CTD-χpod Processing Guide

Andy Pickering

May 5, 2017

Contents

1 Introduction

This is a guide to processing data from CTD-χpods. χpods are self-contained instruments developed by the OSU Ocean Mixing Group to measure turbulence. They have a FP07 thermistor that measures temperature and temperature gradient, sampled at 100Hz.

2 Software

- The processing is done with Matlab codes, which are maintained in a github repository:
  `https://github.com/OceanMixingGroup/mixingsoftware`.
- The CTD-χpod specific codes are in the folder `/CTD_Chipod`.
- Codes for processing raw CTD data (.hex format) are contained in `/ctd_processing`.

3 Data Organziation

Raw data should be organized into folders as listed below. The function `make_ctd_chipod_folders.m` will make the empty folders when you start processing a project.

3.1 Raw Data

- `/Data/raw/Chipod/SNxxxx` : Raw χpod data.
- `/Data/raw/CTD/` : Raw CTD data (.hex,.XMLCON,.hdr).

Processed data is organized as follows:

3.2 Processed Data

- `/Data/proc/Chipod/` Main folder for processed χpod data
- Data for each χpod is stored in `/[whSN]/[pathstr]` where `pathstr` constructed based on Params, for example:
  `zsm20m_fmax7Hz_respcorr0_fc_99hz_gamma20`
  This allows us to run the processing for different Params and easily compare the results.
- `/Data/proc/CTD` Processed CTD data. (/24Hz,/binned).

4 CTD data

CTD data needs to be obtained and processed before running the χpod processing. Processing requires:

1. 24Hz data: used to determine the time offset between the CTD data and χpod data, by aligning (highpassed) dp/dt from the CTD with w estimated by integrating vertical chipod accelerations. 24Hz temperature is also used to calibrate the chipod temperature voltages and convert to physical units.

2. 1-m binned data: used to calibrate chi-pod T, and calculate dT/dz and N^2.

I prefer to use codes in `/mixingsoftware/ctd_processing/` to process standard Seabird hex files into standard mat files to use in chi-pod processing. See `Process_CTD_hex_Template.m` for an example. The data can be processed using other methods, but must contain the specific fields required by the processing routines as listed below:

4.1 24Hz CTD Data

Required fields for 24Hz CTD data are:

- dnum : datenum
- t : temperature [C]
- p : pressure [db]

4.2 1-m Binned CTD Data

Required fields for binned CTD data

- dnum : datenum
- t : temperature [C]
- p : pressure [db]
- s : salinity [psu]
- lat : Latitude [^{o}]
- lon : Longitude [^{o}]

5 Brief Outline of Major Processing Steps

1. Find chipod data for each CTD cast
2. Align chipod data with CTD data
3. Calibrate chipod data
4. Apply chipod calc in 1 sec windows

More details are given in the next section.

6 Processing steps

All templates are located in `/mixingsoftware/CTD_Chipod/Templates/`. In all template files, 'Templates' should be replaced with the project name in both the script name and witihin the script.

1. Check the excel log files to look for any major issues, sensors switched during cruise etc..

2. Modify `Load_chipod_paths_template.m` . This specifies filepaths to raw data, as well as where output will be saved.

3. Modify `Chipod_Deploy_Info_template.m` with info for specific deployment. Much of the rest of the processing uses information from the above two files. *The info for each unit can be found in the excel log file*.

4. Plot the raw chi-pod data (`Plot_Raw_Data_template`?). This will let you see quickly if any sensors or files are obviously bad. If there are bad files you can specify these in a `Bad_File` list so they will not be loaded during processing (this is not necessary, but will reduce time loading bad files, and may prevent bad data from accidentally being used).

5. Modify `MakeCasts_CTDchipod_Template.m` for specific cruise. This script finds χpod data for each cast, aligns the data, calibrates the data, and saves a file with data for each cast.

6. Run `MakeCasts_CTDchipod` for one good cast for each SN. Check time-offset / alignment (figure 4); if not right, probably need to modify `az_correction` or `flip_ax_az` in `Chipod_Deploy_Info`. * Note if χpod clock is off by a large amount (for example you forgot to set clock), processing will not work because it finds the files for each cast by the timestamp in their name. You will need to apply a time offset to the raw files (make copies first) and rename them in this case.

7. Once that is figured out, run `MakeCasts_CTDchipod` for all casts. Data are saved to `/Data/proc/Chipod/cast` and `/Data/proc/Chipod/cal`. If Matlab crashes before finishing (which seems to happen relatively often on my laptop, you can load `proc_info.mat` and look at the `last_icast` field to see where to restart `MakeCasts_CTDchipod`.

