MVP data processing

Lucio Bellomo
e-mail: bellomo@univ-tln.fr

23 June 2015

1 Temperature alignment with Conductivity (μCTD) or Sound Velocity (SVPT)

Two values of Temperature (T) and Conductivity (C) or Sound Velocity (SV), although logged at the same time hence at the same depth, can in fact be misaligned due to *i)* different response times of the respective sensors, *ii)* different positions of the respective sensors along the water flux direction.

It is usually assumed that such misalignment, indicated with a delay τ, can be modeled as

$$\tau = \tau_0 + \frac{\tau_1}{w} \ , \tag{1}$$

where w is the descent velocity (vertical) of the MVP fish. In order to find $\{\tau_0, \tau_1\}$ the approach of [Ullmand and Hebert, JAOT (31), 2014] is followed:

1. the vertical profiles of T and C/SV are divided in $i = 1, N_c$ chunks whose duration is sufficiently higher than the expected value of τ;
2. for each chunk, the i^{th} T and C/SV chunks are cross-correlated and the lag l_i at which the cross-correlation is the highest is found;
3. the median descent velocity w_i within each chunk is computed;
4. the set $\{w_i, l_i\}$ is fitted in the Least Squares sense against the model (1) and the coefficients $\{\tau_0, \tau_1\}$ retrieved.

The idea behind this method is that a variation in T should produce synchronously a variation in C/SV, giving the highest cross-correlation at lag 0. Therefore, the lag at which the cross-correlation is the highest represents the delay between T and C/SV.

<u>Practical consideration #0 - Matlab code</u>
The Matlab script that performs this computation is

Software/corrections/align_CTD_SVPT.m.

<u>Practical consideration #1 - Data filtering</u>
In [Ullmand and Hebert, JAOT (31), 2014], data are low-pass filtered before the cross-correlation computation. Pressure is filtered with a 2 s time constant, than the descent

velocity is computed. Temperature and conductivity/sound velocity are filtered with a 0.5 s time constant. We have kept these values. Nevertheless, no filtering can be performed for the AML μCTD casts (LDA_Cross and LDA_Before), since the sampling frequency was by mistake set at 1 Hz by OSIL after they performed the calibration, which is too coarse compared to the aforementioned time constants.

Practical consideration #2 - Chunk duration

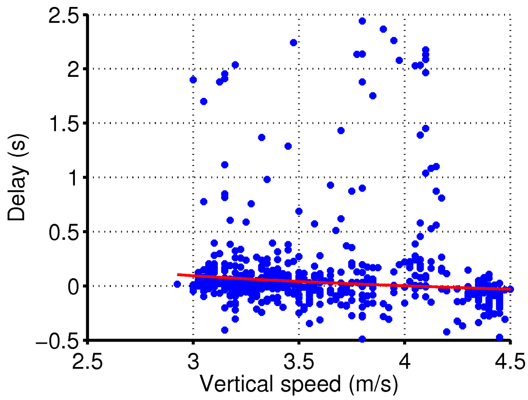
The duration of the chunks in [Ullmand and Hebert, JAOT (31), 2014] is 5 s. We have here chosen 10 s, since with 5 the $\{w_i, l_i\}$ plots are much less well defined (the points seem more chaotic).

1.1 μCTD during LDA_Cross and LDA_Before

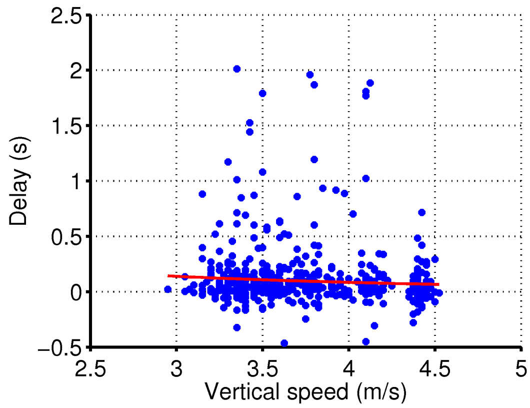
In this configuration, the AML μCTD was mounted at the back of the fish. The conductivity cell is physically aligned with the temperature sensor (no position-induced delay). Furthermore, the cell is of the inductive kind, that is, there is not a duct where the water flows while conductivity is measured (as in Sea Bird conductivity cells). The T vs. C expected delay is therefore very small. Note finally that temperature sensor is only partially in the free water flow, as the structure of the fish partially shades it.

