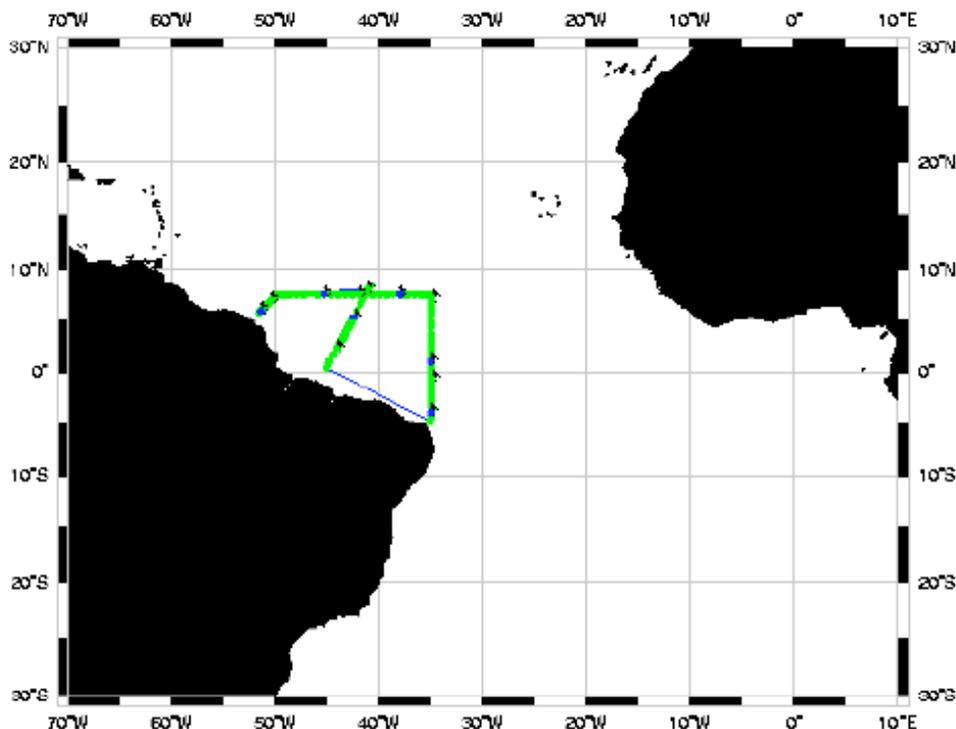


## CRUISE REPORT: AR04EW/AR15

(Updated FEB 2009)



### A.1 Highlights

#### Cruise Summary Information

Section Designation	<b>AR04EW/ AR15</b>		
Expedition designation (EXPCODE)	<b>33LKETAMBOT2_1</b>		
Chief Scientist/Affiliation	<b>Yves Gouriou/ORSTOM*</b>		
Dates	1996 APR 15 - 1996 May 16		
Ship	R/V EDWIN LINK		
Ports of call	Leg 1: Cayenne, French Guiana to Natal, Brazil Leg 2: Natal, Brazil to Cayenne, French Guiana		
Number of stations	95		
Geographic boundaries	34°54.39'W	08°24.03'N	51°33.85'W
		04°46.91'S	
Floats and drifters deployed	0 Floats, 0 Drifters		
Moorings deployed or recovered	0 Deployed, 0 recovered		
Contributing Authors	C. Andrié	B. Bourlès	F. Baurand
	R. Chuchla	P. Fournier	Y. Gouriou
	C. Oudot	J.F. Ternon	

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**Links to text locations**

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

<b>Cruise Summary Information</b>	<b>Hydrographic Measurements</b>
Description of Scientific Program	<b>CTD Data:</b>
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	<b>Bottle Data</b>
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
<b>Underway Data Information</b>	<b>References</b>
Navigation Bathymetry	ADCP/LADCP
Acoustic Doppler Current Profiler (ADCP)	Thermosalinograph
Thermosalinograph	Oxygen Measurements
XBT and/or XCTD	Nutrients
Meteorological Observations	CFCs
Atmospheric Chemistry Data	CO2
<b>Data Processing Notes</b>	<b>Acknowledgments</b>

## A.2 Cruise Summary

### Cruise Track

The cruise track and station locations are shown in [Figure 1](#).

First leg: Cayenne (4°51'N-52°15'W) to Natal (5°48'S-35°18'W).

Second leg: Natal (5°48'S-35°18'W) to Cayenne (4°51'N-52°15'W).

### Number of station

A total of 95 CTD/rosette stations were occupied using a General Oceanics 24 bottle rosette equipped with:

- 24 8-liter Niskin water sample bottles .
- a NIBS Mark IIIa CTD equipped with an oxygen sensor, and bottom proximity alarm.
- a 12 kHz MORS pinger.
- A 150 KHz-RDI L-ADCP (Lowered Acoustic Doppler Current Profiler).

To install the L-ADCP, 2 Niskin bottles have been removed from the rosette.

### Sampling

Double casts were performed for deep stations (bottom > 4000 m). During the first cast 6 water samples were taken between the surface and 500 m, and during the second cast 22 water samples were taken between 500 m and the bottom. The number of water samples per station is distributed as follows:

16 shallow stations with less than 22 water samples.

51 stations with 22 water samples.

27 stations with 28 water samples (double casts).

Salinity, dissolved oxygen, nutrients (nitrate, nitrite, silicate, phosphate) have been measured for every sample, at every station.

Freons (11 and 12) measurements were performed at every station. Between the surface and the bottom for 94 stations.

Total dissolved CO<sub>2</sub> and pH measurements were carried out for all the closed bottles every other station (47 stations).

Surface sampling were carried out at each station to determine CO<sub>2</sub> fugacity and Chlorophyll.

Test stations :

Station N°31: all the bottles closed at 1000 m depth.

Station N°42: all the bottles closed at 2000 m depth.

Station N°72: all the bottles closed at 2000 m depth.

Station N°87: all the bottles closed at 1000 m depth.

At every station 2 bottles were closed at the same depth.

### Floats, Drifters, and Moorings

No floats, drifters, or moorings were deployed during this cruise.

### A.3 List of Principal Investigators

**TABLE 1:** Principal investigators

<b>Name</b>	<b>Responsibility</b>	<b>Institution</b>
Chantal Andrié	Freons	ORSTOM
Bernard Bourlès	S-ADCP, Salinity	ORSTOM
Yves Gouriou	CTD, L-ADCP	ORSTOM
Claude Oudot	Nutrients – O <sub>2</sub>	ORSTOM
Jean-François Ternon	CO <sub>2</sub> parameters	ORSTOM

### A.4 Scientific Program and Methods

The principal objectives of the cruise were :

- To estimate the inter-hemispheric transport of heat, freshwater, nutrients, CO<sub>2</sub>, and CFCs in a key region of the Atlantic ocean.
- To estimate the seasonal variability of the deep circulation. An other cruise, ETAMBOT 1, has been made in an opposite season.
- To repeat the survey of the western equatorial Atlantic ocean made during the CITHER 1 cruise in January- March 1993 (Western part of the A6 section).

The instruments employed in the measurement program consisted of a NBIS Mark IIIa CTD and General Oceanics rosette. Subsidiary instrumentation consisted of a 12 kHz pinger, a bottom proximity alarm, and a L-ADCP. 4 SIS reversing pressure meters and 4 SIS reversing thermometers were installed on the bottles.

After a cast the rosette was placed on the deck and secured. The rosette, the frame, sensors and L-ADCP were watered with fresh water. L-ADCP binary data were downloaded on a PC. Digital instrumentation was read and samples were drawn in the following order :

Freons, oxygen, CO<sub>2</sub> parameters, nutrients, and salinity.

The rosette was stored on deck throughout the cruise and all sampling was performed there.

Acoustic Doppler Current Profiler (ADCP) measurements were made continuously employing a hull mounting 150 kHz unit manufactured by RDI.

No continuous water depth measurements were performed along the track of the ship.

## A.5 Major Problems Encountered on the Cruise

- 1) The salinity sensor of the first CTD probe (n°2756) stopped working normally at station N°9. That station has been occupied again at the end of the cruise (station N°90). We replaced the probe with the spare one (n°2782) at station N°10. Inspection of the first probe, during the call in Natal, showed that the failure was due to the fast temperature sensor of the probe.
- 2) The power supply of the first Deck Unit was insufficient to correctly supply the second CTD probe (n°2782). So the conductivity profiles of stations N° 10 to 13 were noisy. We solved that problem at station N°14 by replacing the Deck Unit. The stations N°4 to N°10 and station N°13 have been sampled again at the end of the cruise (stations N°88 to 95).
- 3) From station N°14 the oxygen sensor of the CTD probe (n°2782) did not work well. Few profiles of oxygen have been made during the first part of the cruise.
- 4) The salinity sensor of the second CTD probe (n°2782) was deteriorated at our arrival in Natal. We changed the probe after the call, replacing the fast temperature sensor of the probe n°2756 by the sensor of the probe n°2782. This CTD probe (n°2756) worked well during the second part of the cruise (and the oxygen sensor too).

The acoustic bases of the deep sounder never worked during the cruise. This failure could have compromised the entire cruise, but :

- a - the track of the ETAMBOT 2 cruise was similar to the track of the ETAMBOT 1 cruise. So we knew more or less the depth at the station position.
- b - we used a mechanical system that rings in the laboratory when the rosette is close to the bottom, generally 15 m above, but for this cruise we stopped the rosette about 25 m above the bottom.

The vertical penetration of the S-ADCP acoustic signal was only 100 m when the ship was on route. This weak vertical penetration was certainly due to turbulence close to the well where the ADCP was placed in. During the stations, when the ship stopped, the vertical penetration of the measurements was about 300 m.

## A.6 List of Cruise Participants

**TABLE 2:** Cruise participant

Name	Responsibilities	Affiliation	Leg
Chantal Andrié	CFCs	ORSTOM	1-2
François Baurand	Nutrients	ORSTOM	1-2
Jean-Michel Bore	Elec. Engineer/CTD/L-ADCP	ORSTOM	1-2
Bernard Bourlès	CTD/S-ADCP/Salinity	ORSTOM	1-2
William Biegun	CFCs	ORSTOM	1-2
Rémy Chuchla	CTD/Salinity	ORSTOM	1-2
Denis Diverres	CO <sub>2</sub>	ORSTOM	1-2
Philippe Fournier	Oxygen	ORSTOM	1-2
Yves Gouriou	Chief Scientist/CTD/L-ADCP	ORSTOM	1-2
Christophe Le Doare	CTD/L-ADCP	ORSTOM	1-2
Frédéric Marin	CTD/salinity	ORSTOM	1-2
Yves Montel	Nutrients	ORSTOM	1-2
Claude Oudot	CO <sub>2</sub>	ORSTOM	1-2
Jean-François Ternon	CFCs	ORSTOM	1-2

ORSTOM : Institut Français de Recherche Scientifique pour le Développement en Coopération

## **B. UNDERWAY MEASUREMENTS**

### **B.1 Navigation**

*(B.Bourlès)*

Navigation data (time, position, course and speed over ground, and fix quality information) were acquired every 15 seconds throughout the ETAMBOT-2 cruise, from the 04/15/1996 at 18h50 TU to the 05/16/1996 at 10h55 TU, with the vessel Magnavox MX200 Global Positioning System (GPS). The GPS was located in the bridge, and navigation information were transmitted to a Personal Computer dedicated to navigation and thermosalinograph measurement acquisition, located in the main laboratory.

Due to a not clarified network problem between the bridge and the laboratory, the registered time was erroneous, yet the position (latitude and longitude) was correct. As the internal acquisition PC clock, and the internal L-ADCP clock, were perfectly synchronized, we used the acquisition-PC clock for time reference. Thus, we registered this PC time at the beginning and at the end of every CTD-O<sub>2</sub> station during the cruise, and used these time reference values to correct the GPS time information, hence the navigation. We first linearly constructed a time reference data base, and then attributed the 'true' position to the correct time, using a 2 minutes time filter. Navigation measurements were also acquired by the S-ADCP acquisition system (see chapter B3), using the RDI 'GPRMC' software. This software calculates the average of GPS successive information around the velocity acquisition times, and registers 'mean' navigation every 5 minutes. The re-calculated navigation data are in very good agreement with this navigation data base (differences are of the order of 1/100 minute), and has been used with confidence for L-ADCP data treatment (see chapter B4).

### **B.2 Echosounding**

None.

### **B.3 Acoustic Doppler Current Profiler (ADCP)**

*(B.Bourlès)*

The S-ADCP system on board the R/V EDWIN LINK is a 153 kHz RD-VM150 Instruments unit with a hull mounted transducer. The four-beam transducer is mounted in a open sea well, and located to port side around the vessel centerline at about 3 meters depth. It is connected by cable to a deck box, containing the processing equipment, and connected to a Personal Computer (AT-286) dedicated to measurement acquisition. Ship's gyrocompass information are collected by the deck box through a synchro to digital interface. Data were collected using the RDI Data Acquisition Software (version 2.48). Information exchanges between the S-ADCP and the acquisition PC were managed by the 'ENSOUT' RDI software. Navigation data (time, position, course and speed over ground, and fix quality information) were acquired with a Magnavox MX4200 Global Positioning System (GPS). Standard setup parameters used were: 8 meter bin and pulse lengths, 4 meter blanking, and 5 minutes ensemble averaging. A reference layer was defined between bins 5 to 15. The first bin was centered at 16 meter depth. Sea salinity value, necessary to calculate the sound velocity during data acquisition, was fixed to 25 off French Guiana because of the influence of fresh Amazon water, and to 35 or 36 (considering the thermosalinograph measurements) in the open sea. The S-ADCP data processing has been made using the Common Oceanographic Data Access System (CODAS-3, version 3) of the Hawaii University (*Bahr et al.*, 1990). The PC clock drift is first determined by comparing PC time with GPS time. The corrected time is then included in the data base. Navigation and transducer temperature are first checked. 'Noisy' bins or profiles are suppressed. Due to the location of the transducer, and to the presence of turbulence along the hull during the vessel course, current velocity profiles were only available during CTD stations, when vessel was stopped. Navigation

and S-ADCP measurements are combined in order to obtain absolute current values. The current velocity is calibrated using the *Pollard and Read* (1989) standard procedure.

