2016 I8S/I9N GO_SHIP Repeat Hydrography Section LADCP Post-Cruise QC Report

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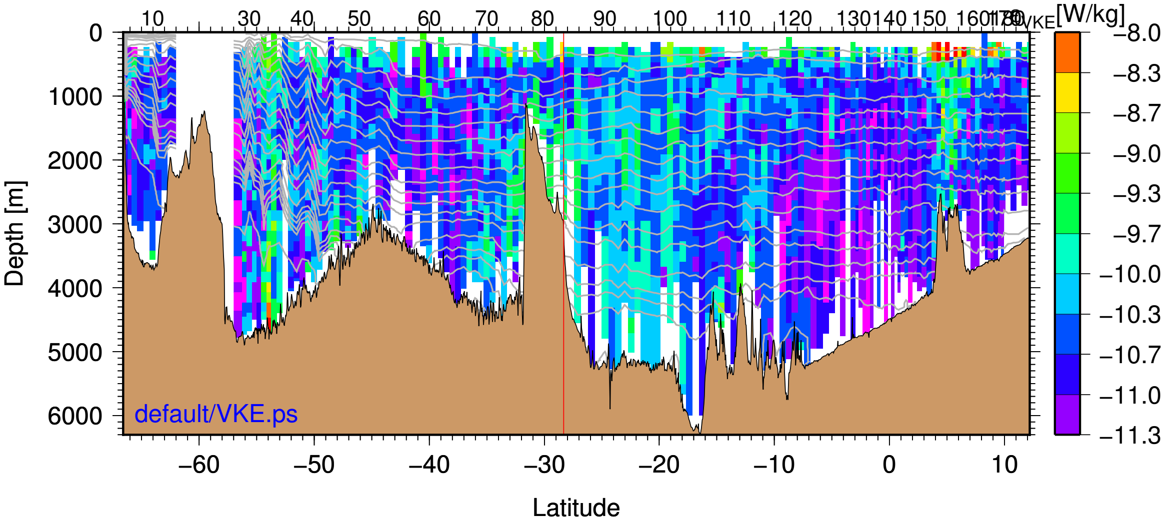

Figure 1: Kinetic energy dissipation estimated from LADCP-derived vertical kinetic energy (VKE) using a finestructure parameterization method built into the processing software for vertical velocity. The red line separates the two cruise legs (I8S and I9N). Regions of apparently elevated dissipation below 600 m or so include the Antarctic Circumpolar Current near 50°S, the Diamantina Escarpment and the adjacent Broken Ridge Plateau near 30°S, the southern half of the Wharton Basin, as well as the crest of the 90°E-Ridge near 6°N.

1 Summary

This report describes the results from the post-cruise quality control of the LADCP data collected during the two legs of the 2016 GO-SHIP (CLIVAR repeat hydrography) re-occupation of the I8S and I9N hydrographic sections on the UNOLS R/V *Roger Revelle*. Using one or two ADCPs installed on the hydrographic rosette (Section 2), full-depth profiles of all three components of the oceanic velocity field were collected at most stations. Entirely different methods are used for processing LADCP/CTD data for horizontal and vertical velocity, requiring separate QC (Sections 3 and 4, respectively).

Main Results: 1) There is good overall agreement ($\Delta u_{\mathrm{rms}} \approx 3$–$5\,\mathrm{cm\cdot s^{-1}}$) between the independent upper-ocean horizontal velocity measurements from the LADCP and SADCP systems for all profiles collected with a dual-head LADCP system (first 13 profiles from leg 1 and all profiles from leg 2),

