2017 P6 GO_SHIP Repeat Hydrography Section LADCP Post-Cruise QC Report

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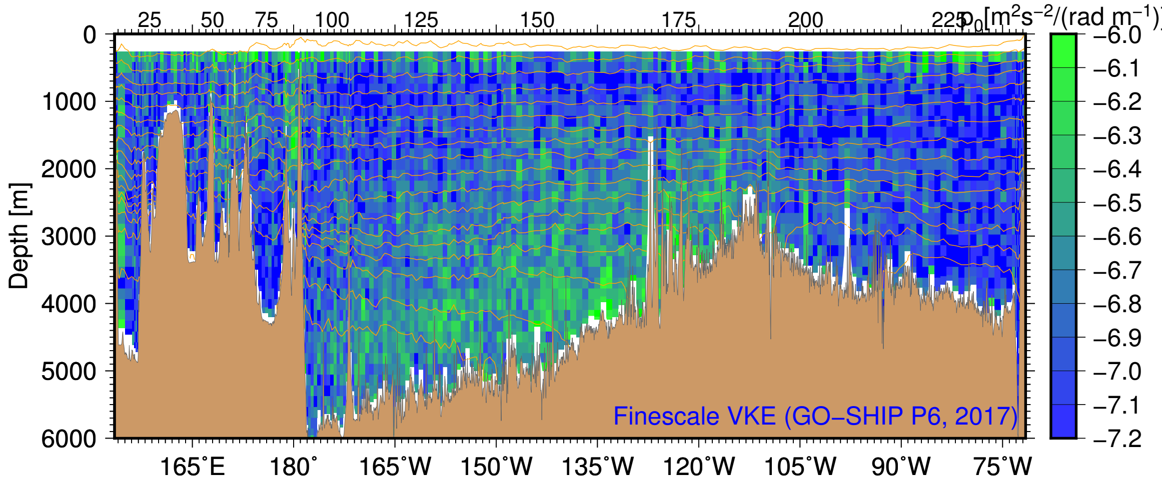

Figure 1: Cross-Pacific zonal section of p_0, a measure of finescale (100–320 m vertical wavelength) Vertical Kinetic Energy (VKE), along 32°S derived from the vertical LADCP velocities collected during the 2017 occupation of the GO-SHIP P6 section; the orange contours show neutral density from uncalibrated CTD data.

1 Summary

This report describes the results from the post-cruise quality control of the LADCP data collected during the two legs of the 2017 P6 GO-SHIP (CLIVAR repeat hydrography) cruise on the UNOLS *R/V Nathaniel B. Palmer*. Using two ADCPs installed on the hydrographic rosette (Section 2), one looking downward (DL) and the other upward (UL), 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 Findings: 1) There is good overall agreement ($<\Delta u_{\rm rms}> \approx 4\,{\rm cm\cdot s^{-1}}$) between the independent upper-ocean horizontal velocity measurements from the LADCP and SADCP systems, indicating that the LADCP-derived horizontal velocities from the 2017 re-occupation of the P6 repeat-hydrography line are of excellent quality. 2) Based on correlations between the independent vertical velocity measurements provided by the two ADCPs, the LADCP-derived $w_{\rm ocean}$ profiles are of high quality as well.

2 Instruments and Data Acquisition

During the first (profiles[1] 1–143) and second (144–250) cruise legs, Alma Castillo Trujillo and Elizabeth Simons, respectively, were responsible for LADCP data acquisition and shipboard QC. Additionally, the processing figures from every 5th profile and from profiles with suspected problems were sent to Thurnherr for additional checks.

Two different ADCP instruments were used during this cruise: the WHM15O #24544 as downlooker (DL) and the WHM300 #24497 as uplooker (UL). Initially (stations 1–13) the ADCPs were mounted on the rosette together with the "IMP" magnetometer/accelerometer package that also serves as connection between the instruments and the battery. Almost immediately there were intermittent but frequent communications problems that were eventually traced to a leak in the IMP pressure case. As a result there are insufficient LADCP data for processing the profiles of stations 6 and 10–13. On station 14 the IMP was replaced with a TRDI star cable and there are processable LADCP data from all remaining stations. However, intermittent communications problems continued during the entire cruise. The resulting profiles with multiple data files were processed with the largest files only. Five out of the final profiles (9, 60, 183, 200 and 221) were processed without any valid UL data.