Absolute velocity profiles were obtained down to about 350 m depth. The original 5 minutes profiles have been averaged into ‘in stations’ profiles; 96 mean velocity profiles are thus available. Standard deviation of velocity mean profiles is of the order of 3 cm s<sup>-1</sup>.

#### References:

- Bahr, F., E. Firing and S. Jiang, Acoustic Doppler current profiling in the western Pacific during the US-PRC TOGA Cruises 5 and 6, *JIMAR Contr. 90-0228, U. of Hawaii*, 162 pp., 1990.
- Pollard, R. and J. Read, A method for calibrating shipmounted acoustic Doppler profilers, and the limitations of gyro compasses, *J. Atmos. Oceanic Technol.*, 6, 859-865, 1989.

#### B.4 L-ADCP measurements

(B. Bourlès, Y. Gouriou, R. Chuchla)

The Lowered Acoustic Doppler Current Profiler (L-ADCP) allows to provide absolute currents over the whole water column. The L-ADCP is a BroadBand 150 kHz RD Instruments unit. It was attached to the ‘rosette’, and two water bottles had to be removed from the ‘rosette’ frame for L-ADCP installation. The L-ADCP acquires velocity profiles during the down and up casts, simultaneously to the CTD-O<sub>2</sub> system. The CTD-O<sub>2</sub>/L-ADCP package was lowered and raised at about 1 m s<sup>-1</sup>, except during the up-cast when the package was stopped to fire the bottles. Standard setup parameters used were: one second sampling rate, one ping per ensemble, 19 bins per ensemble, 16 meter bins width, sea water salinity of 35 and sound velocity of 1500 m s<sup>-1</sup>. Thus, a velocity profile of about 300 m vertical extent is acquired every second. Each ensemble contains the precise time, internal sensor temperature, heading, pitch and roll angles, and vertical velocity of the rosette. Data of each bin contain the three velocity components in earth coordinates, velocity error estimate, backscattered energy and quality parameters (e.g., ‘percent good’). Data have been processed following the method described by *Fischer and Visbeck* (1993), and adapted by *Gouriou and Hémon* (1997). As the L-ADCP did not have pressure sensor, the depth of each cell was computed using the vertical velocity measurements. Then, all the individual profiles were combined in a unique velocity profile over the whole water. At depth, data of the bins perturbed by the bottom reflections were suppressed. The reference velocity was determined using the precise time and position at the beginning and at the end of the profile, generally known thanks to a Global Positioning System (GPS). Error due to this reference velocity determination is estimated to 1 cm s<sup>-1</sup> (*Fischer and Visbeck*, 1993). Here, due to GPS time transmission problems (see navigation chapter), we used the time of position recalculated from ‘true’ navigation information. However, the precision of the L-ADCP measurements is difficult to evaluate at this stage, except in the surface layers by comparison with Ship mounted Acoustic Doppler Current Profiler measurements, where maximum mean differences reach 5 cm s<sup>-1</sup>.

The L-ADCP perfectly worked during all the CTD-O<sub>2</sub> casts; hence, ninety-nine absolute velocity profiles were acquired during the Etambot-2 cruise.

#### References:

- Fischer, J., and M. Visbeck: Deep velocity profiling with self-contained ADCPs, *J. Atmos. Oceanic Technol.*, 10(5), 764-773, 1993.
- Gouriou, Y., and C. Hémon: Traitement des données L-ADCP, *Centre ORSTOM de Cayenne, documents scientifiques n° O.P. 21*, 56pp, 1997.

## **B.5 Thermosalinograph measurements**

(B. Bourlès)

Continuous underway measurements of surface salinity and temperature were made with a Seabird SBE-21 shipboard mounted thermosalinograph (TSG), calibrated one month before the cruise. Water samples were taken below the sea surface at the forward side of the vessel, and forwarded thanks to a pump to the thermosalinograph, located in the main acquisition laboratory. TSG measurements were acquired every 15 seconds. As the sampling hole was certainly too close to the surface, air bubbles contaminated water samples during vessel course, due to pitch and roll, when rough sea conditions occurred (mainly at the beginning of the cruise and off the Amazon mouth). There, raw measurements were noisy and exhibited numerous picks or erroneous values. In the same way, due to unpowerfull pumping, salinity linearly decreased on station, when vessel is stopped. Thus, a first visualization allowed to eliminate every erroneous or doubtful TSG measurement. A second step consisted to filter the measurements (temperature and salinity in a same processing), by using a median filter (Hénin and Grelet, 1996). We kept the median T/S values over a 15-minute time window, after discarding T/S values more than five standard deviations from the mean calculated over the window. Thus, TSG measurements have been filtered and averaged over 15 mn time intervals. However, a comparison with sample salinity measurements and CTD-O<sub>2</sub> temperature measurements is necessary before every quantitative use of these TSG data.

### **Reference:**

Hénin, C., and J. Grelet, A merchant ship thermo-salinograph network in the Pacific ocean, *Deep-Sea Res.*, 43, 11-12, 1833-1855, 1996.

## **B.6 XBTs**

## **B.7 Meteorological Measurements**

(B. Bourlès)

Meteorological measurements were recorded at the beginning of every CTD-O<sub>2</sub> station. These measurements are the following: date, time, position, wind speed ( $\text{m s}^{-1}$ ), wind direction (degrees from geographical north), sea level pressure (mbar), sea level temperature ( $^{\circ}\text{C}$ ), and relative humidity (%). Weather, clouds and sea level conditions have not been recorded.

## C. HYDROGRAPHIC MEASUREMENTS TECHNIQUES AND CALIBRATIONS

### C.1 Sample Salinity Measurements

(P. Fournier and C. Oudot)

Salinity analysis of samples collected during ETAMBOT 2 were carried out onboard with a Guildline™ Portasal™ salinometer model 8410, equipped with an OSI (Ocean Scientific International) peristaltic-type sample intake pump. The instrument was operated in the container-laboratory kept at a constant temperature of 23°C. The bath temperature of the salinometer was adjusted to 24°C. Standardization was effected by use of IAPSO Standard Seawater batch P123 ( $K_{15} = 0.99994$ ).

Every day, the standardization was adjusted before one run of analysis and the standardization drift was checked every two stations (44 samples). The drift was very low : on the average it was  $- 0.00002 \pm .00045$  psu.

Quality control of the salinity data were performed using repeated measurements from replicate samples (all bottles fired at the same depth, twice) and duplicate samples (two different bottles fired at the same depth, seventy-four times). The standard deviations of the two groups of replicate samples are given in the Table 3 below.

**TABLE 3:** Salinity replicate statistics

Station number	42	72
Pressure (dbar)	2020	2500
Number of bottles	22	22
Mean salinity (psu)	34.9772	34.9504
Maximum deviation (psu)	.0013	0.0012
Standard deviation	.0005	.0005

The standard deviation of the seventy-four sample pairs (duplicate), taken at different depths, is 0.0010 psu.

### C.2 Sample Oxygen Measurements

(P. Fournier and C. Oudot)

#### Sampling and techniques

Oxygen samples were taken in calibrated clear glass bottles (capacity = 120 cm<sup>3</sup>) immediately after the drawing of samples for CFCs. The temperature of the water at the time of sampling was measured to allow the conversion of the concentration unit per volume into per mass. The fixing of the dissolved oxygen is immediately performed with reagents before the closure of the glass bottle, according to the method recommended in the WOCE Operations Manual (Culberson, 1991). The samples were stored in the container-laboratory (controlled temperature of  $22 \pm 1^\circ\text{C}$ ) where analyses were carried out, according to the Winkler whole bottle method.

All volumes of glassware to collect samples and to dispense solutions were calibrated by weight and corrections were made for changes in volume with temperature.

The end-point was determined by automatic potentiometric method with a Metrohm™ Titrator™ model 682 and a Dosimat™ 665 burette (10 cm<sup>3</sup>).

The concentration of oxygen dissolved in seawater was converted to mass fraction by use of the following relationship :

$$\text{O}_2 [\mu\text{mol kg}^{-1}] = (44.660 / r_{\text{sw}}) * \text{O}_2 [\text{cm}^3 \text{dm}^{-3}]$$

where  $r_{\text{sw}}$  is the density of the seawater corresponding to the temperature at the sampling time (Millero and Poisson, 1981).

### Reproducibility of measurements

The precision of measurements was estimated from analysis of four groups of replicate (taken from different bottles fired at the same depth) samples and a large number (seventy-nine) of duplicate (two bottles fired at the same depth, changing from one station to the other) samples during successive stations. Table 4 gives the statistics of replicates.

**TABLE 4:** Oxygen replicate statistics

Station number	32	42	72	87
Pressure (dbar)	1030	2020	2500	1000
Number of bottles	22	22	22	22
Mean O <sub>2</sub> concentration (μmol kg <sup>-1</sup> )	152.0	255.1	259.0	153.1
Maximum deviation (μmol kg <sup>-1</sup> )	0.7	0.6	0.3	1.7
Standard deviation (μmol kg <sup>-1</sup> )	0.7	0.2	0.4	0.6

The standard deviation of the seventy-nine sample pairs (duplicate) is 0.5 μmol kg<sup>-1</sup>, *i.e* a value not significantly different from reproducibility of replicates.

### Comparisons with historical data

Comparisons of ETAMBOT 1 data with historical data (SAVE Leg 6, 1989 and TTO-TAS, 1983) are shown in [Figure 2](#). The right insets exhibit the deepest levels. Excepted differences in the upper layers resulting from changes in water masses in the region, principally in bottom panel (TTO-TAS) where the latitude range is wider, the agreement is satisfactory.

### References

- Culberson C.H., 1991. Dissolved oxygen in the WOCE Operations Manual. Vol. 3, Part 3.1.3: WHP Operations and Methods. *WHP Office Report WHPO 91-1*, WOCE Report N° 68/91.
- Millero F. J. and A. Poisson, 1981. International one-atmosphere equation of state of Sea Water. *Deep Sea Res.*, 28, 625-629.

### C.3 Nutrients

(F. Baurand and C. Oudot)

#### Equipment and techniques

Nutrient analyses were performed on a Braun & Luebbe<sup>TM</sup> AutoAnalyzer<sup>TM</sup>II type Technicon<sup>TM</sup> (continuous flow analyzer), according to classical methods (Murphy and Riley, 1955 for silicate – Murphy and Riley, 1962 for phosphate – Wood *et al.*, 1967 for nitrate and nitrite) as described in the Manual of Treguer and Le Corre (1975). Colorimeter signals were processed with an IBM computer using a home-made software (Lechauve *et al.*, 1992).

Sampling for nutrient analysis followed those for gases (freons, oxygen, CO<sub>2</sub> fugacity, total CO<sub>2</sub> and pH) and were carried out in Nalgene bottle (125 cm<sup>3</sup>). Samples were stored until analysis (the maximum delay is six hours) in the container-laboratory controlled in temperature (22°C). The Nalgene bottles were put on the special sample tray of the AutoAnalyzer in such a way as the samples were directly taken from the sampling bottles without transfer via traditional polystyrene cups.

#### Calibration and standards

Volumes of glassware (volumetric flasks and Metrohm<sup>TM</sup> automatic burette model Dosimate<sup>TM</sup> 665) to prepare standards were checked by weight in the shore-laboratory, at a temperature near that in the container-laboratory (22°C).

Nutrient primary standards were prepared from salts (Baker<sup>TM</sup>, anal. grade., certified 99.99 %, for phosphate, nitrate and nitrite ; Carlo Erba<sup>TM</sup>, high purity for silicate) dried at 105°C for two hours. Four primary standards were prepared ashore prior the cruise by dissolving :

- 0.85056 g of potassium dihydrogenophosphate in 1 liter of ultrapure water
- 12.63875 g of potassium nitrate in 1 liter of ultrapure water
- 8.62500 g of sodium nitrite in 1 liter of ultrapure water
- 2.35075 g sodium silica fluoride in 5 liters of ultrapure water

No buoyancy correction were applied to the nominal weights. The ultrapure water was deionized water with a resistivity of 18 MΩ. The primary standard solutions were preserved with chloroform (2 ml per liter).

A mixed secondary standard for phosphate + nitrate and a single secondary standard for nitrite were prepared weekly by dilution with deionized water. Seven working standards were prepared every day in artificial water. Concentrations (μmol l<sup>-1</sup>) were : 0, 10, 20, 40, 60, 90, 120 for silicate ; 0, 0.25, 0.50, 1.00, 1.50, 2.50, 3.00 for phosphate ; 0, 5, 10, 20, 30, 40 for nitrate ; 0, 0.50, 1.00, 1.50, 2.00 for nitrite. The artificial seawater was a 40 ‰ solution of analytical grade sodium chloride.

