Post-Cruise CTD and Oxygen Data Correction

VENTILATE - GO.Sars 2016

In total, 41 stations (numbered 525–565) were taken during the cruise. The geographical positions are shown in Figure 1. Water samples from Niskin bottles were collected at 23 stations (indicated in red in the figure). Station 525 and 526 were test stations (525 was taken in a Norwegian fjord just after the ship left port in Tromsø and is not visible on the map). Station 563 and 564 are the same station, they could have been marked cast 1 and 2 (this is not done in the current data file). The water samples were analysed and used to calibrate the conductivity and oxygen measurements from the CTD instrument. The CTD had two sets of temperature and conductivity sensors (primary and secondary). However, only the primary conductivity and temperature sensors were used as the secondary sensors were unstable throughout the duration of the cruise. The corrections employed follows the same procedure used to correct data obtained during the SNACS cruise in 2015 in the Irminger Sea (58GS20150410), which was based on the GO-SHIP

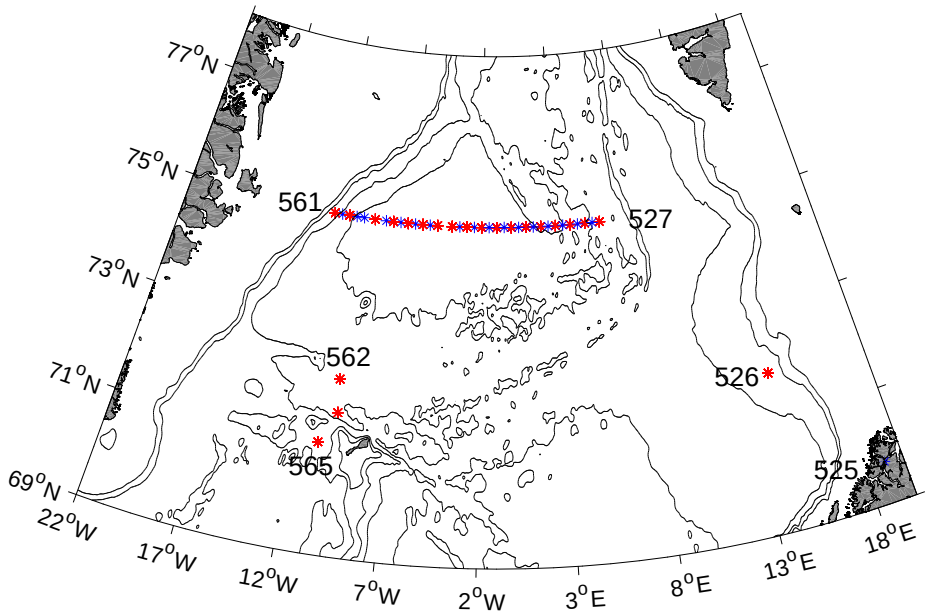

Figure 1: Map showing the position of the cruise stations. Red indicate stations including water samples. The first station (number 525) was taken in a Norwegian fjord just outside of Tromsø on the 2nd of August 2016, while the last station (565) was taken west of Jan Mayen the 11th of August 2016.

manual.

Pressure and temperature

No additional pressure and temperature sensor corrections were applied.

Conductivity

Uncorrected CTD conductivity from the primary sensor - bottle conductivity residuals are shown in Figure 2. The top panel shows uncorrected residuals with station number (time) and the lower panel shows the residuals versus pressure. The residuals are generally small with no clear pattern, except a few outliers which appear to be related to measurements close to the surface.

Calibration of the conductivity sensor was performed using a non-linear least-squares fitting procedure that minimize the residuals. The employed calibration equation was obtained from the GO-SHIP manual (McTaggart et al., 2010):

$$C_{corr} = C + cp2 * P^2 + cp1 * P + c2 * C^2 + c1 * C + c0 \quad (1)$$

where C_{corr} and C is the corrected and measured CTD conductivity, respectively. P is pressure and $cp2, cp1, c2, c1$, and $c0$ are regression coefficients. The coefficients were calculated for each station based on the residuals between the bottle conductivity and the uncorrected CTD conductivity from the primary sensor. That is, the regression coefficients for each station including water samples (shown in Table 1) were determined by applying equation 1 to the bottle conductivity.

