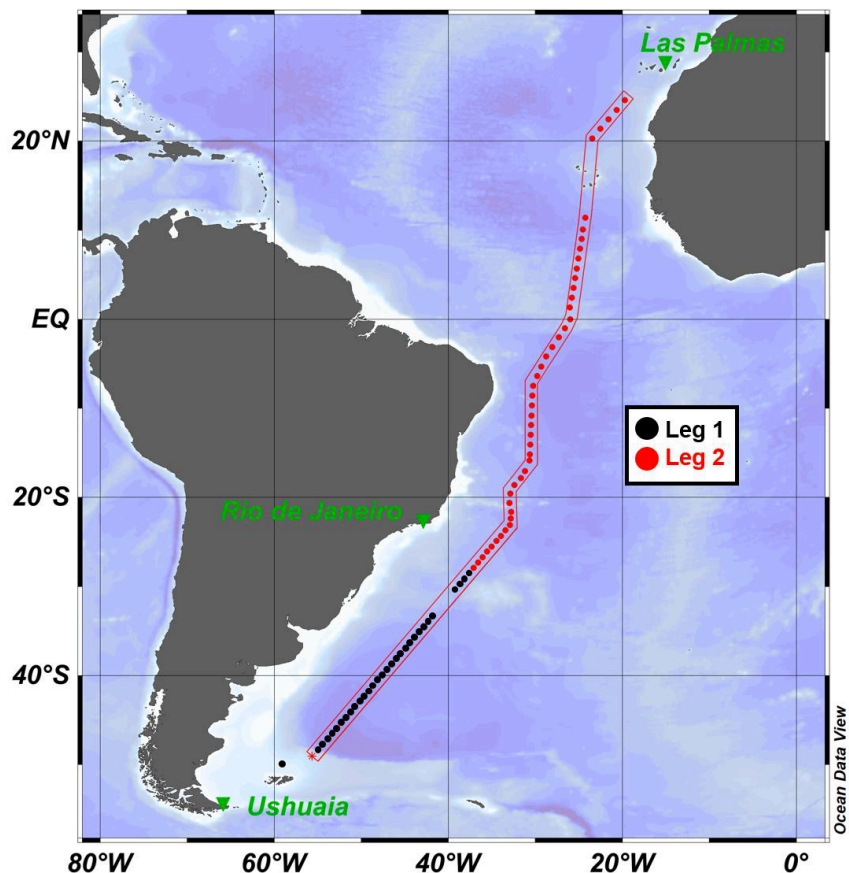


## CRUISE REPORT: A17

(Updated MAY 2020)



### Highlights

#### Cruise Summary Information

Section Designation	<b>A17</b>		
Expedition designation (ExpoCodes)	<b>29HE20190406</b>		
Chief Scientists	<b>Miguel Gil Coto / CSIC-IIM</b>		
Dates	<b>2019-05-18 / 2019-05-18</b>		
Ship	<b>R/V HESPERIDES</b>		
Ports of call	Ushuaia, Argentina, - Rio de Janeiro, Brazil - Las Palmas de Gran Canaria, Spain		
Geographic Boundaries	24.5959		
	-59.1499		-19.7004
	-49.9129		
Stations	78		
Floats and drifters deployed	0		
Moorings deployed or recovered	0		

Contact Information:

**Miguel Gil Coto**

El Consejo Superior de Investigaciones Científicas • Instituto de Investigaciones Marinas

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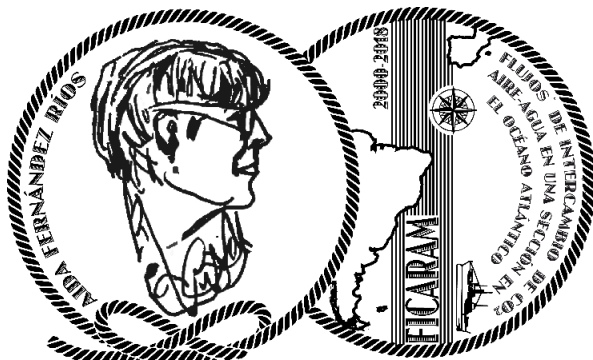
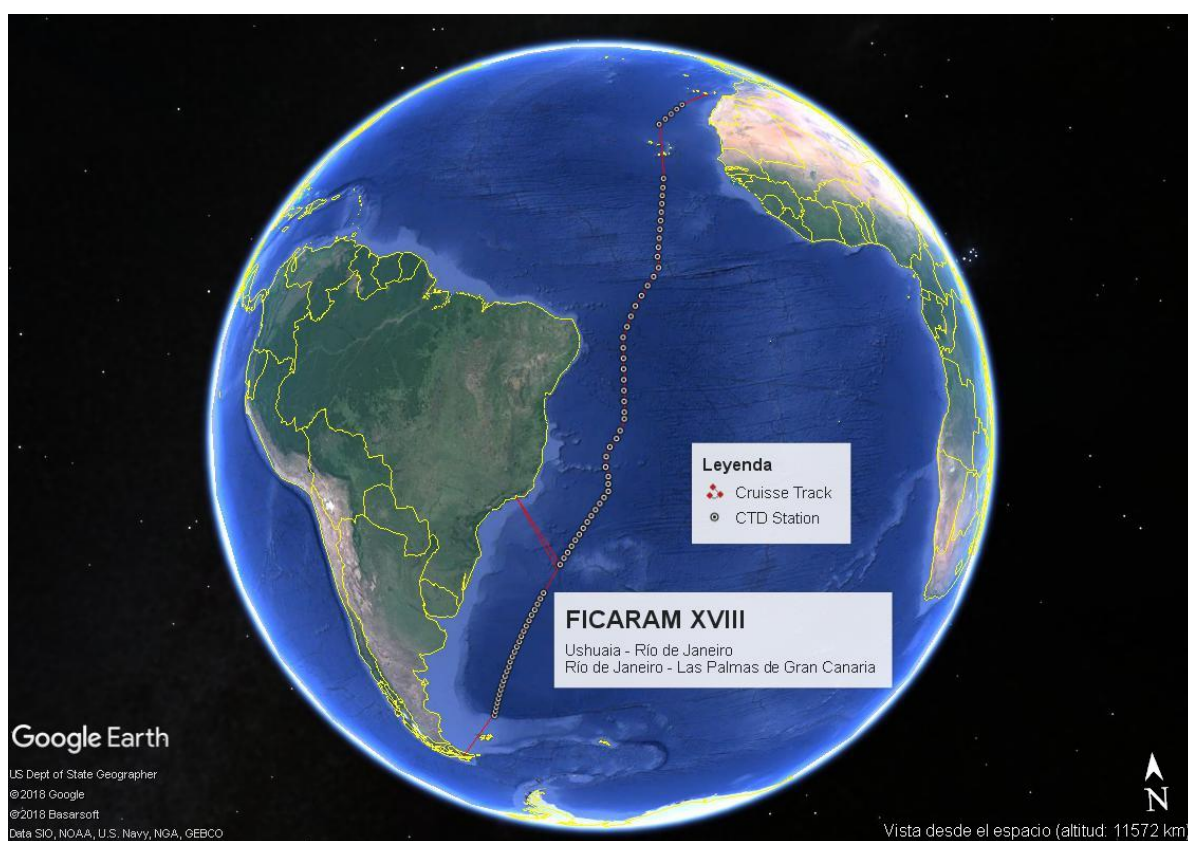
# FICARAM-XVIII Cruise Report

5 April – 19 May 2019

EXPOCODE 29HE20190406

On board BIO Hespérides

Miguel Gil Coto, Marcos Fontela, Maxi Castrillejo Iridoy,  
Fernando Alonso-Pérez, M<sup>a</sup> Jesús Álvarez Fernández, Jesús Rey  
Muras, Alexandre Chamorro, Marta López-Mozos, Carla F.  
Berghoff and Fiz F. Pérez



## 1.- GENERAL OBJECTIVES

The FICARAM-XVIII is the seventeenth repeat of the section conducted in 1994. This section is part of the international program GOSHIP (<http://www.goship.org/CruisePlans.html>) to develop a globally coordinated network of sustained hydrographic sections as part of the global ocean/climate observing system.

The general objective of the FICARAM-XVIII cruise is to assess the climate change by monitoring the keys variables. Firstly, we will investigate the temporal evolution of the anthropogenic carbon storage and the ocean acidification, and evaluate the CO<sub>2</sub> absorption capacity in the South Atlantic region and the Atlantic Equatorial zone. Secondly, we will assess the changes in the surface and in the main thermocline of thermohaline properties and circulation.

This cruise is planned in the frame of the European Project AtlantOs (<https://www.atlantos-h2020.eu/>) funded by H2020. In addition, the following radiotracers were collected and are being analyzed in collaboration with the Laboratory of Ion Beam Physics, ETH-Zurich, Switzerland: radiocarbon (<sup>14</sup>C, level 2 GOSHIP parameter) and anthropogenic uranium (<sup>236</sup>U) and iodine (<sup>129</sup>I).

This report contains the sampling of all the variables at each station along the FICARAM-XVIII section, as well as the analysis of the biogeochemical variables and the preliminary results.

## 2.- PARTICIPANTS

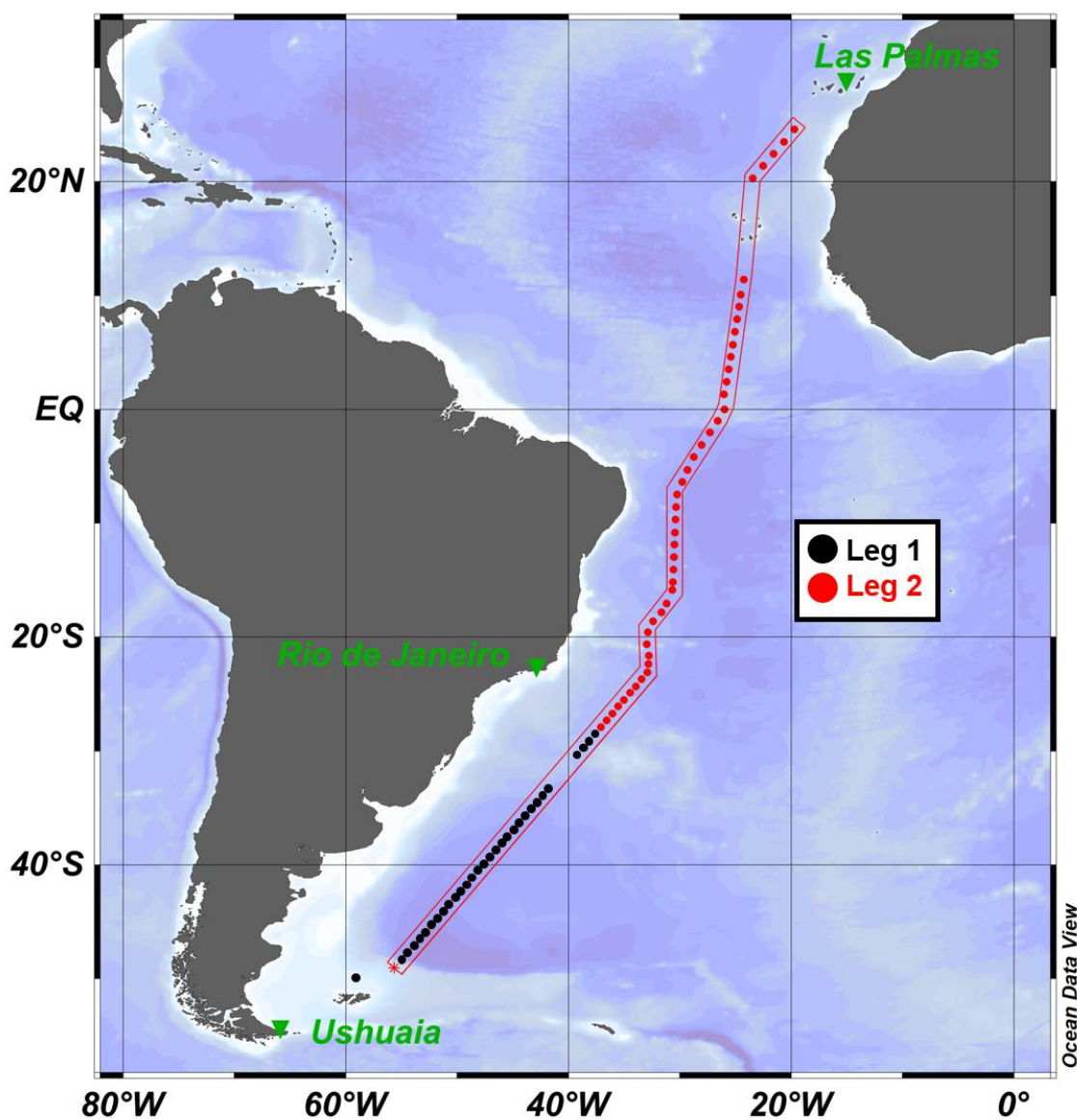
A total of 17 scientists and technicians participated in the cruise FICARAM-XVIII. Three of them left the cruise in Rio de Janeiro at the end of the first leg (\*). The following list contains the team with the tasks developed by each participant.

*Table 1: List of participants.*

Name	Sex	Organization	Task
Miguel Gil Coto	M	CSIC-IIM	Chief Scientist/ CTD measurements
*Fiz Fernández Pérez	M	CSIC-IIM	Responsible Oxygen and Alkalinity
Fernando Alonso Pérez	M	CSIC-IIM	Responsible of Nutrients
Marcos Morente Fontela	M	CSIC-IIM	Oxygen, Alkalinity, TCO <sub>2</sub> and pH
M <sup>a</sup> Jesus Alvarez Fernandez	M	CSIC-IIM	Oxygen, Alkalinity, TCO <sub>2</sub> and pH
Jesús Salvador Rey Muras	M	CSIC-IIM	Sampling and nutrient
Alexandre Chamorro	M	CSIC-IIM	CTD casts
Marta López Mozos	F	UVigo	CTD casts
*Carla F. Berghoff	F	INIDEP Argentina	CTD casts
*Maxi Castrillejo Iridoy	M	ETH Zurich	<sup>14</sup> C/ <sup>129</sup> I/ <sup>236</sup> U sampling
Andrés Giráldez Sotelo	M	CSIC-UTM	Chief Technician & CTD
Javier Vallo Rodríguez	M	CSIC-UTM	Technician, CTD
Antonio Sandoval Díaz	M	CSIC-UTM	Technician, IT & CTD
Iván Casal Barreiro	M	CSIC-UTM	Technician, Mechanic
Ramón Ametller Torres	M	CSIC-UTM	Technician, Mechanic
Xoán Romero Lagoa	M	CSIC-UTM	Technician, IT
Iago López Rodríguez	M	CSIC-UTM	Technician, Chemical

### 3.- HYDROGRAPHIC STATIONS

The cruise was conducted on two legs. The first leg, from station 1 to 34, started in Ushuaia on April 6<sup>th</sup> and ended in Rio de Janeiro on April 23<sup>rd</sup>, 2019. During this first leg the stations 27, 28, 29 and 30 could not be carried out due to bad weather and the impossibility of delaying the day of arrival to Rio de Janeiro. The second leg, from station 35 to 84, started on April 28<sup>th</sup> and ended in Las Palmas de Gran Canaria on May 19<sup>th</sup>, 2019.