The linearity of the calibration curve (Beer's Law) was not valid beyond 20 μmol l<sup>-1</sup> for silicate and nitrate. So, a polynomial (cubic) relationship was chosen for those nutrients.

#### Quality control

The precision of measurements was estimated from analysis of four groups of replicate (taken from different bottles fired at the same depth, during four test stations) samples and a large number (seventy-four) of duplicate (two bottles fired at the same depth, changing from one station to the other) samples during successive stations. [Table 5](#) gives the statistics of replicates. The percent standard deviations (vs.

full range) are 0.3 % for silicate, 0.4 % for phosphate and 0.2 % for nitrate, in agreement with WHP recommendations (WOCE, 1994).

**TABLE 5:** Nutrient replicate statistics

<b>Silicate</b>				
Station number	32	42	72	87
Pressure (dbar)	1000	2000	2500	1000
Number of bottles	22	22	22	22
Mean silicate concentration ( $\mu\text{mol kg}^{-1}$ )	27.32	18.85	23.28	27.19
Standard deviation ( $\mu\text{mol kg}^{-1}$ )	0.13	0.07	0.08	0.35
Percent standard deviation	0.48	0.39	0.35	1.27
Percent standard deviation (vs full range, $120 \mu\text{mol kg}^{-1}$ )	0.11	0.06	0.07	0.29
<b>Phosphate</b>				
Station number	32	42	72	87
Pressure (dbar)	1000	2000	2500	1000
Number of bottles	22	22	22	22
Mean phosphate concentration ( $\mu\text{mol kg}^{-1}$ )	2.09	1.22	1.23	2.08
Standard deviation ( $\mu\text{mol kg}^{-1}$ )	0.01	0.01	0.02	0.01
Percent standard deviation	0.60	0.83	0.38	0.47
Percent standard deviation (vs full range, $3 \mu\text{mol kg}^{-1}$ )	0.42	0.33	0.15	0.33
<b>Nitrate</b>				
Station number	32	72	87	
Pressure (dbar)	1000	2500	997	
Number of bottles	22	22	22	
Mean nitrate concentration ( $\mu\text{mol kg}^{-1}$ )	31.10	19.00	31.45	
Standard deviation ( $\mu\text{mol kg}^{-1}$ )	0.08	0.03	0.05	
Percent standard deviation	0.27	0.17	0.15	
Percent standard deviation (vs full range, $40 \mu\text{mol kg}^{-1}$ )	0.21	0.08	0.12	

The standard deviation of the seventy-four sample pairs (duplicate) is  $0.4 \mu\text{mol kg}^{-1}$  for silicate,  $0.02 \mu\text{mol kg}^{-1}$  for phosphate and  $0.1 \mu\text{mol kg}^{-1}$  for nitrate.

The consistency of phosphate and nitrate data is shown in [Figure 3](#) by the strong correlation between these two nutrients ( $R^2 = 0.9935$ ). The slope of the regression line (15.092) is in good agreement with the Redfield ratio.

## Comparisons with historical data

Comparisons of ETAMBOT 1 data with historical data (SAVE Leg 6, 1989 and TTO-TAS, 1983) are shown in [Figure 4](#). The right insets exhibit the deepest levels. Excepted differences in the upper layers resulting from changes in water masses in the region, principally in bottom panel (TTO-TAS) where the latitude range is wider, the agreement is satisfactory.

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## C.4 CFC-11, CFC-12

(C.Andrié)

### Work on board

During the cruise, three people had in charge sampling and analysis of water samples for CFC measurements.

Sea water samples were directly taken from Niskin bottles using syringes with metallic stopcocks. Samples from the whole water column have been taken. This corresponds to at least 22 samples per profile. 28 samples have been taken for stations with double casts with bottom depth greater than 4500 m (stations 22 to 26, 28 to 35, 51 to 57 and 79 to 85).

Atmospheric measurements have been realized every two days, from syringe samples. Globally, 3725 analyses have been realized, including standards and atmospheric analyses.

The usual precautions have been taken before and during the boarding: Niskin bottles cleaned and stored in a ventilated area in Cayenne before the cruise and then Decon washed on board, bottles rings heated (60°C) and degased in an oven just before the first station.

Important CFC links have perturbed the first analyses on board. The analytical system has been moved in another laboratory, without air conditioning. Finally, measurements were satisfactory, excepted during station 32 where a high F-12 blank made impossible good measurements.

## Analyses and data validation

The gas chromatographic method with electron capture detection is described in Bullister and Weiss (1988), with some minor modifications. The gas vector is ultrapure nitrogen. Validation has been done, for each station, from vertical F11 and F12 profiles and F11/F12 diagrams. Seven F12 data have been rejected (all F11 data have been kept).

The atmospheric secondary standard has been calibrated against a SIO primary standard during four times during the cruise. CFC concentrations are reported in the SIO 1986 scale. For the whole cruise, the reproducibility for the standard content was  $\pm 0.4 \%$  for F12 and  $\pm 0.4 \%$  for F11, so better than for ETAMBOT1.

The atmospheric mixing ratios were 524.5 ppt ( $\pm 1.1 \%$ ) for F12 and 267.1 ppt ( $\pm 1.2 \%$ ) for F11 so in the same order of magnitude than during ETAMBOT1.

Calibration has been done using a 6 levels  $x^2$  curve.

## Analytical performances

The detection limit of the method is obtained during test-stations where all the bottles have been closed at the same level, corresponding to a near-zero CFC content. Differently from CITHER 1, there is not true CFC-free waters in the ETAMBOT area. Our mean contamination level has been determined through a statistical method of the test-stations, the CFC content evolution at 1000 m depth (low-CFC Upper Circumpolar Water) and a comparison with CITHER1 results.

The detection limit determined through the standard deviation over the test-stations at 1000 m (stations 32 and 87) is around  $0.005 \text{ pmol.kg}^{-1}$  for F12 and  $0.008 \text{ pmol.kg}^{-1}$  for F11.

We have examined the evolution of the F11/F12 ratio at the 1000m level in order to separate the part of bottles contamination to the part of the sampled water. Two groups of stations are identified : the mean contamination levels are  $0.003 \text{ pmol.kg}^{-1}$  for F12 and  $0.025 \text{ pmol.kg}^{-1}$  for F11.

These contamination levels have been systematically removed from the CFC values.

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## C.5 Samples Taken for Other Chemical Measurements

### CO<sub>2</sub> system parameters

(J.F. Ternon and C. Oudot)

### Total inorganic carbon (TCO<sub>2</sub>)

Measurements of TCO<sub>2</sub> were made by gas chromatography, according to the method described by Oudot and Wauthy (1978). The method basically consists of gas stripping of the seawater sample (1 cm<sup>3</sup>) after acidification, and of the gas chromatographic analysis of the gas mixture allowing the TCO<sub>2</sub> separation and quantification. Routine calibration of the measurements was performed using liquid standard solutions prepared at the laboratory prior the cruise, according to a procedure adapted from the Goyet and Hacker

(1992) technique. Primary calibration is done by using the Certified Reference Material delivered by A.G. Dickson (Scripps Institution of Oceanography).

Samples were taken from the surface to bottom, every two stations.

Quality control of TCO<sub>2</sub> data has been performed using repeated measurements (duplicate) at each station (two bottles fired at the same depth ; different depth at each station), and "test" stations (all of the bottles closed at the same depth). Results for test stations are shown in Table 6.

**TABLE 6** : TCO<sub>2</sub> replicate statistics

Station number	32	42	72	87
Depth (dbar)	1000	2000	2500	1000
Number of bottles	21	22	17	22
TCO <sub>2</sub> (μmol kg <sup>-1</sup> )	2202.3	2215.9	2225.4	2201.6
Standard deviation (μmol kg <sup>-1</sup> )	9.1	14.2	7.7	6.1

Repeatability of TCO<sub>2</sub> measurements was determined from statistical analysis of duplicate results, according to the relationship (Dickson and Goyet, 1994) :

$$S = (Sd_i^2 / 2n)^{1/2}$$

where d<sub>i</sub> = difference for pair *i* and n = number of pairs (76). For Etambot 2 cruise S = 9.7 μmol kg<sup>-1</sup>.

## pH

The pH measurements were performed according to the potentiometric method on the total hydrogen ion concentration pH scale (Dickson (1993). The total hydrogen ion concentration, [H<sup>+</sup>], is expressed as moles per kilogram of sea water.

Measurements were made using a combination glass/reference electrode ORION™ type ROSS™ and a pHmeter ORION™ model 720A (resolution = 0.1 mv, i.e. 0.0017 pH units). The Nernst response of the electrode was checked in the shore-based laboratory before and after the cruise with two buffers : ‘Tris’ and ‘2-aminopyridine’. The pH electrode was calibrated against the ‘Tris’ buffer before every serial of measurements (every station), and the drift was estimated during each station (22 samples) for correction. The mean drift during a station, throughout the cruise, was 0.1-0.2 mV, i.e. 0.002-0.003 pH units. Seawater samples and buffers were thermostated at 25°C and the temperature was measured with a platine probe (± 0.01°C).

Then, pH data were corrected to *in situ* conditions (temperature and pressure) according to the relationships of Millero (1995) for temperature and Millero (1979) for pressure.

Samples were taken from the surface to bottom, every two stations.

Quality control of pH data has been performed using repeated measurements (duplicate) at each station (two bottles fired at the same depth ; different depth at each station), and "test" stations (all of the bottles closed at the same depth). Results for test stations are shown in [Table 7](#).

**TABLE 7:** pH replicate statistics

Station number	32	42	72	87
Depth (dbar)	1000	2000	2500	1000
Number of bottles	21	21	22	21
pH	7.880	8.014	8.008	7.881
Standard deviation	0.003	0.003	0.002	0.005

Repeatability of pH measurements was determined from statistical analysis of duplicate results, according to the relationship (Dickson and Goyet, 1994) :

$$S = (Sd_i^2 / 2n)^{1/2}$$

with  $d_i$  = difference for pair  $i$  and  $n$  = number of pairs (76). For Etambot 2 cruise  $S = 0.003$  pH units.

### Total alkalinity

Total alkalinity,  $A_T$ , is defined as the number of moles of hydrogen ion equivalent to the excess of following bases formed from weak acids in one kilogram of sample :

$$A_T = [\text{HCO}_3^-] + 2 [\text{CO}_3^{2-}] + [\text{B}(\text{OH})_4^-] + [\text{OH}^-] - [\text{H}^+]$$

$A_T$ , expressed in  $\mu\text{eq kg}^{-1}$ , was estimated as the sum of the components of the right member of the previous relationship, calculated from  $\text{TCO}_2$  and pH measurements. The used equilibrium equations and thermodynamic data for carbonic acid, boric acid and water are identical to those reported in Dickson and Goyet (1994).

Samples were taken from the surface to bottom, every two stations.

Quality control of  $A_T$  data has been performed using repeated measurements (duplicate) at each station (two bottles fired at the same depth ; different depth at each station), and "test" stations (all of the bottles closed at the same depth). Results for test stations are shown in Table 8.

**TABLE 8:**  $A_T$  replicate statistics

Station number	32	42	72	87
Depth (dbar)	1000	2000	2500	1000
Number of bottles	21	21	17	21
$A_T$ ( $\mu\text{eq l kg}^{-1}$ )	2308.7	2280.4	2397.2	2309.9
Standard deviation ( $\mu\text{eq kg}^{-1}$ )	9.4	15.0	8.3	6.8

Repeatability of  $A_T$  measurements was determined from statistical analysis of duplicate results, according to the relationship (Dickson and Goyet, 1994) :

$$S = (Sd_i^2 / 2n)^{1/2}$$

with  $d_i$  = difference for pair  $i$  and  $n$  = number of pairs (76). For Etambot 2 cruise  $S = 10.8 \mu\text{eq kg}^{-1}$ .

## CO<sub>2</sub> fugacity

The fugacity of CO<sub>2</sub> in seawater was determined in air that was in equilibrium with a discrete sample of seawater. The fugacity,  $f\text{CO}_2$ , is related to the partial pressure,  $p\text{CO}_2$ , by the relation (Weiss, 1974) to take into account the non-ideality of CO<sub>2</sub> :

$$f\text{CO}_2 = p\text{CO}_2 \exp\{(B + 2\delta) p_{\text{atm}} / RT\}$$

The partial pressure of CO<sub>2</sub> in wet air is calculated from the molar fraction of CO<sub>2</sub> in dry air,  $x\text{CO}_2$ , the atmospheric pressure,  $P$ , and the H<sub>2</sub>O vapor pressure,  $p_{\text{H}_2\text{O}}$  (Weiss and Price, 1980) :

$$p\text{CO}_2 = x\text{CO}_2 p = x\text{CO}_2 (P - p_{\text{H}_2\text{O}})$$

The molar fraction of CO<sub>2</sub> in equilibrated air was measured with an IR analyzer LI-COR™ model LI6262 . The analyzer was calibrated with three standard gases (329.0 – 360.5 – 407.7 ppm), produced by a French manufacturer, Air Liquide, in agreement with the scale of the Scripps standards.

During the cruise, duplicate seawater samples were taken from only the surface bottle of the General Oceanics rosette and analyzed as described in Oudot *et al.* (1995). Besides, the measurement of atmospheric CO<sub>2</sub> concentration was made twice a day by pumping an air stream taken at a mast at the bow of the vessel.

