A. Cruise Narrative

A.1 Highlights

WOCE AR15, AR04W and AR04E, R/V LE NOROIT, Cruise ETAMBOT 1

Expedition designation (EXPOCODE): 35LLETAMBOT1

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Ship: R/V LE NOROIT

Port of Call: 1st leg: Cayenne (French Guiana) to Natal (Brazil)
2nd leg: Natal (Brazil) to Cayenne (French Guiana)

Cruises Date: September 9, 1995 to October 11, 1995

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 35°W-3°S.
Second leg: Natal (5°48’S-35°18’W) to 35°W-3°S, transit to 0°23’N-45°06’W, then 0°23’N-45°06’W to Cayenne.

Number of station

A total of 85 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.

Due to bad weather condition, there is no station at 35°W-3°S.

Sampling

Double casts were performed for deep stations (bottom > 4500 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:

15 shallow stations with less than 22 water samples.
37 stations with 22 water samples.
18 stations with 24 water samples (L-ADCP removed from the rosette).
11 stations with 28 water samples (double casts).
3 stations with 30 water samples (double casts and L-ADCP removed from the rosette).

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 800 m and the bottom for 75 stations, and between the surface and the bottom for 10 stations.

Total dissolved CO_2 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_2 fugacity and chlorophyll.

Test stations:

Station N°25: all the bottles closed at 1000 m depth.
Station N°85: 12 bottles closed at 1000 m depth, and 12 bottles closed at 2000 m depth.

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

Floats, Drifters, and Moorings

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

A.3 List of Principal Investigators

TABLE 1: Principal investigators

Name	Responsibility	Institution
Chantal Andrié	Freons	ORSTOM
Bernard Bourlès	S-ADCP, Salinity	ORSTOM
Yves Gouriou	CTD, L-ADCP	ORSTOM
Claude Oudot	Nutrients – O_2	ORSTOM
Jean-François Ternon	CO_2 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_2, and CFCs in a key region of the Atlantic ocean.
- To estimate the seasonal variability of the deep circulation. A second cruise, ETAMBOT 2, have 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. 6 SIS reversing pressure meters and 6 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 to a PC. Digital instrumentation was read and samples were drawn in the following order:
Freons, oxygen, CO2 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 deep sounder was used to locate the rosette during the cast.

A. 5 Major Problems Encountered on the Cruise

One station, at 3°S-35°W, has been cancelled due to bad weather condition. Consequently we did not finish the 35°W section and we sailed to Natal (Brazil). After the call in Natal we carried out the stations between 5°S-35°W and 3°30’S-35°W. Again we were not able to make the station at 3°S.

Due to a failure of two L-ADCP acoustic transponders, deep velocity profiles were made only from station N°2 to station N°32 (i.e. 31 velocity profiles).

2 SIS reversing pressure meters and 1 reversing thermometers failed during the cruise.

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	ORSTOM	1-2
Elisabete Braga	Nutrients	IOUSP/SAO PAULO	1-2
Rémy Chuchla	Oxygen	ORSTOM	1-2
Christian Colin	CTD	ORSTOM	2
Denis Diverres	CO_2	ORSTOM	1-2
Gérard Eldin	CTD/S-ADCP	ORSTOM	1
Philippe Fournier	Salinity	ORSTOM	1-2
Yves Gouriou	Chief Scientist/CTD/L-ADCP	ORSTOM	1-2
David Nowicki	CTD/L-ADCP	ORSTOM	1-2
Claude Oudot	CO2	ORSTOM	1-2
Jean-François Ternon	CFCs	ORSTOM	1-2

ORSTOM:	Institut Français de Recherche Scientifique pour le Développement en Coopération
IOUSP:	University of Sao paulo

B. Underway Measurements

B.1 Navigation

By B.Bourlès

Navigation data (time, position, course and speed over ground, and fix quality information) were acquired throughout the ETAMBOT-1 cruise, from the 09/09/1995 at 11h05 TU, every 15 seconds with a Magnavox MX4200 Global Positioning System (GPS). Due to a failure of this GPS, the vessel NALNO GPS was used during the second part of the cruise, from the 09/28/1995 at 13h30 TU to the 10/10/1995 at 15h45 TU.

B.2 Echosounding

None.

B.3 Acoustic Doppler Current Profiler (ADCP)

By B.Bourlès

The Ship mounted Acoustic Doppler Current Profiler (S-ADCP) system on board the N/O LE NOROIT is a 153 kHz RD-VM150 Instruments unit with a hull mounted transducer. The four-beam transducer is mounted in a well, filled with fresh water and closed by a Kevlar acoustic window, and located to the port side around the vessel centerline at 4 meters depth. It is connected by cable to a deck box, containing the processing equipment, and connected to a Personnal 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 aquired with a Magnavox MX4200 Global Positioning System (GPS) during the first part of the cruise, and with the vessel NALNO GPS during the second part. 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 on 16 meter depth.

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. This time drift did not exceed 2 to 3 seconds per day. The corrected time is then included in the data base. Navigation and transducer temperature are first checked. 'Noisy' bins or profiles are suppressed. Navigation and S-ADCP measurements are combined in order to obtain absolute current values. The currents velocity is calibrated using the ***Pollard and Read*** (1989) standard procedure.

Absolute velocity profiles were obtained down to about 300 m depth on station, and down to 190 m depth when steaming (the vertical extension is defined by the depth where the percentage of good bins per ensemble becomes inferior to 30%). The original 5 minutes profiles have been averaged into 'in stations', 'between stations', '1/4 degree' and 'hourly' profiles. Standard deviation of velocity mean profiles is of the order of 3 cm s^{-1}.

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 ship-mounted acoustic Doppler profilers, and the limitations of gyro compasses, ***J. Atmos. Oceanic Technol., 6***, 859-865, 1989.