**Figure 1:** Geographical positions of the stations sampled. The position of some stations was slightly modified to avoid national Brazilian waters. The gap is due bad weather in the station 27, 28, 29 and 30 (see [Table 2](#)).

**Table 2:** Geographical positions of the stations sampled. Red and green stations show the end and the beginning of Leg 1 and 2, respectively.

Station	LATITUDE (DEG. N)	LONGITUDE (DEG. E)	BOTTOM DEPTH (m)	Station	LATITUDE (DEG. N)	LONGITUDE (DEG. E)	BOTTOM DEPTH (m)
0	-49.9129	-59.1499	348	43	-23.1034	-32.8932	4835
1	-48.3060	-54.9245	5620	44	-22.3731	-32.8406	4543
2	-47.6833	-54.4190	5919	45	-21.6187	-32.7854	4461
3	-47.1050	-53.8636	6008	46	-20.6231	-32.9729	4343
4	-46.5194	-53.3412	6014	47	-19.5829	-32.8620	4156
5	-45.9187	-52.7895	6034	48	-18.6250	-32.3918	4424
6	-45.3055	-52.2911	5953	49	-17.8206	-31.6311	4744
7	-44.6922	-51.7171	5959	50	-17.0435	-31.2044	4960
8	-44.1007	-51.2379	5700	51	-15.8737	-30.6910	4962
9	-43.5003	-50.7023	5599	52	-15.1929	-30.6420	4912
10	-42.9070	-50.1976	5661	53	-14.0931	-30.5809	5338
11	-42.3464	-49.6862	5858	54	-12.9835	-30.5344	5255
12	-41.7356	-49.0837	5556	55	-11.8551	-30.4848	5513
13	-41.1206	-48.6743	5619	56	-10.8052	-30.4219	5272
14	-40.5115	-48.1125	5401	57	-9.6887	-30.3664	4685
15	-39.9175	-47.5352	5348	58	-8.5907	-30.3202	5419
16	-39.3057	-47.0281	5223	59	-7.4964	-30.2541	5413
17	-38.6824	-46.4385	5273	60	-6.3926	-29.7781	5222
18	-38.0785	-45.9734	5113	61	-5.3196	-29.3042	5340
19	-37.4883	-45.4616	5193	62	-4.1945	-28.7497	5073
20	-36.9170	-44.9515	4988	63	-3.1030	-28.0355	4989
21	-36.2913	-44.3974	5014	64	-2.0091	-27.3160	4858
22	-35.6830	-43.8986	4956	65	-0.9988	-26.5961	3544
23	-35.1055	-43.3328	4854	66	0.0064	-25.9980	3773
24	-34.4715	-42.8258	4471	67	1.3110	-26.0105	3955
25	-33.8756	-42.3395	4588	68	2.4080	-25.8069	4104
26	-33.3075	-41.8041	4324	69	3.5224	-25.6078	4524
31	-30.3456	-39.2531	4172	70	4.6023	-25.4300	4430
32	-29.7008	-38.6691	4277	71	5.6927	-25.2524	4343
33	-29.1255	-38.1584	4125	72	6.7974	-25.0521	4463
34	-28.4940	-37.6053	4532	73	7.9102	-24.8597	5015
35	-27.9039	-37.0898	4735	74	9.0047	-24.6863	5175
36	-27.3220	-36.5604	4407	75	10.0799	-24.5215	5207
37	-26.7080	-36.0349	4594	76	11.4034	-24.2720	5118
38	-26.0888	-35.5215	4354	77	20.2982	-23.4750	4545
39	-25.5143	-35.0042	4394	78	21.3681	-22.5370	4655
40	-24.9034	-34.4691	4409	79	22.4426	-21.5971	4517
41	-24.5407	-33.9385	4669	80	23.5003	-20.6563	4122
42	-23.8595	-33.4208	4811	81	24.5959	-19.7004	3704



3.1.- CTD

(Miguel Gil Coto, Mata López Mozos and Carla F. Berghoff)

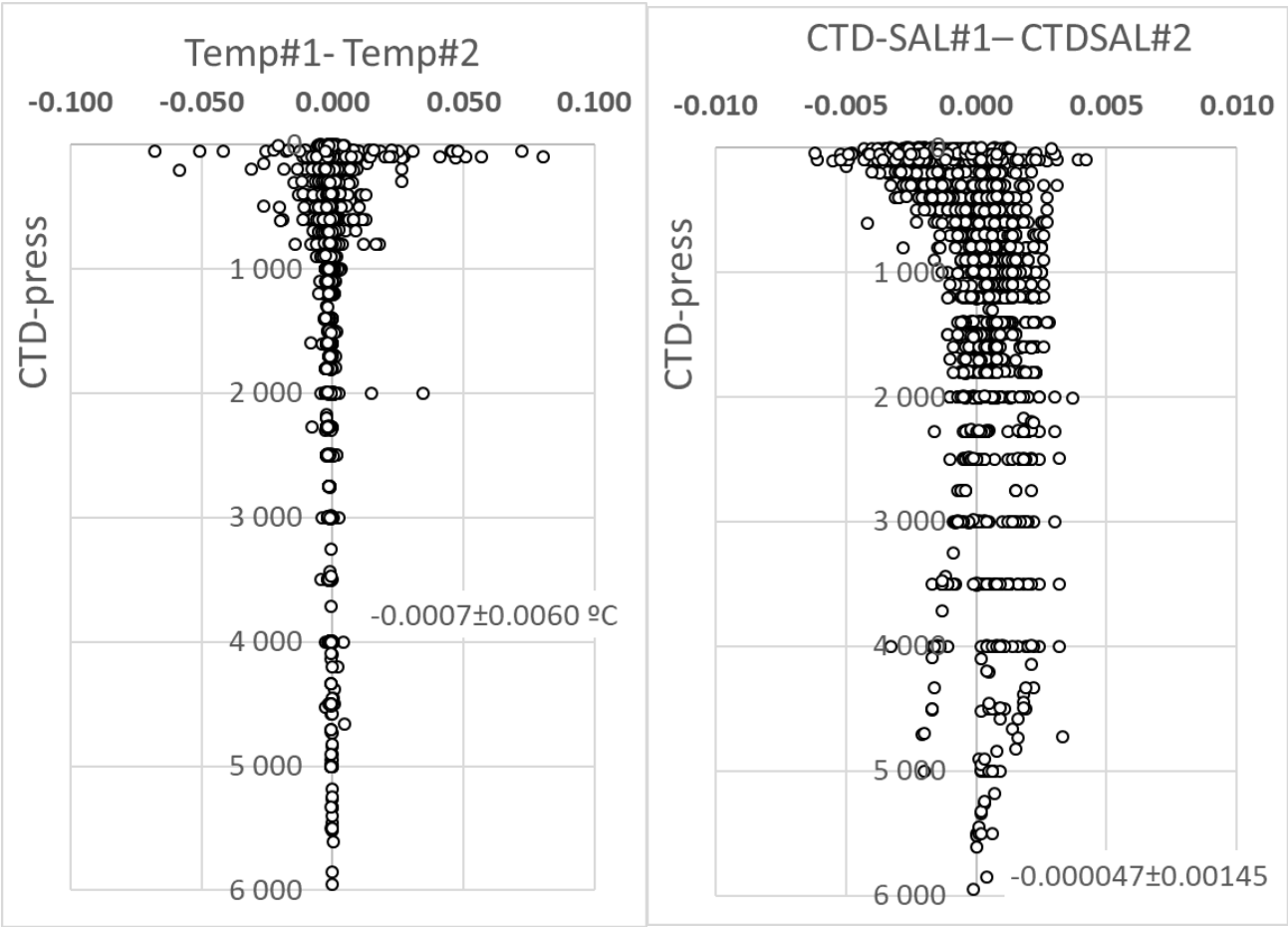
To achieve the general objectives of the cruise, 78 full depth CTD casts were planned between Ushuaia, Argentina, and Las Palmas, Spain (Figure 1). Due to bad weather during the first leg, the sampling resolution was slightly reduced CTD Casts, approximately 20 of them covering at least the upper 2000 m. A SBE911plus (Sea-Bird Electronics) CTD probe was used for the station-based profiling of the water column. The CTD unit was equipped with dual temperature and conductivity sensors, a Digiquartz with TC pressure sensor, a double SBE-43 oxygen probe, a SeaPoint fluorometer and an altimeter. The rosette was equipped with 24 Niskin bottles of 12 L each for the collection of seawater. The series number of the temperature and conductivity is given in Table 3. The available SBE pre and post cruise calibration sheets of temperature, conductivity, oxygen and pressure sensors are include in Annex I. At each station, the cable was deployed at a speed of 1 m/s during the downcast and at about 0.45 m/s or slower in the upper 100 m of the water column. During the upcast, the winch was stopped at 24 depth levels for Niskin bottle sampling.

Several SBE filters were used to process CTD data: 1.datcnv, 2. BottleSum, 3. wilddedit, 4. wfilter, 5. filter, 6. alignctd, 7. celltm, 8. loopedit, 9. Binavg, 10. Derive, 11. DeriveTEOS10 and 12. Buoyancy. Data from CTD stations are delivered as .txt files with ODV format. Two versions, for both CTD and bottle data, have been produced. A folder with CTD data contains all the .cnv (CTD) and .btl (bottle) files.

Table 3: Temperature and conductivity series numbers.  
Salinity corrections is given in **bold**

Station range	Temp#1/Conductivity#1	Temp#2/Conductivity#2
1 to 50	4659/3286 (+ <b>0.009</b> )	4798/3345 (+ <b>0.004</b> )
51 to 62	4659/3010 (+ <b>0.004</b> )	4798/3345 (+ <b>0.004</b> )
63 to 84	4659/3010 (+ <b>0.004</b> )	4798/3770 (+ <b>0.004</b> )

The full depth-profile of temperature and salinity differences is represented for station XX in Figure 2. The two temperature sensors showed a constant difference during the whole cruise. Previously, an additive correction was applied to the temperature of the 4798 probe  $+0.0018^{\circ}\text{C}$  following the post-cruise calibration. The temperature difference is well fitted with a very low average difference.



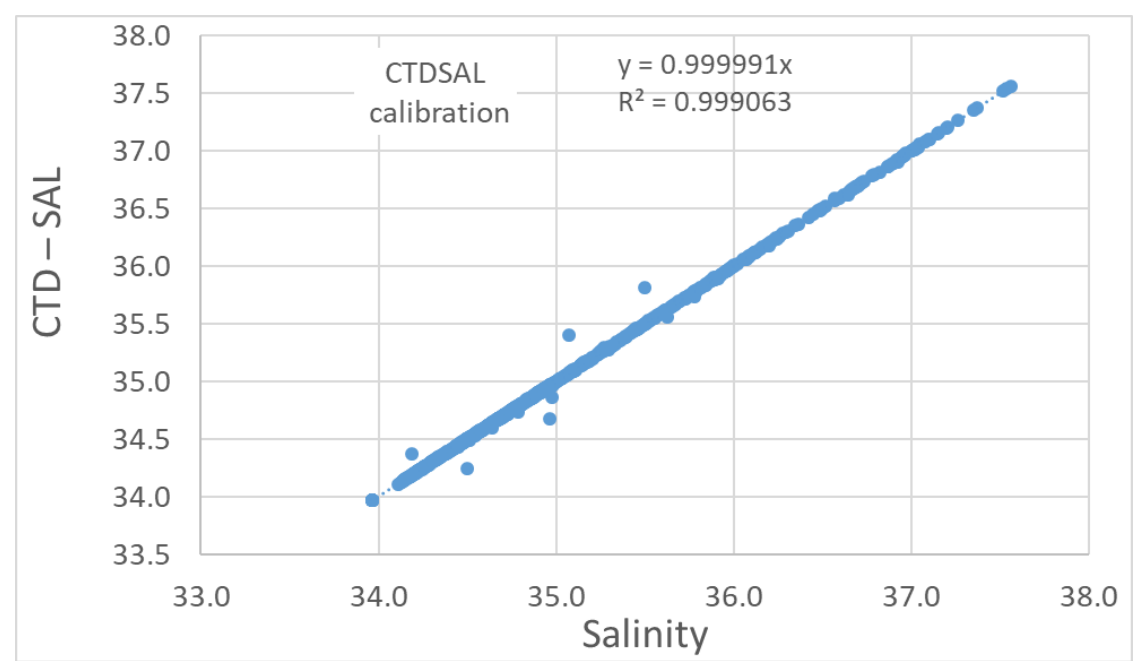
**Figure 2:** Temperature and salinity differences between the two probes for all stations. The mean and standard deviations are also indicated.

### 3.2.- CTD-Salinity Calibration

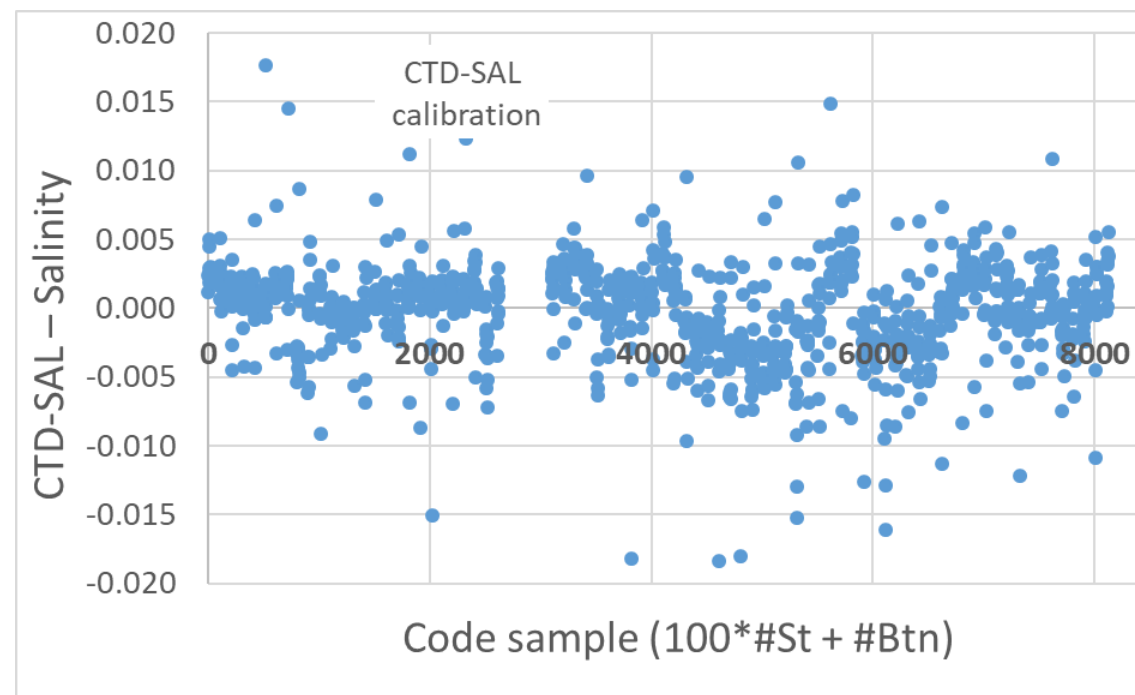
For salinity, an offset in the CTD-Salinity was detected for the 4 conductivity probes. The additivity salinity correction was determined by comparison to salinity measured with an AUTOSAL salinometer in 12 levels per upcast, and at all stations (932 samples). The difference between the two conductivity probes in salinity units is given in Figure 2. The average difference and its standard difference is very low. The salinity of the probe#2 (3345) was discarded in stations 59, 60 and 61.