Then, the CO<sub>2</sub> fugacity measured at 28°C was corrected for in situ temperature according to the temperature dependence equation of Copin-Montégut (1989).

The reproducibility of  $f\text{CO}_2$  measurements was determined from statistical analysis of 86 pairs of duplicate results, according to the relationship (Dickson and Goyet, 1994) :

$$S = (Sd_i^2 / 2n)^{1/2}$$

where  $d_i$  = difference for pair  $i$  and  $n$  = number of pairs (86). For Etambot 2 cruise  $S = 2.2 \mu\text{atm}$ .

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## C.6 CTD Measurements

The following equipment was deployed on the CTD/multisampler underwater frame:

1. Neil Brown Mark IIIa with a polarographic Beckman sensor
2. General Oceanics 8-liter 24 bottle rosette.
3. 6 SIS digital reversing thermometers and 6 SIS digital reversing pressure meters.
4. MORS 12 kHz pinger
5. A bottom proximity alarm
6. L-ADCP 150kHz RDI. 2 bottles have been removed.

CTD data were acquired through an EG&G demodulator, with the OCEANSOFT 1 software. Data were stored on a PC. Raw analogic data were stored on DAT system.

The rosette was not equipped with the non data interrupt rosette firing module.

We had no problems with the rosette and the bottles were fired at the desired depths.

## C.7 CTD Data Collection and Processing

Two CTD-O2 Neil Brown Mark IIIa probes have been used during the cruise.

The N°2756 probe has been used for stations N°1 to N°9. Due to a failure of the fast temperature sensor at station N°9, the N°2782 probe has been used from station N°10 to station N°64. For these stations, the oxygen sensor worked only for a few stations. The N°2756 probe has been repaired at the Natal (Brazil) port of call and used for stations N°65 to N°95. Due to a too weak power supply, conductivity and oxygen profiles of stations N°10 to N°13 are noisy. The problem was solved at station N°14.

### Temperature Calibration

The temperature sensors of the two CTD probes were calibrated before and after the cruise.

The N°2756 probe has been calibrated on December 15, 1995, and on October 30, 1996.

The N°2782 probe has been calibrated on December 6, 1995, and on October 1, 1996.

The temperature sensors have been controlled for the following temperature : 0°C, 5°C, 10°C, 15°C, 20°C, 25°C, 30°C.

### Probe N°2756

The calibration results for the N°2756 are presented on [figure 5a](#). Between the pre- and post-calibration the temperature sensor presents a drift of :

- 0.006°C in average
- 0,008°C at a temperature of 0°C (maximum)
- 0.000°C at a temperature of 10°C (minimum).

We considered that the incertitude on the temperature measurements is of  $\pm 0.003^\circ\text{C}$ .

The solid line represents the 5<sup>th</sup> order polynomial adjustment applied to the CTD temperature measurements.

### Probe N°2782

The calibration results for the N°2782 probe are presented on [figure 5b](#). Between the pre- and post-calibration the temperature sensor presents a drift of :

- 0.002°C in average
- 0.005°C at a temperature of 5°C (maximum)
- 0.000°C at a temperature of 10°C (minimum).

We considered that the incertitude on the temperature measurements is of  $\pm 0.001^\circ\text{C}$ .

The solid line represents the 5<sup>th</sup> order polynomial adjustment applied to the CTD temperature measurements.

The CTD temperature has been compared to SIS reversing thermometer measurements. The SIS thermometers have been calibrated before and after the cruise, at the same dates than the CTD temperature sensor. The [figures 6](#) show the temperature difference between the SIS and CTD measurements. The SIS and CTD temperature data have been calibrated before the comparison. The [figures 6](#) show that there is a bias between the two types of measurements: a bias of  $+0.017^\circ\text{C}$  for the N°T\_216 thermometer and  $+0.007^\circ\text{C}$  for the N°T\_707 thermometer. The laboratory calibrations point out an important drift at the 0°C temperature reference ( $+0.025^\circ\text{C}$  for the N°T-216 thermometer and  $+0.015^\circ\text{C}$  for the T\_707 thermometer) for the SIS thermometers. The observed bias was constant during the whole cruise, and does not depend on the probe we used. We are thus confident in the probe measurements and we attributed the observed bias to the SIS thermometer measurements.

## **Pressure Calibration**

The pressure sensor of the CTD was calibrated before and after the cruise.

The N°2756 probe has been calibrated on December 15, 1995, and on October 30, 1996.

The N°2782 probe has been calibrated on December 6, 1995, and on October 1, 1996.

In order to estimate the hysteresis of the pressure sensor, laboratory calibration have been performed:

- 1 – for increasing pressure (down casts)
- 2 – for decreasing pressure (up casts)

### Probe N°2756 ([Figure 7](#))

The pressure sensor did not drift a lot during the 6-months interval (less than 2 dbar) and the difference between the pre-calibration and post-calibration is constant at every depth ([Figure 7](#)). We fitted the results of the calibration with a 5 order polynomial curve.

The CTD down-cast pressure measurements are calibrated by using the coefficients obtained in the laboratory for increasing pressure, at a temperature of 20°C. For the up casts we used the calibration

coefficients obtained in the laboratory for decreasing pressure, at a temperature of 15°C. This was an arbitrary choice, as we had no means to know the temperature of the pressure CTD sensor. The use of two different reference temperatures, for the up- and down-cast calibration, induced different pressure values at 6000 m (Figure 7). The discrepancy is negligible at 5000 m, the maximum depth of the measurements.

#### Probe N°2782 (Figure 8)

The calibration coefficient of the N°2782 probe have been computed by A.Billant of the Laboratoire d'Océanographie Physique of the IFREMER center in Brest.

For the shallow casts (depth < 500 m) we used only the calibration coefficients obtained for increasing pressure, estimating that the hysteresis is negligible.

The pressure measured by the CTD can be compared to the SIS digital reversing pressure meters. The SIS have been calibrated in the laboratory before and after the cruise at the same date than the CTD pressure sensor. The calibration has been made at a temperature of 2°C close to the temperature at which they were used. The figure 9 present the pressure difference between the SIS and CTD measurements after calibration. The comparisons show that the SIS corrected pressure and CTD corrected pressure are equal with an incertitude of 5 dbar.

### **Salinity Calibration**

The calibration of the CTD conductivity sensor is made by comparing the CTD conductivity measurements, at the depth where the bottles are closed, to the in-situ conductivity of the water samples. The CTD conductivity measurements are corrected from the temperature and pressure effect on the conductivity cell. The CTD conductivity measurements are calibrated using a linear regression. The polynomial coefficients are computed iteratively.

#### **IMPORTANT**

The rosette was not equipped with a non-data interrupt rosette firing module. Due to this deficiency, the conductivity measurements were perturbed during the up-cast profile. We judged the perturbation sufficiently important to modify the normal calibration procedure: to find the calibration coefficients, we compared the water sample conductivity to the CTD conductivity measurements of the DOWN-cast instead of the UP-cast. We used the pressure of the up-cast water sample to find the CTD conductivity in the down-cast profile. This method is similar to that used for the calibration of the oxygen sensor. That procedure gave correct results, but has the disadvantage of eliminating an important number of water samples between the surface and 1500 dbar.

#### **CALIBRATION**

Note that:

- the CTD n°2756 has been used for stations N°1 to N°9 and for stations N°65 to N°95
- CTD conductivity are unusable below 2580 dbar for the station N°8.
- CTD conductivity are unusable below 1500 dbar for the station N°9.
- CTD conductivity profiles of station N°10, N°11, N°12, N°13 are unusable.
- The CTD conductivity sensor has been cleaned before stations N°20, N°36, n°49, n°65, n°80.
- The stations made in shallow water (bottom < 1500 m) are : N°1, N°2, N°3, N°4, N°5, N°63, N°64, N°65, N°66, N°94, N°95.

**TABLE 9:** Calibration coefficient for the CTD conductivity sensor

Stations	Number of used samples	Number of Retained samples	Standard deviation (0 – 6000 m)	Coefficients	
				C1	C2
1 ->7	75	59	0.0085	1.000496	-0.02704
8	19	19	0.0121	1.000926	-0.03716
14 -> 19	129	94	0.0023	0.999995	-0.00495
20	22	20	0.0037	0.999848	-0.00924
21 -> 22	56	51	0.0028	0.999738	-0.00472
23	28	23	0.0014	0.999909	-0.01206
24	28	26	0.0052	0.999938	-0.01093
25 -> 27	78	59	0.0024	0.999903	-0.01145
28 -> 29	56	38	0.0014	0.999920	-0.00792
30	28	24	0.0038	0.999940	-0.01248
31	22	21	0.0044	1.000356	-0.02149
33	27	26	0.0023	0.999975	-0.01149
34	28	26	0.0037	0.999534	0.00674
35 -> 37	70	57	0.0040	0.999981	-0.01047
38 -> 44	128	94	0.0022	0.999910	-0.01056
45 -> 46	44	38	0.0045	0.999969	-0.01034
47 -> 48	44	36	0.0032	0.999912	-0.01009
49 -> 56	216	178	0.0023	0.999624	-0.01279
57 -> 64	153	114	0.0029	0.999248	0.01352
65 -> 71	118	86	0.0026	1.004005	-0.01560
73 -> 77	108	81	0.0019	0.999951	-0.01345
78 -> 94	355	266	0.0022	0.999925	-0.01986

2043 water samples have been taken out during the cruise. Eliminating the samples of the test stations N°32, N°42, N°72, and N°87, of stations N°9, N°10, N°11, N°12, and N°13 as well as the bad measurements, we retained 1832 water samples for the calibration. 1436 comparisons have been retained by the minimization process (78.2% of the measurements).

The [figure 10](#) shows the resulting conductivity difference after the calibration procedure.

The difference is lower than  $0.001 \text{ mmho cm}^{-1}$  for 17% of the samples.

The difference is lower than  $0.003 \text{ mmho cm}^{-1}$  for 50% of the samples.

## CONTROL

To control the quality of the calibration,  $\theta$ -S diagrams have been compared:

1. Between successive stations of the cruise.
2. Between stations made at the same position during the cruise (N°26 and N°84).
3. Between different cruises.

1.  $\theta$ -S diagrams of consecutive stations made during the cruise have been systematically compared. The differences ( $\geq 0.0005$ ), for potential temperature lower than  $1.9^\circ\text{C}$ , have been systematically reported

in the following table. The difference is positive when the station in the first column has a salinity greater than the station in the second column.

**TABLE 10:** Salinity comparison between contiguous profiles of the ETAMBOT 2 cruise

ETAMBOT 2 Station Number	ETAMBOT 2 Station Number	Salinity Difference
14	15	<b>0.0020</b>
15	16	<b>-0.0020</b>
16	17	0.0015
17	18	-0.0010
20	21	0.0015
34	35	0.0010
47	48	<b>-0.0020</b>
48	49	<b>0.0020</b>
57	58	-0.0010
58	59	<b>0.0020</b>
73	74	<b>-0.0020</b>
75	76	0.0010

The comparison is satisfactory. Only 8 comparisons show a difference greater than 0.0010. No correction have been made to these salinity profiles.

2. During the ETAMBOT 2 cruise, 9 stations have been made at the same geographical position, but only the stations N°26 and N°84 (41°20'W-7°30'N) are sufficiently deep to allow a meaningful comparison. The comparison is reported on [Figure 11](#). On the  $\theta$ -S diagrams the salinity difference, for a given temperature, does not exceed 0.0010, below the potential temperature 1.9°C.
3. The ETAMBOT 2 cruise exactly repeats the cruise track of the ETAMBOT 1 cruise and the western part of the CITHER 1 cruise (WHP A6 and A7 lines).

Omitting the shallow stations, 80  $\theta$ -S diagrams of the ETAMBOT 1 and ETAMBOT 2 cruises have been compared. The differences, for potential temperature lower than 1.9°C, have been systematically reported in the following [table](#). The difference is positive when the station in the first column has a salinity greater than the station in the second column.

**TABLE 11:** Salinity comparison between ETAMBOT 1 and ETAMBOT 2 profiles

ETAMBOT 2 Station Number	ETAMBOT 1 Station Number	Salinity difference
15	15	<b>-0.0020</b>
20	20	0.0010
24	24	-0.0010
33	33	0.0010
36	36	0.0010
43	42	<b>-0.0020</b>
49	48	-0.0010
51	50	0.0010
69	68	<b>0.0020</b>
73	71	0.0010
74	72	<b>0.0020</b>
75	73	0.0010
86	84	<b>-0.0020</b>

Likewise 40  $\theta$ -S diagrams of the ETAMBOT 2 and CITHER 1 cruise have been compared. The salinity differences are reported in the following table.

**TABLE 12:** Salinity comparison between ETAMBOT 2 and CITHER 1 profiles

ETAMBOT 2 Station Number	CITHER 1 Station Number	Salinity difference
15	133	<b>-0.0030</b>
19	137	-0.0010
20	138	0.0010
33	151	<b>0.0020</b>
34	153	0.0010
43	114	-0.0010
48	110	0.0010
52	106	0.0010

The difference observed at the ETAMBOT 2 station N°15 has not been corrected.

### Oxygen Calibration

CTD oxygen were calibrated by fitting to sample values using the method described in *Owens and Millard [1985]*<sup>1</sup>.