B.4 L-ADCP measurements

By B.Bourlès,Y.Gouriou, R.Chuchla

The Lowered Acoustic Doppler Current Profiler (L-ADCP) allows to provide absolute currents over the whole water column. We used a BroadBand 150 kHz RD Instruments ADCP. It was attached to the 'rosette', and two water bottles were 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_2 system. The CTD-O_2/L-ADCP package was lowered and rised at a nominal speed of 1 m s^{-1}, except during the upcast when the package was stopped to fire the bottles. We used the following setup parameters: 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^{-1}. 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 perturbed by the bottom reflections were suppressed. The reference velocity was determined using the GPS time and position at the beginning and at the end of the profile. Error due to this reference velocity determination is estimated to 1 cm s^{-1} (***Fischer and Visbeck***, 1993). 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^{-1}.

Due to the failure of two of the four L-ADCP transducer beams, thirty-two (over eighty-five CTD-O_2 casts) absolute velocity profiles were acquired at the beginning of the Etambot-1 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

None

B.6 XBTs

B.7 Meteorological Measurements

By B. Bourlès

Meteorological measurements were recorded every three hours, from the 09/09/1995-12h00 TU to the 10/10/1995-18h00 TU, by the deck officer of the R/V LE NOROIT. These measurements are the following: date, time, position, dry thermometer temperature (°C), moist thermometer temperature (°C), dew point temperature (°C), sea level pressure (mbar), sea level temperature (°C), and relative humidity (%). Weather, clouds and sea level conditions have not been recorded. Wind measurements were erroneous due to direction correction problems.

C. Hydrographic Measurements Techniques and Calibrations

C.1 Sample Salinity Measurements

By P.Fournier and C.Oudot

Salinity analysis of samples collected during ETAMBOT 1 were carried out onboard with a Guildline^{TM} Portasal^{TM} 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 ± .00045 psu.

Quality control of the salinity data were performed using repeated measurements from replicate samples (bottles fired at the same depth at station N°25 and N°85) and duplicate samples (two different bottles fired at the same depth, sixty-nine times). The standard deviations of the three groups of replicate samples are given in the Table 3 below.

TABLE 3: Salinity replicate statistics

Station number	25	85
Pressure (dbar)	997	2001
Number of bottles	12	12
Mean salinity (psu)	34.7542	34.9779
Maximum deviation (psu)	.0008	0.0010
Standard deviation	.0004	.0006

The standard deviation of the sixty-nine sample pairs (duplicate), taken at different depths, is 0.0009 psu.

C.2 Sample Oxygen Measurements

By P.Fournier and C.Oudot

Sampling and techniques

Oxygen samples were taken in calibrated clear glass bottles (capacity = 120 cm3) 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 23°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 MetrohmTM TitratorTM model 682 and a DosimatTM 665 burette (10 cm3).

The concentration of oxygen dissolved in seawater was converted to mass fraction by use of the following relationship:
O2 [µmol kg-1] = (44.660 / rho-sw) * O2 [cm3 dm-3]
where rho-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 three groups of replicate (taken from different bottles fired at the same depth) samples and a large number (sixty-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	25	85
Pressure (dbar)	997	2001
Number of bottles	22	12
Mean O2 concentration (µmol kg-1)	153.3	252.1
Maximum deviation (µmol kg-1)	1.8	1.0
Standard deviation (µmol kg-1)	0.8	0.4

The standard deviation of the sixty-nine sample pairs (duplicate) is 0.4 µmol kg-1, i.e a value not significantly different from reproducibility of replicates, excepted the first station (# 0), carried out as a trial station.

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 pannel (TTO-TAS) where the latitude range is wider, the agreement is satisfactory.

References

Culberson C.H., 1991. Dissoved 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

By F.Baurand and C.Oudot

Equipment and techniques

Nutrient analyses were performed on a Braun & Luebbe^{TM} AutoAnalyzer^{TM}II type Technicon^{TM} (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_2 fugacity, total CO_2 and pH) and were carried out in Nalgene bottle (125 cm^3). 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^{TM} automatic burette model Dosimate^{TM} 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^{TM}, anal. grade., certified 99.99%, for phosphate, nitrate and nitrite ; Carlo Erba^{TM}, 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 ($\mu mol\ l^{-1}$) 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 %o solution of analytical grade sodium chloride.

The linearity of the calibration curve (Beer's Law) was not valid beyond 20 $\mu mol\ l^{-1}$ 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 three groups of replicate (taken from different bottles fired at the same depth, during three test stations) samples and a large number (seventy) 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 0.1 for silicate, 0.5 for phosphate and 0.3 for nitrate, in agreement with WHP recommendations (WOCE, 1994).

TABLE 5: Nutrients replicate statistics

Silicate

Station number	25	85	85
Pressure (dbar)	997	2001	997
Number of bottles	22	12	12
Mean silicate concentration (µmol kg^{-1})	27.18	17.43	27.95
Standard deviation (µmol kg^{-1})	0.13	0.05	0.12
Percent standard deviation	0.46	0.27	0.43
Percent standard deviation (vs full range, 120 µmol kg^{-1})	0.11	0.04	0.10

Phosphate

Station number	25	85	85
Pressure (dbar)	997	2001	997
Number of bottles	22	12	12
Mean phosphate concentration (µmol kg^{-1})	2.12	1.28	2.26
Standard deviation (µmol kg^{-1})	0.01	0.00	0.01
Percent standard deviation	0.68	0.35	0.70
Percent standard deviation (vs full range, 3 µmol kg^{-1})	0.48	0.15	0.53

Nitrate

Station number	25	85	85
Pressure (dbar)	997	2001	997
Number of bottles	22	12	12
Mean nitrate concentration (µmol kg^{-1})	30.98	19.39	33.17
Standard deviation (µmol kg^{-1})	0.12	0.03	0.06
Percent standard deviation	0.39	0.17	0.18
Percent standard deviation (vs full range, 40 µmol kg^{-1})	0.30	0.08	0.15

The standard deviation of the seventy sample pairs (duplicate) is 0.4 µmol kg^{-1} for silicate, 0.02 µmol kg^{-1} for phosphate and 0.3 µmol kg^{-1} for nitrate.

