Cruise Report: LADCP data from CLIVAR/GOSHIP P16S 2014

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Personnel

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System description

The University of Hawaii (UH) ADCP group used a two Teledyne/RDI Workhorse Lowered Acoustic Doppler Current Profilers (LADCPs) to measure full-depth ocean currents during the 2014 CLIVAR/GOSHIP P16S cruise from Hobart, Australia, to Papeete, Tahiti aboard the *RVIB Nathaniel B. Palmer*.

A 150 kHz instrument (WH150, serial number 16283, firmware 50.40, with beams 20° from vertical) was deployed on every cast. It was mounted near the base of the rosette by an anodized aluminum collar connected to three struts that were in turn bolted to the rosette frame.

Beginning at station 63, a 300 kHz instrument (WH300, model WHS-I-UG300, serial no. 12734, firmware 50.40) was mounted in a collar at the top of the rosette with beams facing upward. It collected data on every subsequent station, except during station 78, when a serial communications issue kept it from sampling.

From station 4 to station 63, an Inertial Motion Processor (IMP), was mounted to the floor of the rosette. This was the second cruise this new instrument has been used on. It was made by Andreas Thurnherr, of the Lamont-Doherty Earth Observatory and contains accelerometers for tilt and roll and magnetic flux gate compasses. The idea is to improve on similar measurements made by the LADCPs to better determine the orientation of the rosette while the LADCPs are sampling. This is particularly important near the Earth's magnetic poles, where the compasses on LADCPs have often proved unreliable. The IMP contains a Raspberry Pi computer running Arch Linux and measures accelerations and magnetic flux at 100 Hz. It communicates via a WiFi interface.

There were numerous other instruments mounted on the rosette. A rough schematic of positions of the LADCP and other devices is shown in Figure 1. Particularly worth noting are the altimeter, a possible source of acoustic interference, and the bottom contact switch, which had a weight dangling 10 m below. That was within the blanking interval of the WH150 so probably had little effect, though it certainly was visible to the altimeter.

Power for the LADCPs and IMP was provided by a Deep Sea Power & Light sealed oil-filled marine battery (model SB-48V/18A, serial number 01527). It sat in a custom-made stainless-steel basket in the rosette frame. Figure 1 shows the arrangement of instruments in the rosette.

Between casts, a single power/communications cable connected each LADCP and battery to a computer and a DC power supply to initialize the LADCP, collect data after casts, and recharge the battery. Communication with the instrument was managed by a custom serial communication package.

Operating parameters

The WH150 used nominal 16 m pulses and 8 m receive intervals (assuming a standard $1500\,\mathrm{m\,s^{-1}}$ speed of sound). The blanking interval (distance to first usable data) was 16 m.

A staggered pinging pattern was used, with alternating 1.2 s and 1.6 s periods between pings. This was to avoid a problem referred to as Previous Ping Interference (PPI), which happens when a strong echo off the bottom from a previous ping overwhelms the weak scattering signal from the water column. PPI occurs at a distance above the ocean floor of $\Delta z = \frac{1}{2}c\Delta t\cos\theta$ where Δt is the period between pings, c is the speed of sound, and θ is the beam angle from vertical. With constant ping rates, the artifact hits a single depth, essentially invalidating all data at that depth. By alternating delays, we lose half the data at two depths, but have some data through the entire column.