The corrected residuals, after calibration, are shown in Figure 3 with the according mean and standard deviation. The mean residual is closer to zero and the spread is smaller.

In order to correct the whole dataset (including stations without water samples) we estimated the mean of each calibration coefficient. This was done after excluding outliers ($> \pm 1$ standard deviation). Outliers and the mean calibration coefficients are indicated in red and bold, respectively, in Table 1.

Oxygen

Calibration of the SBE-43 oxygen sensor on the CTD was performed using a non-linear least-squares fitting procedure that minimize the residuals between the measured CTD oxygen and the dissolved O_2 bottle samples. Bottle oxygen was

determined by Winkler titration. The resulting values given in ml/l were converted to $\mu mol/kg$ seawater. This was done by multiplication with 44.66 $\mu mol/l$ (reverse of molar volume of real oxygen) and by division with density of seawater which was calculated at standard pressure and bottle draw temperature.

The uncorrected CTD oxygen - bottle oxygen residuals are shown in Figure 4. There are some outliers related to one specific station (537). These were excluded during the calibration. Uncorrected residuals without these outliers are shown in Figure 5.

The employed calibration equation was obtained from the GO-SHIP manual (Uchida et al., 2010):

$$O_2 = S_{oc} * \left(V + V_{off} + \tau_{20} * e^{(D_1 * p + D_2 * (T-20))} * \frac{dV}{dt}\right) \\ *O_{sat} * (1 + A * T + B * T^2 + C * T^3) * e^{((E*P)/(273+T))} \tag{2}$$

where O_2 is oxygen (in $\mu mol/kg$), V is the measured CTD oxygen voltage, and dV/dt is the temporal gradient of the oxygen voltage in Vs^{-1}. T and P are the temperature and pressure, respectively, and S_{oc}, V_{off}, τ_{20}, D_1, D_2, A, B, C, and E are calibration coefficients provided by the SBE company for the specific sensor. For each station S_{oc}, V_{off}, τ_{20}, and dV/dt were determined by non-linear least squares fits to in situ water sample oxygen data. That is, equation 2 was solved for each station for the bottle data in order to determine these four coefficients. Saturated oxygen concentration (O_{sat}) was determined at in situ pressure and temperature via sw_satO2.m and potential density (σ_0).

After the four coefficients were estimated for each station (shown in Table 2) the corrected CTD oxygen was calculated using equation 2. Figure 6 shows the corrected residuals with station number and pressure. The mean residual is closer to zero (~ -0.0036 $\mu mol/kg$) and the spread is smaller.

In order to correct the whole dataset (including stations without water samples) we estimated the mean of each calibration coefficient following a similar procedure as for the conductivity (ref. Table 2). Outliers ($> \pm 2$ standard deviations) are marked red in the table.

During the cruise we had some problems with the CTD oxygen sensor. We observed several spikes and shifts in the measured oxygen. Spikes (as in station 528, 530, 531, and 533) are not removed/smoothed in the current dataset. Station number 529 and 537 had several spikes/shifts in the profile. Since these two stations also differ a lot from the bottle oxygen/ the calibration coefficients were considered outliers, they are flagged as questionable (=3) in the dataset. All other stations are flagged 2 (no noted problems).

Table 1: Regression coefficients for conductivity determined by solving equation 1 for each station including water samples. Red values (> ±1 standard deviation) are not included in the mean at the bottom of the table (bold).