8. Modify and run `add_plot_ctd_Template.m`. This will add CTD data to the `proc_info` strucutre and make a summary plot of temp and sal for the transect.

9. Run `SummarizeProc_Template`. This makes some summary tables and figures from the 'Xproc.mat' data saved during `MakeCasts_CTDchipod`. The two latex tables it produces can be copied and pasted into the Latex notes template.

10. `Plot_TP_profiles_EachCast_Template.m` For each cast, this plots the temperature derivative from all chi pod sensors on the same scale so you can compare them and check for bad profiles. Figures are save to `/Figures/TPprofiles/`. This is another good place to check that the up/down designations are correct; the title for the designated direction will be green. The corresponding profile should be less noisy than the other direction.

11. Modify `DoChiCalc_Template.m` and run for all casts. This does the chi calculation for all the cast files made in `MakeCasts_CTDchipod`. Data are saved to `/Data/proc/Chipod/avg/`

12. Modify and run `Make_Combined_Chi_Struct_Template`. This will combine all the processed 'avg' files for each cast into a single structure 'XC'.

13. Modify and run `PlotXCsummaries_Template` to make summary plots from the combined 'XC' structure.

14. Run `Make_kml_Template.m` to make a kml file of CTD cast positions that can be viewed in Google Earth.

15. Screen processed casts... `VisCheck_TP_profiles` , `Combine_XC_sensors_I09` etc..?

7 χpod Processing Parameters

Variable parameters for the processing are specified in a 'Params' structure.

- fmax : Maximum frequency to integrate temperature gradient spectrum to (default 7 Hz). In practice this varies with each sensor.
- gamma : Assumed mixing efficiency (default 0.2).
- `resp_corr` : Option to apply frequency response correction (default 0).
- fc : Cutoff frequency for response correction (if applied) (default 99 for naming purposes).
- `z_smooth` : The distance [m] over which N^2 and dT/dz are smoothed (default 10m).

8 Output File Formats

8.1 /cast

'Raw' (ie uncalibrated) χpod data for each cast. Structure 'cast' with fields:

- datenum

- T1 = Temperature [V]
- T1P - dT/dt [V]
- AX - X-acceleration [V]
- AZ - Z-acceleration [V]
- `chi_files` - List of raw chipod files from which data was combined into this structure.
- `time_range` - Time range of CTD cast.
- castname - Name of CTD cast.

Ex. filename :

8.2 /cal

Calibrated data for each cast. Up and down casts are saved in separate files. Structure 'C' with fields:

- datenum
- P [db]
- T1P - dT/dt [Ks^{-1}]
- fspd - [ms^{-1}]
- castidr - up/down
- info
- ctd

Ex. filename : `rh10011_SN2013_downcast.mat`

8.3 /avg

Result of χpod calculations. Contains data points for each 1 sec window.

- Params
- datenum
- P - [db]
- N2 - [s^{-2}]

- dTdz $[Km^{-1}]$
- fspd - $[ms^{-1}]$
- T $[^oC]$
- S [psu]
- theta
- sigma
- chi1- χ $[K^2s^{-1}]$
- eps1 - ϵ $[Wkg^{-1}]$
- KT1 - K_T $[m^2s^{-1}]$
- TP1var
- samplerate - [hz]
- nu
- tdif
- lat - $[^o]$
- lon - $[^o]$
- castname
- castdir
- Info

Ex. filename : `avg_08402_downcast_SN1013_T1.mat`

9 Notes

There is a template for standard latex notes that can be modified for each cruise/deployment: `Chipod_Notes_Template_AP`.

10 Post-processing Analysis

- Plot χpod time-offsets. The time-offset should drift linearly with time, and may be reset during the cruise. Typically should be less than 20 sec (depends on how accurately time was set). In some cases, the time was set wrong (off by a day, wrong time zone etc.); in this case the processing script needs to be modified to correct this.
- Compare different sensors and cast directions: The quality of data obtained depends heavily on the setup of the CTD and the χpod mounting. Typically the upward looking sensors on the upcasts are the cleanest data.
- Sensitivity to parameters: see details below.

11 Sensitivity Analysis

The sensitivity of the results to different parameters should be examined, including `fmax` and `z_smooth`.

