How to Process Velocity Data Collected with Explorer ADCPs Installed on Slocum Gliders with a Re-Implementation of the LADCP Shear Method

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1 Introduction

This "how-to" document describes how to use the re-implementation of the shear method for LADCP processing described by *Thurnherr* (2010) to process data collected with TRDI Explorer ADCPs installed on Webb Slocum gliders, as described in *Thurnherr et al.* (2015). There are two important restrictions:

1. Currently, standard Slocum floats do not sample instrument attitude (pitch, roll and heading) at sufficient temporal resolution. For high-quality velocity profiles, external attitude measurements are required.
2. Velocity data from the up-dive portions of a glider dive cannot be used because of the forward-tilted orientation of the Explorer ADCPs in the gliders. As a consequence, GPS data cannot be used to reference the baroclinic velocity profiles resulting from the shear method.

2 Data and Software Requirements

LADCP processing software. The re-implemented shear method is called `LADCPproc`. It is written entirely in perl and requires the several sub-modules to be installed, all available for download from `http://www.ldeo.columbia.edu/LADCP`. Instructions for installing the software can be found in the file `README.Install` that is part of the `LADCPproc` distribution.

PD0 file from Explorer ADCP. This is a standard binary file produced by the ADCP. It contains attitude data either from the glider (in which case the velocities will not be of very high quality) or from a dedicated external attitude sensor.

Glider data file. The following command sequence using standard Slocum glider software was used to produce the ASCII files for the test profiles described in *Thurnherr et al.* (2015):

```
dbd2asc unit_202-2014-119-10-0.dbd > dba
dbd2asc unit_202-2014-119-10-0.ebd > eba
dba_merge dba eba | dba2_glider_data
```

Each line in the output file produced by these commands contains a glider record with 2100 fields (values). Counting field numbers from 1, time (in seconds) in the example data is field #2089, latitude #555, longitude #564, pressure #2097, temperature #2098 and conductivity #2096.

3 Data-Processing Steps

Processing of standard LADCP/CTD casts with the re-implementation of the shear method is described in the file `README.ProcessData`, which is part of the `LADCPproc` distribution. Processing data from gliders requires additional steps:

Split Data Into Individual Dives. `LADCPproc` expects each input file to contain data from a single down-/up-dive combination. For glider dive sequences containing multiple down-/up-dives in a single file, both the Explorer data and the glider time series need to be split into single-dive files at the upper turning points. For the glider data, the turning points can be determined from the pressure record, and the data file can be split into individual dives with any text editor.

For the Explorer data, there are two utilities (part of `ADCP_tools`) that can be used to split the data files. Assuming that the `PD0` file from a glider dive sequence is called `diveseq07.PD0`, the following steps have to be carried out:

1. Create a time series of depth vs. ensemble number with

```
mkProfile diveseq07.PD0 > diveseq07.tis
```

2. Manually determine the ensemble numbers separating the individual dives (upper turning points) from this time series, including the first and last ensemble numbers (e.g. a sequence with 3100 ensembles from three dives might generate the following list: 1 1030 2055 3100
3. Use this list to split the `PD0` file into individual dives with

```
splitPD0 diveseq07.PD0 1 1030 2055 3100
```

Pre-Process Glider Time-Series. LADCP velocity processing requires 1 Hz time series of elapsed time (in seconds), CTD pressure (in dbar), temperature (in °C, using ITS-90 temperature scale), salinity (in psu), as well as latitude and longitude (in decimal degrees) in a single file per dive. The file can be constructed as follows

1. From the ASCII glider data files extract time (in seconds), latitude, longitude, pressure (convert to dbar), temperature and conductivity.
2. Subtract the minimum value (start time) from all time values to obtain elapsed time.
3. Calculate salinity from pressure, temperature and conductivity using standard methods.
4. Use linear interpolation to re-sample the resulting time series at 1 Hz and to fill missing values.

Define Glider-Specific Processing Parameters. Slocum/Explorer data cannot be processed with standard parameters. As described in the file `README.ProcessData`, processing parameters are usually defined in a setup file. The following shows the contents of the processing setup file `LADCPproc.params` used for the test profiles described in *Thurnherr et al.* (2015):

```
$CTD_ASCII_sampfreq        = 1;   # glider-data sampling frequency
$CTD_ASCII_press_field     = 2;   # field number of pressure in glider file
$CTD_ASCII_temp_field      = 3;   # field number of temperature in glider file
$CTD_ASCII_salin_field     = 4;   # field number of salinity in glider file
$CTD_ASCII_lat_field       = 5;   # field number of latitude in glider file
$CTD_ASCII_lon_field       = 6;   # field number of longitude in glider file

$pitch_offset = 11;               # Explorer ADCP is pitched forward by 11 degrees
$max_tilt = 90;                   # ascent pitch (30deg) + $pitch_offset + "noise"

$BT_max_depth_error = 200;        # disable those bottom-tracking filters ...
$BT_max_bin_spread = 20;          # ... that assume small instrument tilt
```

Determine Time Lags. Data processing with `LADCPproc` is based entirely on elapsed times. As a result, a time lag has to be determined for each pair of corresponding ADCP and Glider time series, even if the instrument clocks were synchronized perfectly. Unfortunately, the algorithm used for LADCP/CTD processing requires surface-wave-related heave motion and does not work Glider/Explorer data. Time lagging must therefore be carried out manually. For the test profiles described in *Thurnherr et al.* (2015) the following method was used:

1. Create file `w.timser` containing unlagged time series of w_{CTD} and w_{LADCP} using

   ```
   LADCPproc -s LADCPproc.params -l 0 -t w.timser DV07_1.PD0 DV07_1.1Hz >/dev/null
   ```

2. Use these time series to determine the offset (in seconds) required to bring `CTD_w` plotted against `elapsed` into agreement with `ADCP_w` plotted against `elapsed+offset`.

Calculate Horizontal Ocean Velocities. Once the correct time lag has been determined, the data from an individual glider dive can be processed as described in the file `README.ProcessData`, except that the time lag must be specified with the `-l` option to `LADCPproc`. Thus, if the time lag is 5.3 s,

```
LADCPproc -s LADCPproc.params -l 5.3 -p DV07_1.shprof -b DV07_1.BT DV07_1.PD0 DV07_1.1Hz
LADCPintsh -r DV07_1.BT DV07_1.shprof > DV07_1.prof
```

will produce, in the first step, a file with vertical-shear profiles (`DV07_1.shprof`) and a file with BT-referenced absolute velocities near the seabed (`DV07_1.BT`). In the second step, the shear profiles are vertically integrated and referenced with the integration constants determined from the BT velocities, to yield a profile of absolute ocean velocity in file `DV07_1.prof`.

The test profiles described in *Thurnherr et al.* (2015) were gridded at 2 m vertical resolution (`-o 2`) using RDI bottom-track data (`-r`). All other parameters were left at their default value.

References

Thurnherr, A. M., 2010: A practical assessment of uncertainties in full-depth velocity profiles obtained with Teledyne/RDI Workhorse Acoustic Doppler Current Profilers. *J. Atm. Oc. Tech.* **27**, 1215–1227.

Thurnherr, A. M., D. Symonds, and L. St. Laurent, 2015, March): Processing Explorer ADCP data collected on Slocum gliders using the LADCP shear method. *Proceeding, CWTMC'15 (IEEE).*