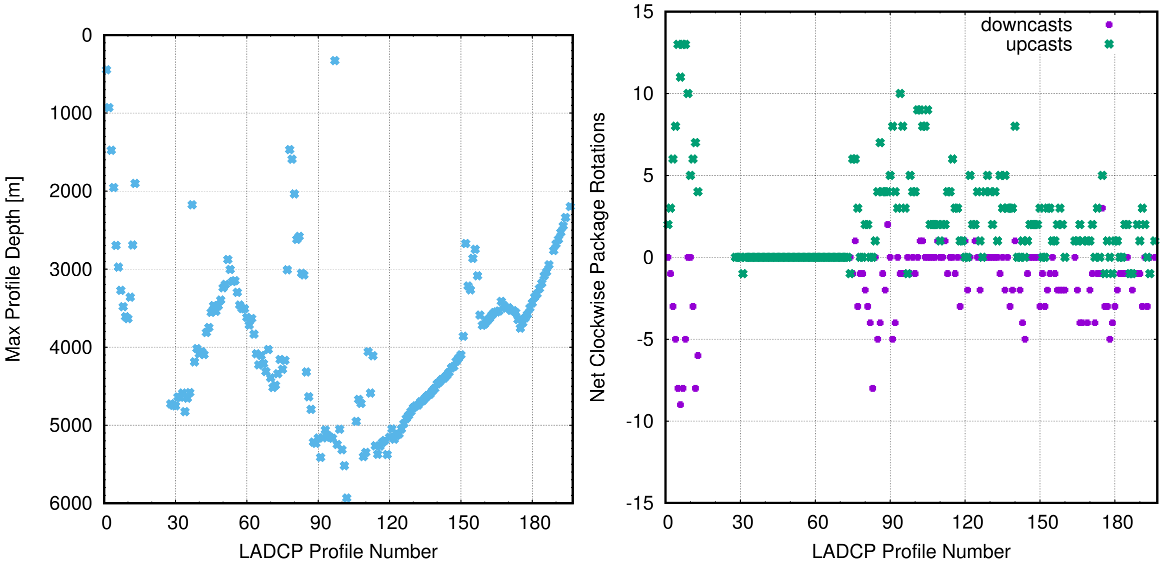

Figure 2: Profiling parameters. Left panel: Maximum depth. Right panel: Net package rotations.

indicating that those profiles are of very good quality. Out of the remaining 56 profiles that had to be collected with a single-head system (all from the first leg), 22 are likely of good quality and another 6 are possibly usable, but the remaining 28 are likely bad. 2) In contrast to the horizontal velocities, all available profiles of LADCP-derived vertical velocity are likely of good quality, as indicated by correlations between the single-instrument vertical velocity measurements provided by the two ADCPs (where available) and the physically reasonable patterns of VKE-derived turbulence levels across the entire cruise (Figure 1).

2 Instruments and Data Acquisition

During the first cruise leg (I8S), LDEO engineer Phil Mele was responsible for LADCP data collection and shipboard QC. The data were also transmitted to shore for processing and monitoring by Thurnherr. During the second cruise leg (I9N), LDEO Ph.D. student Takaya Uchida collected the data and carried out shipboard processing and QC. Diagnostic figures as well as the data were also transmitted to shore for monitoring and additional processing by Thurnherr.

Four different ADCP instruments were used during this cruise. Initial configuration (profiles 1–13[1]) consisted of two TRDI WHM300, #149 as downlooker (DL) and #13330 as uplooker (UL). On recovery from profile 14 the CTD rosette was lost and with it the entire LADCP system. After a (baker's) dozen profiles (15–27) without LADCP system, a single ADCP, WHM300 #150, was installed as a DL on the backup rosette for the remainder of the cruise leg (profiles 28–83). For the second cruise leg (profiles 84–168) another WHM300 (#12734) was added to the rosette as an UL.

The default setup for the ADCPs was to record beam-coordinate velocity data with 8 m pulses/bins and no blanking. In an attempt to increase instrument range for the DL-only profiles the pulse/bin

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[1] The LADCP profile numbers used throughout in this report are identical to the CTD station numbers. The LADCP data distribution contains the file `STATIONNUMBERS.nc`, which associates LADCP profile numbers with CTD station and cast numbers.