12 Standard Plots made by processing

- `castname_Fig0_RawCTD` (Figure 1).
- `castname_Fig1_RawChipodTS` (Figure 2).
- `castname_Fig2_w_TimeOffset` (Figure 3)
- `castname_Fig3_w_TimeOffset_Zoom` (Figure 4). Shows a zoomed-in period of the time-offset. The two timeseries should match in the lower panel.
- `castname_Fig4_w_dTdtSpectraCheck` (Figure 5). This compares the analog dT/dt (T1P) to the differentiated T signal. The spectral amplitudes should agree up to a certain frequency where the digital dT/dt becomes dominated by noise. If the spectra below the noise level don't match, the time-constant used in calibration might need to be modified.
- `castname_Fig5_T_P_dTdz_fspd` (Figure 6). Summary of the alilgned and calibrated data.
- `castname_Fig6_downcast_chi_T1_avgPhist` (Figure 7).
- `castnameFig7__upcast_chi_SN600_T1_avg_chi_KT_dTdz` (Figure 8). Summary of the final data ('avg' structure).

13 Example Figures

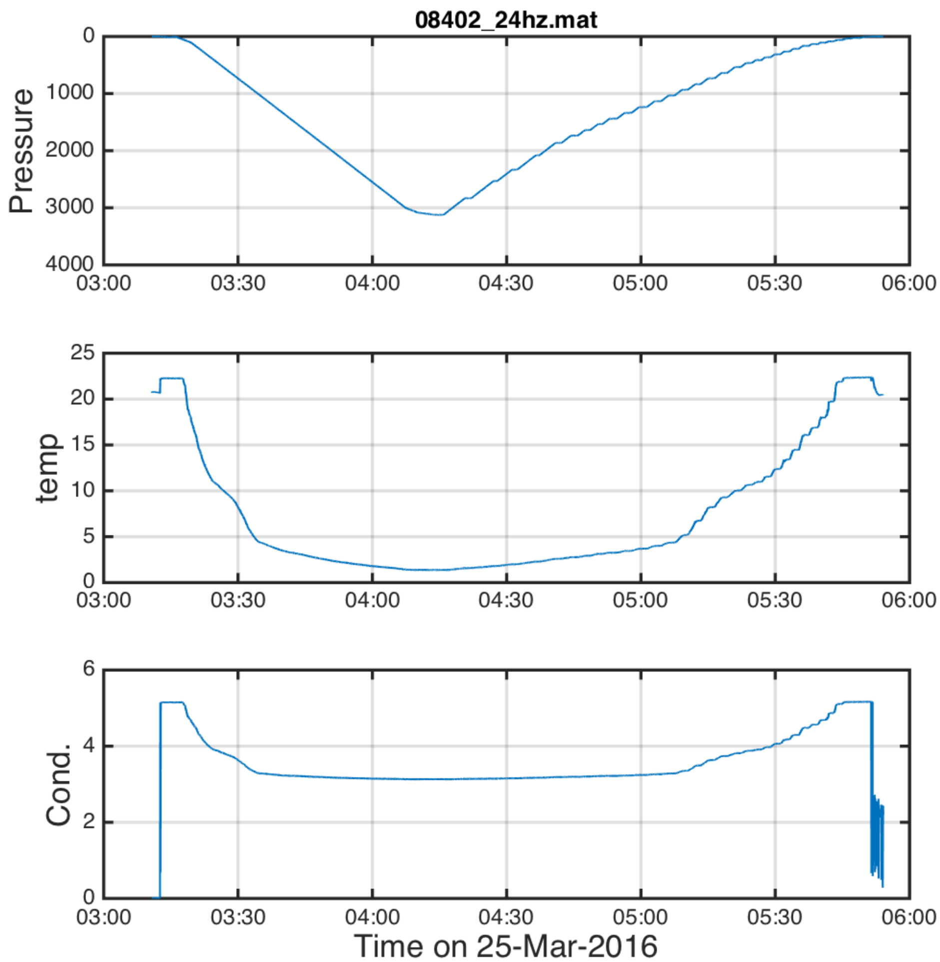

Figure 1: Time-series of raw CTD data for one cast: (a) Pressure (b) Temperature (c) Conductivity.