During the cruise the oxygen sensor worked for stations N°14 to N°22, N°29 to N°36 using the N°2782 probe, and for stations N°1 to N°8, N°65 to N°95 using the N°2756 probe. Furthermore several oxygen profiles are noisy. **All these profiles have been calibrated but they must be used with cautious.**

<sup>1</sup> Owens, W.B., and R.C. Millard, A new algorithm for CTD oxygen calibration, *J.Phys. Oceanogr.*, 15, 621-631, 1985.

1041 samples have been used to calibrate the data. 966 samples (92.7%) have been retained during the fitting process. The following Table shows the results of the calibration :

**TABLE 13:** Calibration results for the oxygen sensor

Station Number	Number of used samples	Number of retained samples	Standard deviation (0 – 5000 m) $\mu\text{mol kg}^{-1}$
1 -> 8	94	92	3.0
14 -> 22	20	181	1.5
29	28	28	2.9
30	28	28	2.8
31	22	22	1.6
33	28	26	0.8
34	28	27	1.6
36	22	20	1.9
65 -> 71	118	111	1.6
73 -> 86	347	322	1.8
88 -> 94	119	109	1.5

The [figures 12](#) show the differences, in  $\mu\text{mol kg}^{-1}$ , between the oxygen samples and the down-cast CTD measurements.

The difference is lower than  $1 \mu\text{mol kg}^{-1}$  for 27% of the samples .

The difference is lower than  $2 \mu\text{mol kg}^{-1}$  for 65% of the samples .

#### CONTROL

As for the salinity profiles, the comparison with the oxygen profiles of the ETAMBOT 1 have been made.

**TABLE 14:** Oxygen comparison between ETAMBOT 1 and ETAMBOT 2 profiles

N° de station ETAMBOT 2	N° de station ETAMBOT 1	Oxygen difference $\mu\text{mol kg}^{-1}$
14	14	-2.0
19	19	-1.0
20	20	-1.0
30	31	-1.0
73	71	-1.0
80	78	-1.0

#### NOTE

The CTD oxygen profiles have not been de-spiked. Some profiles show important spikes in the upper thermocline.

The CTD oxygen profiles have not been filtered.

## Acknowledgements

This project has been supported by ORSTOM as part of the Programme National d'Etude de la Dynamique du Climat, and its WOCE/France subprogramme.

## Figure Captions

Figure 1: Cruise track and station position.

Figure 2: Oxygen versus salinity for ETAMBOT 2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S], and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

Figure 3: Nitrate – phosphate correlation for ETAMBOT 2 cruise data.

Figure 4: Silicate versus temperature for ETAMBOT 2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S] and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

Figure 5: Temperature difference, in °C, between the laboratory reference temperature and the temperature measured by the probe. The solid represent the 5<sup>th</sup> order polynomial minimizing the differences.

- a) calibration results for the N°2756 CTD probe
- b) calibration results for the N°2782 CTD probe

Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

Figure 7: Pressure difference, in dbar, between the laboratory reference pressure and the pressure measured by the N°2756 probe. The solid represent the 5<sup>th</sup> order polynomial minimizing the differences.

- a) calibration for increasing pressure at a 20°C temperature (down cast).
- b) calibration for decreasing pressure at a 15°C temperature (up cast).

Figure 8: Calibration curve for the pressure sensor of the N°2782 CTD probe

- a) calibration for increasing pressure (down cast).
- b) calibration for decreasing pressure (up cast).

Figure 9: Pressure difference, in dbar, between SIS and CTD measurements (after calibration).

Figure 10: Conductivity difference, in mmho/cm, between water sample and CTD measurements, after calibration.

- a) difference as a function of station number.
- b) difference as a function of pressure.

Figure 11:  $\theta$ -S diagram of repeated ETAMBOT 2 stations N°26 and N°84 (41°40'W-7°30'N).

Figure 12: Dissolved oxygen difference, in  $\mu$  mol kg<sup>-1</sup>, between water sample and CTD measurements.

- a) difference as a function of station number.
- b) difference as a function of pressure.

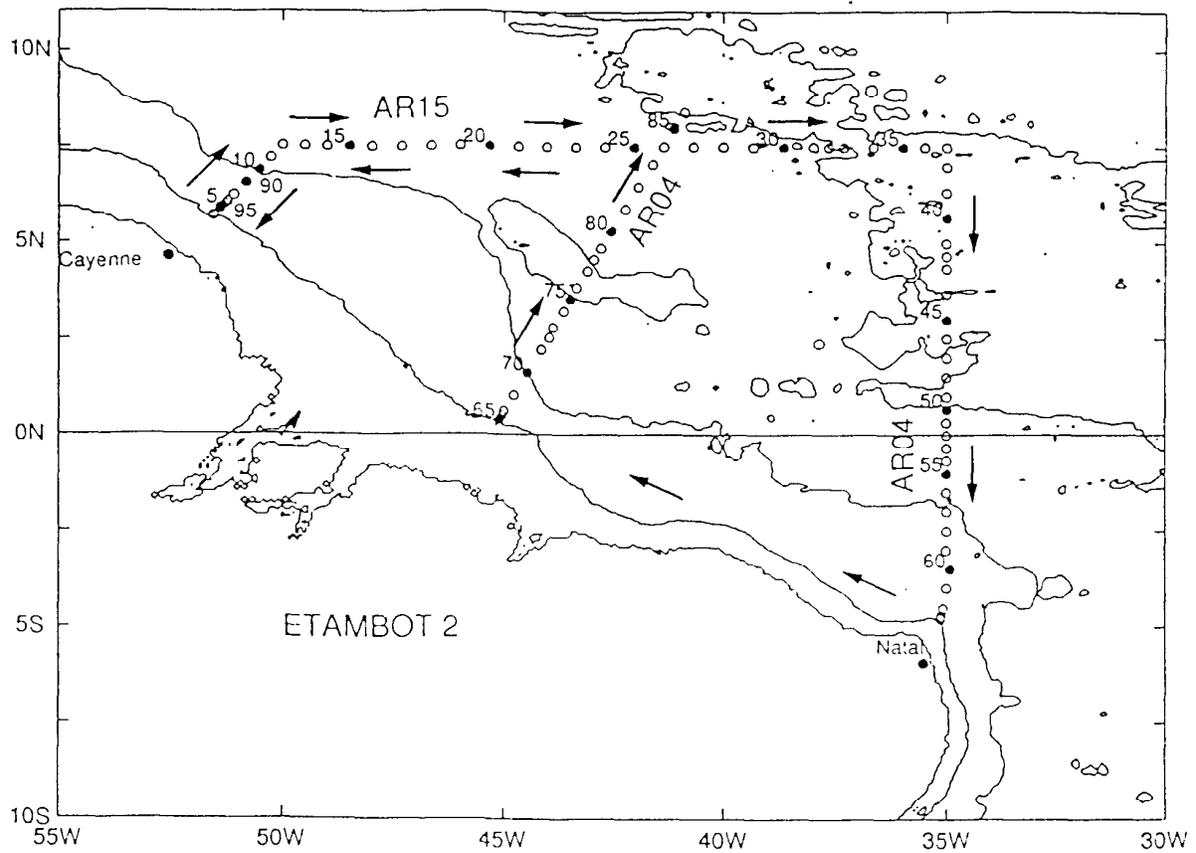


Figure 1: Cruise track and station positions.

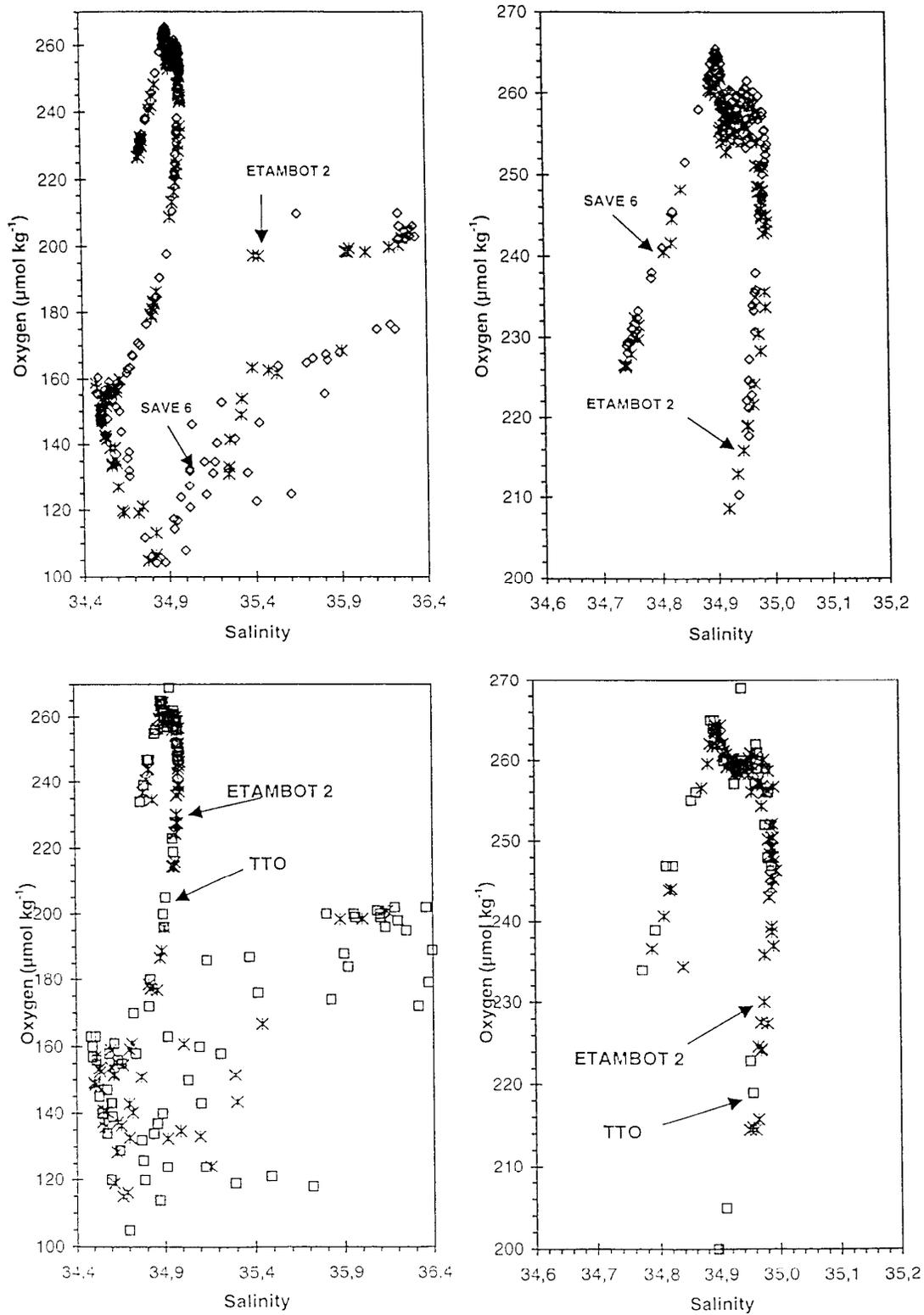


Figure 2: Oxygen versus salinity for ETAMBOT2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S], and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

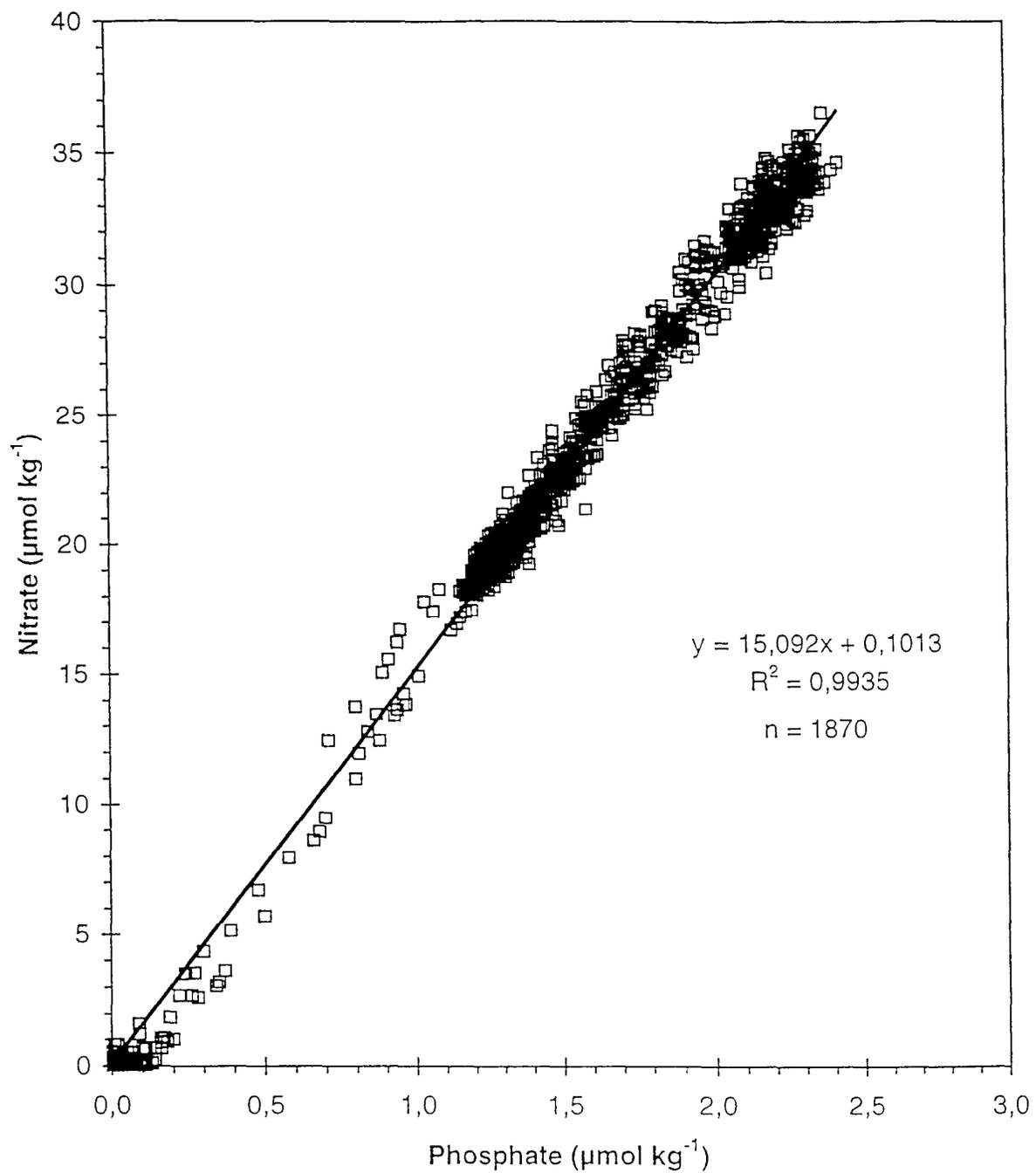


Figure 3: Nitrate – phosphate correlation for ETAMBOT2 cruise data.