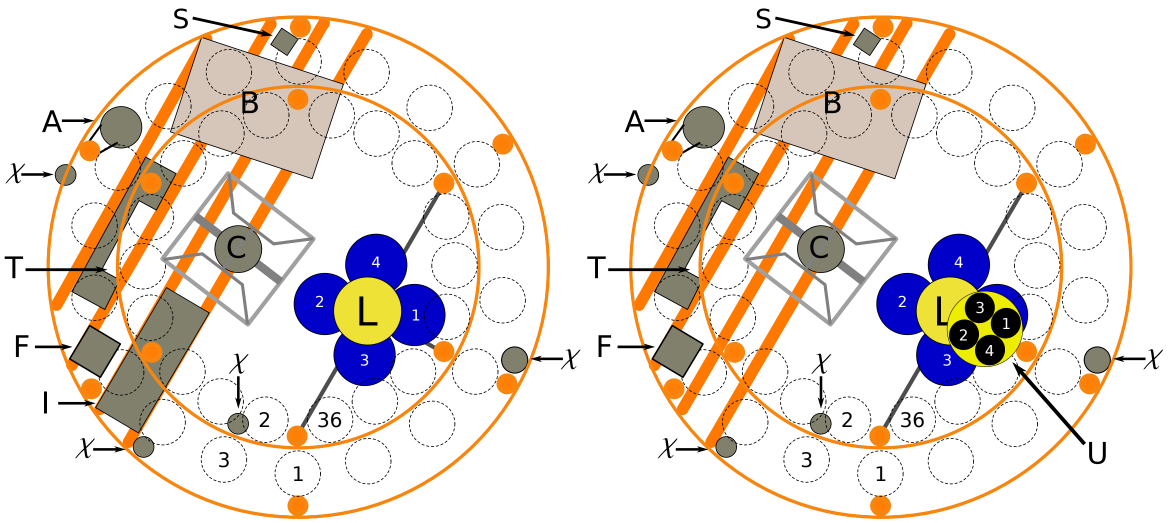

Figure 1: Schematic plan view of instrument and bottle locations on the rosette before (left) and after the upward-looking WH300 was mounted. Orange elements are parts of the rosette frame. Bottle locations are indicated by dashed circles and numbers. Instruments are identified by letters: L, LADCP (WH150); U, Up-looking LADCP (WH300); B, Battery for LADCP/IMP power; I, IMP; S, bottom contact Switch; C, CTD;A, Altimeter (120 kHz Benthos echosounder); T, transmissometer; F, Fluorometer for chlorophyll-A; and χ, elements of the χ-pod fast temperature system. White numerals show ADCP beam positions.

The WH150 control file

```
CR1     # factory defaults
PS0     # Print system serial number and other info.
WM15    # sets LADCP mode; WB -> 1, WP -> 001, TP -> 000100, TE -> 00000100
TC2     # 2 ensembles per burst
TB 00:00:02.80     ### also try old BB settings, 2.6 and 1.0
TE 00:00:01.20
TP 00:00.00
WN40    # 40 cells, so blank + 320 m with 8-m cells
WS0800  # 8-m cells
WT1600  # 16-m pulse
WF1600  # Blank, 16-m
WV330      # 330 is max effective ambiguity velocity for WB1
EZ0011101  # Soundspeed from EC (default, 1500)
EX00100    # No transformation (middle 1 means tilts would be used otherwise)
CF11101    # automatic binary, no serial
LZ30,230   # for LADCP mode BT; slightly increased 220->230 from Dan Torres
CL0        # don’t sleep between pings (CL0 required for software break)
```

The WH300 used 8 m pings, blanking intervals, and receive ranges. For stations 63 to 67, the instrument was set to listen through 20 depth bins of 8 m each, for a total range of 168 m. That proved excessive, as signal strength was usually too weak beyond 5 bins. Starting as station 68, the number of depth bins were reduced to 10, and the period between pings shortened to 0.53 s.

The WH300 control file (stations 68 and higher)

```
CR1     # Factory defaults
PS0     # Print system serial number and configuration
WM15    # Sets LADCP mode WP->1; WB->1; TE->00:00:01; TP->00:01
```

```
TC1     # 1 ensemble per burst
TB 00:00:00.53  # Time between bursts
TE 00:00:00.00  # Minimum time between ensembles
TP 00:00.00     # Minimum time between pings
WP 1        # 1 ping per ensemble
WN10        # 10 cells. That’s beyond the useful range for most of the cast.
WS0800      # 8 m cells (No WT command means transmit length also 8 m)
WF0800      # 8 m blank
WV330       # Ambiguity velocity
EZ0011101  # Manual sound speed, depth, salinity; others from ADCP sensors
EX00100    # No transformation (middle 1 means tilts would be used otherwise)
CF11101
```

Data processing

Data were processed using version IX.8 of Andreas Thurnherr’s implementation of Martin Visbeck’s LADCP inversion method, developed at the Lamont-Doherty Earth Observatory of Columbia University. The LDEO code is written in Matlab, and performs a long chain of calculations, including transforming the raw LADCP data to Earth coordinates; editing out suspect data; meshing with CTD data from the cast and simultaneous shipboard ADCP and GPS data; then running both an inverse method and a shear-based algorithm to obtain ocean currents throughout the profile. The shear-based calculation is used as a check on the inverse method–if they agree, confidence in the solution is enhanced. The LDEO code is available at `ftp://ftp.ldeo.columbia.edu/pub/LADCP`.

Only preliminary data processing was performed during the cruise; full processing takes more time than was available. The automatic data editing is not completely adequate, as ocean bottom reflections are not always edited out and the algorithms for detecting and discarding PPI require more work. When the data are fully processed, they will be made available on the UH ADCP website, `http://currents.soest.hawaii.edu` as part of the CLIVAR ADCP archive.