Station	cp2	cp1	c2	c1	c0
526	5,98E-04	-3,76E-01	-1,39835	95,51721	-1571,99329
527	-6,61E-11	-1,73E-08	-0,00006	0,00398	-0,06976
529	-6,03E-10	1,24E-06	-0,00049	0,03060	-0,48159
531	-4,93E-12	-4,13E-07	-0,00020	0,01212	-0,18969
533	3,20E-10	-1,06E-06	0,00029	-0,01844	0,29011
535	-1,20E-09	2,58E-06	-0,00024	0,01695	-0,29143
537	9,56E-10	-3,01E-06	0,00039	-0,02859	0,49799
539	1,44E-11	-2,31E-07	0,00015	-0,00949	0,14486
541	-6,67E-10	1,89E-06	-0,00014	0,00859	-0,13946
543	3,98E-10	-1,30E-06	0,00007	-0,00474	0,07277
545	-6,67E-12	-2,51E-07	0,00005	-0,00326	0,04707
547	1,67E-10	-8,76E-07	-0,00002	0,00126	-0,01869
548	-3,03E-10	2,36E-07	-0,00247	0,14835	-2,22965
550	-2,14E-10	-1,56E-08	-0,00020	0,01291	-0,21254
552	6,77E-10	-2,92E-06	-0,00049	0,02708	-0,37236
554	3,77E-10	-1,98E-06	-0,00118	0,06852	-0,99721
556	-8,48E-11	-3,54E-07	-0,00033	0,01912	-0,28084
559	4,97E-09	-1,79E-05	0,00050	-0,03577	0,63095
561	-1,67E-08	3,81E-05	0,00212	-0,12574	1,84499
562	-1,52E-10	-9,01E-08	-0,00016	0,01045	-0,17183
563	4,13E-08	-1,12E-04	-0,36841	21,35097	-309,26532
564	4,12E-09	-6,93E-06	0,00054	-0,03460	0,55322
565	3,78E-09	-7,54E-06	0,00064	-0,04128	0,65921
MEAN	**-2,03E-10**	**-3,93E-08**	**-0,00006**	**0,00276**	**-0,03400**

Table 2: Regression coefficients for oxygen determined by solving equation 2 for each station including water samples. Red values ($> \pm 2$ standard deviations) are not included in the mean at the bottom of the table (bold).

Station	S_{oc}	V_{off}	τ_{20}	dV/dt
526	0,57192	-0,57609	0,17917	1,60E-05
527	0,53125	-0,46992	3,24000	0,00032
529	0,58760	-0,63524	0,16200	1,60E-05
531	0,57031	-0,58284	0,16200	1,60E-05
533	0,54722	-0,53246	0,16200	1,60E-05
535	0,51983	-0,42831	0,16200	1,60E-05
537	0,53418	-0,47464	3,24000	0,00032
539	0,54233	-0,49304	3,24000	0,00032
541	0,53824	-0,48404	3,24000	0,00032
543	0,53984	-0,48841	3,24000	0,00032
545	0,53609	-0,47497	0,16200	1,60E-05
547	0,54986	-0,50657	3,24000	0,00032
548	0,53952	-0,48697	3,24000	0,00032
550	0,54330	-0,49565	3,24000	0,00032
552	0,53472	-0,46906	0,16200	1,60E-05
554	0,54600	-0,49988	3,24000	0,00032
556	0,52416	-0,44892	0,16206	1,60E-05
559	0,53680	-0,47515	0,16209	1,60E-05
561	0,54497	-0,49137	0,18694	1,86E-05
562	0,54133	-0,49156	3,24000	0,00032
563	0,51872	-0,43545	3,24000	0,00032
564	0,53739	-0,48401	3,24000	0,00032
565	0,53636	-0,47518	0,16200	1,60E-05
MEAN	**0,54020**	**-0,48929**	**1,84283**	**0,00018**