The results are presented in Fig. 1. The delays are relatively scattered, although most of them lie between -0.5 and 1 s. Therefore, all the points with a delay larger than 1 s have been discarded for the fitting computation. When merging LDA_Cross and LDA_Before, the optimum values are

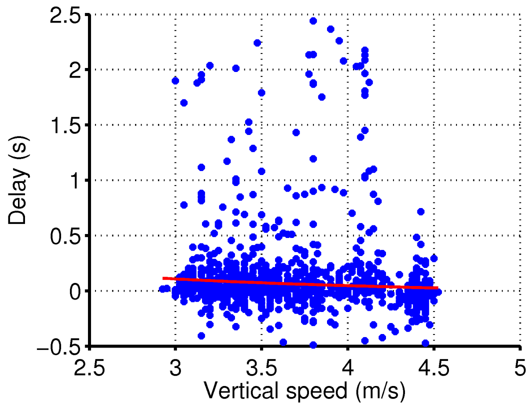
$$\tau_0 = -0.13528 \text{ s} \quad \text{and} \quad \tau_1 = 0.72684 \text{ dbar} . \tag{2}$$



(a) LDA_Cross



(b) LDA_Before



(c) Overall

FIGURE 1: Descent velocity vs. delay $\{w_i, l_i\}$ cross-correlation results for LDA_Cross and LDA_Before. The blue points are the values found for every chunk, whereas the red line is the fit according to (1).

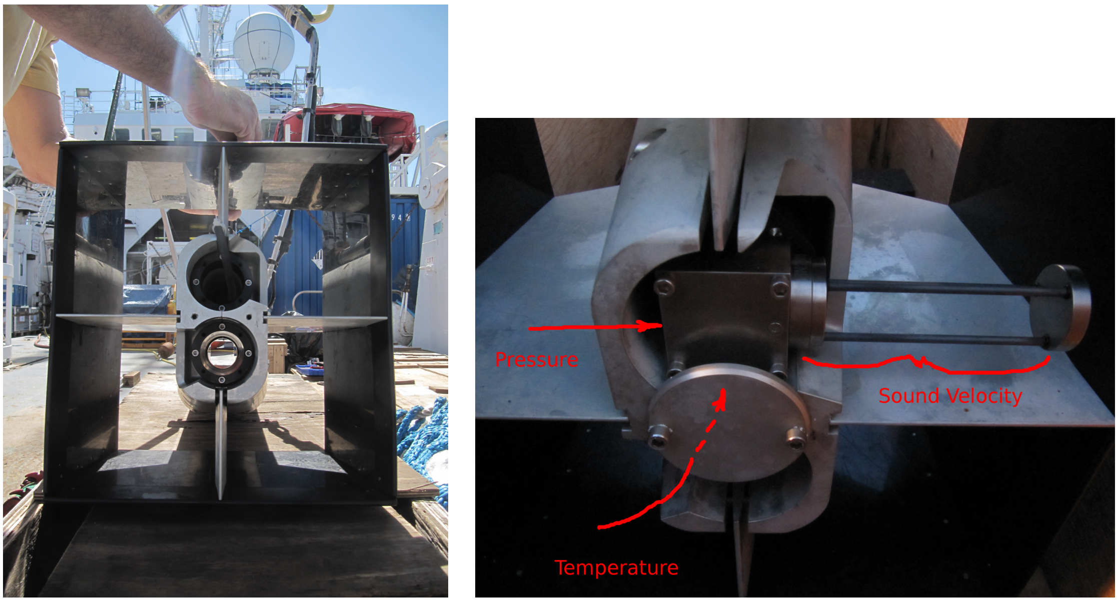
1.2 SVPT during LDA_After

Although here the SVPT was mounted as for the rest of the mission, in this case the SVPT was placed at the back of the fish (as the μCTD), whereas starting from LDB_Cross the SVPT was placed roughly at the longitudinal center of the fish (see FIG. 4). Therefore, this case is treated by itself. When the SVPT is at the back of the fist, the pressure and temperature sensors are really out of the water flow (see FIG. 2). The results are expected to be very bad.