Figure 3 and Figure 4 illustrate the regression line and the differences between the salinity values as inferred from the mean of the two CTD sensors after calibrations given in Table 3 and the AUTOSAL salinometer.



**Figure 3:** Regression between the salinity values as inferred from the mean of the two CTD sensors after calibrations given in Table 3 and the AUTOSAL salinometer.



**Figure 4:** Difference between the salinity of the two CTD sensors after the calibration given in Table 3 and the AUTOSAL salinometer.

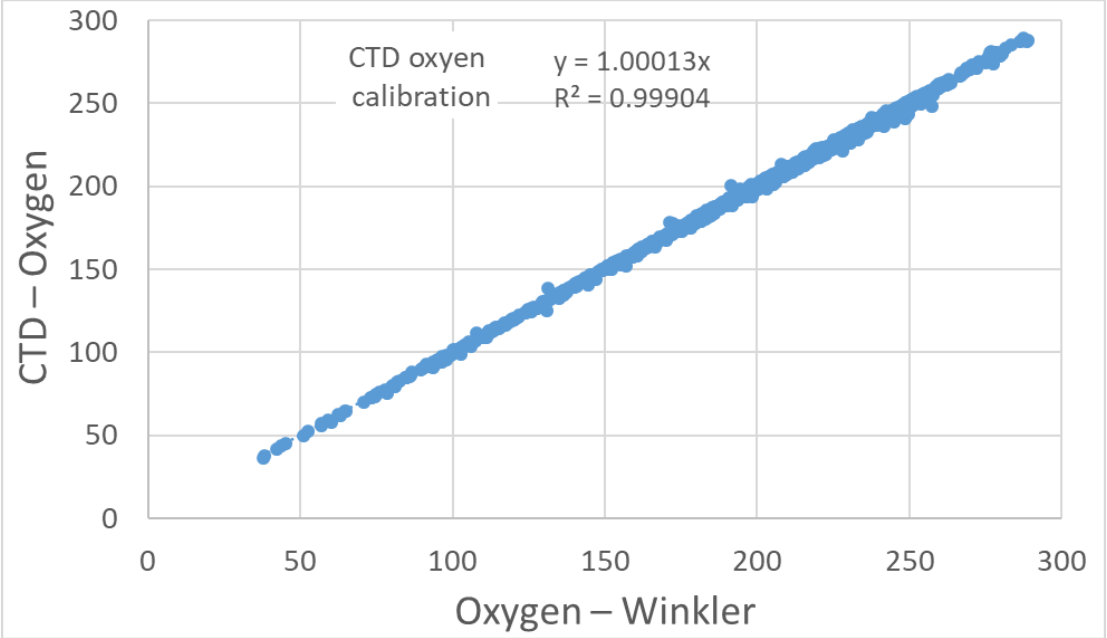
### 3.3.- CTD-Oxygen Calibration

The two oxygen sensors have shown high reliability and the values obtained during the upstream casts have shown a high correlation ( $r^2=0.9987$ ) with a ratio of 0.981 between CTD-OXY#1 and CTD-OXY#2. Therefore, we have proceeded first in each profile to adjust the values of probe#1 to the values of probe#2 and then to average between them. At station 62, the second oxygen probe showed a drift below 3250 dbars and these data were discarded. Subsequently, the average down cast CTD-OXY values were compared station by station against the oxygen measurements done with the Winkler method on samples collected in the upstream run, max. 24 samples per station, at all stations (n=76). After, we proceeded to search and match each sample of the upcast profile with the sample of the downcast profile that meets the condition of minimizing at the same time the difference in pressure and density referred to 2000 bars. For this we have converted, or scaled, the pressure profile to a density profile referred to 2000 dbar using the equation:

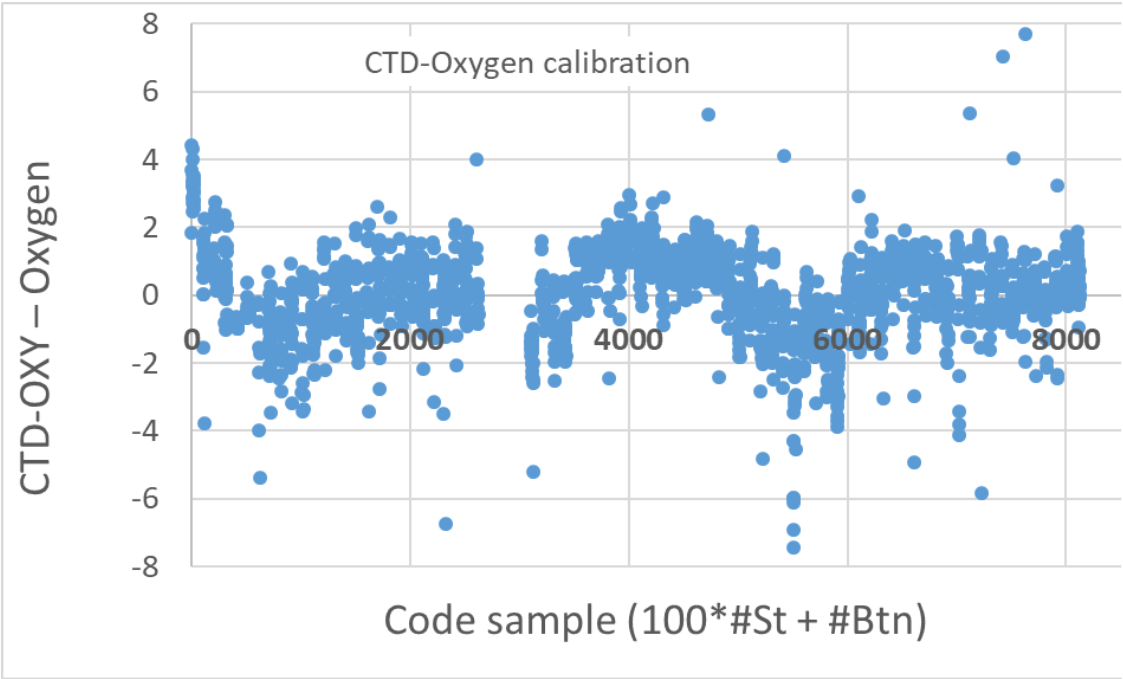
$$(\text{Density}_{2000} - 1) = 1.668 * \text{Log} (\text{Press}(\text{dbar})) + 31.336$$

and later we look in the downcast profile for the minimum quadratic distance with the coordinates of the O<sub>2</sub> Winkler measurement (upcast discrete sample). A factor between the O<sub>2</sub> value measured by Winkler and the average value obtained by the average of both O<sub>2</sub> probes is computed in each matching. A maximum of 24 factors are obtained in each profile depending of the Winkler measurements available. Then, with the factors obtained, they are interpolated meter by meter to apply to the fully downcast profile, which allows the calibration of each CTD-OXY average value multiplied by the interpolated factor.

Figure 5 and Figure 6 illustrate the regression line and the differences between the salinity values as inferred from the mean of the two CTD sensors after calibrations given in Table 3 and the AUTOSAL salinometer.



**Figure 5:** Regression between the oxygen values as inferred from the mean of the two CTD sensors after calibrations using the Winkler measurements.



**Figure 6:** Differences between the oxygen values as inferred from mean of the two CTD sensors after calibrations and the Winkler measurements.

3.4.- CTD-O<sub>2</sub> results

Figures 7, 8 and 9 show the potential temperature, salinity and oxygen of downcast-CTD data.

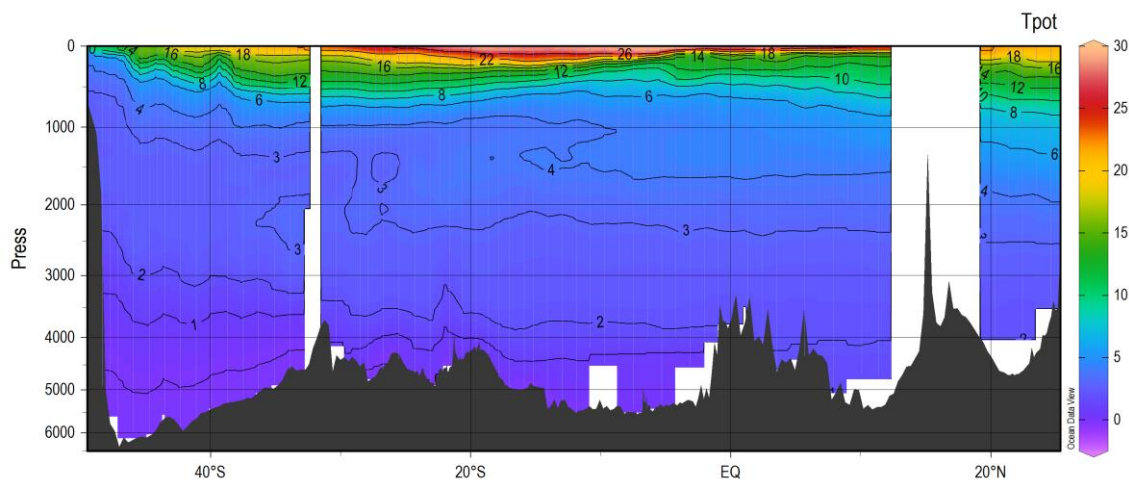


Figure 7: Potential Temperature distribution along the FICARAM-XVIII section.

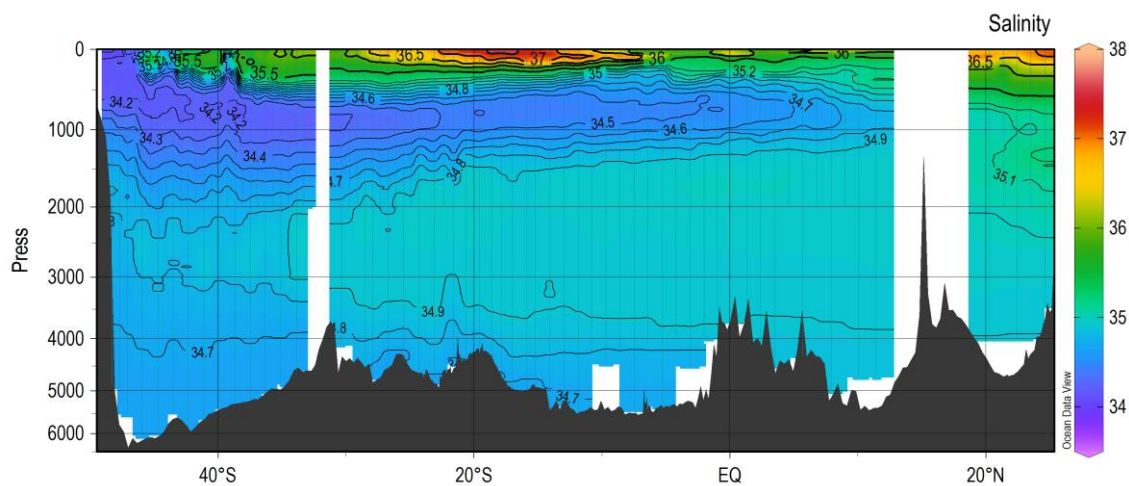


Figure 8: Salinity distribution along the FICARAM-XVIII section.

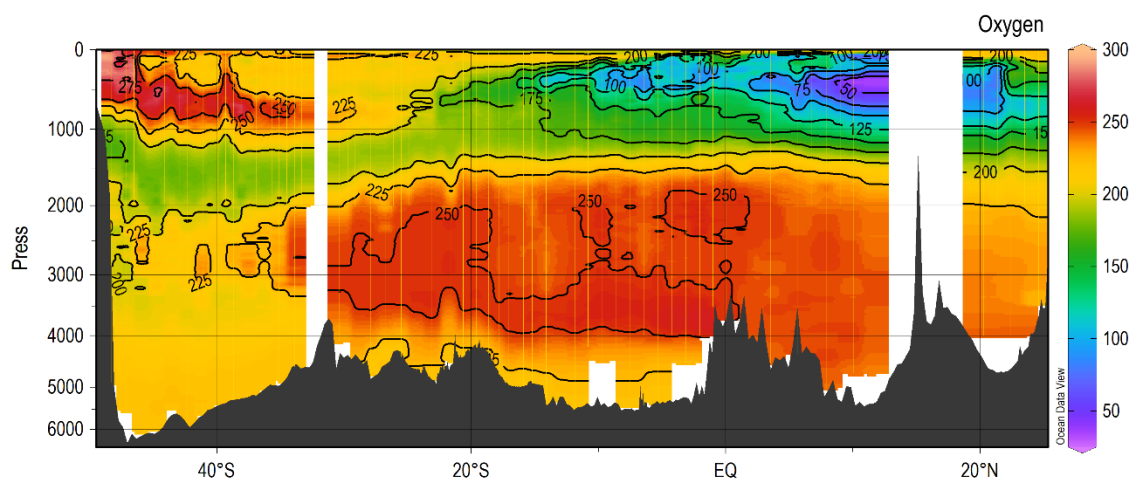


Figure 9: Vertical distribution of CTD-Oxygen along the FICARAM-XVIII section.

#### 4. CHEMICAL ANALYSIS

A total of 7819 samples were collected during FICARAM-XVIII from the Niskin bottles of the CTD-rosette. The sampling of the different variables followed the strict order given in Table 3. The total number of samples collected for each variable during this cruise is also given in Table 3. The geographical position of the station and the bottom depth are given in Table 2.