During profile 97 beam #3 of the DL ADCP failed. Because the performance of the instrument remained otherwise good, because no spare WM150 was available, and because the range of the WH300 uplooker was marginal in that region of relatively weak accoustic backscatter it was decided to continue data acquisition without replacing the ADCP with the bad beam with a 300 kHz instrument. The UL performed well throughout the entire cruise. Both ADCPs were set up to record velocity data with 8 m pulses/bins and zero blanking. Staggered pinging was used to avoid previous ping interference, which is particularly important for 150 kHz instruments. See cruise report for additional information.

The left panel of Figure 2 shows the maximum profile depths. The topography of the first part of the cruise (the first 100 stations or so) is characterized by significant roughness in the Coral Sea and across a backarc basin just north of New Zealand. After crossing the deep Kermadec Trench around station 100 the seafloor becomes much smoother and rises gradually toward the EPR crest near station 188 before descending into the Chile Basin and, finally, rising again at the South American continental slope. Except for the three profiles from stations 93, 94 and 119, which were located in water deeper than 6000 m, bottom-track information is available for all profiles.

The right panel of Figure 2 shows the number of rotations experienced by the rosette. The fact that the instrument rotated primarily counterclockwise during the downcasts and clockwise during the upcasts with approximately equal number of rotations suggests that there was comparatively little stress on the wire during this cruise.

LADCP data quality is sensitively dependent on instrument range (Figure 3, left panel), which depends on the acoustic scattering environment. During the second half of the P6 cruise, acoustic backscatter was quite weak, with WH300 ranges below 65 m (an empirical limit for good horizontal-velocity profiles collected with single-ADCP systems) in most profiles after station 90 or so. The problem was compounded by a DL beam going bad on station 97, causing a significant reduction in instrument range, but the range of the 3-beam 150 kHz ADCP nevertheless remained above the 4-beam range of the 300 kHz UL for the remainder of the cruise, and the combined range of the two ADCPs was greater than 80 m in all dual-head profiles. Since the DL-only profiles (9, 60, 183, 200

[1]LADCP profile numbers, which are equal to the CTD station numbers of this cruise, are used throughout in this report. The LADCP data distribution contains the file `STATIONNUMBERS.nc`, which associates LADCP profile numbers with CTD station and cast numbers. The CTD station and cast numbers are also printed in the titles of all diagnostic figures produced by the LDEO_IX software.

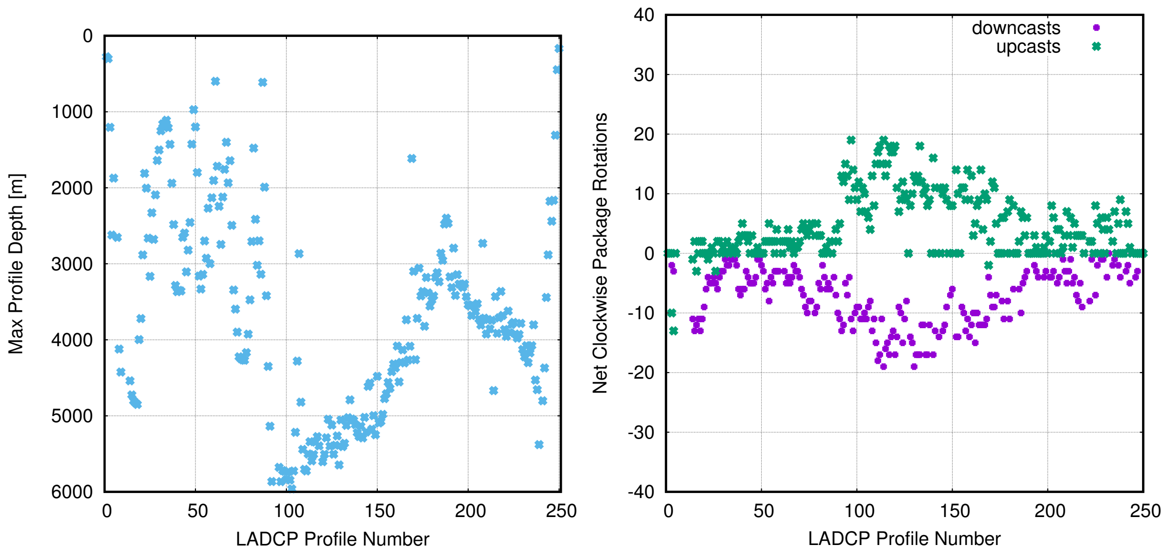

Figure 2: Profiling parameters. Left panel: Maximum depth. Right panel: Net package rotations.

