1 Introduction

During the Antarctic Intermediate Water (AAIW) winter cruise, direct velocity measurements were made by the Chereskin lab group of Scripps Institution of Oceanography (SIO) from hull mounted shipboard acoustic Doppler current profilers (SADCPs) and from a Lowered Acoustic Doppler Current Profiler (LADCP).

2 Shipboard ADCPs

2.1 Instrumentation

Data was recorded from two shipboard ADCPs: an Ocean Surveyor 75 kHz phased array (OS75) and an RD Instruments 150 kHz narrowband ADCP (NB150).

The OS75 is standard ship’s equipment on R/V Knorr. The OS75 ADCP transducer was mounted in an instrument well located near the center line of the ship and below the laundry room. The well is open to the sea, and the transducer is located at approximately 5 m depth, with beam 3 oriented 45 deg to starboard.

The NB150 is an obsolete instrument, no longer supported by the manufacturer, that was installed by WHOI on request from the PI specifically for the AAIW cruise in order to profile currents at higher resolution and at shallower depths than the OS75. The NB150 ADCP transducer was mounted in an instrument well located below the lower lab at frame 85, about 8 feet starboard of the center line. The well is open to the sea, and the transducer is located at approximately 5 m depth, with beam 3 oriented 45 deg to starboard. The NB150 that was installed in Miami for AAIW failed prior to the ship’s arrival in Punta Arenas, Chile. A second complete system was sent via air freight. Although the system had checked out satisfactorily at WHOI, it reported error messages after installation on Knorr. In actual use, the problem was very low signal on beam 2 (unsuitable for a 4-beam velocity solution). We collected NB150 data with the intention of implementing a 3-beam solution.

2.2 Data acquisition

Single ping ADCP data from both instruments and ancillary navigation streams (GPS, gyrocompass, and POS/MV) were collected on a Dell 1-U rack-mounted server running the Linux operating system (Mandrake 10.2) using UHDAS, a data acquisition and processing software suite written by Eric Firing and Jules Hummon, University of Hawaii. The data were processed in real-time on the Linux server (currents.knorr.whoi.edu) and were recorded in duplicate on a pair of internal, mirrored hard disks. Data were copied to Mac G4 laptops via a network (Samba) exported filesystem for further processing. The primary heading source was the ship’s gyrocompass, and heading corrections were made using the POS/MV. After applying the heading corrections, the overall additional calibration was an amplitude of 1.0 and a phase of 0.0 degrees. This calibration will be refined in post-processing.
2.3 Sampling parameters

The NB150 operating parameters used during AAIW were 50 depth bins and an 8 m blank, range bin, and pulse length. The OS75 ADCP was configured to collect data in narrowband mode. The OS75 operating parameters were 70 depth bins and a 16 m blank, range bin, and pulse length.

2.4 Data processing

Overall, the quality of the OS75 ADCP and navigation data acquired during AAIW was excellent. High precision GPS was available throughout the cruise, with an estimated single position fix accuracy of 1 m. The estimated accuracy of the POS/MV heading corrections is 0.1° (King and Cooper, 1992). The overall error in absolute currents is estimated at 1-2 cm s\(^{-1}\) (Chereskin and Harris, 1997). The main problems encountered were bubble sweepdown when the bow thruster was used to maintain station and during rough weather and heavy seas. The maximum profiling range of the OS75 was about 850 m, but this depth range was drastically curtailed when bubbles were severe.

The NB150 data were processed using a 3-beam solution. Where the data overlap with the OS75, they are of higher resolution. Unlike the OS75, the NB150 was not affected by bubbles from the bow thruster. It was negatively affected by bubble sweepdown during rough weather and heavy seas. The maximum range was about 225 m; typical range was 180 m.

3 Lowered ADCP

3.1 Instrumentation

The lowered ADCP was Chereskin’s 150 kHz RDI Phase 3 broadband ADCP, serial number 1394, firmware versions 1.16 (XDC), 5.52 (CPU), 3.22 (RCDR), and C5d3 (PWRTIM). The LADCP has custom 30° beam angles. It was mounted on the outer edge of the CTD rosette, about 1 inch above the bottom of the frame. A rechargeable lead acid gel cell battery in an oil-filled plastic case (SeaBattery, Ocean Innovations, La Jolla, CA) was mounted in a steel box that was hose-clamped to the bottom of the rosette frame.