The IMP is still an experimental device; processing routines are still being worked on and no significant analysis was attempted beyond ensuring that the data were intake and made some sense.

Data gathered

WH150 data were successfully obtained in every cast at each station. WH300 data were gathered during stations 63 to 77 and 79 through 90. IMP data Preliminary vertical profile plots of each station were made available on the ship’s website within 12 hours of each cast.

Problems encountered

We had no major hardware or software problems during the cruise. The biggest issue is one that always plagues deep LADCP profiles in oligotrophic regions: the acoustic signal relies on backscatter from mm- to cm-sized particles, and there are too few to get much range from the instruments. The WH150 had an effective range of 320 m near the surface, but was reduced to about 80 m at depth. The WH300 was added to increase the data available to the inversion, but only managed 8 m to 16 m at depth. That was a significant addition to the data, particularly since it pinged almost 3X as often as the WH150, so the quality of the profiles clearly improved.

Whether they improved enough to be oceanographically useful is still open to question. Preliminary analysis by Tonia Capuano found suspiciously high diffusivities in the deep ocean north of Station 60 or so, implying that the currents are exaggerated, even after the addition of the WH300. Work is ongoing to improve the inversion, but we may just be facing a limitation of available instrumentation. The end of the cruise appeared mildly better, with more signal at depth.

This was the first deployment of the WH150, and it started out with all 4 beams equally strong. As the cruise progressed, beam 3 weakened relative to the others, until its useful range was only 65% of the other beams. Curiously, it appeared to recover somewhat, rising back to about 85% by the end of the cruise. It may be that it suffered more than the other beams from the very small signals.

There was considerable acoustic noise sensed by both instruments, though the source was not obvious. The Benthos 120 kHz altimeter is an obvious candidate, since it was on the rosette. The ship's multibeam and depth sounders could be responsible. The shipboard ADCPs are also possible sources of noise, but those frequencies are absorbed by seawater, so should not have much effect when the package is a few kilometers down. There was an odd noise signature that was only visible part of the time in the WH300 data, implying either an irregular source, or a highly directional one.

In any case, acoustic noise affected a small fraction of the data and is usually easy to edit out, so it should have little effect on the overall data quality.

Sample data plots

We made both vertical profiles of individual plots and contour plots along the cruise track available on the ship's network. A contour plot of data from the entire cruise (autoref fig:contour) may be the best capsule summary of the preliminary data.