The results are in this case chaotic. There is hardly a pattern, confirming that the position of the SVPT at the back of the fish is totally unexploitable. Notice that for the μCTD, the results are not as bad since although the pressure sensor is at the same position of FIG. 2, the temperature sensor is - as mentioned previously - at least partially in the water flow, whereas here it is completely shaded.

At any rate, the parameters value found are

$$\tau_0 = 1.03965 \text{ s} \quad \text{and} \quad \tau_1 = 0.72826 \text{ dbar} . \tag{3}$$



(a) (b)

FIGURE 2: Position of the SVPT sensor (and of the μCTD one as well) during LDA_Before.

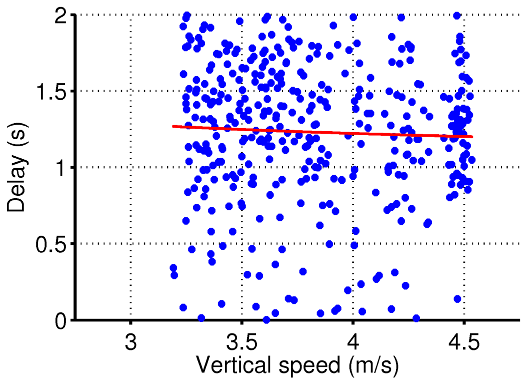


FIGURE 3: Descent velocity vs. delay $\{w_i, l_i\}$ cross-correlation results for LDA_After. The blue points are the values found for every chunk, whereas the red line is the fit according to (1).

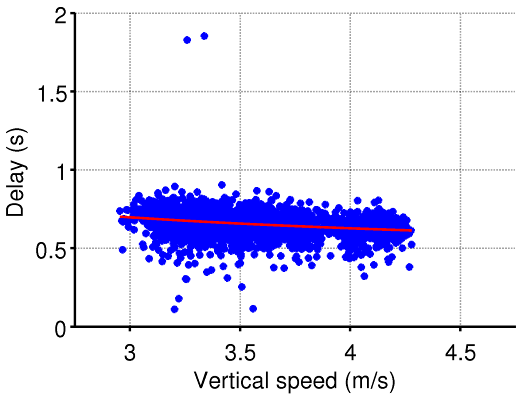
1.3 SVPT from LDB_Cross until the end

After moving the SVPT at the center of the fish, with all the sensors nicely in the water flow, the cross-correlation results become very clean. There are hardly outliers, and the delay grows a little at lower descent velocities. Assuming that the sound velocity response time does not change with w, this result is consistent with the classic model of the response time of a thermistor, which is supposed to decrease slightly with descent velocity (see again [Ullmand and Hebert, JAOT (31), 2014]).

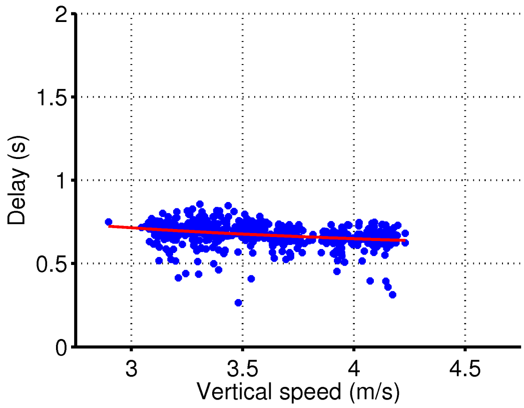
The final values for the model parameters are

$$\tau_0 = 0.41884 \text{ s} \quad \text{and} \quad \tau_1 = 0.84381 \text{ dbar} . \tag{4}$$

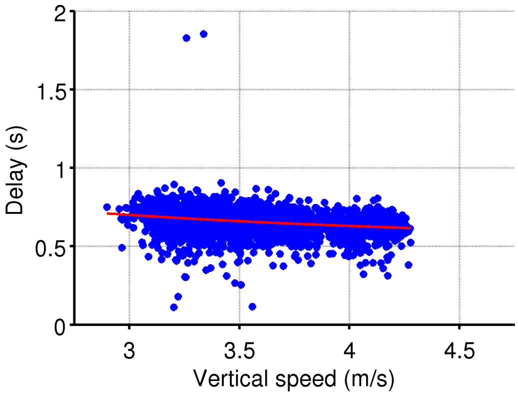
FIGURE 4: Position of the SVPT sensor from LDB_Cross until the end.