**Table 3.** Amount of seawater samples collected for each variable during the cruise.

Variable	Number of samples
Oxygen	1852
pH	1852
C <sub>T</sub>	142
Alkalinity	887
<sup>14</sup> C	290
Nutrients	1852
Salinity	924
<sup>236</sup> U and <sup>129</sup> I	30
<b>Total</b>	<b>7829</b>

##### 4.1.- Salinity

*Alex Chamorro and Miguel Gil Coto*

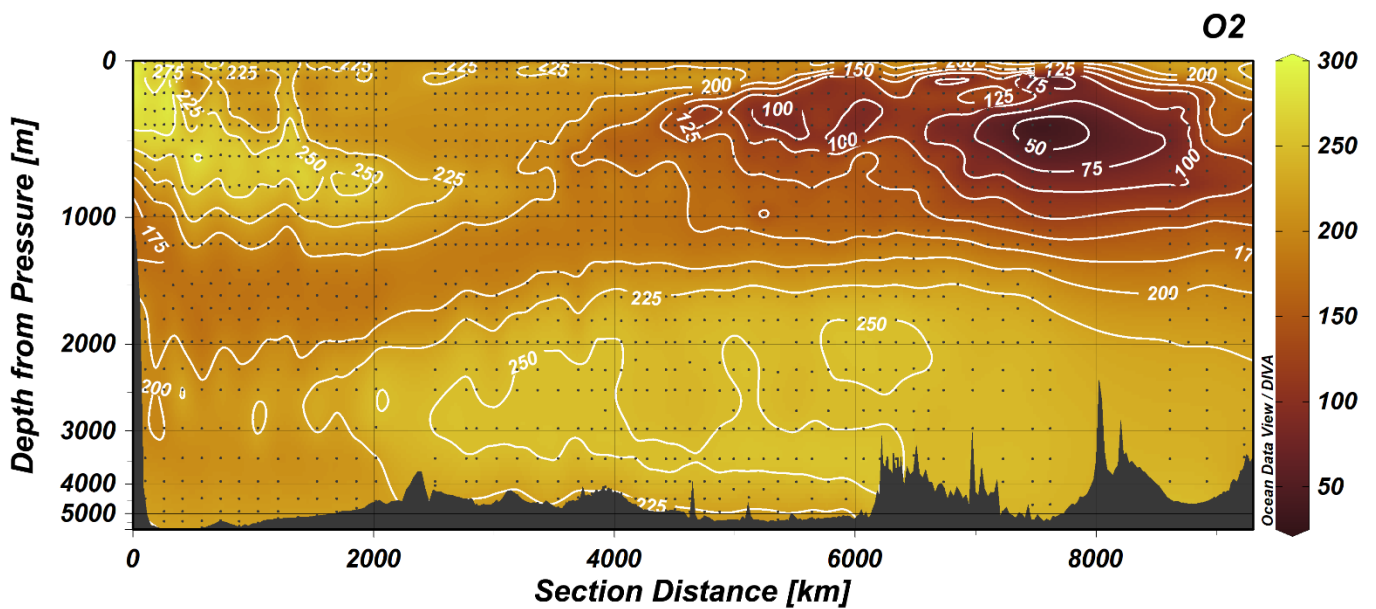
To calibrate the conductivity values, we used the Portasal Guildline 8400B salinometer (SN: 69517) that was on board the research vessel . The instrument was maintained, as much as possible, in stable temperature conditions. The salinometer has a nominal resolution of 0.002 PSU. Water samples were taken in each station at 12 levels for calibration purposes. Samples were stored in the laboratory at controlled temperature until the analyses. Then, samples were analyzed using the Portasal Guildline and calibrated with IAPSO standard seawater (OSIL Batch P161 K<sub>15</sub>=0.999987).

##### 4.2.- Oxygen

*Marcos Fontela, Fiz F. Pérez and M<sup>a</sup> Jesús Álvarez Fernández*

Samples for dissolved oxygen were collected at all the stations at all the sampling depths during the FICARAM-XVIII cruise to investigate the ocean ventilation, changes in anthropogenic CO<sub>2</sub>, and to calibrate the O<sub>2</sub> sensor of CTD. Full depth stations consisted of 24 sampling levels. In short stations, the CTD went down to 2000m, and 14 depth levels were sampled.

The O<sub>2</sub> samples were always the first being collected from the Niskin bottles. Samples were collected in calibrated flasks (~120 mL) with a PVC pipe avoiding bubble formation. The O<sub>2</sub> samples were analyzed following the widely applied Winkler method. Sample fixation (precipitation) was done by adding 0.6 mL of manganous salt (MnCl<sub>2</sub>·4H<sub>2</sub>O) and 0.6 mL of alkali-iodide solution (NaOH + NaI). These samples were stored in darkness at least 12 hours before being measured. Then, 0.6 mL of sulphuric acid was added to dissolve the precipitate and to titrate the O<sub>2</sub> sample with thiosulfate using an automatic 5 mL burette “*Titrande Metrohm*”. Concentration of thiosulfate solution was periodically controlled by standardization with potassium iodate 0.02N for each measurement session. Blanks were also measured before each measurement session. The concentration of dissolved O<sub>2</sub> in seawater was calculated and reported in  $\mu\text{mol kg}^{-1}$ , after considering the temperature of the sample at sampling, the moment of fixation and the stoichiometry and volume of the consumed thiosulfate. The distribution of dissolved O<sub>2</sub> along the FICARAM-XVIII section is represented using Ocean Data View, ODV (Schlitzer, 2011), in Figure 10.



**Figure 10:** Vertical distribution of dissolved O<sub>2</sub> along the FICARAM-XVIII section.

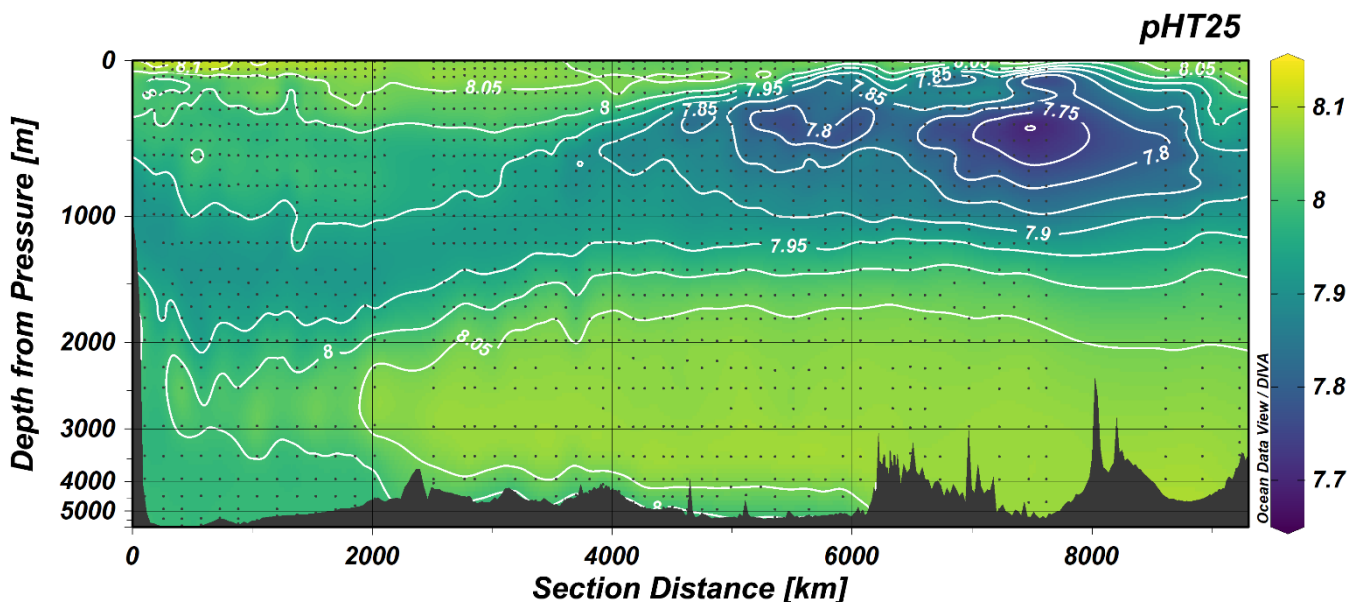


### 4.3.- pH

*M<sup>a</sup> Jesús Álvarez Fernández, Marcos Fontela, Fiz F. Pérez*

Seawater sampled for the determination of pH were taken at 24 (full-depth)/14 (mid-depth) depth levels in all the stations along the FICARAM-XVIII section. pH samples were taken directly from the Niskin bottles into special optical glass spectrophotometric cells of 28 mL of volume and 100 mm of path length. These cells were carefully stored in a thermostatic bath at 25.0°C approximately one hour before the analysis pH measurements were performed using the spectrophotometric method described in Clayton and Byrne (1993). This method consists of adding 75  $\mu$ L of m-cresol purple (mCP) to the seawater sample and measuring its absorbance at 3 wavelengths, i.e.,  $\lambda_{HI}$  = 434 nm;  $\lambda_I$  = 578 nm and  $\lambda_{non-abs}$  = 730 nm. The reaction of interest at seawater pH is the second dissociation  $HI^-(aq) = H^+(aq) + I^{2-}(aq)$  in which I is the indicator. Then, the total hydrogen ion concentration can be determined by  $pH = pK_2 + \log_{10} [I^{2-}] / [HI^-]$ . Absorbance measurements were performed with a Perkin Elmer Lambda 850 UV-VIS spectrophotometer on board the R/V Hespérides. pH values were given following the equations described in Dickson *et al.* (2007), who includes a correction due to the difference between the seawater and the acidity indicator ( $\Delta R$ ).

The preliminary pH results of the FICARAM-XVIII section on the total scale and 25°C ( $pH_{T25}$ ) were plotted using ODV (Schlitzer, 2011), as it is shown in Figure 11.

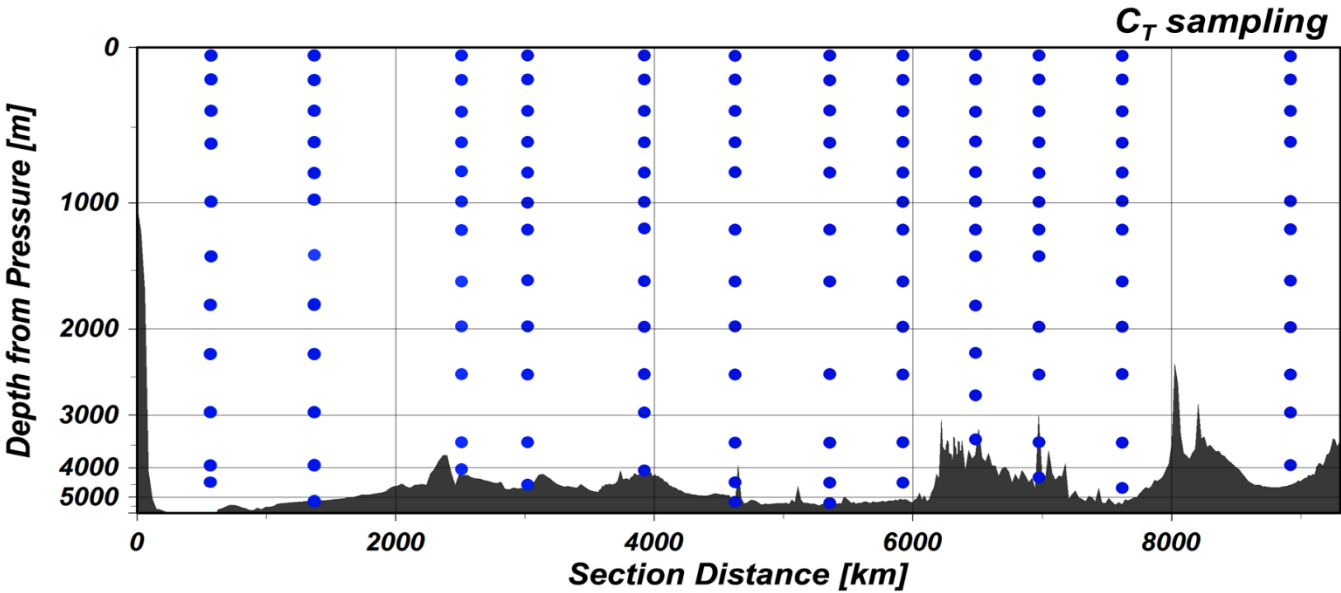


*Figure 11: Vertical distribution of  $pH_{T25}$  along the FICARAM-XVIII section.*

4.4.- Total Inorganic Carbon (C<sub>T</sub>) sampling

*M<sup>a</sup> Jesús Álvarez Fernández, Marcos Fontela, Fiz F. Pérez, Fernando Alonso-Pérez*

A total of 142 samples were collected for the determination of total carbon (C<sub>T</sub>). The relative positions of the samples in the water column is shown in Figure 12. Samples were collected at 12 depths spanning the whole water column, and at 12 stations, following the sampling for radiocarbon. The main purpose of this sampling was the allow the comparison between the measured C<sub>T</sub> and the one computed from pH and A<sub>T</sub> measurements. The sample was collected in amber vials (100 ml) that were rinsed and filled from the bottom with seawater using a silicon tube attached to the Niskin bottles, allowing the seawater to overflow (half of the bottle volume) and avoiding air bubbles. A headspace of 1% of the bottle volume was left empty. Each sample was subsequently poisoned with 500 µL of saturated aqueous solution of mercuric chloride (HgCl<sub>2</sub>). Then, the bottle was sealed with aluminum capsules and crimping tools, and stored in a cool dark-isolated place. These samples will be analyzed in the laboratories of IIM-CSIC in Vigo (Spain) using an AIRICA equipment during fall/winter 2019. The analysis consists on acidifying an aliquot of 2 mL with H<sub>3</sub>PO<sub>4</sub> in a glass stripping chamber. Then, the resulting CO<sub>2</sub> gas is carried in the equipment by a free-CO<sub>2</sub> gas (N<sub>2</sub>) into a non-dispersive infrared gas analyzer (LICOR 6262). Analyses of Certified Reference Material of CO<sub>2</sub> will be performed in order to control the accuracy of C<sub>T</sub> measurements.