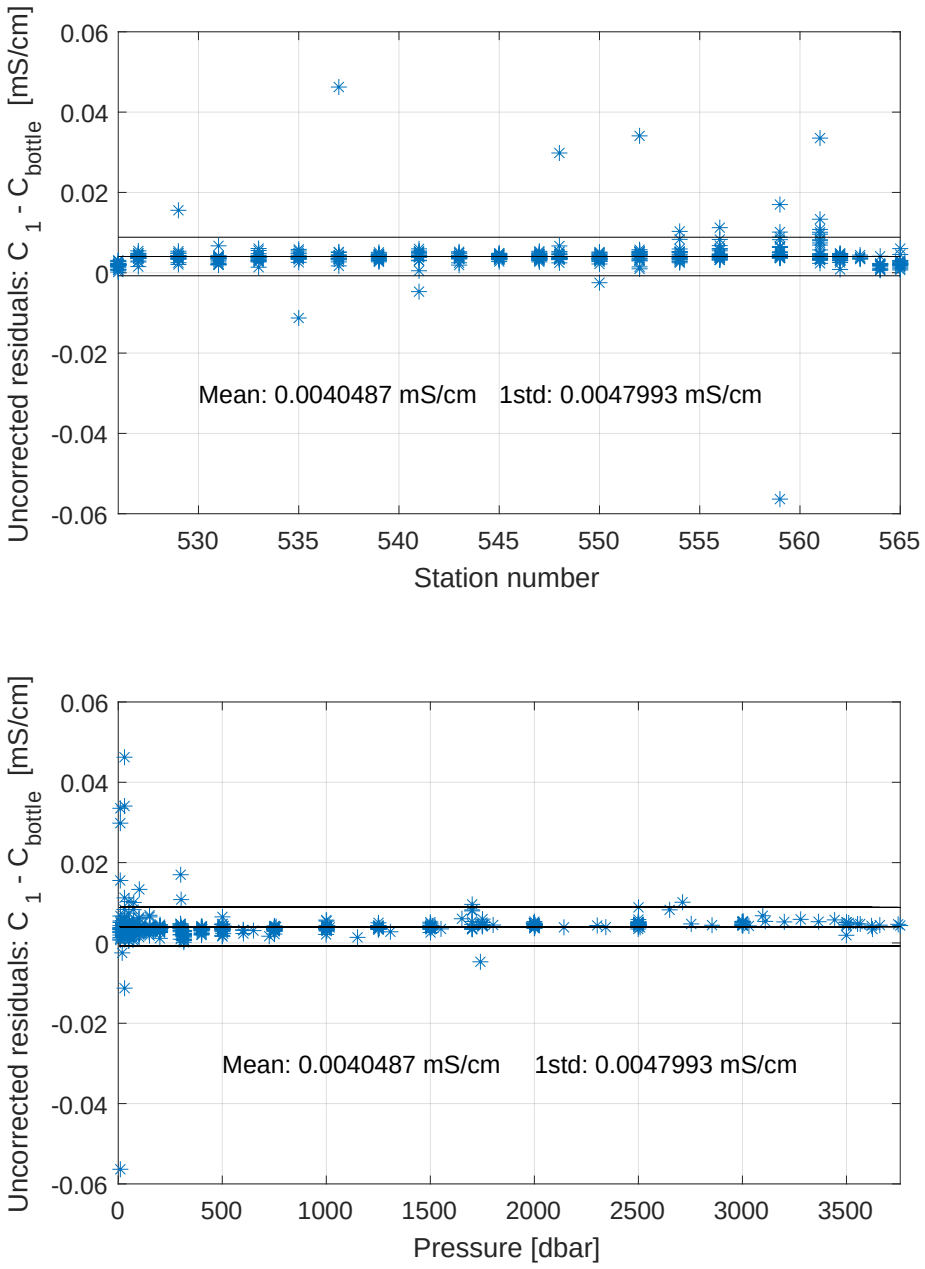

Figure 2: Uncorrected residuals: CTD conductivity from the primary sensor (C_1) - bottle conductivity (C_{bottle}) versus station number (top) and pressure (bottom). The mean residual and $\pm$ 1 standard deviation are indicated by the black lines.