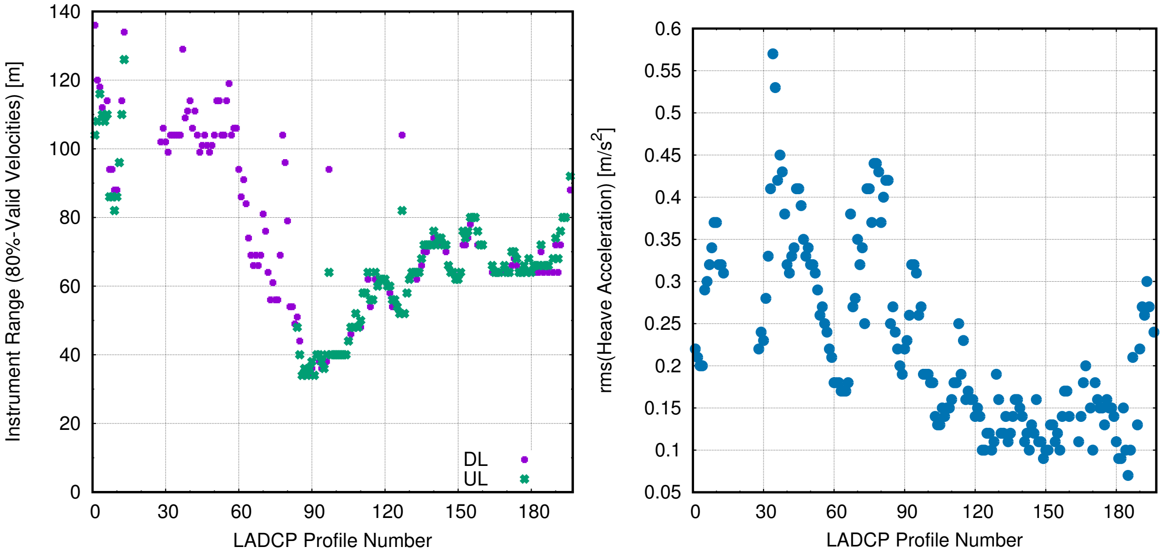

Figure 3: Left panel: Instrument range. Right panel: *rms* acceleration due to vessel heave (sea state).

length was increased to 10 m (profiles 31–86). Staggered pinging was used to avoid previous ping interference. With the exception of profiles 188 and 195 there are LADCP data from all stations. See cruise reports for additional information.

Figure 2 shows the maximum profile depths, as well as the number of net rotations experienced by the CTD package. With the exception of profiles 37 (2175 m max. depth) and 97 (330 m max. depth), all profiles extend across the full ocean depth (left figure panel). Except for profiles 28–74 when the backup rosette was weather-vaning, rosette rotation tended to be opposite during down- and upcasts indicating that the winch wire was in approximate equilibrium with the load (right panel).

LADCP data quality is sensitively dependent on instrument range (Figure 3, left panel), which depends on the acoustic scattering environment. During most of the I8S/I9N cruise acoustic backscatter was comparatively strong, resulting in the total (summed UL and DL ranges for dual-headed profiles) range exceeding 65 m (an empirical limit for good horizontal-velocity data) in most profiles. Sea state is also known to affect LADCP data quality; in the right panel of Figure 3 sea state is quantified as the *rms* vertical package acceleration. There is a clear break around LADCP profile 100, with mostly calm seas north of about 20°S.

3 Horizontal Velocity

The overall quality of the horizontal LADCP velocities is assessed by processing all profiles with the velocity-inversion method (LDEO_IX_13 software), using the bottom-track (BT) and ship-drift (GPS) constraints and comparing the resulting LADCP velocities near the sea surface to the corresponding SADCP velocities. Based on data from other cruises, high-quality LADCP and SADCP velocities typically agree within 3–6 $\mathrm{cm\cdot s^{-1}}$ when averaged over a few profiles. The LADCP profiles from the second cruise leg (I9N) clearly fit this criterion (Figure 4), as do the dual-head profiles from the first leg (1–13). Many of the single-head profiles (28–83) collected during the first cruise leg fail the criterion, on the other hand. In order to separate the good from the bad profiles in this range, the plots created during processing were inspected and the "diagnostic profiles" (processed without the