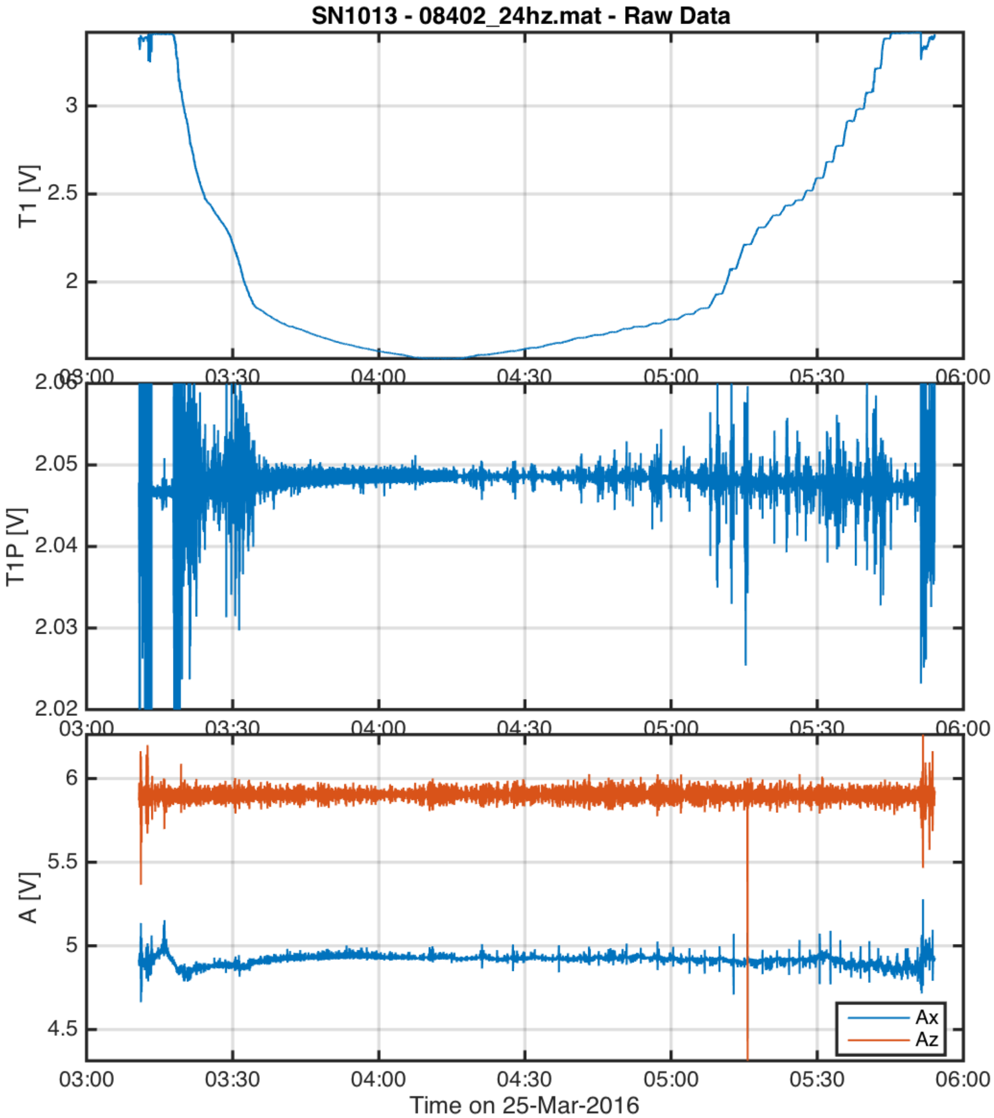

Figure 2: Time-series of raw χpod data (voltages) for one cast: (a) Temperature (b) dT/dt (c) Accelerometer.