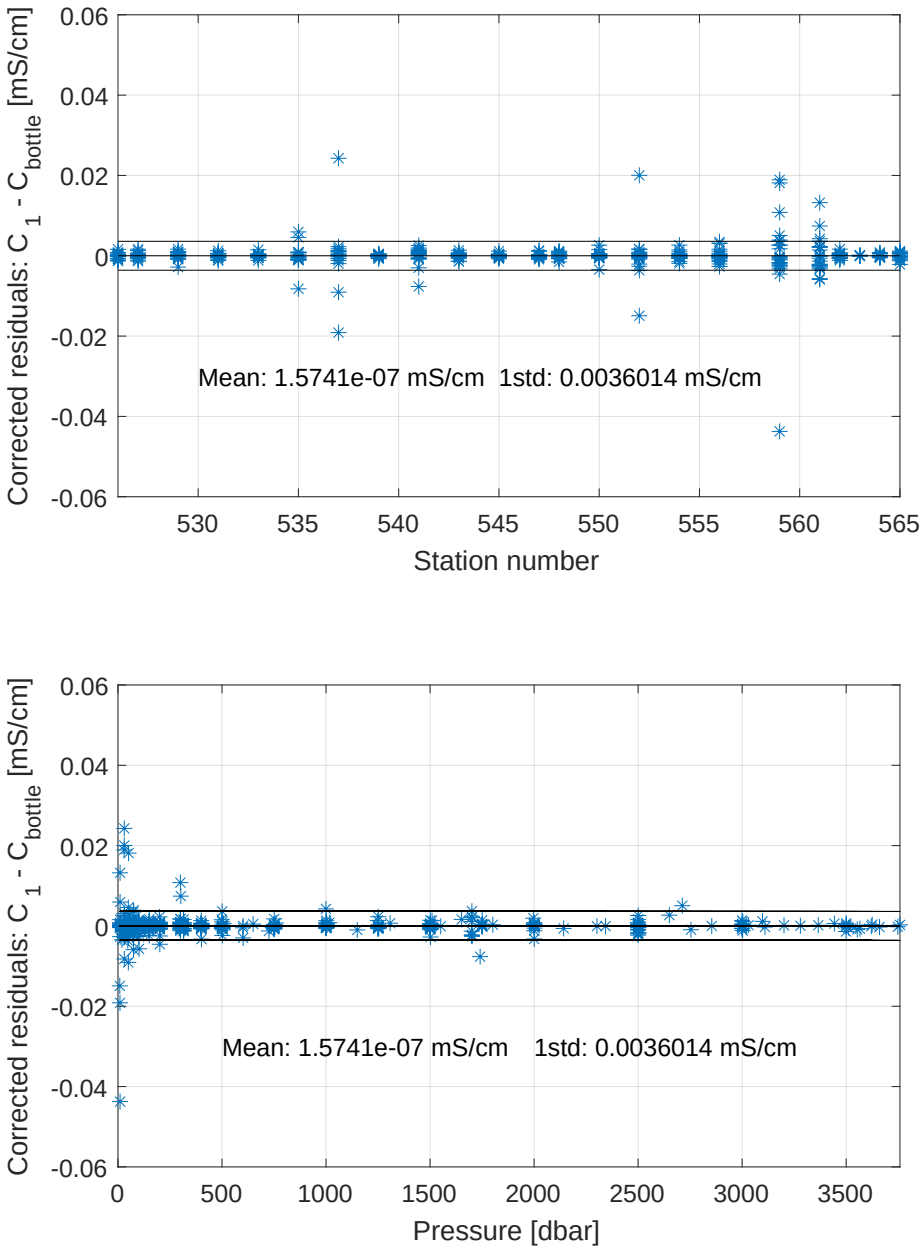

Figure 3: Corrected residuals: Corrected CTD conductivity (C_1) - bottle conductivity (C_{bottle}) versus station number (top) and pressure (bottom). The mean residual and $\pm$ 1 standard deviation are indicated by the black lines.