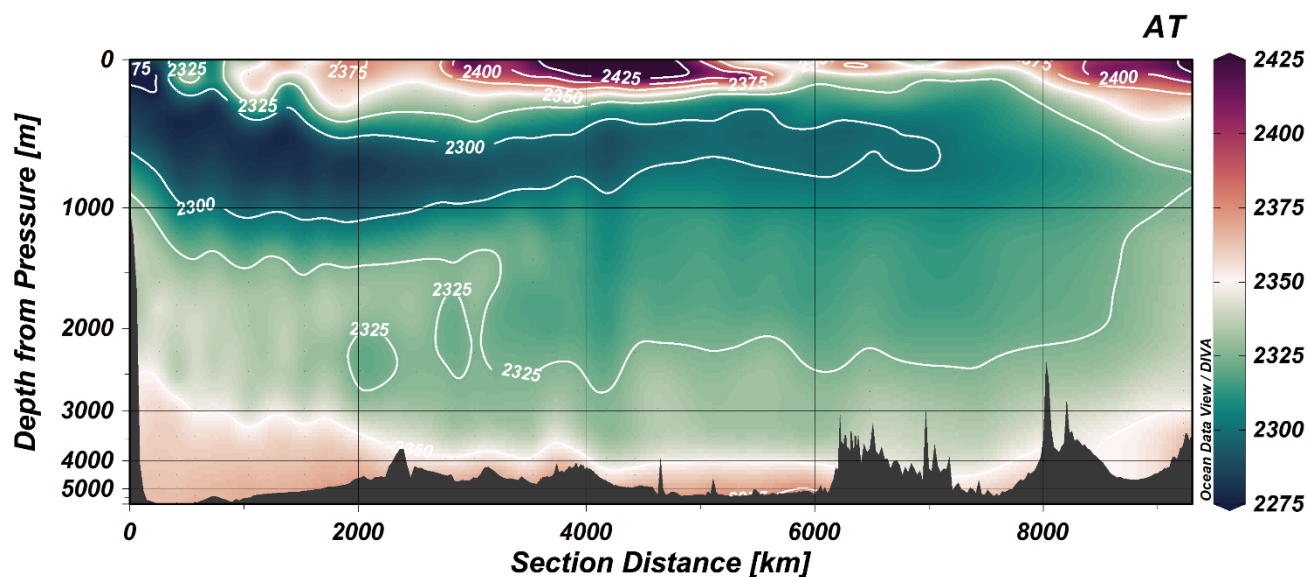
*Figure 12: Position of samples collected for the analysis of Total inorganic carbon (C<sub>T</sub>).*

#### 4.5.- Total Alkalinity ( $A_T$ )

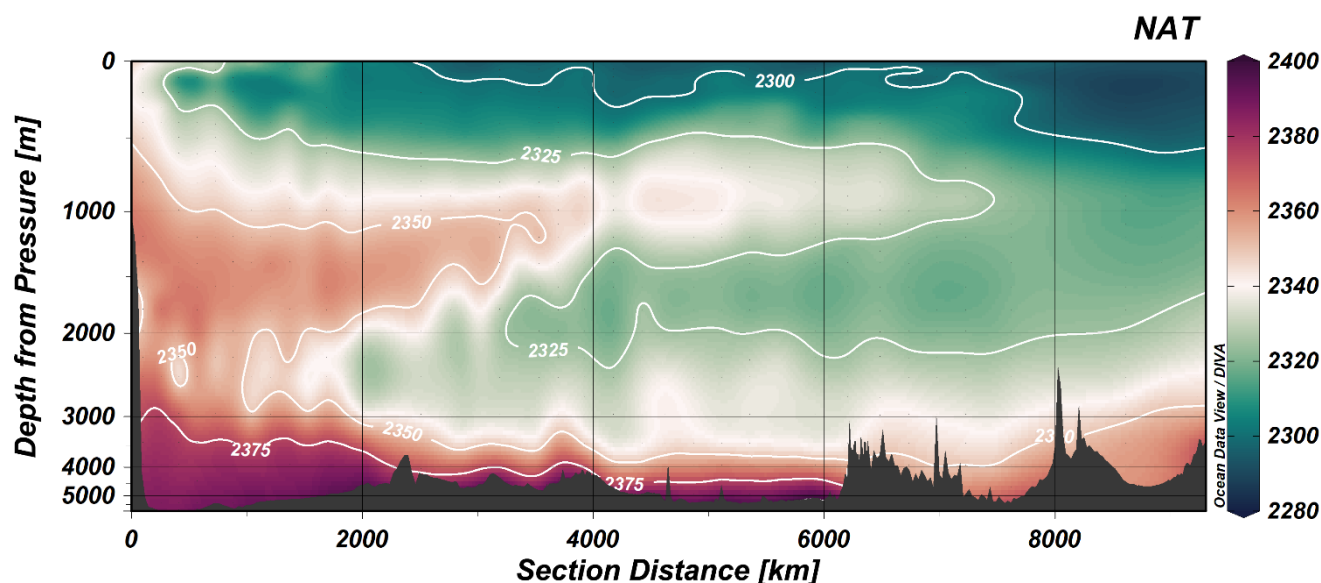
*Marcos Fontela, M<sup>a</sup> Jesús Álvarez Fernández, Fiz F. Pérez*

Samples of  $A_T$  were taken during the FICARAM-XVIII section in 41 stations, almost half of the total stations. Clean borosilicate glass bottles (600 mL) were rinsed and filled from the bottom using a silicon tube, overflowing half a volume. Samples were stored before the on-board analyses. Measurements of  $A_T$  were done by a one endpoint method using an automatic potentiometric titrator (Dosino 800 Metrohm) with a combined glass electrode (Perez and Fraga, 1987). A Knudsen pipette (~185 mL) was used to transfer the samples into an open Erlenmeyer flask in which the potentiometric titration was carried out with HCl (0.1 M). The final volume of titration was determined by means of two pH readings after the endpoint of 4.45 was reached (Mintrop et al., 2000). These  $A_T$  measurements were done in 14 sets of analysis. In order to estimate the accuracy of the  $A_T$  method, the certified reference material (CRM) of  $\text{CO}_2$  from batch 177 was analysed. The CRM was provided by Dr. Andrew Dickson. In addition, an extra calibration (substandard) was made by using a closed container of 75 L filled with open ocean surface water.

The distribution of  $A_T$  and normalized  $A_T$  concentrations in  $\mu\text{mol}\cdot\text{kg}^{-1}$  during FICARAM-XVIII are shown as ODV sections in Figures 13 and 14.



**Figure 13:** Vertical distribution of  $A_T$  ( $\mu\text{mol kg}^{-1}$ ) along the FICARAM-XVIII section



**Figure 14:** Vertical distribution of  $NA_T$  ( $\mu\text{mol kg}^{-1}$ ) along the FICARAM-XVIII section

## 4.6.- Nutrients

*Fernando Alonso-Pérez, Jesús Rey-Muras*

Dissolved nutrients were sampled after dissolved oxygen, total inorganic carbon, pH,  $^{14}\text{C}$  and alkalinity. Samples were withdrawn to 30 mL solid-polyethylene containers after rinsing twice with the same water. Samples were preserved in the dark at  $4^\circ\text{C}$  when analyses started more than one hour after collection, and they were analysed no more than 12 hours after collection. Nutrient analyses were performed with a SKALAR segmented flow auto-analyser. Nitrate+nitrite, phosphate and silicate were simultaneously determined. Determination procedure was settled at a pumping cycle of 120 seconds sucking the sample and 80 seconds sucking from a milli Q water reservoir. Every analysis spent  $\sim 8$  mL of sample. Determinations of nitrate, phosphate and silicate were carried out following methods described by Hansen and Grassoff (1983) with some improvements (Mouriño and Fraga, 1985).

### Calibration

Primary standards for nitrate+nitrite, phosphate and silicate were performed from nutrient salt materials ( $\text{KNO}_3$ ,  $\text{KH}_2\text{PO}_4$  and  $\text{Na}_2\text{SiF}_6$ , respectively) dried 24 hours over silica gel prior to weigh. Primary solutions were performed with milli-Q in calibrated volumetric flasks. A stock standard solution was prepared by mixing the three primary standards and preserved in the dark at  $4^\circ\text{C}$ . Daily working standard solutions were produced dissolving different volumes of the stock standard solution in low nutrient

seawater (LNSW). These solutions were prepared every two days and preserved in the dark at 4°C. Concentrations of each nutrient in the working standard solution are showed in Table 4.

**Table 4:** Working calibration standards.

STD	Volume (mL)		Concentration (μmol L <sup>-1</sup> )			
	Stock STD	Final Volume	NO <sub>3</sub> <sup>-</sup>	NO <sub>2</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>2-</sup>	SiO <sub>2</sub>
1	1	500	11.246		0.916	41.233
2	2	500	22.505		1.833	82.513
3	3	500	35.963		2.929	131.856
4	3	500		34.685		

Different LNSWs were used during the cruise. Nutrient concentrations of these LNSWs are showed in Table 5. At station 3, water deeper than 4500 metres, corresponding to Antarctic Bottom Water (AABW) was collected in order to have a high nutrient standard. AABW standard was since then measured every day of analysis; its nutrient concentration is showed in Table 5.

**Table 5:** Nutrient concentrations ± standard deviation for Low Nutrient Sea Waters (LNSW) and Antarctic Bottom Water (AABW)

	Stations	Concentration (μmol L <sup>-1</sup> )		
		NO <sub>3</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>2-</sup>	SiO <sub>2</sub>
LNSW1	0-42	1.28 ± 0.24	0.20 ± 0.02	0.82 ± 0.04
LNSW2	43-84	0.02 ± 0.02	0.00 ± 0.00	0.80 ± 0.05
AABW	3-84	33.49 ± 0.25	2.26 ± 0.02	131.91 ± 0.99

**Precision**

The WOCE (World Ocean Circulation Experiment) requirements for precision (Joyce *et al.*, 1991) are silicate 0.2% full scale (150μmol kg<sup>-1</sup>), nitrate 0.2% full scale (40μmol kg<sup>-1</sup>), and phosphate 0.4% full scale (2.5 μmol kg<sup>-1</sup>).

**Consistency of measurements. Quality control**

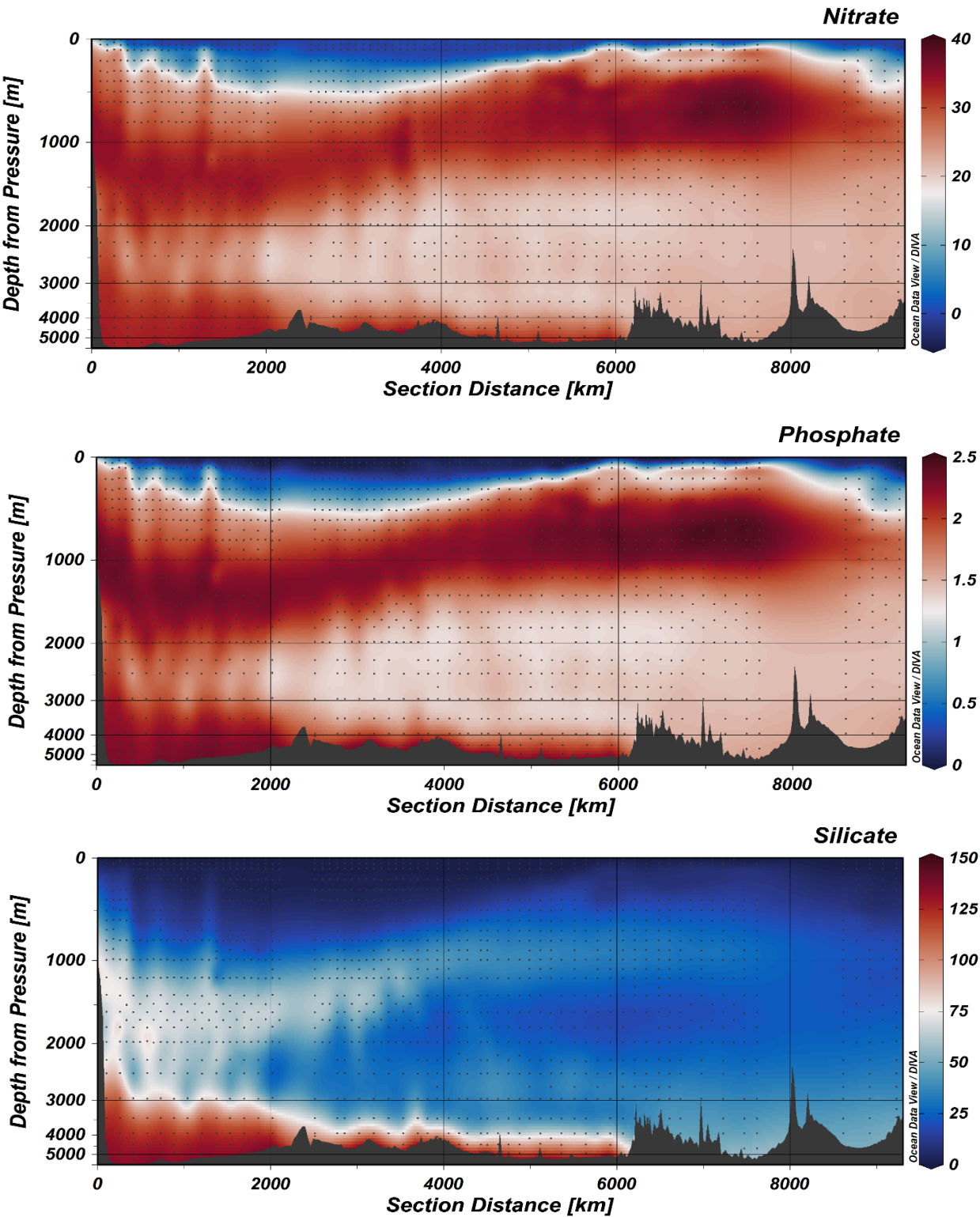
At station 0, the 24 oceanographic bottles were fired at the same depth, 150 m. Results are showed in Table 6, standard deviation was 0.13 for nitrate, 0.01 for phosphate and 0.26 for silicate. Standard deviations referred to full scale were lower than WOCE requirements in the case of silicate and phosphate and 0.13 % higher for nitrate.

**Table 6:** Summary of differences between quality control measurements

	Average	S.D.	C.V. fs (%)
Nitrate	21.02	0.13	0.33
Phosphate	1.48	0.01	0.39
Silicate	5.69	0.04	0.03

*Preliminary Results*

The vertical distributions in the concentrations of nitrate, phosphate and silicate for the FICARAM-XVIII section are showed in Figure 16.



