of being reliable and flexible. In the first six months of operation, the system has collected over 3000 km of data and been deployed from four different vessels. The system clearly has the expected depth range and measurement resolution; in fact, system performance exceeded our expectations.

Acknowledgments

We thank Endeco/YSI and RDI Instruments for their help in designing and integrating the ADCP with the v-fin, Daniel Torres for assistance with custom software development and Oceaneering’s “Team Towfish” for their professional field operations and support.