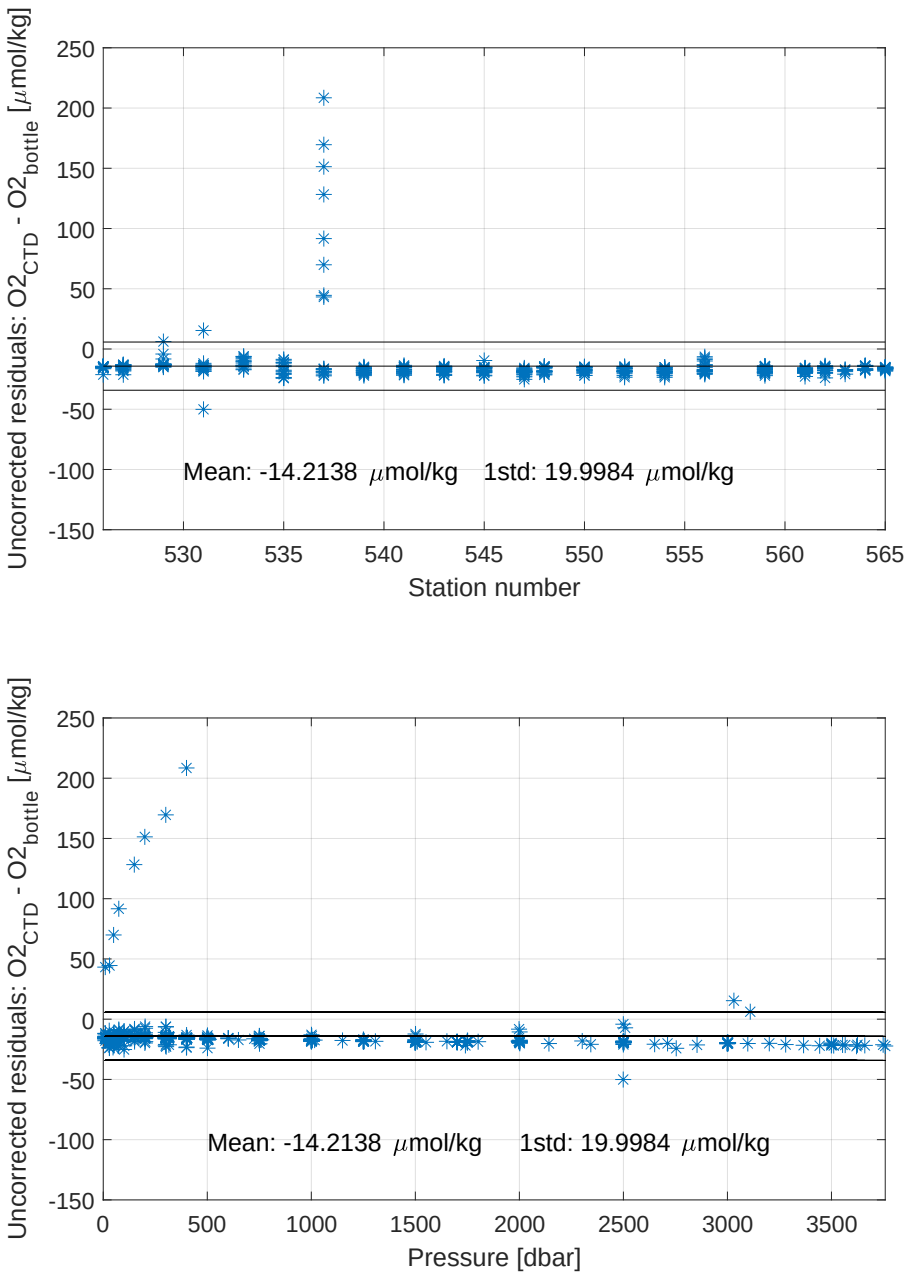

Figure 4: Uncorrected residuals: CTD oxygen - bottle oxygen versus station number (top) and pressure (bottom). The mean residual and ± 1 standard deviation are indicated by the black lines.