(a) LDB



(b) LDC



(c) Overall

FIGURE 5: Descent velocity vs. delay $\{w_i, l_i\}$ cross-correlation results for LDB and LDC. The blue points are the values found for every chunk, whereas the red line is the fit according to (1).

2 Post-calibration

The MVP data (T, C or SV, Chla) should be post-calibrated against more reliable data such as those measured by the CTD system mounted on the Rosette. Classical Least Squares Minimization fitting is applied.

For T and C/SV, the following model is used

$$V^{\mathrm{c}} = \alpha_0 + \alpha_1 V + \alpha_2 p \ , \tag{5}$$

where V is the uncorrected parameter measured by the MVP, V^{c} is the post-calibrated one, and p is pressure measured by the MVP. The minimization is

$$\boldsymbol{\alpha} = \arg\min \sum_{i=1}^{N} \left(\hat{V}_i - V_i^{\mathrm{c}} \right)^2 \ , \tag{6}$$

where $i = 1 \dots N$ is the index running through the N available values and $\hat{V}$ is the parameter measured by the CTD. By differentiating this with respect to each coefficient α one obtains the linear system

$$\begin{bmatrix} N & \sum_i V_i & \sum_i p_i \\ \sum_i V_i & \sum_i V_i^2 & \sum_i V_i p_i \\ \sum_i p_i & \sum_i V_i p_i & \sum_i p_i^2 \end{bmatrix} \begin{bmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} \sum_i \hat{V}_i \\ \sum_i \hat{V}_i^2 \\ \sum_i \hat{V}_i p_i \end{bmatrix} \ , \tag{7}$$

which can be simply solved by inverting the left-hand side matrix.

For Chla, the manufacturer (Wetlabs) gives a simpler model without pressure dependence. The previous system must then be reduced by one line/column (those involving p). Wetlabs' model is slightly different than (5), as the coefficients are written as

$$V^{\mathrm{c}} = SF \left(V - DC \right) \ , \tag{8}$$

where DC are the Dark Counts (the value the fluorometer should give in a complete dark scene) and SF is the Scale Factor. In this case, V must be the Voltage output by the fluorometer. It follows then that

$$SF = \alpha_1 \quad \text{and} \quad DC = -\frac{\alpha_0}{\alpha_1} \ . \tag{9}$$

Practical consideration #0 - Matlab code

The Matlab scripts that perform these computation are

Software/corrections/postcal_rosetteCTD_temp.m,
Software/corrections/postcal_rosetteCTD_cond.m,
Software/corrections/postcal_rosetteCTD_soundVel.m,
Software/corrections/postcal_rosetteCTD_chla.m.

Practical consideration #1 - Post-calibration of the Rosette's CTD
Keep in mind that the Rosette's CTD needs some post-calibration as well. Namely, The CTD shall be sent back to Sea Bird (T and C) and the data reprocessed with the new calibration parameters (responsible: Gilles Rougier). The Chla data shall instead be fitted against in-situ measurements from the Nyskin bottles (responsible: Sophie Dupouy).
Practical consideration #2 - Post-calibration of the Rosette's CTD
Seven tests. For the MVP, station mode should be avoided ... reflection

2.1 Results

The results presented here are preliminary and serve the sole purpose to show how the code works. More work definitely needs to be done on this, if MVP data have to exploited, especially if quantitative analyses are targeted that demand precise values for temperature, salinity, density, and chlorophyll-a concentration.