3.2 Data acquisition

A Mac G4 laptop computer running OSX (Panther 10.3.9) was used to upload an LADCP command set prior to each cast, using serial communication and a python terminal emulator (rditerm.py). Data acquired during the cast were stored internally on a 20 MB EPROM recorder. Data recovery used the terminal emulator, a public domain ymodem program (lrb), and a shell script to change the baud rate (change_baud) once the ymodem transfer was initiated.
3.3 Sampling protocol

Commands were uploaded from a file for deployment. The profiler was instructed to sample in a 2 ping burst every 2.6 seconds, with 0 s between pings and 1 s between (single-ping) ensembles, resulting in a staggered ping cycle of [1 s, 1.6 s]. Other relevant setup parameters were 16x16 m bins, 16 m blank, 16 m pulse, bandwidth parameter WB1, water mode 1, and an ambiguity velocity of 330 cm s$^{-1}$. Data were collected in beam coordinates.

The battery pack was recharged after every cast, using an AmRel linear programmable power supply. The power supply was set to 57.31 V constant voltage and 1.8 A maximum current. Typically, at the end of a cast, the power supply was current-limited at the maximum current. The power supply switched within about 10 min to constant voltage as the current level dropped. Charging was stopped nominally at 0.6 A in order to minimize the chance of overcharging, although the power supply resorts to trickle charging as the battery approaches full charge. Since lead acid gel cells outgas small amounts of hydrogen gas when overcharged/discharging, it is necessary to vent the pressure case. The pressure case was vented every few casts. There was a small but noticeable amount of outgassing.

3.4 Data processing

The LADCP provides a full-depth profile of ocean current from a self-contained ADCP mounted on the CTD rosette. Using the conventional “shear method” for processing (e.g., Fischer and Visbeck, 1993), overlapping profiles of vertical shear of horizontal velocity are averaged and gridded, to form a full-depth shear profile. The shear profile is integrated vertically to obtain the baroclinic velocity and the resulting unknown integration constant is the depth-averaged or barotropic velocity. This barotropic component is then computed as the sum of the time-averaged, measured velocity and the ship drift (minus a small correction, less than 1 cm s$^{-1}$, to account for a nonconstant fall rate) (Fischer and Visbeck, 1993; Firing, 1998). Errors in the baroclinic profile accumulate as $1/\sqrt{N}$ where $N$ is the number of samples (Firing and Gordon, 1990). This error translates to the lowest baroclinic mode and, for a cast of 2500 m depth, it is about 2.4 cm s$^{-1}$ (Beal and Bryden, 1999).

The barotropic component is inherently more accurate, because the errors result from navigational inaccuracies alone. These are quite small with P-code GPS, about 1 cm s$^{-1}$ (2 to 4 cm s$^{-1}$ without). Comparisons with Pegasus suggest that the LADCP can measure the depth-averaged velocity to within 1 cm s$^{-1}$ (Hacker et al., 1996). The rms difference between Pegasus and LADCP absolute profiles are within the expected oceanic variability, 3-5 cm s$^{-1}$ (Send, 1994), due primarily to high frequency internal waves.

In previous experiments the interference layer, which results from the previous ping reflecting off the bottom, has caused a large data gap in the LADCP profile, causing an uncertain velocity offset (several cm s$^{-1}$) between the parts of the profile on either side of the gap. For this experiment bottom velocities were greatly improved by using Chereskin’s instrument which pings asynchronously, thereby avoiding complete data loss in the interference layer. A second problem with data loss arises at the bottom of a CTD/LADCP cast, when the package is held 10 m above the sea bed for bottle sampling. At this distance the instrument is ‘blind’ since the blank after transmit
is order 20 m, and a time gap in the data stream will result in an uncertainty in the absolute velocity. We attempted to minimize the stop at the bottom of the cast to keep this gap to a minimum.

Initial processing was done with the University of Hawaii CODAS software. The method is the traditional shear method outlined in Fischer and Visbeck (1993) as implemented by Eric Firing in the UH CODAS LADCP software. CTD time series data were available immediately following the cast which provided more accurate depth than from integrating LADCP vertical velocity as well as calculated sound speed at the transducer. Typically LADCP casts were analyzed through to absolute velocity, including CTD data, prior to the next station.

During the cruise, the casts were also processed with Martin Visbeck’s LADCP Matlab processing routines, version 8a. The method (Visbeck, 2002) differs from the shear method in that an inverse technique is used which includes two additional constraints, the bottom velocity estimate and the average shipboard ADCP profile during the cast. In principle, the Firing shear and Visbeck inverse methods should agree when no additional constraints are included in the inverse, but at the moment the methods have shown unexplained differences on some data sets (Brian King, pers. comm.) Qualitatively, the absolute currents computed between the 2 methods agreed reasonably well. Detailed comparisons will be made in post-processing. Preliminary comparisons of shipboard and lowered ADCP data also showed fairly good agreement and suggest that the shipboard data will be a useful constraint in the inverse method utilized by Visbeck.

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4 References


Figure 1: LADCP section across the Subantarctic Front, stations 009 to 020. Upper panel is eastward current (cm/s). Lower panel is northward current (cm/s). Red line on station map indicates location of section.