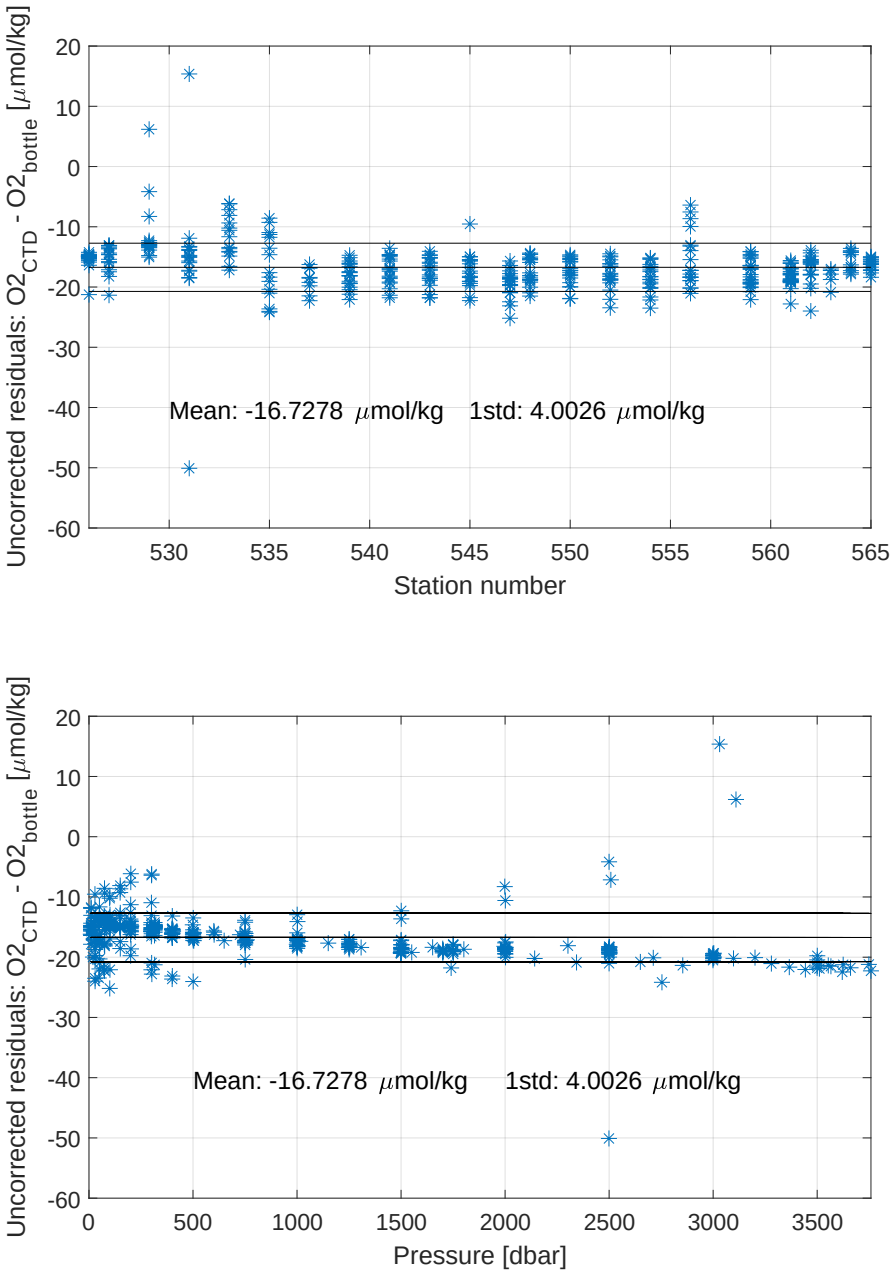

Figure 5: Uncorrected residuals: CTD oxygen - bottle oxygen versus station number (top) and pressure (bottom). Outliers from station 537 are removed (compare with Figure 4). The mean residual and ± 1 standard deviation are indicated by the black lines.