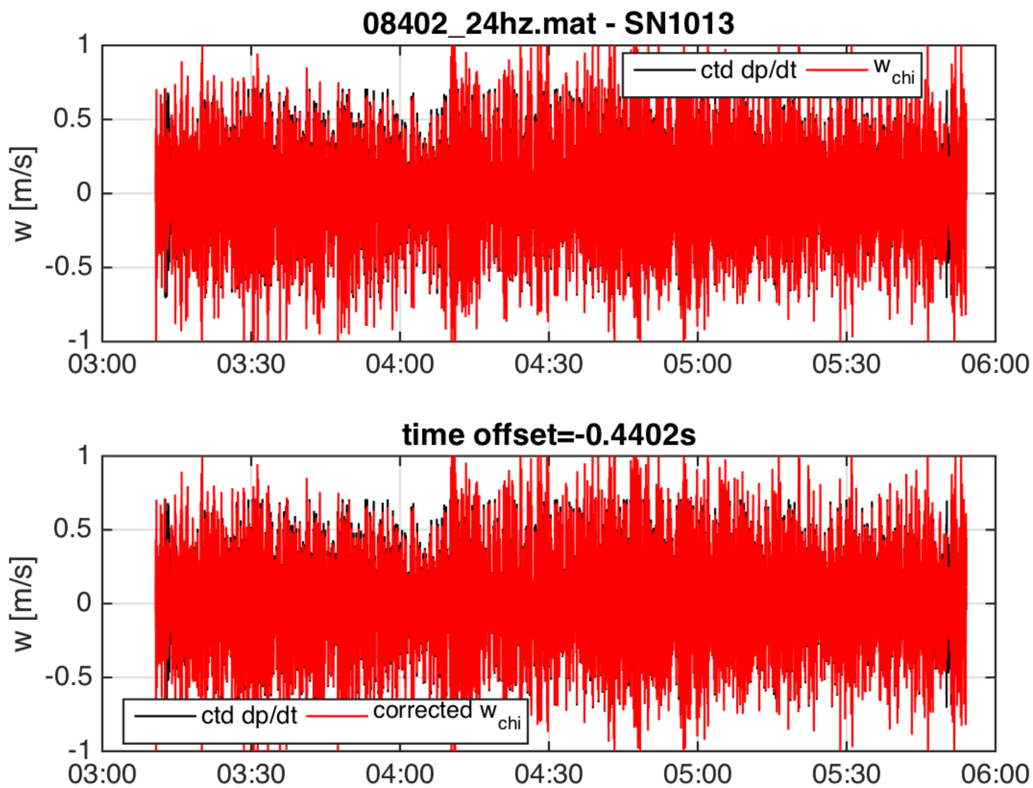

Figure 3: Time series of dp/dt from CTD and integrated vertical accelerations from χpod . Top is original, bottom is after time-offset applied to χpod.

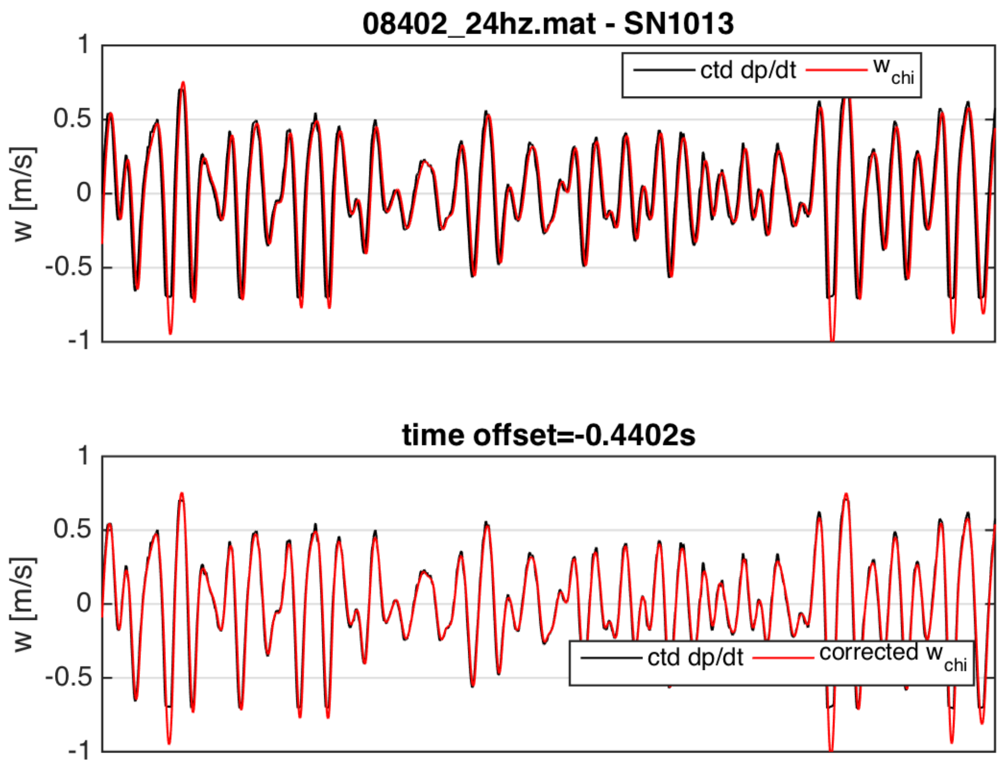

Figure 4: Zoom-in of previous plot allowing one to check if time-offset is correct. Bottom panel should match.

