Cruise Report: LADCP data from CLIVAR/Carbon PO2E 2013

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Personnel

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System description

The University of Hawaii (UH) ADCP group used a Teledyne/RDI Workhorse 150 kHz Lowered Acoustic Doppler Current Profiler (LADCP, serial number 16283, with beams 20° from vertical) to measure ocean currents during the spring 2013 CLIVAR/Carbon P02E cruise from Honolulu, Hawaii to San Diego, California. The instrument was held near the base of the rosette by an anodized aluminum collar connected to three struts that were in turn bolted to the rosette frame. Secondary restraint was provided by a ratchet strap tightened around the instrument and tied to an upper strut of the frame. Power for the LADCP was provided by a Deep Sea Power & Light sealed oil-filled marine battery (model SB-48V/18A, serial number 01527). It was fastened with cord to the rosette frame. Figure 1 shows the arrangement of instruments in the rosette.

Between casts, a single power/communications cable connected the 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 LADCP 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

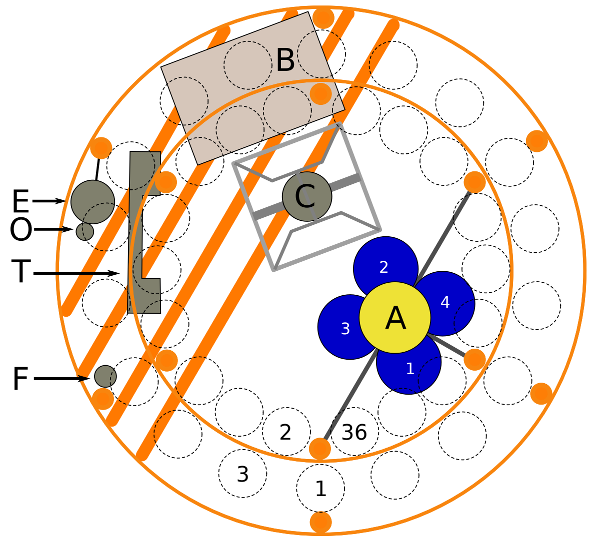

Figure 1: Schematic plan view of instrument and bottle locations on the rosette. Orange elements are parts of the rosette frame. Bottle locations are indicated by dashed circles and numbers. Instruments are identified by letters: A, ADCP; B, Battery for ADCP power; C, CTD;E, Echosounder (120 kHz Benthos altimeter); O, oxygen sensor (secondary); T, transmissometer; and F, Fluorometer for chlorophyll-A. White numerals show ADCP beam positions after the 90° clockwise twist on April 23.

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.