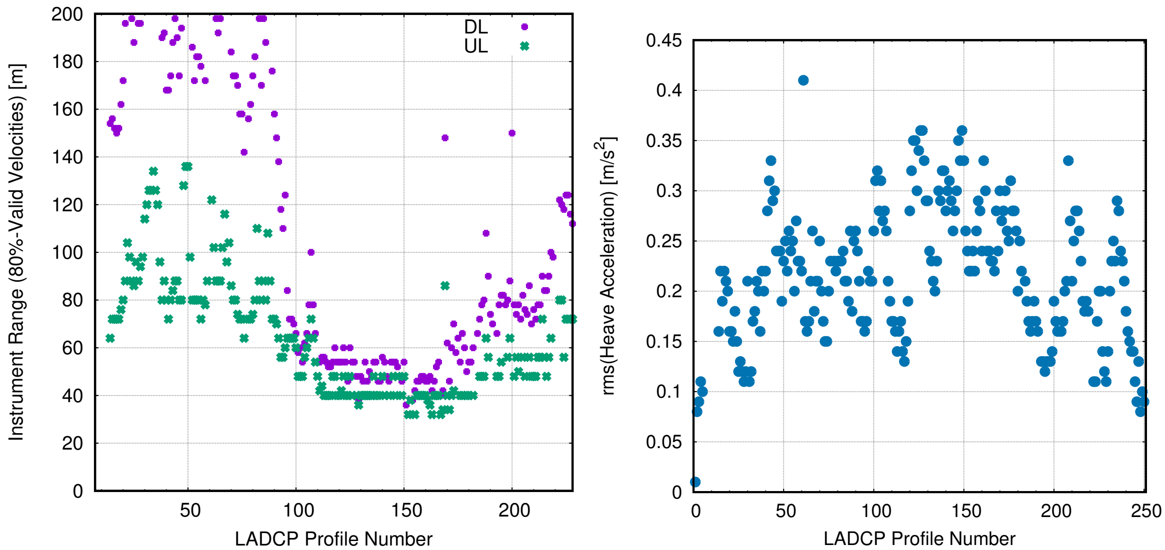

Figure 3: Left panel: Instrument range. Right panel: *rms* acceleration due to vessel heave (sea state).

and 221) all have ranges greater than 65 m, too, all P6 LADCP profiles are expected to yield good horizontal velocities.

Package motion due to surface waves (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. Calm seas are typically associated with accelerations below $0.2\,\mathrm{m{\cdot}s^{-2}}$ or so, implying significant wave-related package motion roughly in the middle third of the cruise. For context, the peak values around $0.35\,\mathrm{m{\cdot}s^{-2}}$ are small compared to values from the Southern Ocean, which frequently exceed $0.4\,\mathrm{m{\cdot}s^{-2}}$,

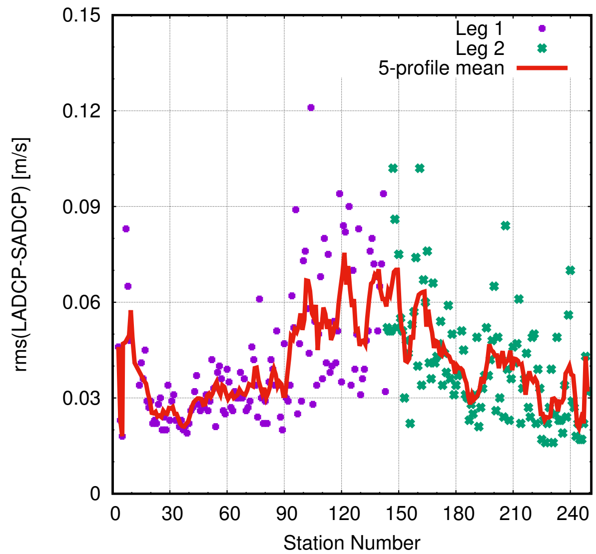

Figure 4: *rms* LADCP-SADCP horizontal velocity differences; low values indicate good agreement.

indicating that sea state is not expected to have a strong detrimental effect on the quality of the P6 LADCP profiles.