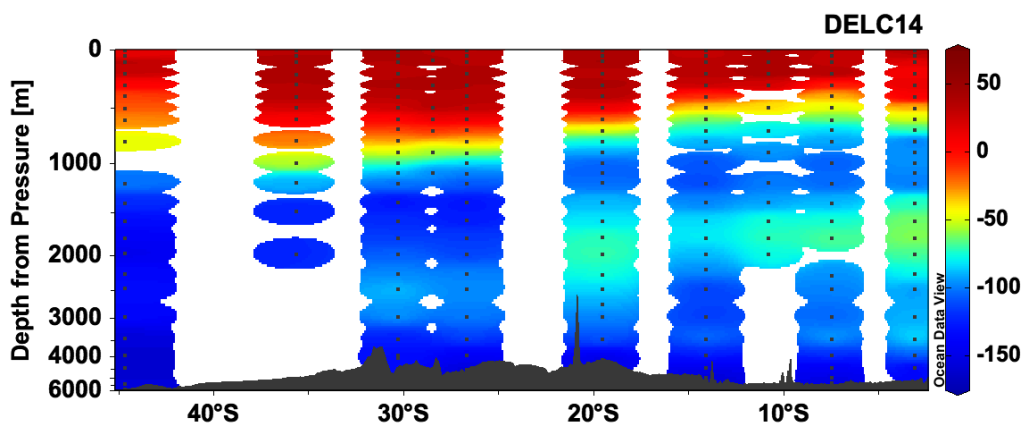
*Figure 16: Vertical distribution of nitrate, phosphate and silicate ( $\mu\text{mol kg}^{-1}$ ) along the FICARAM-XVIII section.*



#### 4.7.- Long-lived radionuclides ( $^{14}\text{C}$ , $^{129}\text{I}$ , $^{236}\text{U}$ )

##### *Maxi Castrillejo*

Seawater samples were collected between 44.697 N and -3.110 N for the determination of  $^{14}\text{C}$  (n=290),  $^{129}\text{I}$  (n=30) and  $^{236}\text{U}$  (n=30) by using the Niskin bottles mounted in the CTD rosette as the sampling device. The sampling for  $^{14}\text{C}$  was planned to overlap as much as possible with previous  $^{14}\text{C}$  GEOSECS and SAVE positions. Following recommendations of Robert Key and Ann McNichol, the sampling for  $^{14}\text{C}$  aimed for the following sampling resolution: one full-depth profile (24 depths) every 5 degrees of latitude/longitude change, and at least one shallow profile (1500-2000 m, 15 samples) between full-depth stations. The sampling for  $^{129}\text{I}$  and  $^{236}\text{U}$  was designed to re-visit two stations (47 and 63) that were sampled previously in 2013 to assess the temporal evolution of these tracers in interior ventilation waters. The seawater for  $^{14}\text{C}$  was collected into serum 120 mL glass bottles by avoiding the formation of bubbles and allowing to overfill at least one full volume before collection of the sample. Right after collection, each bottle was sealed with a rubber septum, a metallic ring and crimped. A syringe was used to remove any remaining air bubble within the sample and to poison the seawater with 30  $\mu\text{L}$  of saturated aqueous solution of  $\text{HgCl}_2$ . The samples were stored in the dark at room temperature until further analyses at ETH Zurich. The glass bottles had been previously cleaned with diluted HCl and deionized water, dried and properly sealed in the Laboratory of Ion Beam Physics at ETH-Zurich. A total of 10 samples were collected for  $^{14}\text{C}$  laboratory intercalibration exercises with NOSAMS. For  $^{129}\text{I}$  and  $^{236}\text{U}$ , between 5 and 7 L of seawater were collected from the Niskin bottles into plastic cubitainers, tightly sealed and stored in cardboard boxes to ensure dark conditions. As of May 2020,  $^{14}\text{C}$  has been measured in 70% of the samples and preliminary results are represented in the ODV section displayed in Figure 17. Details on the extraction and graphitization of  $^{14}\text{C}$  are given in Casacuberta et al., (2020). The remaining measurements of  $^{14}\text{C}$ ,  $^{129}\text{I}$  and  $^{236}\text{U}$  are expected to be done within year 2020.



*Figure 17: Vertical distribution of  $D^{14}\text{C}$  (‰) along the FICARAM-XVIII section.*

## 5.- ACKNOWLEDGEMENTS

The obtained results are of great quality and the overall balance is very satisfying. Successful achievement of main part of the objectives was possible due to the optimal coordination between the excellent crew of the BIO Hespérides led by the Commander Jose Emilio Regodón Gómez and scientific-technical team. Therefore, we would like to thank the crew of the BIO Hespérides that positively surprised us by their willingness, skills and professionalism, providing us everything we needed and solving any problems that we had, always with enthusiasm. We appreciate the technicians of the UTM-CSIC for their professionalism and good availability to solve the problems that arose during the cruise. Acknowledgments to the FICARAM-XVIII scientists group for their hard work and understanding by sharing common equipment, without weakening at any time. Especially to those who made the two phases of the cruise. Maxi Castrillejo also appreciates the great help for radionuclides sampling of the scientists and technicians onboard. They have demonstrated their competence, know-how and humanity. In addition, we have enjoyed a friendly time on board both at work and during leisure. All this has contributed to the success of the cruise. Thank you all!

## 6.-REFERENCES

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## **7.-ANNEX I (CTD-O2 Calibration sheets)**

# CALIBRATION SHEETS



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SENSOR SERIAL NUMBER: 4659  
CALIBRATION DATE: 31-Jul-19

SBE 3 TEMPERATURE CALIBRATION DATA  
ITS-90 TEMPERATURE SCALE

## COEFFICIENTS:

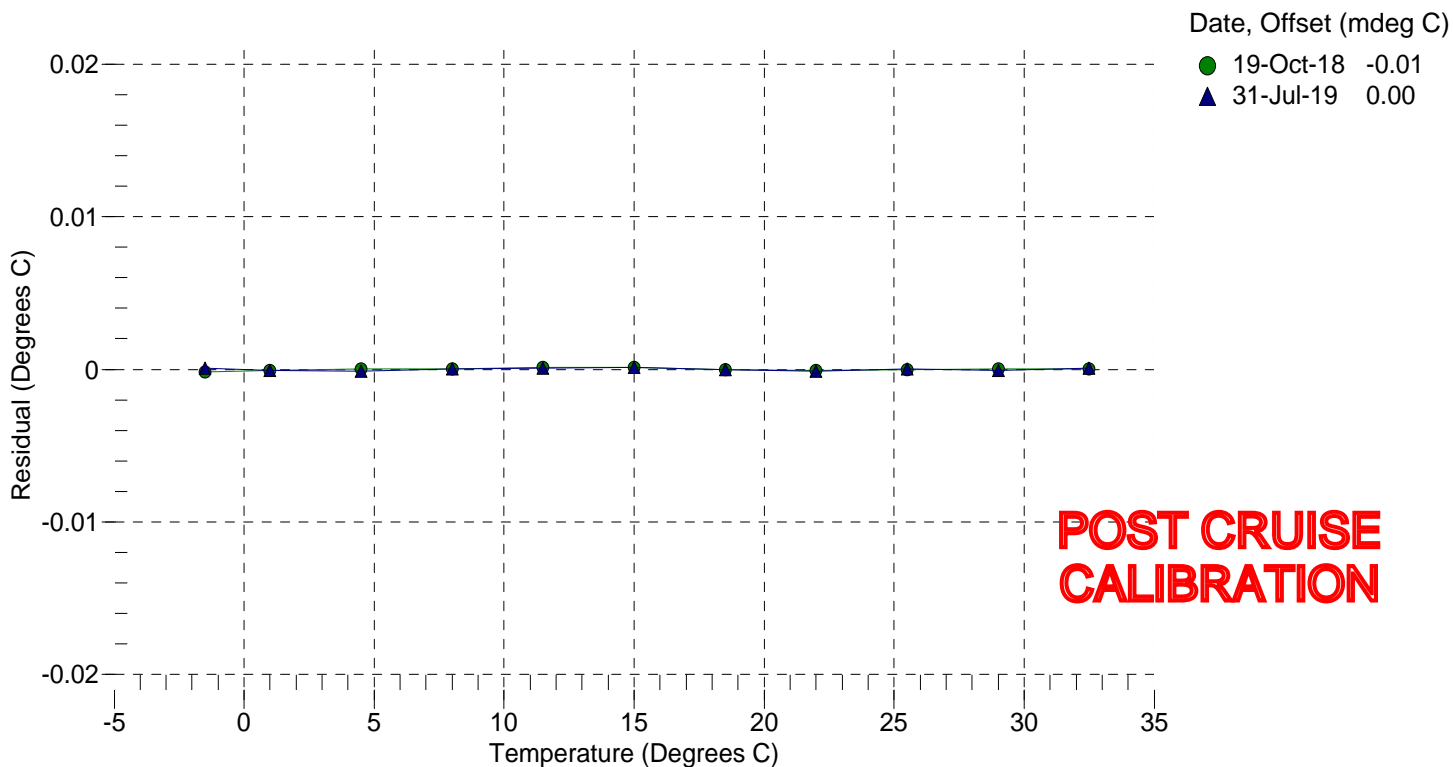
g = 4.38545139e-003  
h = 6.41697282e-004  
i = 2.19922416e-005  
j = 1.92367353e-006  
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3118.643	-1.4999	0.00007
1.0000	3298.623	0.9999	-0.00006
4.5000	3563.058	4.4999	-0.00011
8.0000	3842.413	8.0000	0.00002
11.5000	4137.072	11.5001	0.00008
15.0000	4447.433	15.0001	0.00010
18.5000	4773.867	18.5000	-0.00003
22.0000	5116.762	21.9999	-0.00011
25.5000	5476.499	25.5000	0.00005
29.0000	5853.370	28.9999	-0.00006
32.4999	6247.749	32.5000	0.00005

f = Instrument Output (Hz)

Temperature ITS-90 (°C) =  $1 / \{ g + h[\ln(f_0 / f)] + i[\ln^2(f_0 / f)] + j[\ln^3(f_0 / f)] \} - 273.15$

Residual (°C) = instrument temperature - bath temperature





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SENSOR SERIAL NUMBER: 4798  
CALIBRATION DATE: 22-Aug-19

# SBE 3 TEMPERATURE CALIBRATION DATA ITS-90 TEMPERATURE SCALE

## COEFFICIENTS:

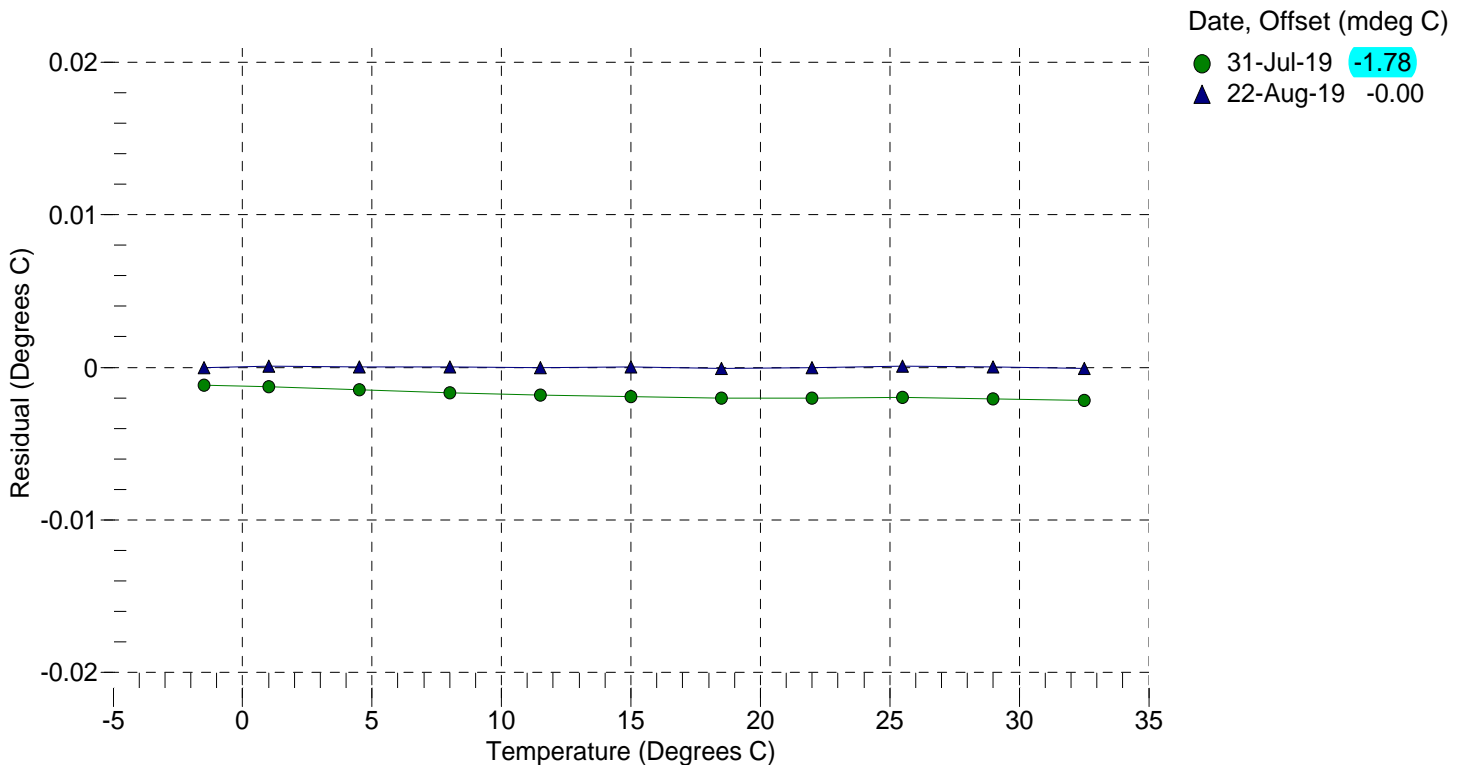
g = 4.37210129e-003  
h = 6.30287718e-004  
i = 1.96398318e-005  
j = 1.37891463e-006  
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3104.869	-1.5000	-0.00005
1.0000	3286.578	1.0001	0.00006
4.5000	3553.775	4.5000	0.00002
8.0000	3836.337	8.0000	0.00001
11.5000	4134.705	11.5000	-0.00003
14.9999	4449.317	14.9999	0.00001
18.5000	4780.608	18.4999	-0.00007
22.0000	5128.995	22.0000	-0.00001
25.5000	5494.881	25.5001	0.00007
29.0000	5878.649	29.0000	0.00004
32.5000	6280.686	32.4999	-0.00005

f = Instrument Output (Hz)

Temperature ITS-90 (°C) =  $1 / \{ g + h[\ln(f_0 / f)] + i[\ln^2(f_0 / f)] + j[\ln^3(f_0 / f)] \} - 273.15$

Residual (°C) = instrument temperature - bath temperature





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SENSOR SERIAL NUMBER: 3286  
CALIBRATION DATE: 22-Oct-19

SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.92862069e+000  
h = 1.43823009e+000  
i = -3.35334599e-004  
j = 1.01609894e-004

CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

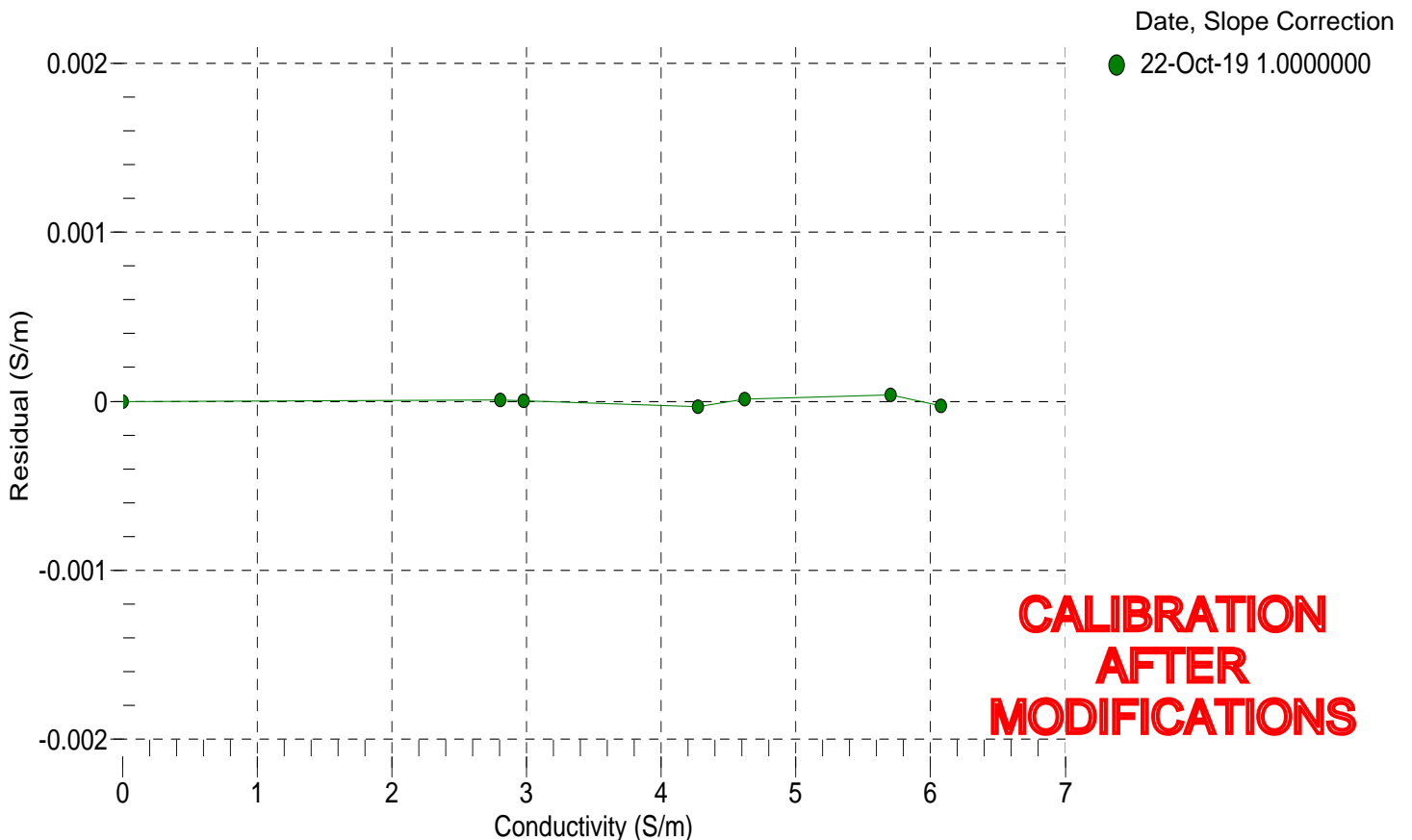
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.62759	0.00000	0.00000
-1.0000	34.8262	2.80530	5.13722	2.80531	0.00001
1.0000	34.8270	2.97679	5.25177	2.97679	0.00000
15.0000	34.8280	4.27290	6.04740	4.27286	-0.00003
18.5000	34.8279	4.61974	6.24306	4.61975	0.00001
29.0000	34.8262	5.70376	6.81812	5.70379	0.00004
32.5000	34.8204	6.07662	7.00488	6.07660	-0.00003

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars);  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Conductivity (S/m) =  $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity







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SENSOR SERIAL NUMBER: 3345  
CALIBRATION DATE: 22-Oct-19

SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -9.97464755e+000  
h = 1.54819169e+000  
i = -2.78915404e-003  
j = 3.13182191e-004

CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

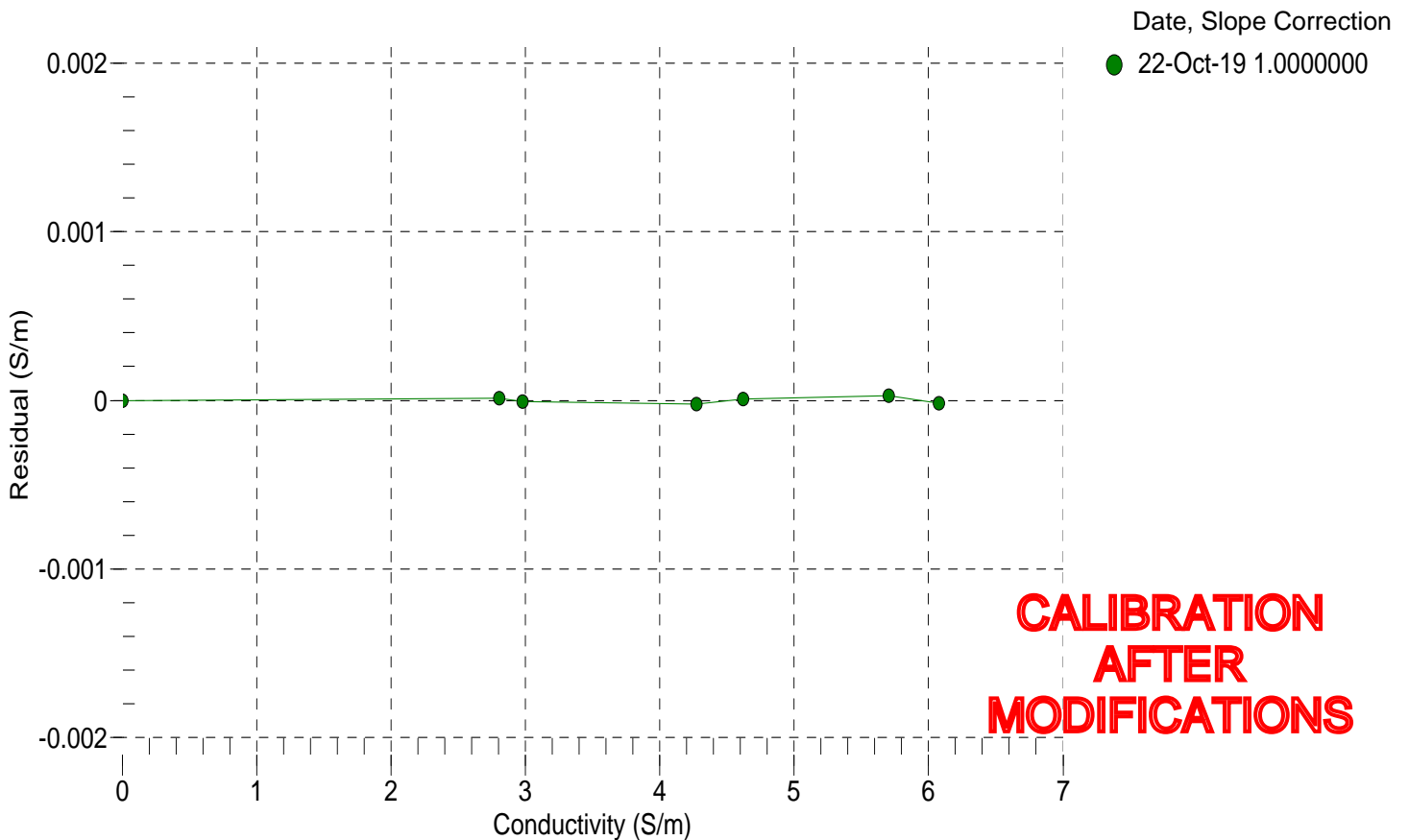
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.54243	0.00000	0.00000
-1.0000	34.8262	2.80530	4.96591	2.80531	0.00001
1.0000	34.8270	2.97679	5.07658	2.97678	-0.00001
15.0000	34.8280	4.27290	5.84525	4.27288	-0.00002
18.5000	34.8279	4.61974	6.03422	4.61975	0.00001
29.0000	34.8262	5.70376	6.58953	5.70378	0.00003
32.5000	34.8204	6.07662	6.76984	6.07661	-0.00002

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars);  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Conductivity (S/m) =  $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity





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SENSOR SERIAL NUMBER: **3010**  
CALIBRATION DATE: 30-Jul-19

SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.04242493e+001  
h = 1.49239411e+000  
i = 3.20935913e-004  
j = 5.46772320e-005

CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

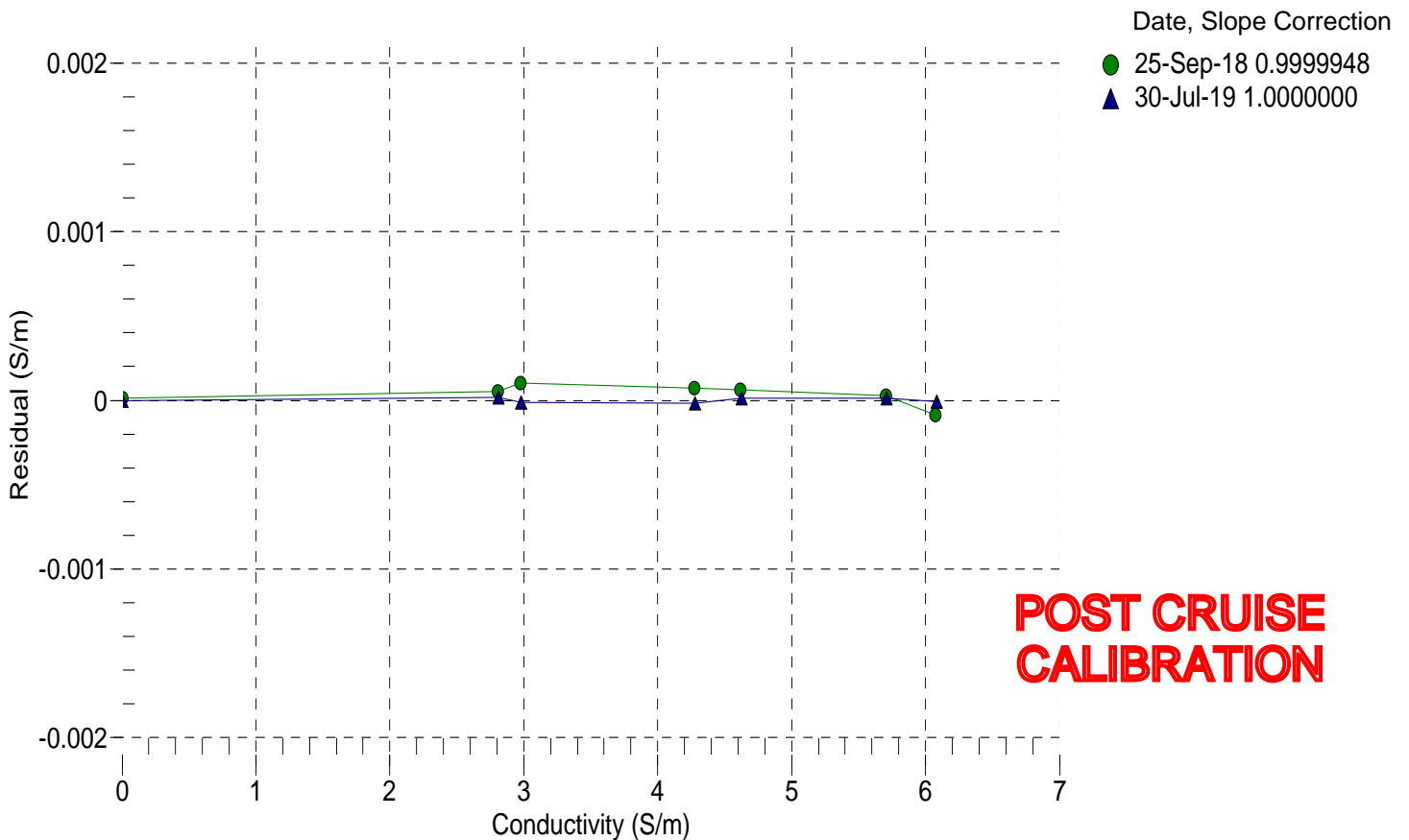
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.64181	0.00000	0.00000
-1.0000	34.8804	2.80926	5.07507	2.80927	0.00002
1.0000	34.8815	2.98101	5.18681	2.98099	-0.00001
15.0000	34.8832	4.27895	5.96372	4.27893	-0.00002
18.5000	34.8830	4.62626	6.15492	4.62628	0.00001
29.0000	34.8804	5.71163	6.71718	5.71165	0.00001
32.5000	34.8651	6.08354	6.89921	6.08353	-0.00001

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars);  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Conductivity (S/m) =  $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity





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SENSOR SERIAL NUMBER: 3770  
CALIBRATION DATE: 25-Sep-18

SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.01927495e+001  
h = 1.42881945e+000  
i = -1.33599213e-003  
j = 1.73954819e-004

CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

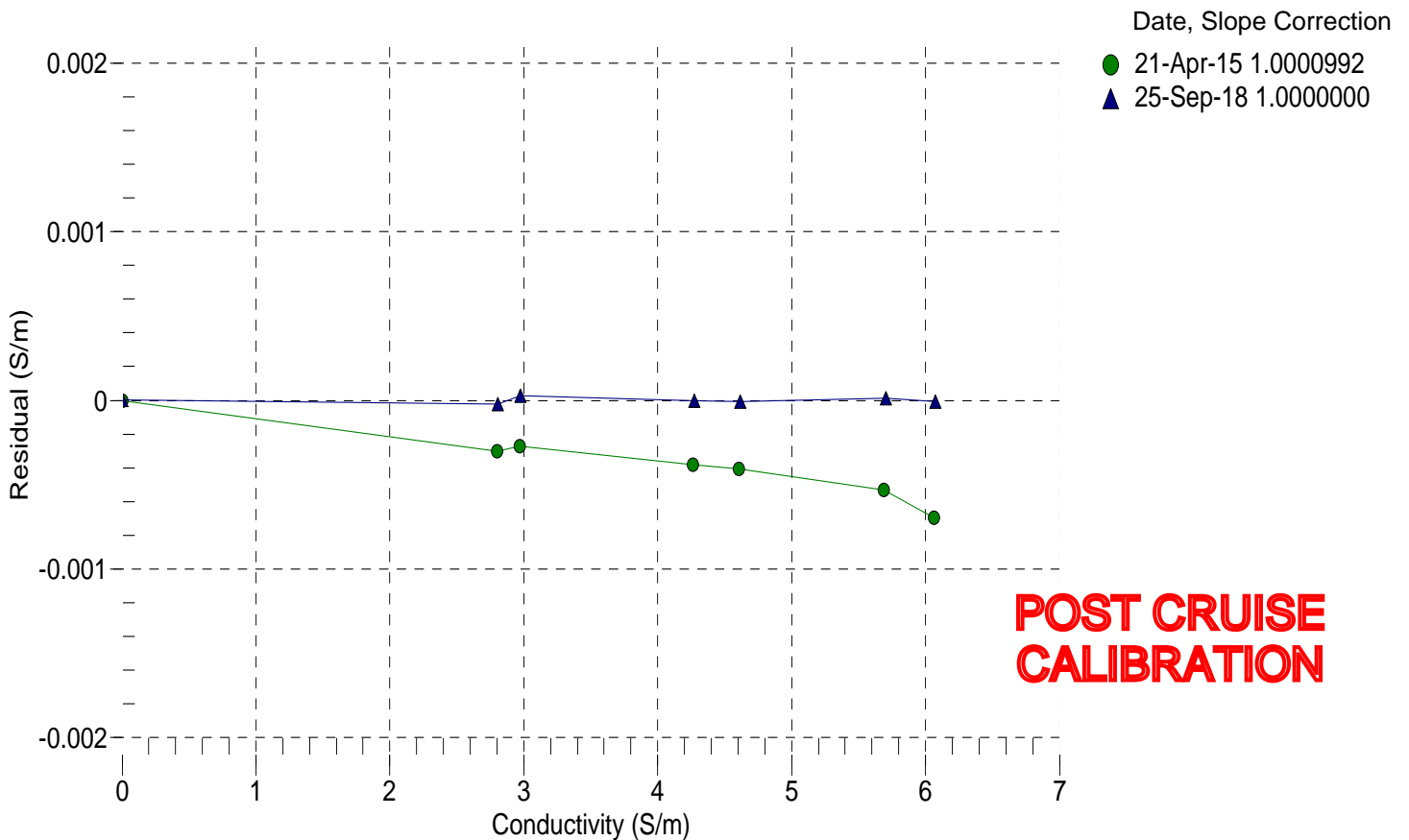
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.67307	0.00000	0.00000
-1.0000	34.8206	2.80489	5.17751	2.80487	-0.00002
1.0000	34.8204	2.97628	5.29220	2.97631	0.00003
15.0000	34.8216	4.27219	6.08926	4.27219	-0.00000
18.5000	34.8213	4.61896	6.28529	4.61895	-0.00001
29.0000	34.8173	5.70246	6.86149	5.70248	0.00001
32.5000	34.8078	6.07468	7.04843	6.07467	-0.00001

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars);  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Conductivity (S/m) =  $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \epsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 0847

CALIBRATION DATE: 30-Mar-16

SBE 9plus PRESSURE CALIBRATION DATA

10000 psia S/N 99754

## DIGIQUARTZ COEFFICIENTS:

C1 = -4.388274e+004

C2 = -7.635515e-001

C3 = 1.363660e-002

D1 = 3.635500e-002

D2 = 0.000000e+000

T1 = 3.005140e+001

T2 = -5.285295e-004

T3 = 4.304690e-006

T4 = 1.582920e-009

T5 = 0.000000e+000

## AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.28759e-002

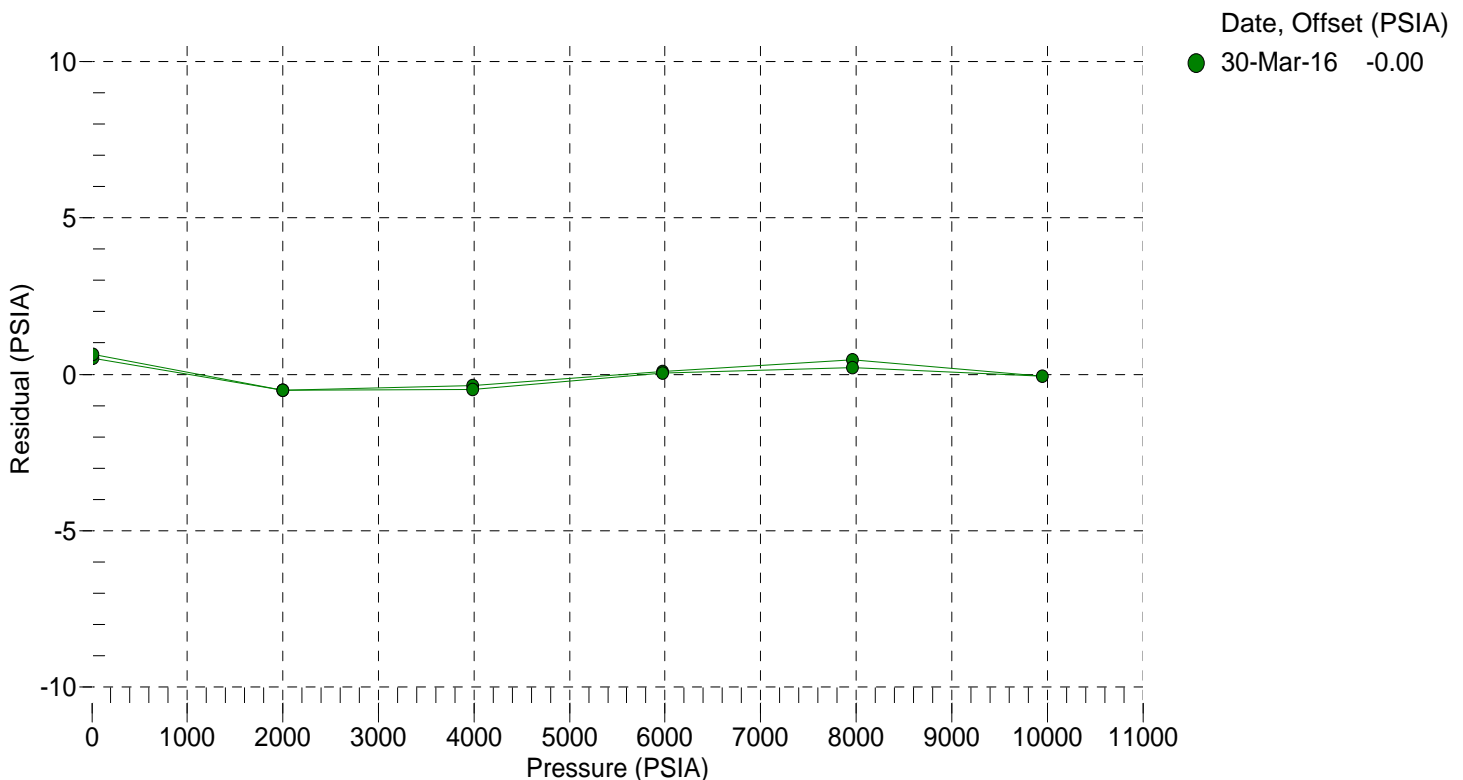
AD590B = -8.52722e+000

Slope = 1.00004

Offset = 2.1683 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
13.539	33291.20	22.5	10.895	14.040	0.501
2000.204	34034.50	22.6	1996.473	1999.694	-0.510
3987.255	34760.10	22.7	3983.602	3986.900	-0.355
5973.505	35468.40	22.7	5970.225	5973.599	0.094
7960.090	36160.70	22.7	7957.096	7960.546	0.456
9947.163	36837.70	22.8	9943.569	9947.096	-0.067
7960.290	36160.70	22.8	7957.048	7960.499	0.209
5974.028	35468.60	22.8	5970.685	5974.059	0.031
3988.050	34760.40	22.8	3984.272	3987.569	-0.481
2001.080	34034.90	22.8	1997.339	2000.560	-0.520
13.540	33291.40	22.9	11.036	14.181	0.641

Residual (PSIA) = corrected instrument pressure - reference pressure





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SENSOR SERIAL NUMBER: 0707  
CALIBRATION DATE: 09-Aug-19

# SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:  
Soc = 0.4660  
Voffset = -0.5099  
Tau20 = 1.07  
A = -4.5461e-003  
B = 2.0245e-004  
C = -3.3289e-006  
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS  
D1 = 1.92634e-4  
D2 = -4.64803e-2  
H1 = -3.300000e-2  
H2 = 5.00000e+3  
H3 = 1.45000e+3

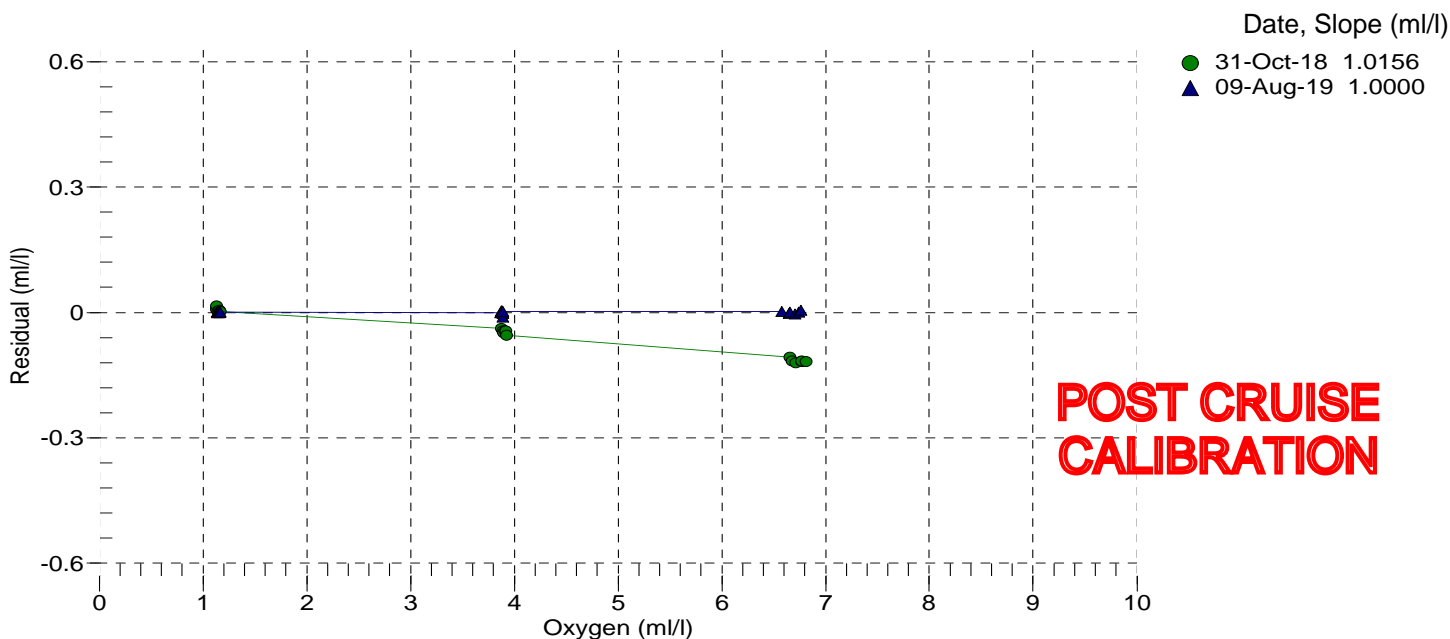
BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.14	6.00	0.00	0.796	1.14	0.00
1.14	12.00	0.00	0.845	1.14	-0.00
1.14	20.00	0.00	0.911	1.15	0.00
1.16	26.00	0.00	0.965	1.16	0.00
1.16	30.00	0.00	1.000	1.16	-0.00
1.17	2.00	0.00	0.771	1.17	0.00
3.87	6.00	0.00	1.483	3.87	-0.00
3.88	2.00	0.00	1.377	3.88	0.00
3.88	12.00	0.00	1.651	3.88	0.00
3.89	30.00	0.00	2.159	3.89	-0.00
3.89	26.00	0.00	2.037	3.88	-0.01
3.89	20.00	0.00	1.872	3.89	0.00
6.58	30.00	0.00	3.303	6.58	0.00
6.65	2.00	0.00	1.997	6.65	-0.00
6.66	6.00	0.00	2.186	6.66	0.00
6.70	12.00	0.00	2.478	6.70	-0.00
6.74	20.00	0.00	2.871	6.74	0.00
6.76	26.00	0.00	3.175	6.77	0.01

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)

Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* Oxsol(T,S) \* exp(E \* P / K)

Residual (ml/l) = instrument oxygen - bath oxygen



## CCHDO Data Processing Notes

- **File Online Carolina Berys**

[Cruises\\_Report\\_FICARAM-XVIII.pdf \(download\)](#) #470d4

**Date:** 2020-05-12

**Current Status:** unprocessed

- **File Online Carolina Berys**

[29HE20190406\\_ct1.zip \(download\)](#) #aa5fc

**Date:** 2020-05-12

**Current Status:** unprocessed

- **File Submission Robert Key**

[29HE20190406\\_ct1.zip \(download\)](#) #aa5fc

**Date:** 2020-05-12

**Current Status:** unprocessed

**Notes**

The CTD data and Cruise report red from Fiz Perez today. He reported that the CTD data were in exchange format but this will need to be checked.

PLEASE edit the most recent version of the bottle data file under headings for carbon data (alk, ph, dic) so that "Who:" is set to Marcos Fontela, Fiz F Pere, Anton Velo

- **File Submission Robert Key**

[Cruises\\_Report\\_FICARAM-XVIII.pdf \(download\)](#) #470d4

**Date:** 2020-05-12

**Current Status:** unprocessed

**Notes**

The CTD data and Cruise report red from Fiz Perez today. He reported that the CTD data were in exchange format but this will need to be checked.

PLEASE edit the most recent version of the bottle data file under headings for carbon data (alk, ph, dic) so that "Who:" is set to Marcos Fontela, Fiz F Pere, Anton Velo



- **File Online Carolina Berys**

[29HE20190406.exc.csv \(download\)](#) #14663

**Date:** 2020-04-28

**Current Status:** unprocessed

- **File Submission Robert Key**

[29HE20190406.exc.csv \(download\)](#) #14663

**Date:** 2020-04-10

**Current Status:** unprocessed

**Notes**

This version includes slightly revised CTD values. Updates red from Anton Velo 4/8/2020

- **File Online Carolina Berys**

[29HE20190406.exc.csv \(download\)](#) #9069b

**Date:** 2020-03-04

**Current Status:** unprocessed

- **File Submission Robert Key**

[29HE20190406.exc.csv \(download\)](#) #9069b

**Date:** 2020-02-28

**Current Status:** unprocessed

**Notes**

I submitted this file on 2/13/20, but that version had a transposition of day and month in the expocode. Corrected here. No other changes.