The consistency of phosphate and nitrate data is shown in Figure 3 by the strong correlation between these two nutrients ($R^2 = 0.9914$). The slope of the regression line (15.016) 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.

References

Lechauve J.J., Baurand F. and C. Oudot, 1992. Manuel d'utilisation ASTECH (Analyse du Signal TECHnicon). ***Doc. Techn. Centre ORSTOM de Brest***, n° 67, 35 p.

Mullin J.B. and J.P. Riley, 1955. The spectrophotometric determination of silicate-silicon in natural waters with special reference to sea water. ***Anal. Chim. Acta***, 12: 162-170.

Murphy J. and J.P. Riley, 1962. A modified simple solution method for the determination of phosphate in natural waters. ***Anal. Chim. Acta,*** 27: 31-36***.***

Tréguer P. and P. Le Corre, 1975. Manuel d'analyse des sels nutritifs dans l'eau de mer (utilisation de l'AutoAnalyzer II Technicon). ***Université de Bretagne Occidentale***, Brest, 2ème édition., 110 p.

WOCE , 1994. WOCE Operations Manual. Vol. 3, Part 3.1.3: WHP Operations and Methods. ***WHP Office Report WHPO 91-1,*** WOCE Report N° 68/91, Revision 1, November 1994.

Wood E.D., Armstrong F.A.J. and F.A. Richards, 1967. Determination of nitrate in sea-water by cadmium-copper reduction to nitrite. ***J. Mar . Biol. Ass. U.K***., 47: 23-31.

C.4 CFC-11, CFC-12

by C.Andrié

Work on board

During the cruise, two 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. All of the samples at the surface and samples corresponding to depths greater than 800 m have been taken. This corresponds to at least 17 samples per profile or 22 when double casts have been realized for bottom depth greater than 4500 m. Complete profiles have been realized for 11 stations (stations 5, 6, 36, 42, 57, 64, 65, 67, 69, 70, 81).

Atmospheric measurements have been realized every two days, from syringe samples. Globally, 2580 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 at the beginning of the cruise.

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. The reproducibility, for the standard, for the whole cruise, was ± 0.9% for F12 and ± 2.2% for F11. Mean atmospheric mixing ratio were 514 ppt (± 1.6 ‰) for F12 and 270 ppt (± 3.4 %) for F11.

The atmospheric distribution shows an inter-hemispheric gradient around 0.46 ppt/° lat for F12 and 0.3 ppt/°lat for F11. Reproducibility over all the measurements is 2% for F12, 3.5% for F11, 3.2% for F11/F12.

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. 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 (A6 and A7 WHP lines) results.

The detection limit determined through the standard deviation over the test-stations at 1000 m (stations 25 and 85) is around 0.004 $pmol.kg^{-1}$ for F12 and 0.01 $pmol.kg^{-1}$ 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:

- stations 5 to 23 with high F11/F12 ratio (7.3 ± 3): for this set, an important contamination part is evident. The respective contamination levels are 0.002 $pmol.kg^{-1}$ for F12 et 0.033 $pmol.kg^{-1}$ pour F11.

- stations 24 to 84 with lower F11/F12 ratio (2.7 ± 1). For this set the mean contamination levels are 0.002 $pmol.kg^{-1}$ for F12 and 0.007 $pmol.kg^{-1}$ for F11. These contamination levels have been systematically removed from the CFC values.

References

Bullister, J.L., and R.F. Weiss, Determination of CCl_3F and CCl_2F_2 in seawater and air, ***Deep-Sea Res.,*** 35, 839-853, 1988.

C.5 Samples Taken for Other Chemical Measurements

CO_2 system parameters

by J.F. Ternon and C.Oudot

Total inorganic carbon (TCO_2)

Measurements of TCO_2 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^3) after acidification, and of the gas chromatographic analysis of the gas mixture allowing the TCO_2 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_2 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_2 replicate statistics

Station number	25	85	85
Depth (dbar)	997	2001	997
Number of bottles	22	12	11
TCO_2 ($\mu mol\ kg^{-1}$)	2196.1	2197.7	2121.6
Standard deviation ($\mu mol\ kg^{-1}$)	8.2	10.3	8.4

Repeatability of TCO_2 measurements was determined from statistical anlysis of duplicate results, according to the relationship (Dickson and Goyet, 1994):

$$S = (\sum d_i^2 / 2n)^{1/2}$$

where d_i = difference for pair ***i*** and n = number of pairs (32). For Etambot 1 cruise S = 6.8 µmol kg^{-1}.

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$^+$], 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	25	85	85
Depth (dbar)	997	2001	997
Number of bottles	21	11	12
pH	7.983	8.041	7.880
Standard deviation	0.0020	0.0014	0.0027

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

$$S = (\sum d_i^2 / 2n)^{1/2}$$

where d_i = difference for pair ***i*** and n = number of pairs (33). For Etambot 1 cruise S = 0.002 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:

$$A_T = [HCO_3^-] + 2\,[CO3^{2-}] + [B(OH)_4^-] + [OH^-] - [H^+]$$

A_T, expressed in µeq kg^{-1}, was estimated as the sum of the components of the right member of the previous relationship, calculated from 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 Dikson 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	25	85	85
Depth (dbar)	997	2001	997
Number of bottles	21	12	11
A_T (µeql kg^{-1})	2307.7	2294.8	2303.8
Standard deviation (µeq kg^{-1})	7.8	8.1	10.9

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

$$S = (\sum d_i^2 / 2n)^{1/2}$$

where d_i = difference for pair ***i*** and n = number of pairs (32). For Etambot 1 cruise S = 7.0 µeq kg^{-1}.