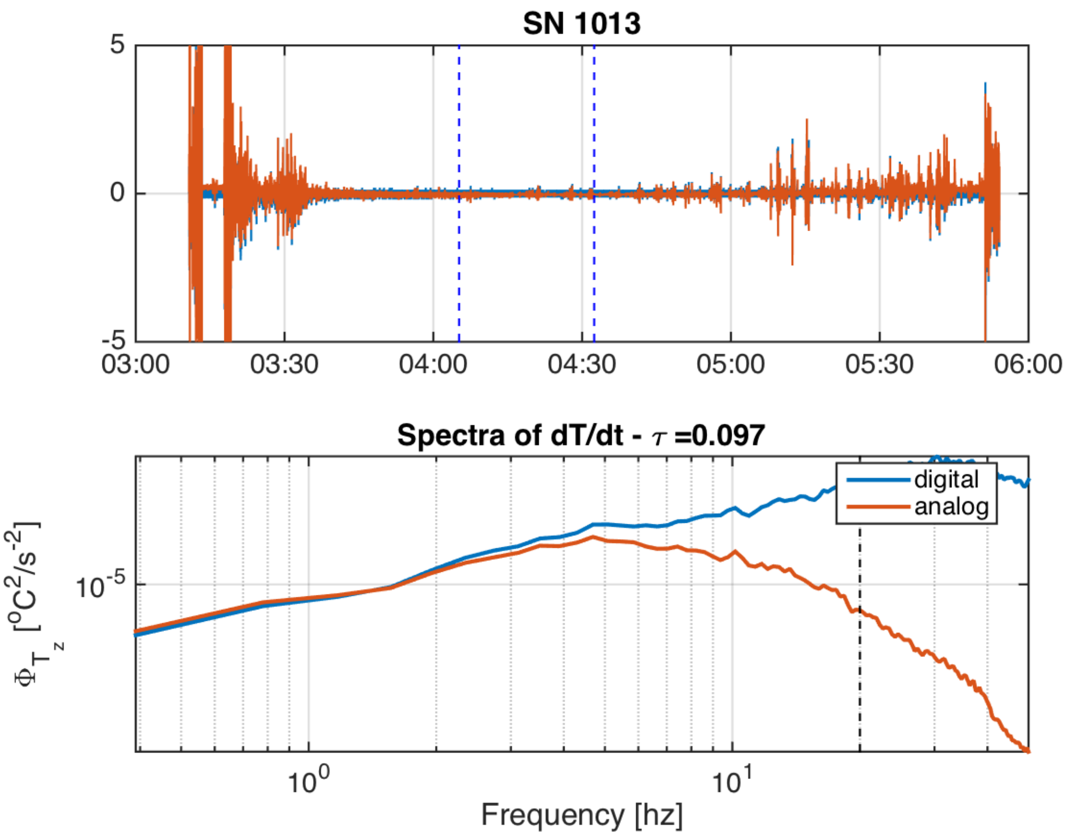

Figure 5: dT/dt spectra for analog (TP) and digital derivatives. Spectra levels should match; if not time-constant may be wrong.