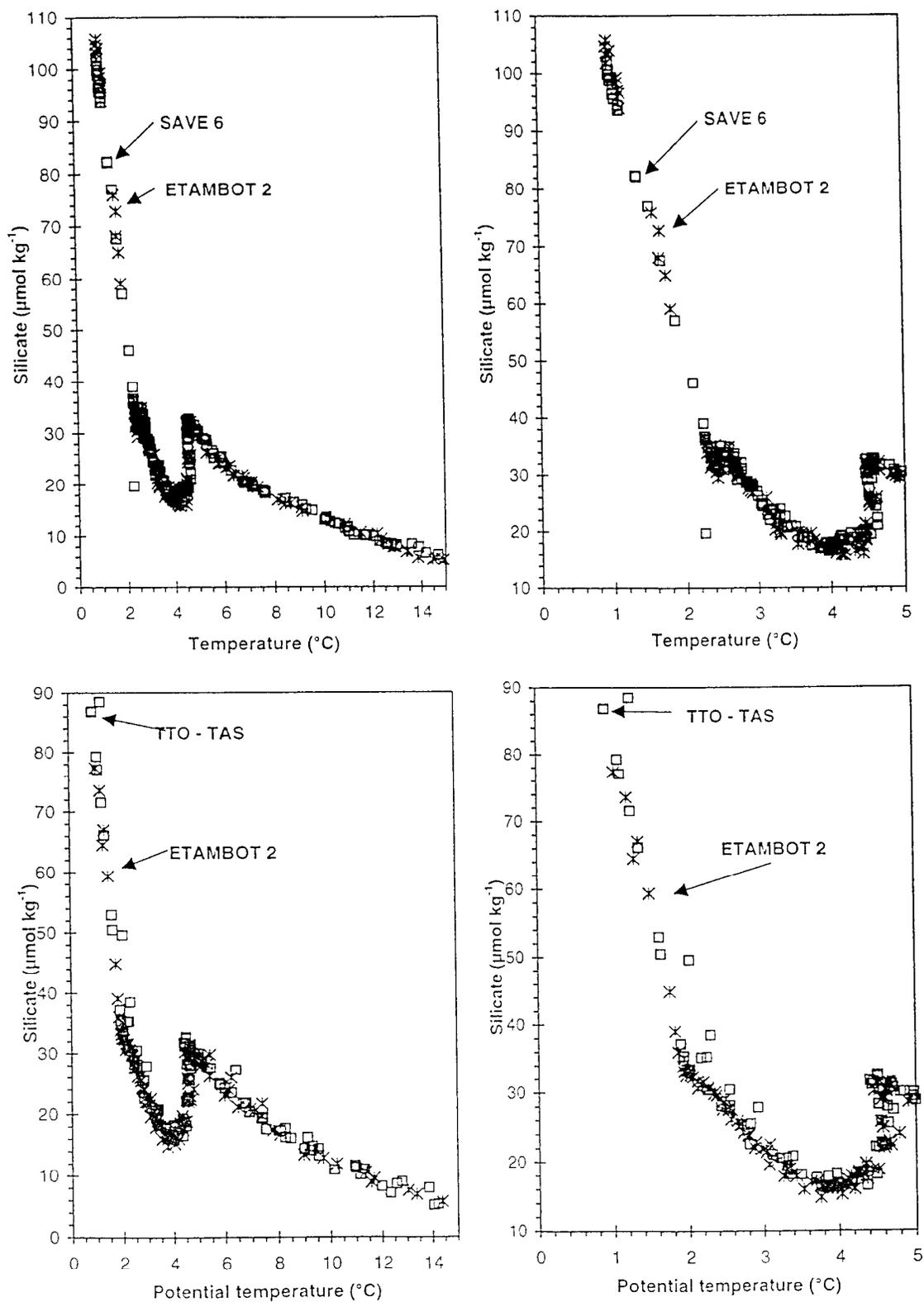


Figure 4: Silicate versus temperature for ETAMBOT2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S] and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

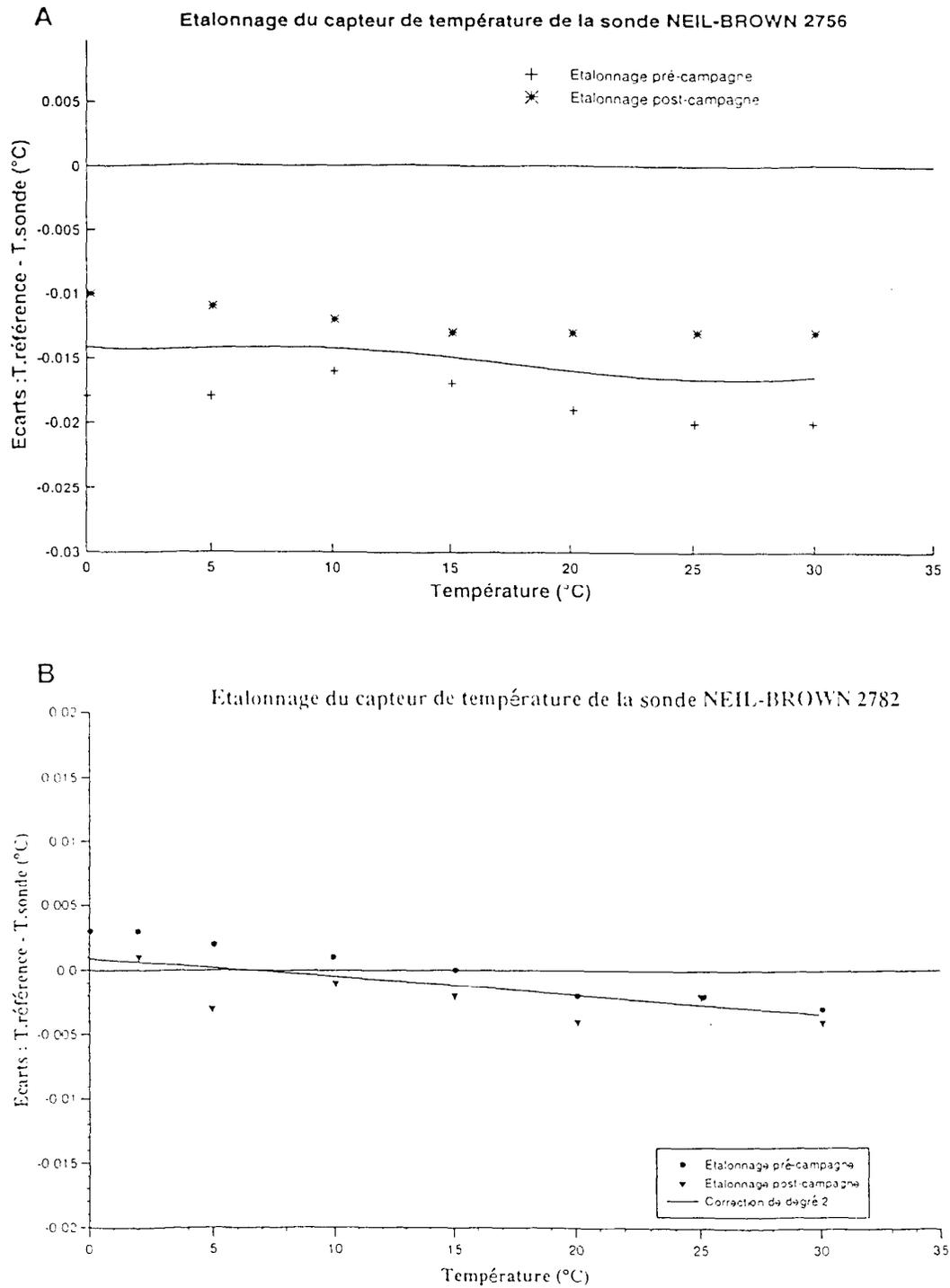


Figure 5: Temperature difference, in °C, between the laboratory reference temperature and the temperature measured by the probe. The solid represent the 5<sup>th</sup> order polynomial minimizing the differences.

- a) calibration results for the N°2756 CTD probe  
 b) calibration results for the N°2782 CTD probe