The LADCP 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)
```

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.

Data gathered

Data were successfully obtained in every cast at each station. 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, but there were a few glitches. The ADCP twice slipped down in its collar and had to be lifted up and re-secured. The odd noise problem from the last leg continued. Beam 2 was conspicuously weaker than the others. As before, the noise was related to instrument position. Since beam 2 was in the what appeared to be the bad spot, before the test cast we tried turning the instrument about 30° clockwise to get all beams as far from the CTD frame as possible. The test cast was not deep enough for an unequivocal test of the orientation, but the next 3 casts revealed that beam 2 was worse than before, so we turned it back before station 92.

It is possible that the Benthos 120 kHz altimeter caused acoustic interference, but exactly the same altimeter and rosette were used during the CLIVAR A20/A22 cruises without the same symptoms. Another possibility is that some instrument on the rosette or along the cable introduced electrical noise. We have not really resolved the problem, but are satisfied that the effects on the data are small.

We had a more fundamental problem through much of the deep basin. Data from individual pings are noisy; many pings must be averaged together to get useful information. This becomes the limiting factor in determining current velocities deep in the ocean, where particles of sufficient size to scatter the 1 cm wavelength of the WH150 are scarce. The effective range of the instrument dropped to roughly 80 m. This was much worse than in P02E, where range was typically $> 150\,\mathrm{m}$, even in the deep ocean. Range dropped gradually; it does not appear to be due to failing transducers, but rather to a lack of scatterers.

The net effect is that deep currents are poorly constrained and the inversions indicate improbably strong shear, more likely inaccurate inversions than real ocean current velocities. We will attempt to tune the inversions and constraints to yield more physically plausible results, but there may not be sufficient data density to constrain deep currents within error bounds of $10\,\mathrm{cm\,s^{-1}}$.

Sample data plots

Figure 2 compares the last station of Leg 1 with the first of Leg 2, which was a replicate, occurring in the same spot 9 days later. The two profiles differ quite a bit. In the absence of strong currents, motion is dominated by tides, internal waves, and inertial motion. These all have time scales of a day or less, so features seen by the LADCP cannot be expected to last much longer than that. It also means that comparisons with geostrophic velocities tendto be messy, as Sabine Mecking and Gunnar Voet showed in their last cruise update.

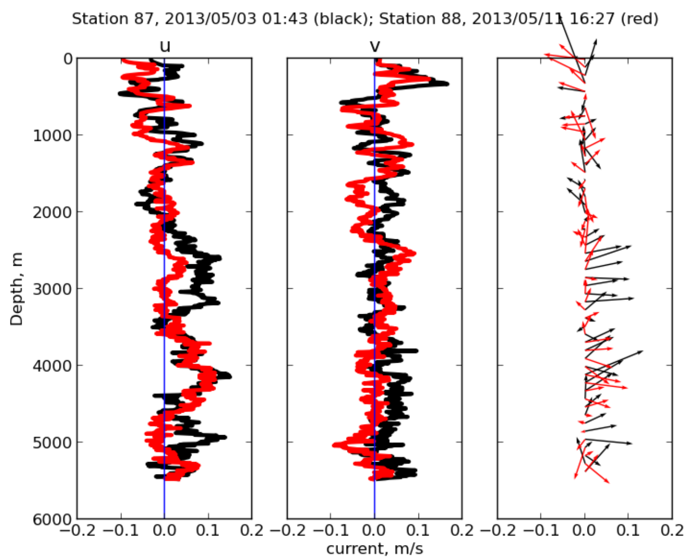

Figure 2: Comparison between the last station of P02W (station 87) and the first station of P02E (station 88). The left plot is ocean velocity in the east-west direction. Positive values are to the east. The middle plot is similar, but north is positive. The third plot has the same data, where the arrows represent horizontal speed and direction at the depth of the arrow origin.

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 may be the best capsule summary of the preliminary data (Figure 3). The strongest well-known current crossed was the California current, at about 121°W. Current speed was about $0.27\,\mathrm{m\,s^{-1}}$ to the SE. As mentioned above, some of the deep currents (below 3000 m or so) may be artifacts of the inversion rather than actual currents.

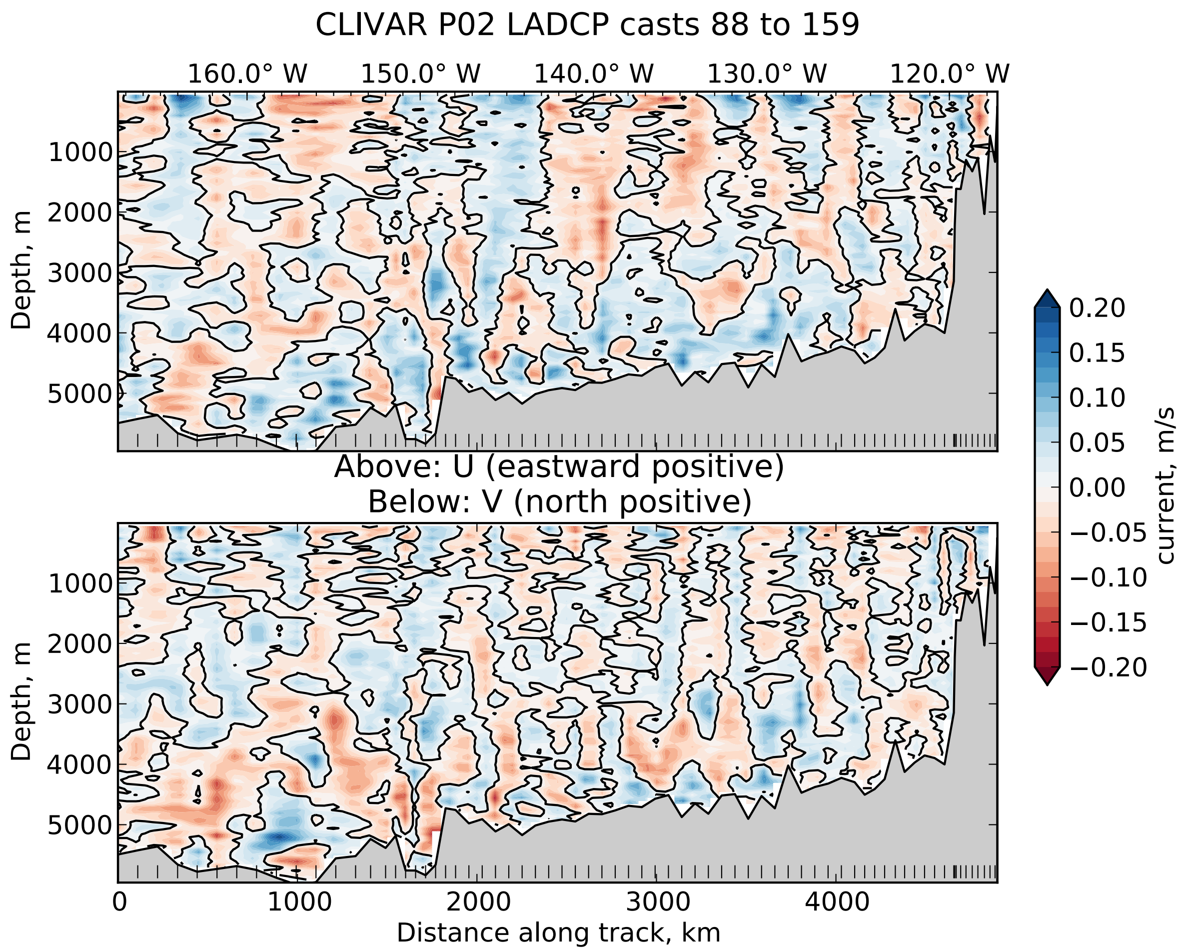

Figure 3: Contour plot of P02E stations 88 to 159. Tick marks along the bottom of each plot are station locations. The California current is indicated by the blue CC.