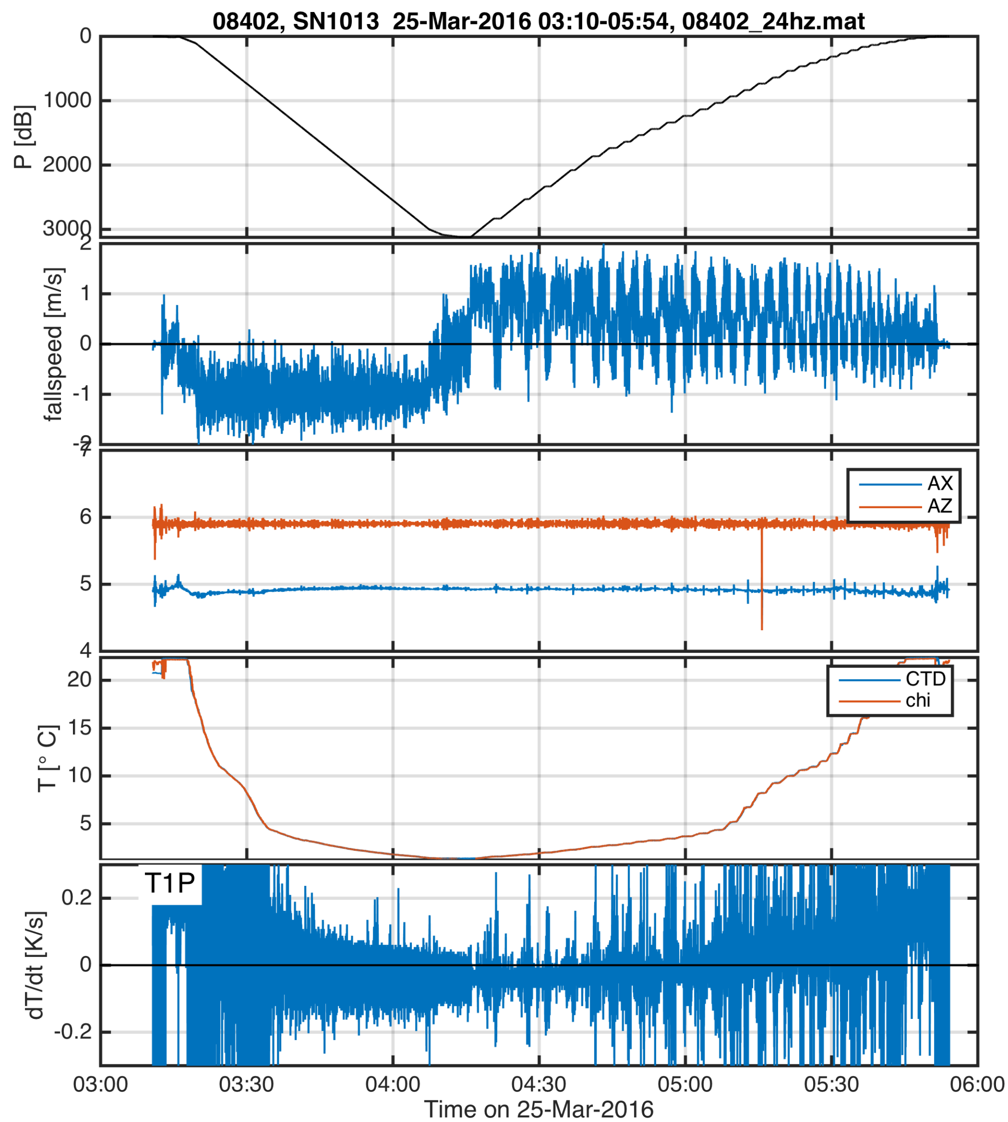

Figure 6: Time series of aligned and calibrated χpod data for one cast.

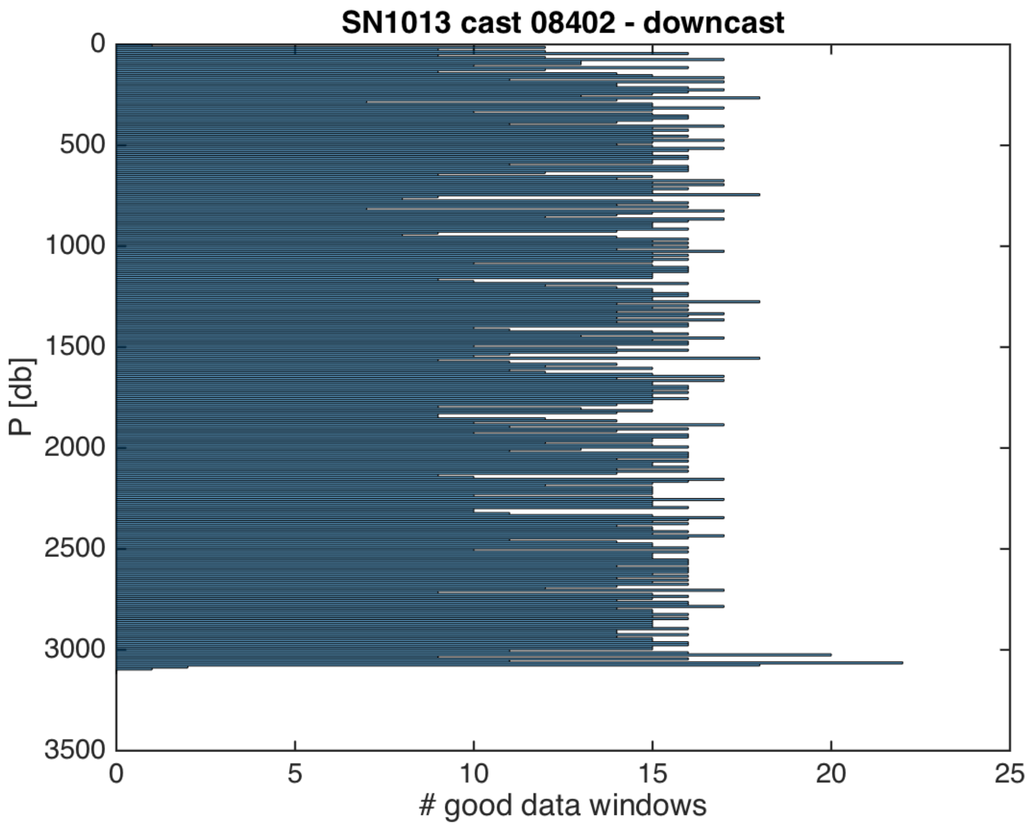

Figure 7: Histogram of the number of good χpod data windows in each 10m depth bin.