CO_2 fugacity

The fugacity of CO_2 in seawater was determined in air that was in equilibrium with a discrete sample of seawater. The fugacity, fCO_2, is related to the partial pressure, pCO_2 , by the relation (Weiss, 1974) to take into account the non-ideality of CO_2:

$$fCO_2 = pCO_2 \exp\{(B + 2\delta)\, p_{atm} / RT\}$$

The partial pressure of CO_2 in wet air is calculated from the molar fraction of CO_2 in dry air, xCO_2, the atmospheric pressure, P , and the H_2O vapor pressure, p_{H2O} (Weiss and Price, 1980):

$$pCO_2 = xCO_2\, p = xCO_2\, (P - p_{H2O})$$

The molar fraction of CO_2 in equilibrated air was measured with an IR analyzer LI-COR™ model LI6262 . The analyzer was calibrated with three standard gases (329.0 – 349.6 – 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_2 concentration was made twice a day by pumping an air stream taken at a mast at the bow of the vessel.

Then, the CO_2 fugacity measured at 28°C was corrected for in situ temperature according to the temperature dependence equation of Copin-Montegut (1989).

The reproducibility of $\mathbf{f}CO_2$ measurements was determined from statistical analysis of 63 pairs of duplicate results, according to the relationship (Dickson and Goyet, 1994):

$$S = (\sum d_i^2 / 2n)^{1/2}$$

where d_i = difference for pair ***i*** and n = number of pairs (63). For Etambot 1 cruise S = 2.9 µatm.

Chlorophyll a and Phaeophytin

by C. Oudot and J. Neveux

During the cruise, seawater samples were taken from only the surface bottle of the General Oceanics rosette for determination of chlorophyll and phaeopigments as described in Neveux and Lantoine (1993) by the spectrofluorometric method.

Seawater was filtered on Whatman GF/F filter (diameter = 47 mm, porosity = 0.45 µm). The filters were stored at –25°C until the analysis in the shore-based laboratory.

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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 140kHz 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

By Y. Gouriou

Temperature Calibration

The temperature sensor of the CTD was calibrated before and after the cruise, on June 9, 1995 and December 15, 1995. The temperature sensor has been controlled for the following temperature: 0°C, 5°C, 10°C, 15°C, 20°C, 25°C, 30°C.

The calibration results are presented on figure 5. Between the pre- and post-calibration the temperature sensor presents a drift of:

- 0.010°C in average
- 0,012°C at a temperature of 0°C (maximum)
- 0.008°C at a temperature of 10°C, 15°C, and 20°C (minimum).

We considered that the incertitude on the temperature measurements is of ±0.005°C.

The solid line represents the 5th 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 a drift of the temperature difference from the station N°1 to the station N°35. That drift is not confirmed by the other comparisons (figures 6). In a first step the CTD temperatures have been corrected from that drift, but the calibration of the salinity sensor was not satisfactory, as confirmed by the comparisons of the θ-S diagrams of the ETAMBOT 1 cruise with the CITHER 1 cruise (WHP Line A7). We then decide not to correct the CTD temperatures from the drift observed.

Note that:

- if the CTD temperature sensor presents a drift of 0.011°C (at a laboratory temperature of 5°C) between the pre- and post-calibration, the SIS thermometer also drifted. The SIS thermometer T-106 and the SIS thermometer T-7 present a drift of 0.009°+C and 0.007°C respectively.
- as the rosette was not equipped with a non-data interrupt rosette firing module, the CTD measurements (temperature, conductivity, oxygen) were perturbed when a bottle was closed. It is likely that the precedent comparison suffered from that deficiency.

Pressure Calibration

The pressure sensor of the CTD was calibrated before and after the cruise, on June 9, 1995 and December 15, 1995.

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)

The pressure sensor did not drift a lot during the 6-months interval (2 dbar at maximum) 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.

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 figures 8 present the pressure difference between the SIS and CTD measurements before calibration. The solid line represents the calibration curve (SIS+CTD pressure) we should apply to that difference. 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. 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:

- We used the same CTD conductivity sensor during the whole cruise.
- The CTD conductivity sensor has been cleaned before stations N°20, N°50,and N°71.
- The stations made in shallow water (bottom < 1500 m) are: N°1, N°2, N°3, N°4, N°5, N°58, N°63, N°64, N°65.

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 -> 14	246	181	0.0039	1.000318	-0.02146
15 –> 21	159	119	0.0019	1.002110	0.07511
22 -> 24	78	64	0.0029	1.003115	-0.12824
26 -> 27	55	45	0.0030	0.999611	0.00476
28 -> 37	243	187	0.0018	1.001014	-0.03890
38 -> 56	413	331	0.0018	1.000381	-0.01719
57	24	23	0.0065	0.997654	0.06776
58 -> 62	81	54	0.0021	1.000008	-0.00415
63 -> 70	124	104	0.0018	1.000123	-0.01022
71 -> 84	345	264	0.0014	1.000399	-0.02139

1847 water samples have been taken out during the cruise. Eliminated the samples of the test stations N°25 and N°85, as well as the bad measurements, we retained 1768 water samples for the calibration. 1372 comparisons have been retained by the minimization process (77.6% of the measurements).

The figure 9 shows the resulting conductivity difference after the calibration procedure. Only the station N°57 presents an important dispersion as the measurements between the surface and 1500 m have not been rejected by the minimization process (that station being calibrated separately).

The difference is lower than 0.001 mmho cm^{-1} for 23% of the samples.
The difference is lower than 0.003 mmho cm^{-1} for 60% of the samples.

CONTROL

To control the quality of the calibration, θ-S diagrams have been compared:

1. Between successive stations of the cruise.
2. Between stations made at the same position during the cruise (N°27 and N°82).
3. Between different cruises.