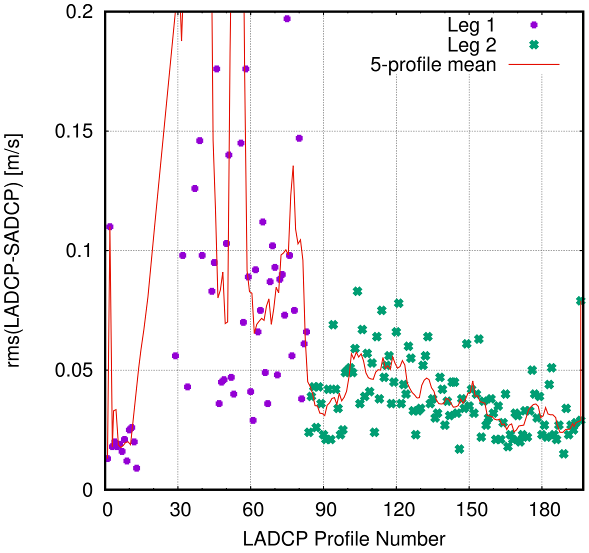

Figure 4: *rms* LADCP-SADCP horizontal velocity differences; red line shows 5-profile moving average.

Quality Flag	Profile List
A	1–13, 84–187, 189–194, 196
B	29, 32, 34, 40, 44, 47–49, 52–53, 57, 60–61, 66–67, 71, 73–74, 77, 80–82
C	45, 51, 62–63, 70, 83
missing	14–27, 188, 195
bad	28, 30–31, 33, 35–39, 41–43, 46, 50, 54–56, 58–59, 64–65, 68–69, 72, 75–76, 78–79

Table 1: Quality of horizontal-velocity profiles. The “A” profiles were collected with dual-head systems and there are no special concerns. The “B” profiles were collected with a DL only; visual inspection of diagnostic plots indicates that these profiles are likely good as well. The “C” profiles are somewhat less certain but at least some of them may also be okay. Only the profiles with quality flags A–C were submitted for archiving.

SADCP constraint) were visually compared to the fully constrained profiles, yielding 22 likely good profiles and an additional 6 that are possibly good, which leaves 28 horizontal-velocity profiles that are likely bad (Table 1). Somewhat unexpectedly, no correlation was found between profile quality and instrument range or sea state. It seems therefore likely that the data quality was adversely affected by the lack of rotation (”weather-vaning”) of the CTD rosette, although this is little more than speculation. For final horizontal-velocity processing, the LADCP data were re-processed with all available referencing constraints, including the SADCP velocities. Only the horizontal-velocity profiles with quality flags A–C were submitted for archiving.