2.1.1 Temperature

Post-calibration run on Test_7 (see Report_Utilization_MVP_OUTPACE_2015.pdf), results in Fig. 6. The calibration is done on T, and the corrected profile match better the CTD one. Nonetheless, the salinity computed with the corrected T isn't satisfactory with respect to the one measured with the CTD. A pressure dependence appears on the resulting salinity error, although the correction on temperature is in fact pressure-dependent.

2.1.2 Conductivity

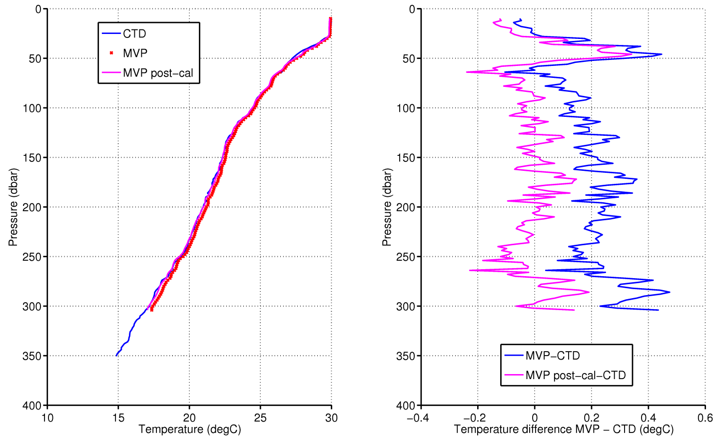
Post-calibration run on Test_1 (see Report_Utilization_MVP_OUTPACE_2015.pdf), results in Fig. 7. The result is in this case slightly better, a pressure-dependent error on salinity is still present, 0.2 psu at 300 m that is roughly half the one observed for T.

2.1.3 Sound Velocity

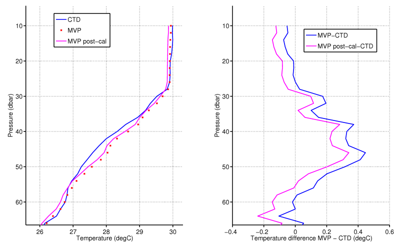
Post-calibration run on Test_7 (see Report_Utilization_MVP_OUTPACE_2015.pdf), results in Fig. 8. In this case the corrected salinity is worse than the uncorrected one! This is nonetheless rather unsurprising, as the MVP measures sound velocity *directly* through a celerimeter, whereas the sound velocity issued from the CTD is a derived quantity (so that its precision depends on both the precision of its T and C sensors).

2.1.4 Chlorophyll-a concentration

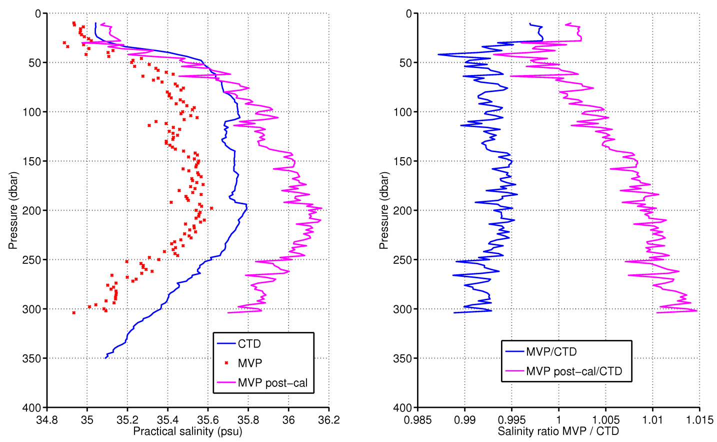
The post-calibration works well and the resulting parameters have been added in the namelist (parameters section) of the L1toL2.m script.