1. θ-S diagrams of consecutive stations made during the cruise have been systematically compared. The differences (>= 0.0005), 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 10: Salinity comparison between contiguous profiles of the ETAMBOT 1 cruise

ETAMBOT 1 Station Number	ETAMBOT 1 Station Number	Salinity Difference
8	9	**0.0020**
10	11	0.0010
19	20	0.0005
21	22	**0.0020**
22	23	0.0005
23	24	0.0010
24	26	**-0.0050**
30	31	0.0005
34	35	0.0005
37	38	-0.0010
49	50	0.0005
50	51	-0.0005
55	56	0.0005
69	70	-0.0005
70	71	0.0010
71	72	-0.0005

Remarks

- Station N°8 and N°9: the 0.0020 difference is observed above 2°C. Other tracers also show properties differences.
- Station N°21 and N°22, and station N°24 and N°26 (station N°25 is a test station): No error have been found in the sample analysis that could explained the observed difference. The comparison between the θ-S diagrams of these stations and stations made at the same locations during the CITHER 1 cruise (WHP A6 line) confirm the differences observed (see below).

2. The comparison of the stations made at the same position during the cruise (N°27 and N°82) show that there are perfectly superimposed for potential temperature smaller than 1.9°C (Figure 10).

3. Comparison with preceding cruises
   The ETAMBOT 1 cruise repeats exactly the western track of the CITHER 1 cruise, along the 7°30’N latitude and 35°W longitude. Excluding shallow stations, about 40 θ-S diagrams have been compared. The result of that visual comparison is shown in the following table. Only the stations where the differences are equal or greater than 0.0005 are reported:

TABLE 11: Salinity comparison between ETAMBOT 1 and CITHER 1 profiles

ETAMBOT 1 Station Number	CITHER 1 Station Number	Salinity difference
11	129	-0.0010
16	134	-0.0005
19	137	0.0005
22	140	**-0.0020**
23	141	**-0.0035**
24	142	**-0.0050**
35	154	-0.0005
36	155	-0.0005

The comparison is good except for the station N°22, 23, and 24. The differences observed for those stations are coherent with the differences observed between the stations N°21 and N°22, and the station N°24 and N°26 of the ETAMBOT 1 cruise.

We then decide to correct the salinity profiles of the stations N°22, N°23, and N°24:

0.0020 has been added to the CTD salinity profile of station N°22.
0.0035 has been added to the CTD salinity profile of station N°23.
0.0050 has been added to the CTD salinity profile of station N°24.

Furthermore the θ-S diagrams of the repeated-ETAMBOT 1 stations N°27 and N°82 are perfectly superimposed with the θ-S diagrams of the CITHER 1 station N°144 (Figure 11), for potential temperatures lower than 1.9°C.

Oxygen Calibration

The same CTD oxygen sensor has been used during the whole cruise.

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

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

1847 oxygen samples have been gathered during the cruise. Excluding the samples of the test stations N°25 and N°85 as well as the bad sample analysis, 1777 samples have been used to calibrate the data. 1667 samples (93.8%) have been retained during the fitting process. The following Table shows the results of the calibration:

TABLE 12: Calibration result for the oxygen sensor

Station Number	Number of used samples	Number of retained samples	Standard deviation (0-5000 m) µmol kg^{-1}
1 -> 6	72	66	1.7
7 -> 10	88	85	1.8
11	22	20	0.9
12	22	22	2.6
13	22	19	0.7
14	21	20	1.2
15	21	21	1.4
16	22	22	1.1
17	22	22	1.0
18	21	21	0.8
19	22	22	1.3
20	21	21	0.7
21	28	28	1.7
22	28	27	1.7
23	28	27	1.0
24 -> 26	53	53	1.8
27 ->30	99	95	1.2
31 -> 35	124	111	1.2
36	22	20	0.7
37 -> 38	43	42	1.5
39	22	22	2.4
40	22	22	1.5
41	22	21	0.9
42	21	19	0.4
43 -> 46	86	82	1.6
47 -> 49	64	62	1.5
50 -> 54	108	97	1.1
55 -> 57	70	64	1.6
58 -> 62	81	72	1.8
63 -> 70	130	115	1.3
71 -> 83	326	303	1.7
84	24	24	1.7

The figures 12 show the differences, in µmol kg^{-1}, between the oxygen samples and the down-cast CTD measurements.

The difference is lower than 1 µmol kg^{-1} for 33% of the samples .
The difference is lower than 2 µmol kg^{-1} for 74% of the samples .

CONTROL

The figure 13 shows the CTD oxygen profiles of the repeated station N°27 and N°82. The profiles are well adjusted to the oxygen samples. The difference observed at the bottom disappears on the θ-O_2 diagram.

As for the salinity profiles, the comparison with the oxygen profiles of the CITHER 1 have been made. Along the 7°30’N latitude the comparison is good (figure 14). Along the 35°W longitude some systematic differences are observed: they are reported in the following Table:

TABLE 13: Oxygen comparison between ETAMBOT 1 and CITHER 1 profiles

ETAMBOT 1 Station number	CITHER 1 Station number	Oxygen difference in µmol kg^{-1}
37	119	-3.0
38	118	-3.0
39	117	-4.0
40	116	-4.0
41	115	-3.0
42	114	-1.5
43	113	-2.0
46	111	-3.0
47	110	-3.0
48	109	-2.0
50	107	-1.0
51	106	-1.0
52	105	-2.0
53	104	-2.0
54	103	-1.5
55	102	-2.5

These differences are generally observed between 2000 m and the bottom (Figure 15a). For every cruise the CTD oxygen profiles are well fitted to the samples. The bias observed seemed to be confirmed by the repeated stations performed during the CITHER 1 cruise at 7°30’N-35°W, station N°119 and N°156 (Figure 15b). As fifteen days separates those 2 stations we are not able to say if that difference is due to a natural variability.