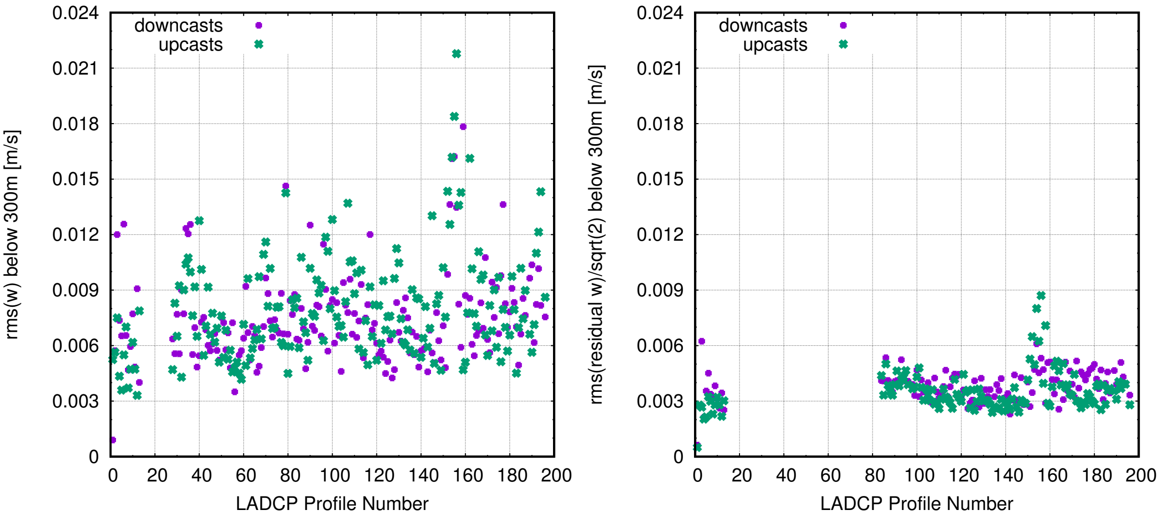

Figure 5: Vertical ocean velocity signal and noise. Left panel: Per-profile *rms* w_{ocean} below 300 m from the DL vs. profile number (signal). Right Panel: Per-profile estimates of measurement noise derived from UL/DL regression residuals of the dual-head profiles below 300 m.

4 Vertical Velocity

In order to process the LADCP data for vertical ocean velocity the `LADCP_w` software, version 1.3, was used. In addition to high-quality velocity data from the ADCPs, vertical-velocity processing also requires 24 Hz CTD time series with very few or no missing scans. Missing CTD scans appear to make the CTD clock run fast, resulting in time-lag offsets that "slip" during a profile. During I8S/I9N, CTD data transmission problems were very infrequent; only two profiles (36 and 37) have significant numbers of dropped scans, which do not appear to affect the final w_{ocean} profiles in either case (not shown). The left panel of Figure 5 shows the *rms* vertical ocean velocity below 300 m for all profiles; signal levels range between $\approx 3\,\mathrm{mm\cdot s^{-1}}$ and $2\,\mathrm{cm\cdot s^{-1}}$, with some evidence for the upcast data being noisier (higher *rms* w on average) than the downcast data. [Since LADCP measurements of w_{ocean} near the surface can be contaminated by biology the data from the top 300 m of the water column are ignored in this analysis.]

In contrast to LADCP-derived horizontal velocity, the two w measurements at a given depth (from the DL and UL) are largely[2] independent. This allows measurement noise to be estimated from the residuals of linear regressions of UL- to DL-derived w (right figure panel). [Assuming independent and equal errors in both instruments the regression residuals are scaled by $1/\sqrt{2}$ to estimate the noise levels.] For most dual-head profiles, inferred measurement noise of w_{ocean} is below $6\,\mathrm{mm\cdot s^{-1}}$, which is typical of high-quality LADCP-derived vertical-velocity profiles.

Comparing the two panels of Figure 5 indicates that the vertical-velocity residuals are generally lower than the measured signals, i.e. the LADCP-derived w_{ocean} profiles are not dominated by measurement noise. The comparatively high measurement noise observed in some of the profiles between 150 and 160 is likely due to the higher levels of w_{ocean} observed in the same region. Noting that the results shown in the figure are all relevant for vertical velocity profiles derived with a single ADCP we tentatively conclude that all 180 available vertical-velocity profiles from I8S/I9N are likely of good

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[2] Only low-frequency errors in the CTD package-velocity time series give rise to ADCP-measurement errors that are correlated between the two ADCPs.

Quality	Profile List
good	1–13, 28–187, 189–194, 196
missing LADCP data	14–27, 188, 195
too shallow for VKE	1, 97

Table 2: Quality of vertical-velocity and VKE profiles. Profiles 1 and 97 are not deep enough to calculate wavenumber spectra with the default 320 m-wide windows.

quality (Table 2). [Since the instrument heading is not used at all for vertical velocity processing, we don't expect lack of instrument rotation ("weather-vaning") to degrade the vertical velocity profiles.]

Applying a finescale parameterization based on Vertical Kinetic Energy (VKE), estimates of kinetic energy dissipation ϵ_{VKE} were derived from all sufficiently deep vertical-velocity profiles. Each ϵ sample is calculated from all available spectra (down- and upcast, DL and UL where available) in half-overlapping 320 m-thick windows. The resulting spatial distribution of turbulence (Figure 1) makes physical sense across the entire sampling region, consistent with the inference that all vertical velocity profiles are likely of good quality. [In particular, there are no clear indications of elevated noise levels in the single-head profiles 28–83.]