(a)

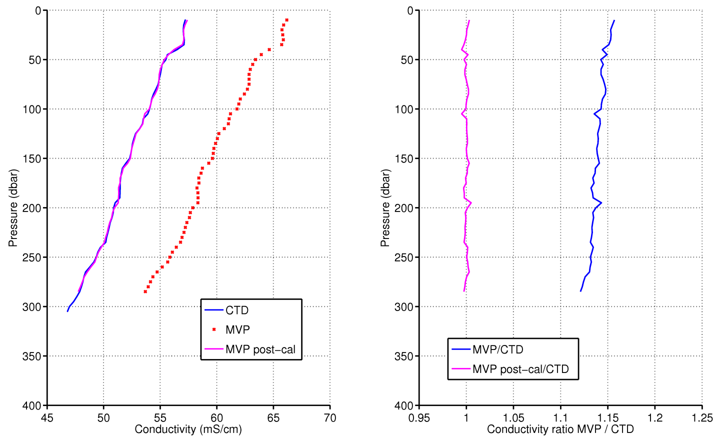


(b) zoom of (a) in the upper 65 m

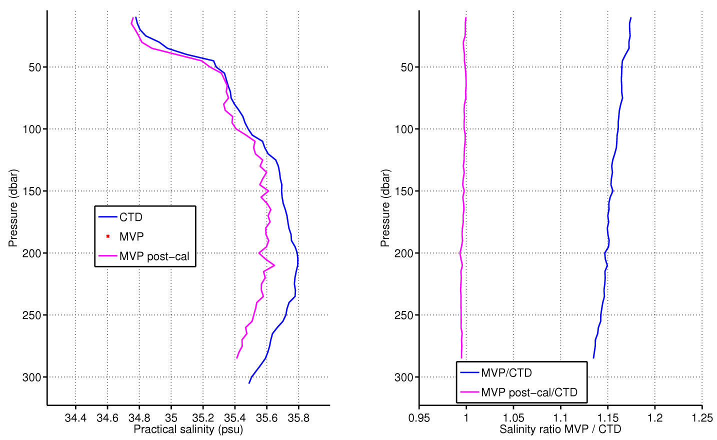


(c)

FIGURE 6: Post-calibration on temperature. (a,b) Temperature profiles, (c) resulting salinity profiles.

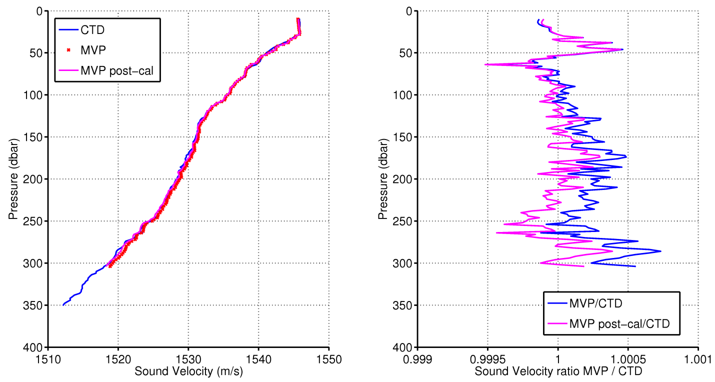


(a)

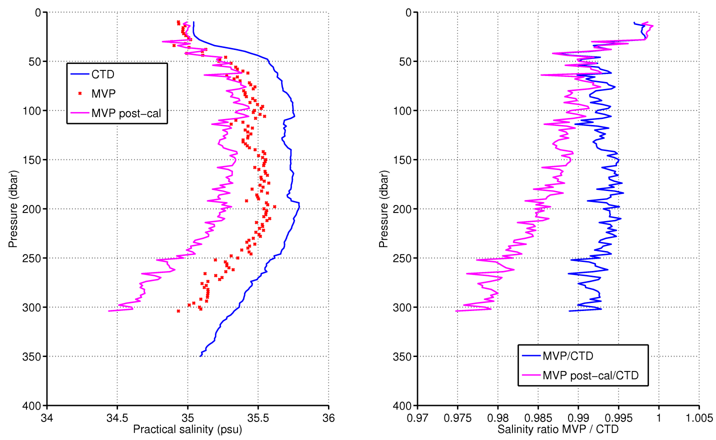


(b)

FIGURE 7: Post-calibration on conductivity. (a) Conductivity profiles, (b) resulting salinity profiles.



(a)



(b)

FIGURE 8: Post-calibration on sound velocity. (a) Sound velocity profiles, (b) resulting salinity profiles.