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

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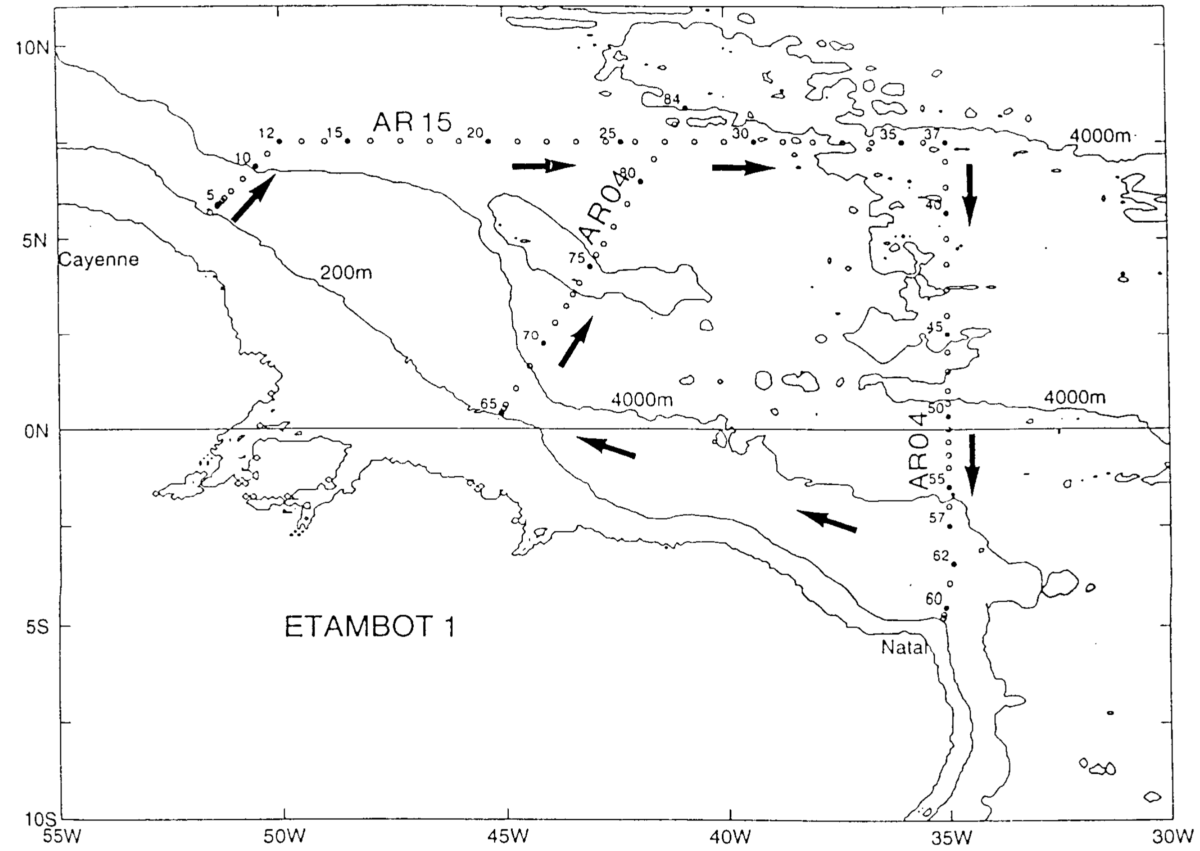


Figure 1: Cruise track and station position.