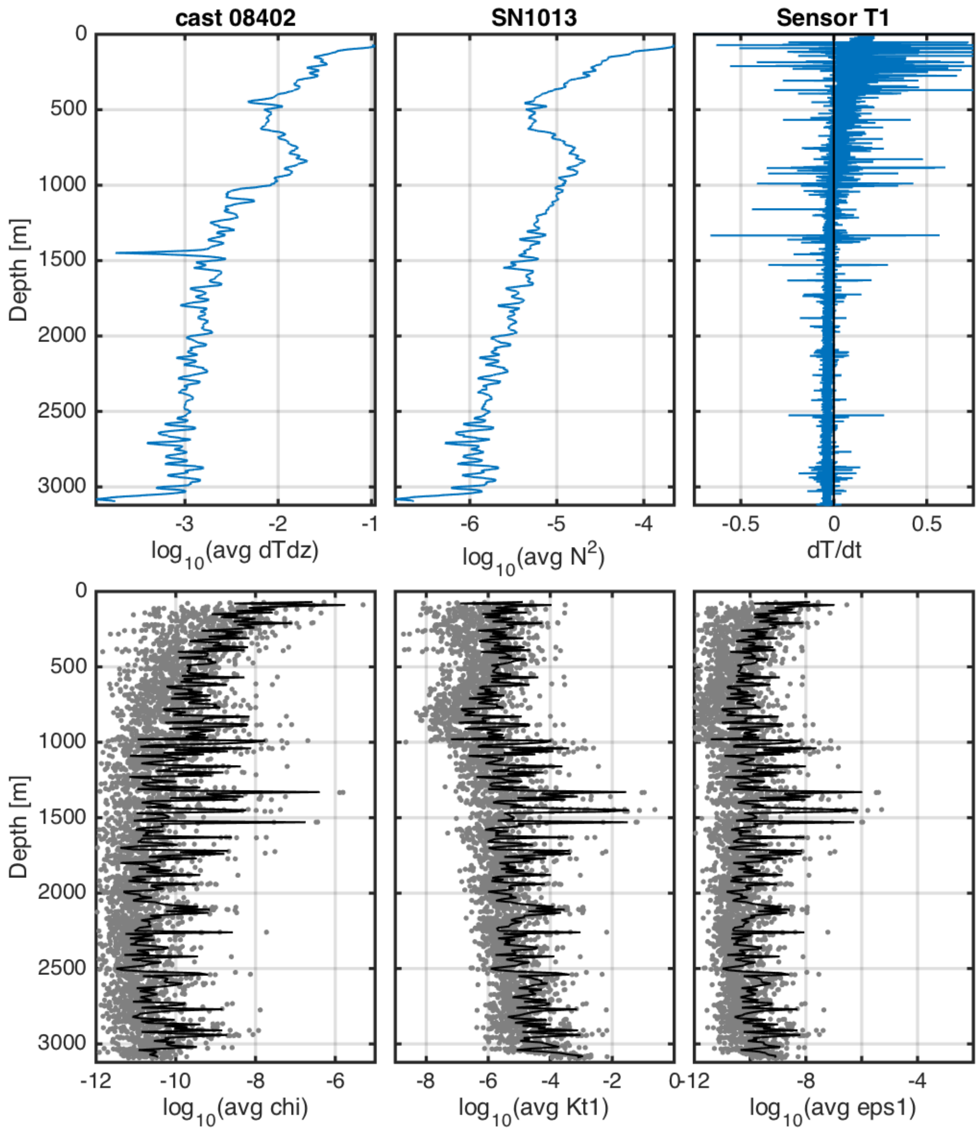

Figure 8: Results of chipod calculation for one cast. Black lines in lower panel are 10m binned averages. Note the spike in dT/dz near 1500m that likely causes false high values of χ.

14 m-files

Processing files are kept in a GitHub repository `/mixingsoftware/CTD_Chipod/mfiles/`

- `AlignChipodCTD` : Align CTD and chipod data.
- `Compute_N2_dTdz_forChi`
- `get_chipod_chi` : Main function that does chipod calculation.
- `load_chipod_data`
- `MakeCtdChiWindows`
-