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 data from the 2017 P6 occupation clearly fit this criterion (Figure 4). Only in the middle of the section, roughly between profiles 90 and 170, are there velocity discrepancies around 6 $\mathrm{cm \cdot s^{-1}}$, and the number of profiles with significantly higher discrepancies is small. Both low acoustic backscatter and sea state likely contributed to this pattern (Figure 3). Diagnostic plots were inspected from all profiles with velocity discrepancies exceeding 6 $\mathrm{cm \cdot s^{-1}}$, but no data anomalies were found.

For final horizontal-velocity processing, the LADCP data were re-processed with all available referencing constraints, including the SADCP velocities. As a result, the final velocity uncertainties are smaller than the discrepancies shown in Figure 4, at least for the profiles with errors above 3 $\mathrm{cm \cdot s^{-1}}$, which is the nominal accuracy of horizontal velocity from high-quality LADCP profiles. In summary, the quality of the final processed horizontal velocities derived from the 2017 P18 LADCP data is excellent. (Possible exceptions are profiles 1 and 2, both short and shallow casts where the seabed was not detected correctly and for which no good SADCP data are available. There are no indications that the resulting horizontal velocity profiles, referenced with GPS data alone, are bad, however, and they are included in the archive.)

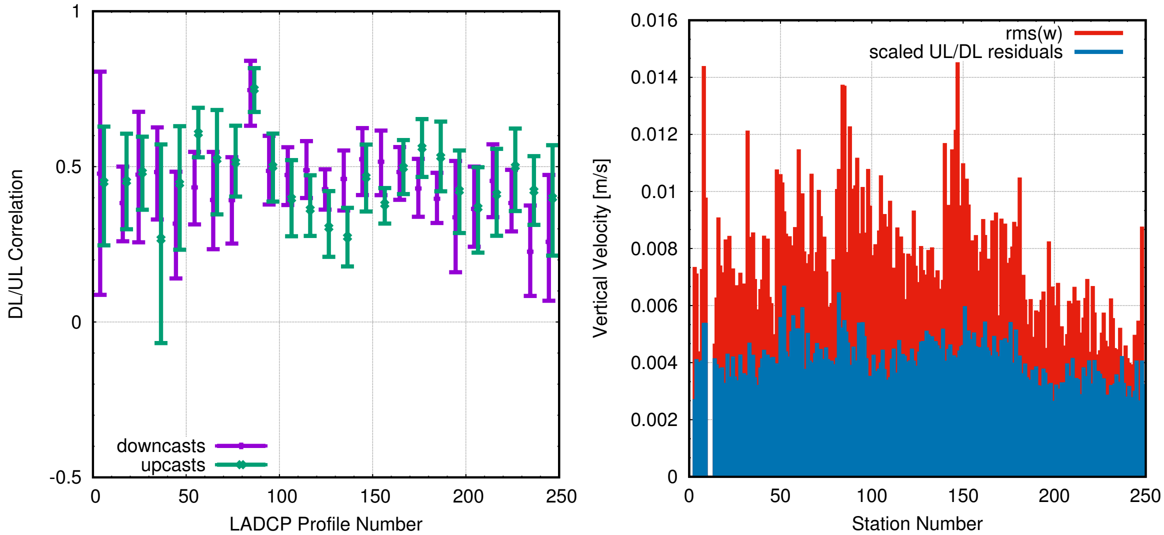

Figure 5: Left panel: Correlation coefficient of DL/UL vertical velocity correlation vs. profile number, averaged in groups of 10 profiles with error bars from bootstrapping. Right Panel: Vertical-velocity signal (red; *rms* w) and noise (blue; *rms* DL/UL regression residuals scaled by $2^{-0.5}$) vs. profile number. Data from the uppermost 300 m are excluded.