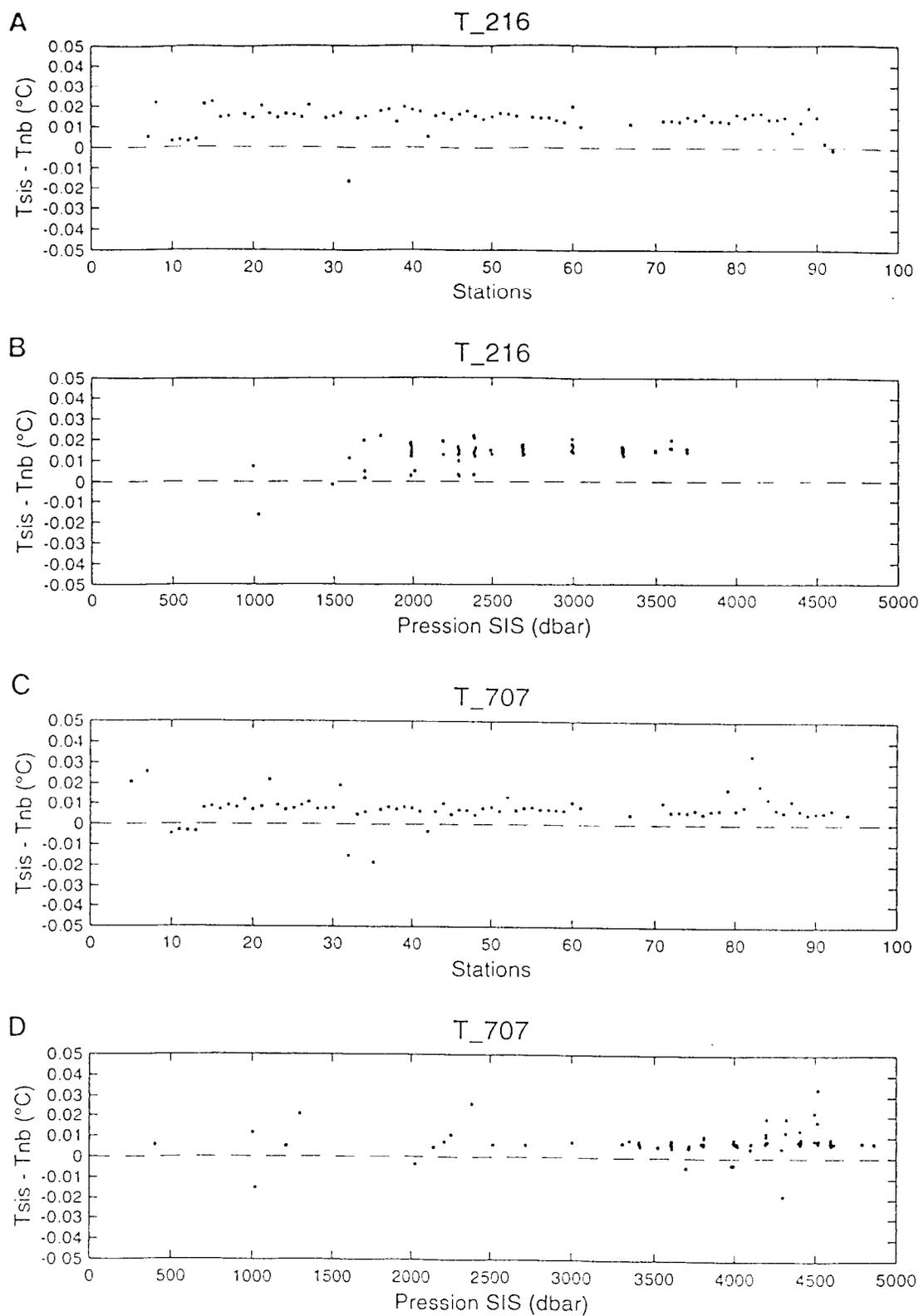


Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

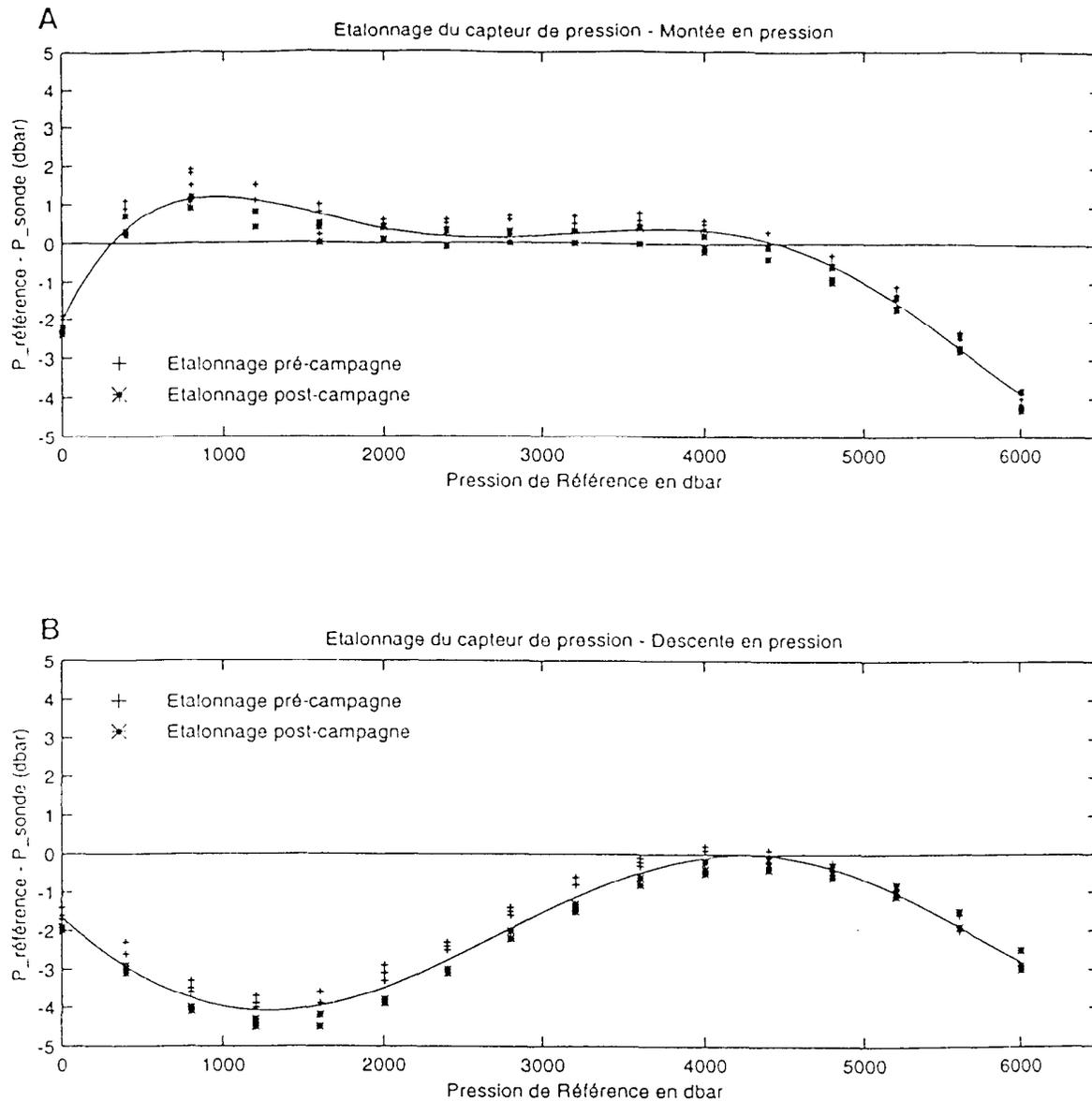


Figure 7: Pressure difference, in dbar, between the laboratory reference pressure and the pressure measured by the N°2756 probe. The solid represent the 5<sup>th</sup> order polynomial minimizing the differences.

- calibration for increasing pressure at a 20°C temperature (down cast).
- calibration for decreasing pressure at a 15°C temperature (up cast).

## Correction de l'indication du capteur de pression

Sonde NEIL-BROWN 2782

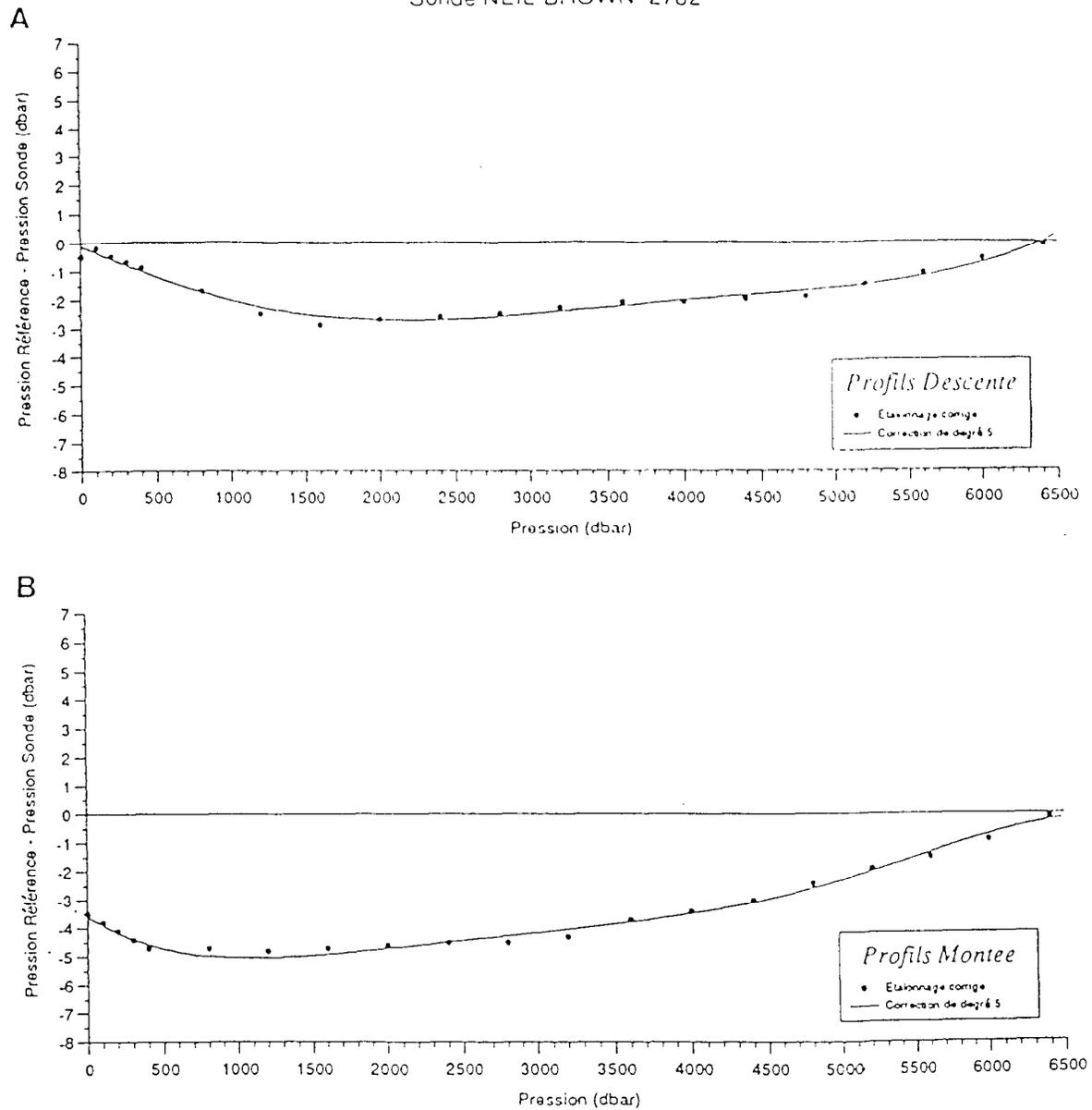


Figure 8: Calibration curve for the pressure sensor of the N°2782 CTD probe  
 a) calibration for increasing pressure (down cast).  
 b) calibration for decreasing pressure (up cast).

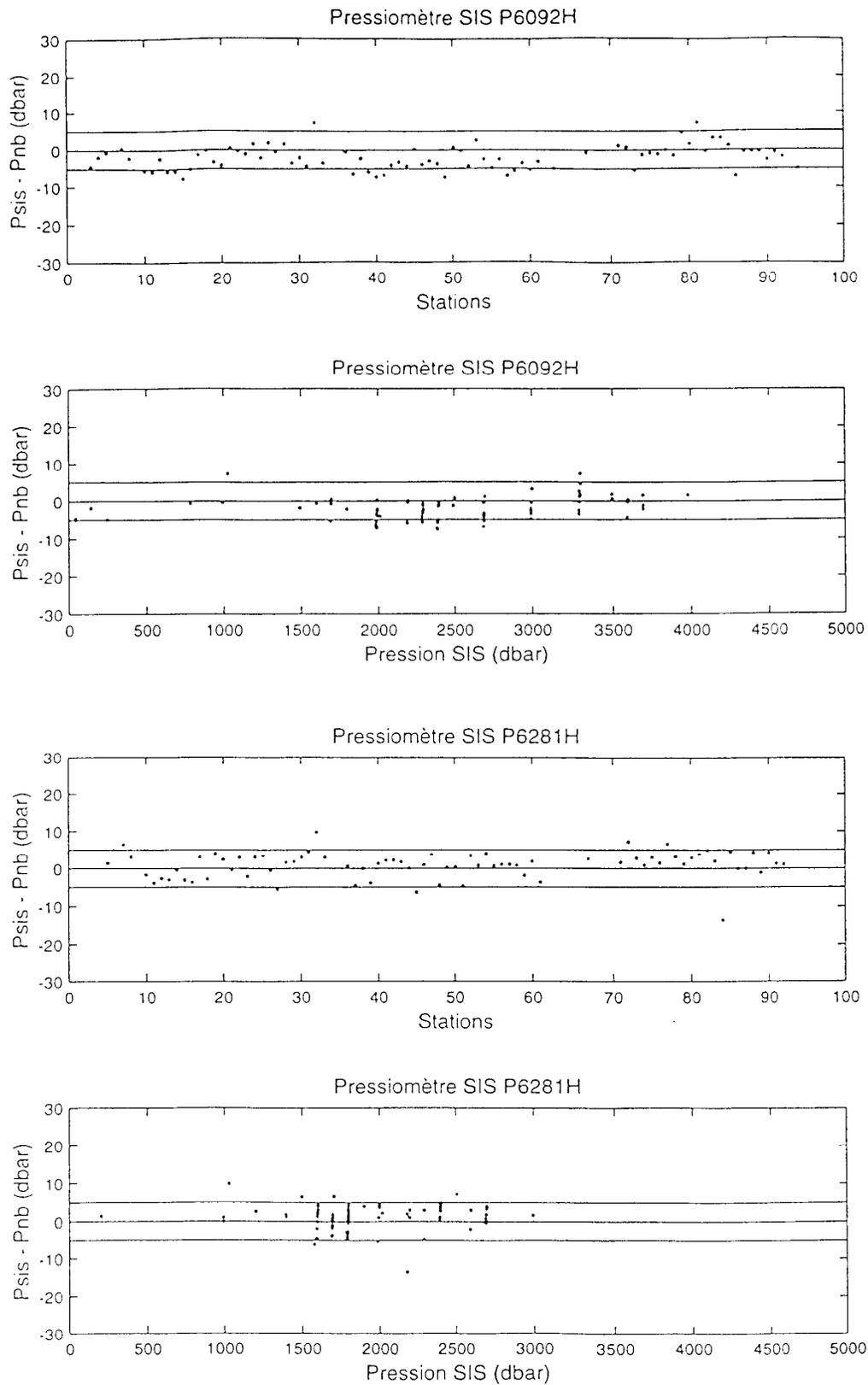


Figure 9: Pressure difference, in dbar, between SIS and CTD measurements (after calibration).