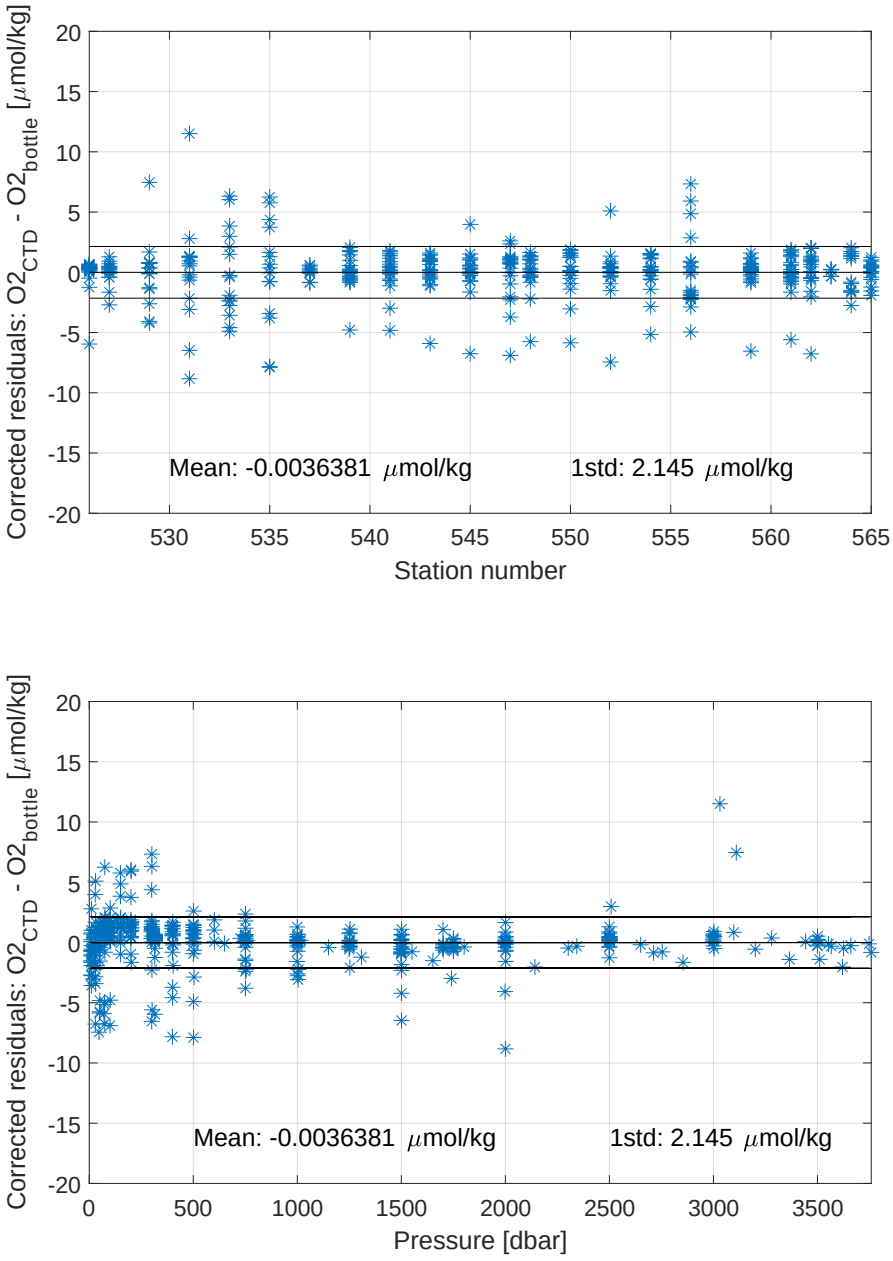

Figure 6: Corrected residuals: CTD oxygen - bottle oxygen versus station number (top) and pressure (bottom). The mean residual and ± 1 standard deviation are indicated by the black lines.