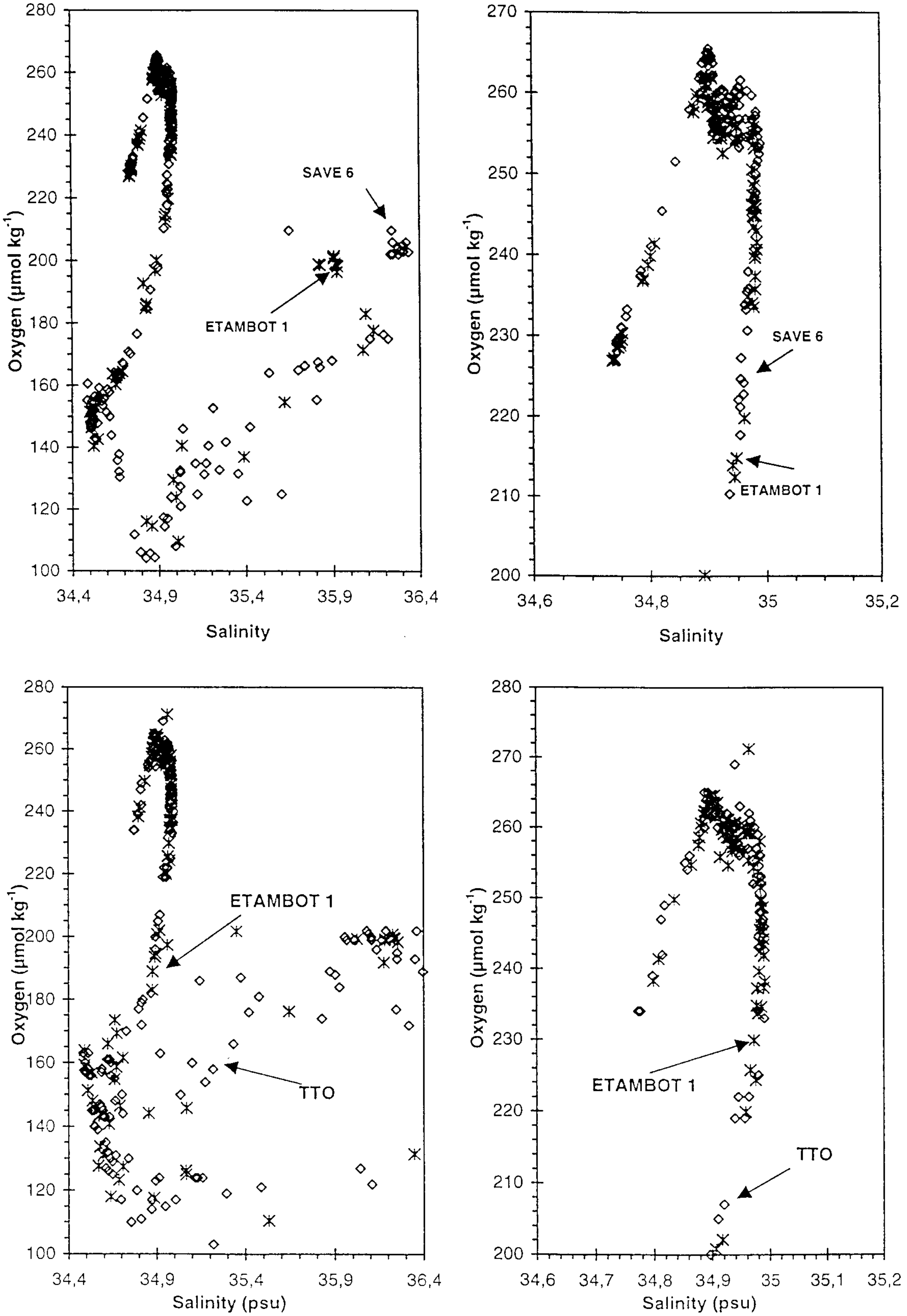


Figure 2: Oxygen versus salinity for ETAMBOT 1 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S] and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

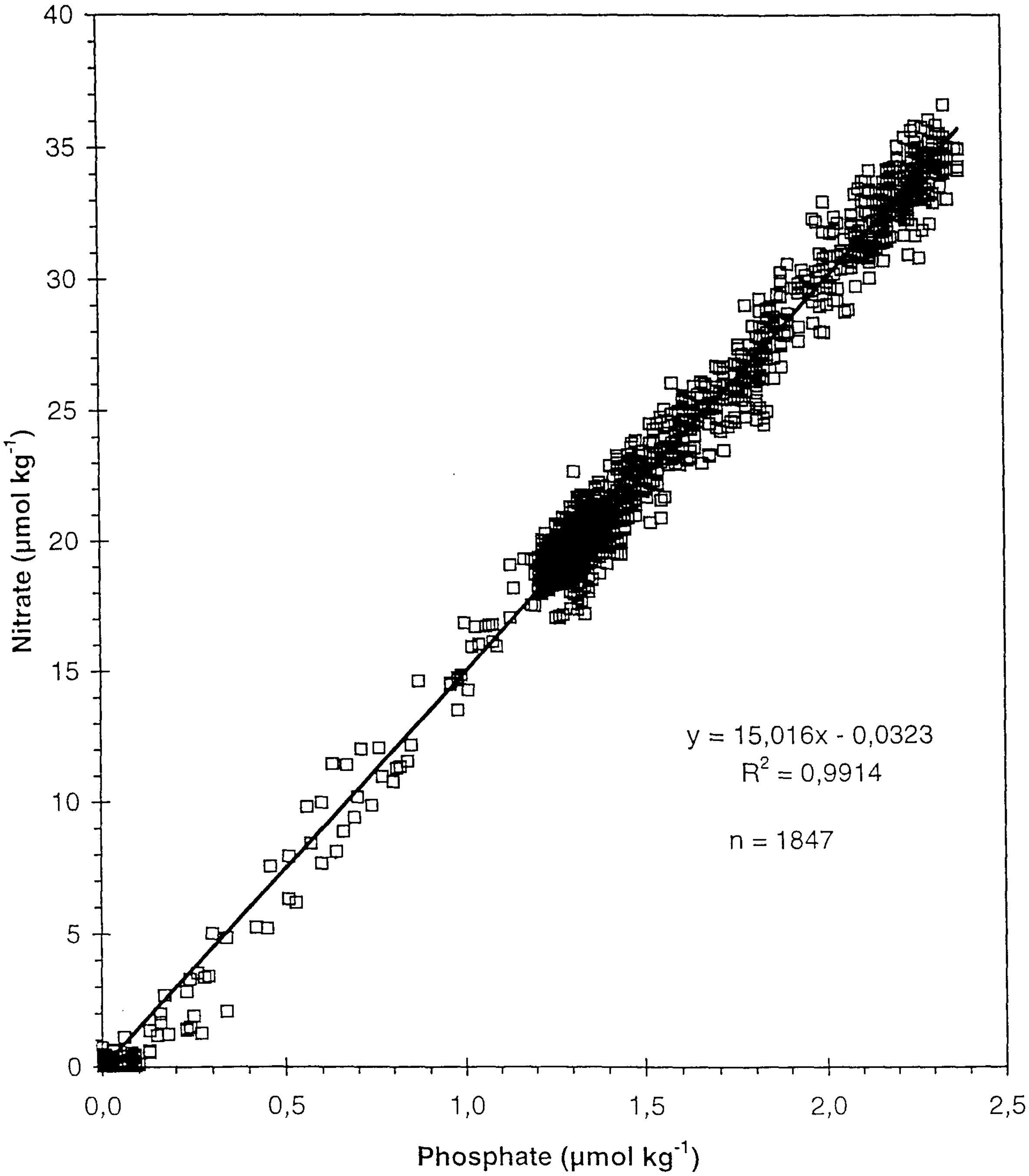


Figure 3: Nitrate – phosphate correlation for ETAMBOT 1 cruise data.