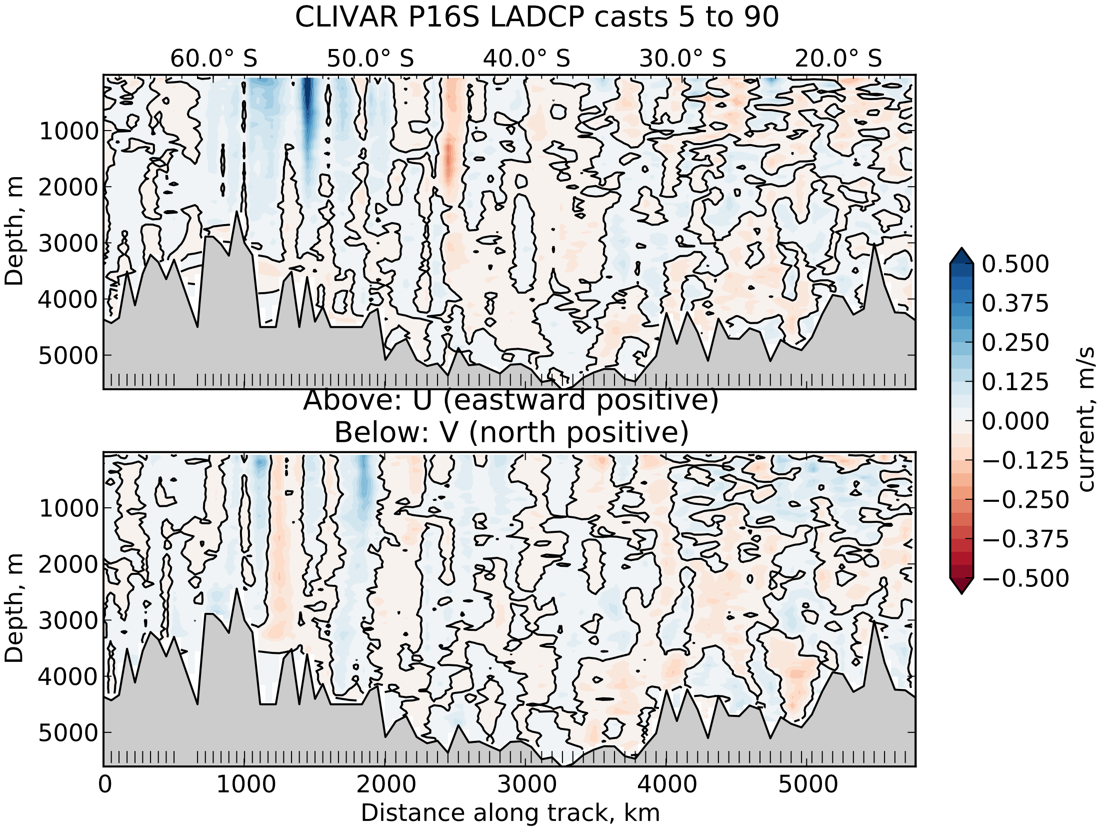

Figure 2: Contour plot of P16 stations along 150°W. Tick marks along the bottom of each plot are station locations.

The strongest current was the Antarctic Circumpolar Current (ACC), at 54°S. Rather surprising was the second strongest current,at 45°S moving west at $0.3\,\mathrm{m\,s^{-1}}$ at a depth of 1500 m. A profile of the currents at 45°S is shown in Figure 3, together with CTD traces from that station and the previous one. An eddy shed by the interaction of the ACC and Antarctic-Pacific Ridge is the obvious source of such a current, but eddies usually bring in water from different regions, whereas the water in station 45 seemed identical to 44, but the features around 1400 m were thicker. That seems like an internal wave. Andreas Thurnherr of LDEO (who was also responsible for the IMP), found vertical currents above and below the high-velocity core that changed from upward as the rosette was going down to downward as the rosette was pulled back up.

Currents through the rest of the basin are much weaker, though it is striking that current features south of about 40°show a much greater vertical extent than they do father north.

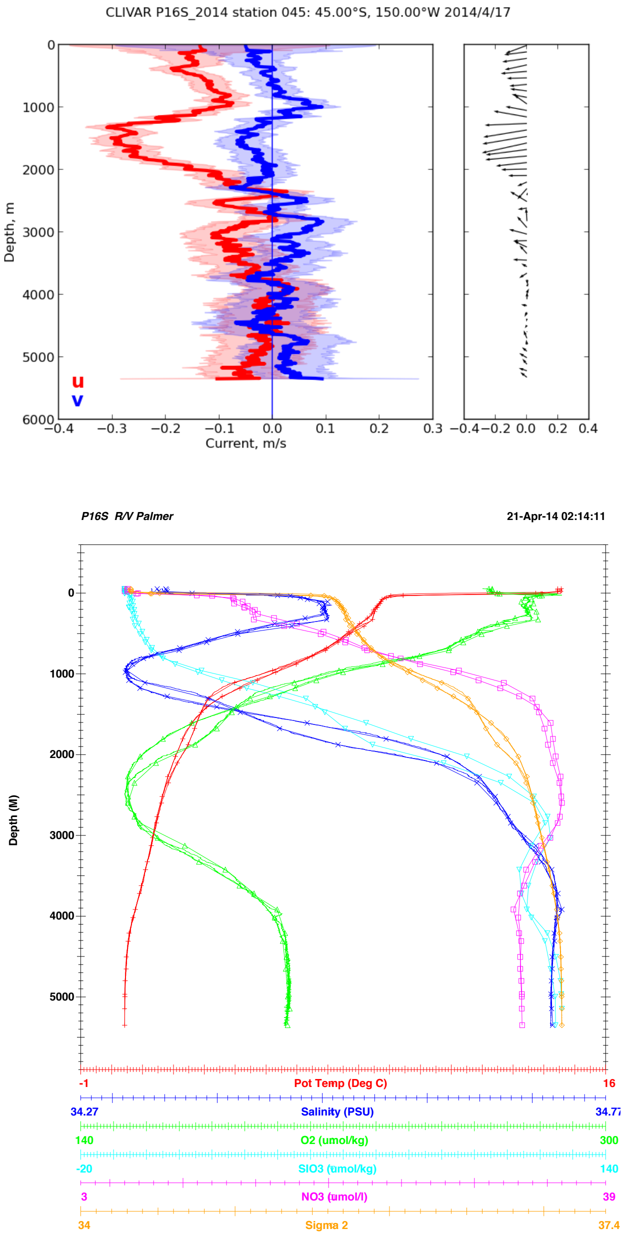

Figure 3: LADCP profile(left) of station 45 at 45°S and CTD profiles at stations 44 and 45. Station 45 traces can be identified by the inflections in the curves at 1500 m.