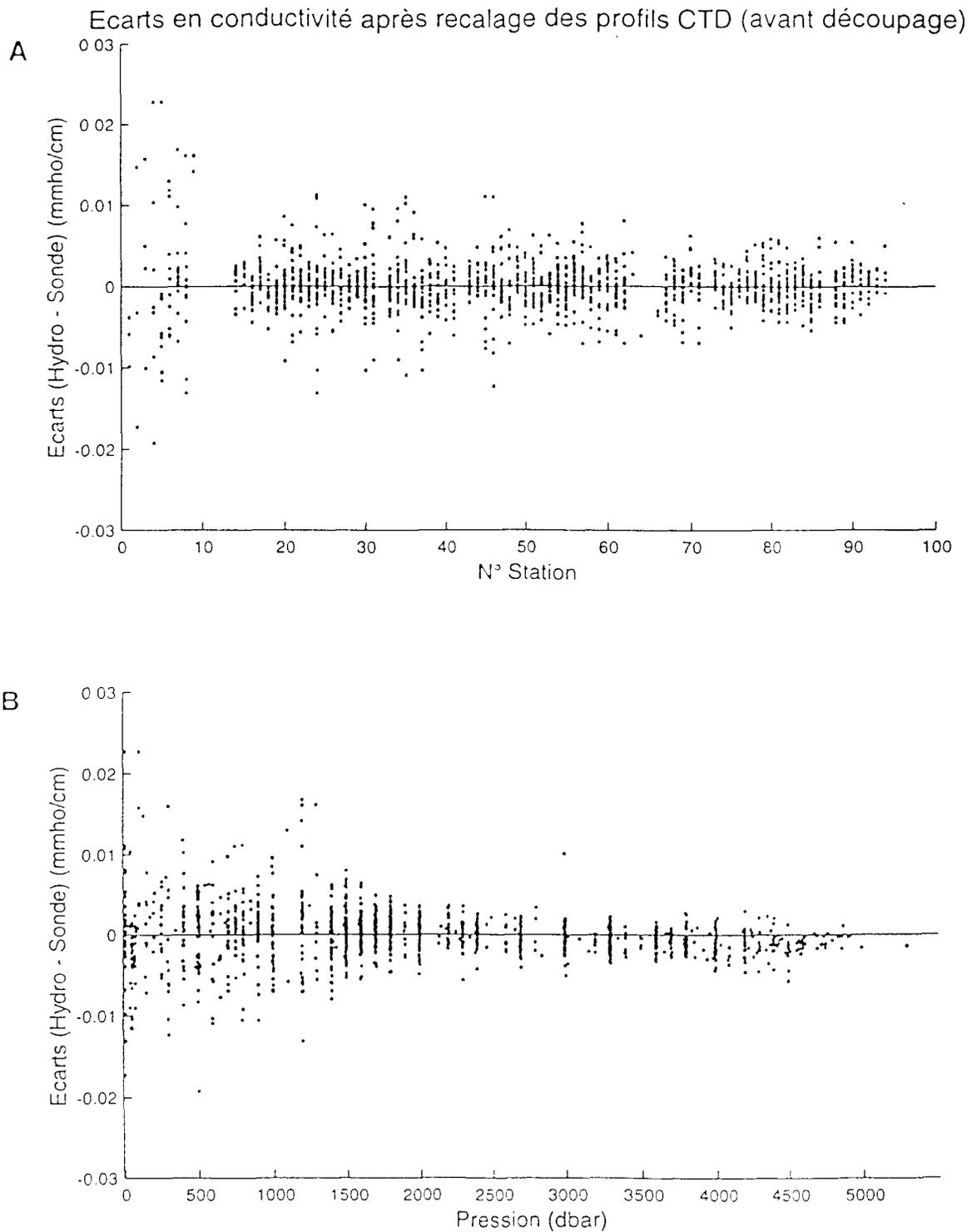


Figure 10: Conductivity difference, in mmho/cm, between water sample and CTD measurements, after calibration.

- a) difference as a function of station number.
- b) difference as a function of pressure.

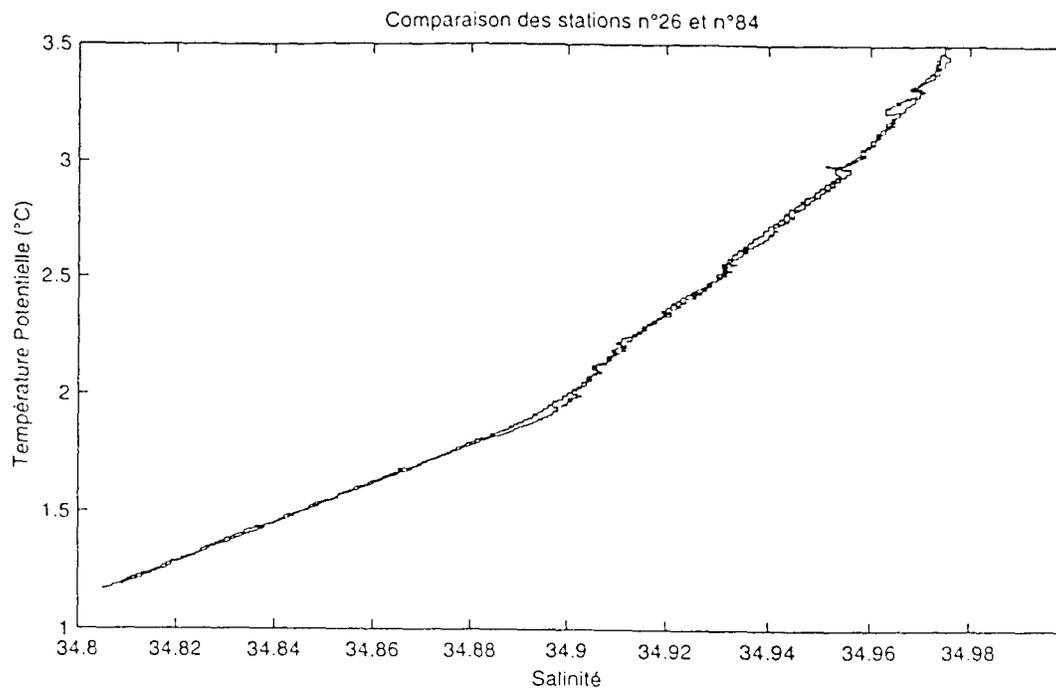


Figure 11:  $\theta$ -S diagram of repeated ETAMBOT2 stations N°26 and N°84 (41°40'W-7°30'N).

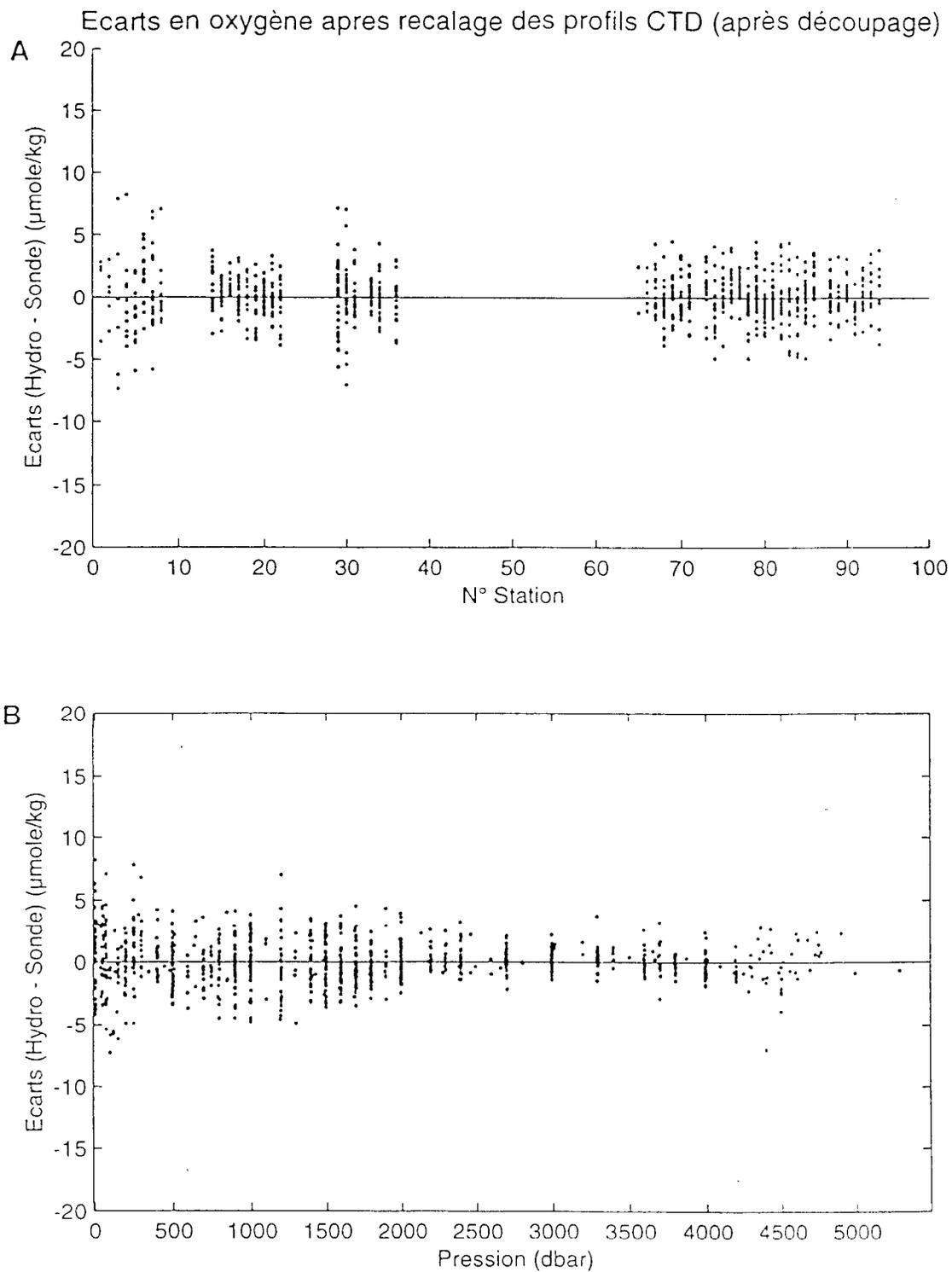


Figure 12: Dissolved oxygen difference, in  $\mu\text{mol kg}^{-1}$ , between water sample and CTD measurements.  
a) difference as a function of station number.  
b) difference as a function of pressure.

## WHPO Data Processing Notes

Date	Contact	Data Type	Event Summary
04/23/98	Gouriou	Cruise Report	Submitted (hard copy)
04/28/98	Gouriou	CTD/BTL/SUM	Submitted for DQE
03/10/99	Bartolacci	CTD/BTL/SUM*	Website Updated
02/14/00	Gouriou	CTD/BTL/SUM	Status changed to Public
06/02/00	Huynh	Cruise Report	pdf, txt versions online,
08/04/00	Huynh	Cruise Report	new pdf w/ figs online
01/01/08	Bartolacci	BTL/Cruise Report	Small edits made
			<p>It was brought to our attention by a user that the station 42 of the bottle file for ar04_hhy.txt was missing the column of values for FCO2. PH and QUALT1 columns were shifted over. QUALT1 column was missing quality byte for this column as well.</p> <ul style="list-style-type: none"> <li>• Added -9.0 values in the FCO2 column, and added a 5 quality byte (not reported) to the QUALT1 column.</li> <li>• Added place holding zeros to all leading decimal values (eg. .07 to 0.07).</li> <li>• Added place holding zeros to all trailing decimal values (eg. 1. to 1.0)</li> <li>• Realigned first three data columns and headers.</li> <li>• Realigned and corrected spelling of QUALT1 header.</li> <li>• edited date/name stamp (previous stamp was: 20010323SIOUCSD this is incorrect).</li> <li>• ran wocecvt with no errors.</li> <li>• replaced online version with newly edited file and RCS'd this action.</li> </ul>
01/10/02	Bartolacci	BTL	Reformatted data online
			<p>I have edited the file to correct the misalignment of the missing station data and also the other columns as well. There is a new file for this cruise online now. My student and I are also working on the others on your list you sent to Steve to see why they haven't get gotten into exchange. It's usually just minor reformatting that keeps these cruises in the exchange queue. Karla is going to investigate and generate the easier exchange files. I'll tackle any remaining ones, and we'll keep you posted on our progress, or you can keep checking the website for updated files.</p> <p>On Fri, 21 Dec 2001, Tom Haine wrote: Steve, I've been looking at the repeat .txt files. I think the FCO2 data are missing from STNNBR 042 in ar04_hhy.txt. At least, there's 1 less column for this station.</p>
01/11/02	Uribe	BTL	Exchange file online
			Bottle file has been converted to exchange and put online.
03/04/02	Uribe	CTD	Exchange file online
			CTD has been converted to exchange and put online.

<b>Date</b>	<b>Contact</b>	<b>Data Type</b>	<b>Event Summary</b>
04/10/02	Lebel	CFCs	Final CFC data submitted
	<p>The data disposition is: Public  The file format is: Plain Text (ASCII)  The archive type is: NONE - Individual File  The data type(s) is: Other: final CFC data  The file contains these water sample identifiers:  Cast Number (CASTNO)  Station Number (STATNO)  Bottle Number (BTLNBR)  Sample Number (SAMPNO)  LEBEL, DEBORAH would like the following action(s) taken on the data:  Merge Data  Place Data Online  Update Parameters  Any additional notes are:  These are the finalized CFC data for Etambot2 (AR04H). Scale is SIO98, units are pmol/kg.  Includes QUALT2 word.</p>		
07/23/02	Buck	CTD	Expocode edited to reflect HYD
	<p>Changed expocode in CTD file from 35LKETAMBOT2 to 33LKETAMBOT2 to match SUM file and HYD file.</p>		
02/10/03	Bartolacci	CTD	lat/lon inconsistent
	<p>For some time now we have been trying to clean up the last of the repeat cruises and incorporating current meter cruise data has fallen into this category. We were forwarded CTD data and two email correspondences by Jim Crease for the KN04 cruise.</p> <p>I am working on formatting these CTD files into a WOCE CTD format and a summary file. I am having some difficulties with the inconsistent lat/lon values recorded in the files. The values in the files that we obtained are of differing precision and in some cases exceed any possible lat/lon value.</p> <p>Can you please help? We have no cruise or data documentation for these files and presently do not even know who the Chief Scientist was on cruise! Could you please forward a data contact with whom I might correspond to regarding these matters? We would like to button this up as soon as possible and any information you could give us would be greatly appreciated.</p>		