4 Vertical Velocity

In order to process the LADCP data for vertical ocean velocity the `LADCP_w` software, version 1.4, 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. In contrast to other recent GO-SHIP cruises, there are no indication for CTD data transmission problems during P6, attesting to the high quality of the CTD winch system on the Palmer.

There are vertical-velocity profiles from all P6 stations with valid LADCP data. Dissipation estimates from a finestructure parameterization method *(Thurnherr et al.,* GRL 2015) are available from all stations except those without valid LADCP data (6 & 10–13) and two stations at both ends of the section (1, 2, 249, 250), which are not deep enough for the spectral method to be applied.

In contrast to LADCP-derived horizontal velocity, the two w measurements at a given depth (from the DL and UL ADCP) are largely[2] independent. Diagnostics based on linear regressions between UL vs. DL-derived w are therefore useful measures of profile quality. The left panel of Figure 5 shows the resulting correlation coefficients for the P6 LADCP data below 300 m, calculated from w_{ocean} profiles processed at the default 40 m vertical resolution. Based on experience with other data sets, high-quality LADCP profiles typically have DL-UL correlation coefficients above 0.3 when averaged over a few profiles. The P6 LADCP profiles clearly fit this criterion — the apparent outlier group with correlation coefficients consistently above 0.5 are profiles 81–89 crossing the Havre Trough, where the highest VKE levels were observed on this cruise.

The right panel of Figure 5 shows the vertical velocity signal and noise levels for all dual-head profiles. The red bars show profile-averaged w_{ocean} below 300 m. (LADCP vertical velocity measurements near the surface are often contaminated by biological effects.) The blue bars show the

[2] Only errors in the CTD package-velocity time series that persist over time scales of minutes can give rise to vertical-velocity errors that are correlated between the two ADCPs.

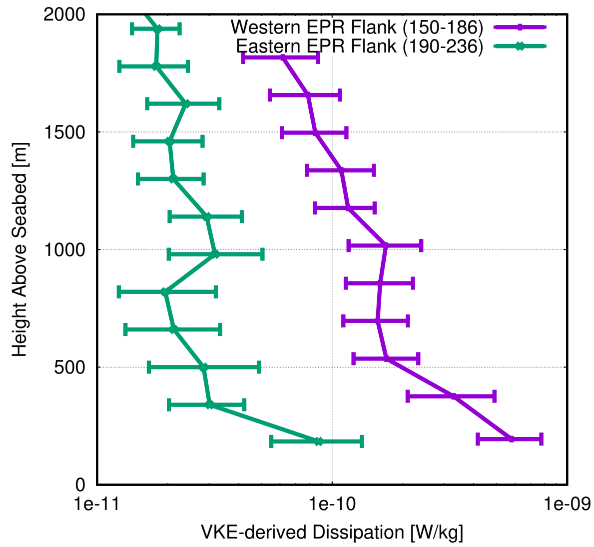

Figure 6: Average height-above-bottom profiles of finescale VKE from the eastern and western flanks of the EPR. VKE is rescaled as dissipation using an empirical scaling *(Thurnherr et al.,* GRL 2015). Error bars indicate 95% confidence from bootstrapping.

corresponding *rms* noise estimates, defined here as the DL-UL regression residuals scaled by $1/\sqrt{2}$. Based on experience with other data sets, high-quality LADCP w profiles typically have residual noise levels in the range 0.003–$0.006\,\mathrm{m{\cdot}s^{-1}}$. The P6 LADCP profiles clearly fit this criterion, too. The profile-averaged Vertical Kinetic Energy (VKE) levels observed during P6 ranged between $0.004\,\mathrm{m{\cdot}s^{-1}}$ and $0.015\,\mathrm{m{\cdot}s^{-1}}$, with the w signal exceeding the noise level in all profiles. East of the EPR crest (station 188) profile-averaged VKE levels are generally lower than west of the EPR crest. A section plot of finescale VKE reveals, among other patterns, that the cross-EPR difference is due to a thick layer of elevated finescale VKE over the entire western EPR flank (Figure 1). Average EPR-flank profiles of finescale VKE, rescaled as dissipation using an empirical scaling *(Thurnherr et al.,* GRL 2015), indicate that the differences are significant (Figure 6).