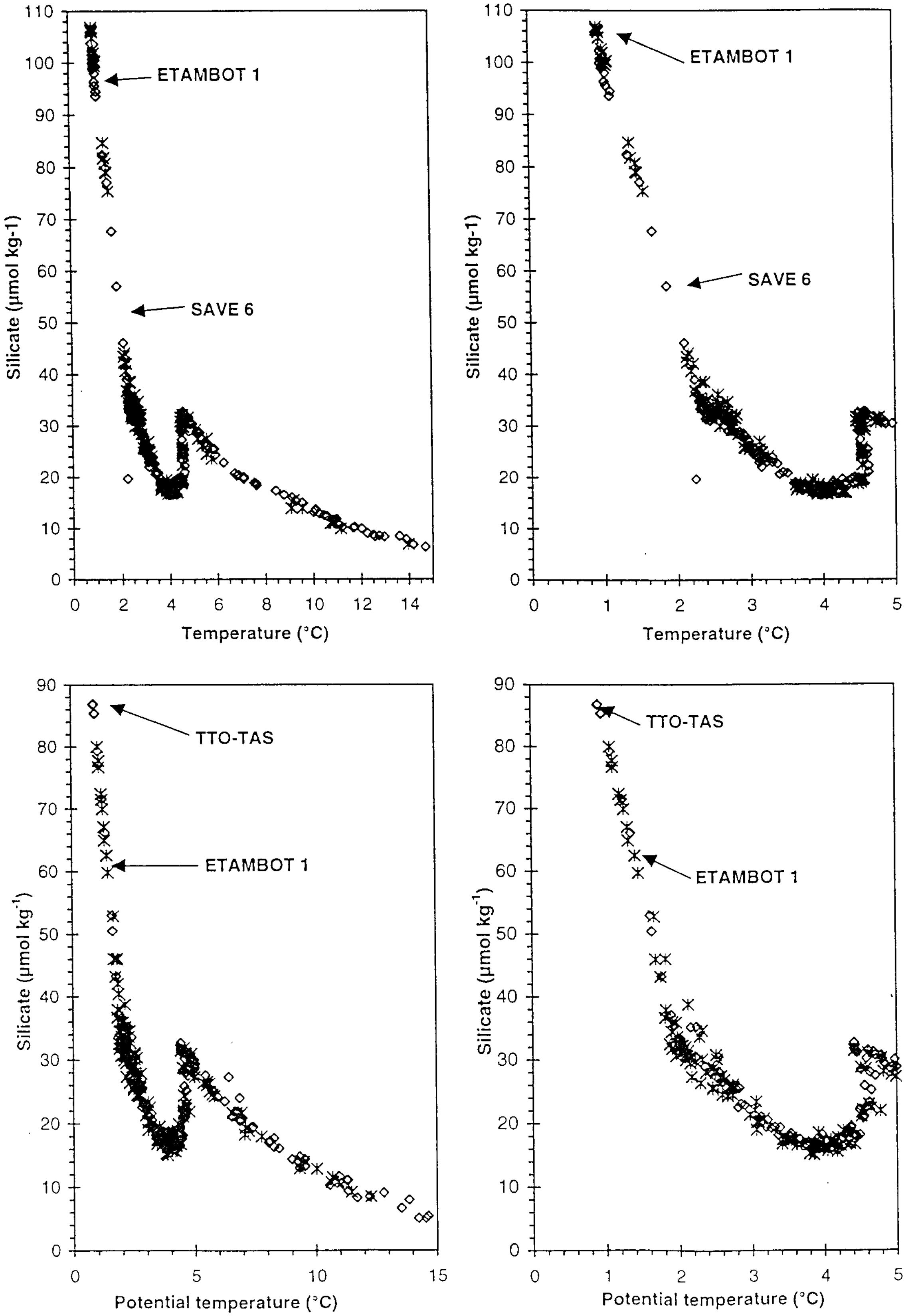


Figure 4: Silicate versus temperature for ETAMBOT 1 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S] and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

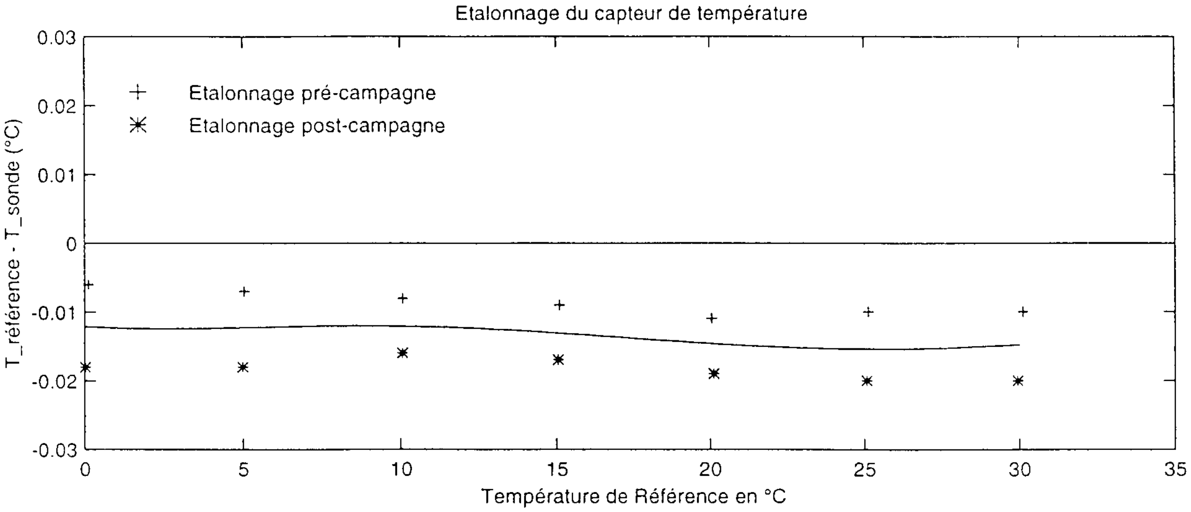


Figure 5: Temperature difference , in °C, between the laboratory reference temperature and the temperature measured by the probe. The solid represent the 5^{th} order polynomial minimizing the differences.(+: calibration before the cruise. *: calibration after the cruise).

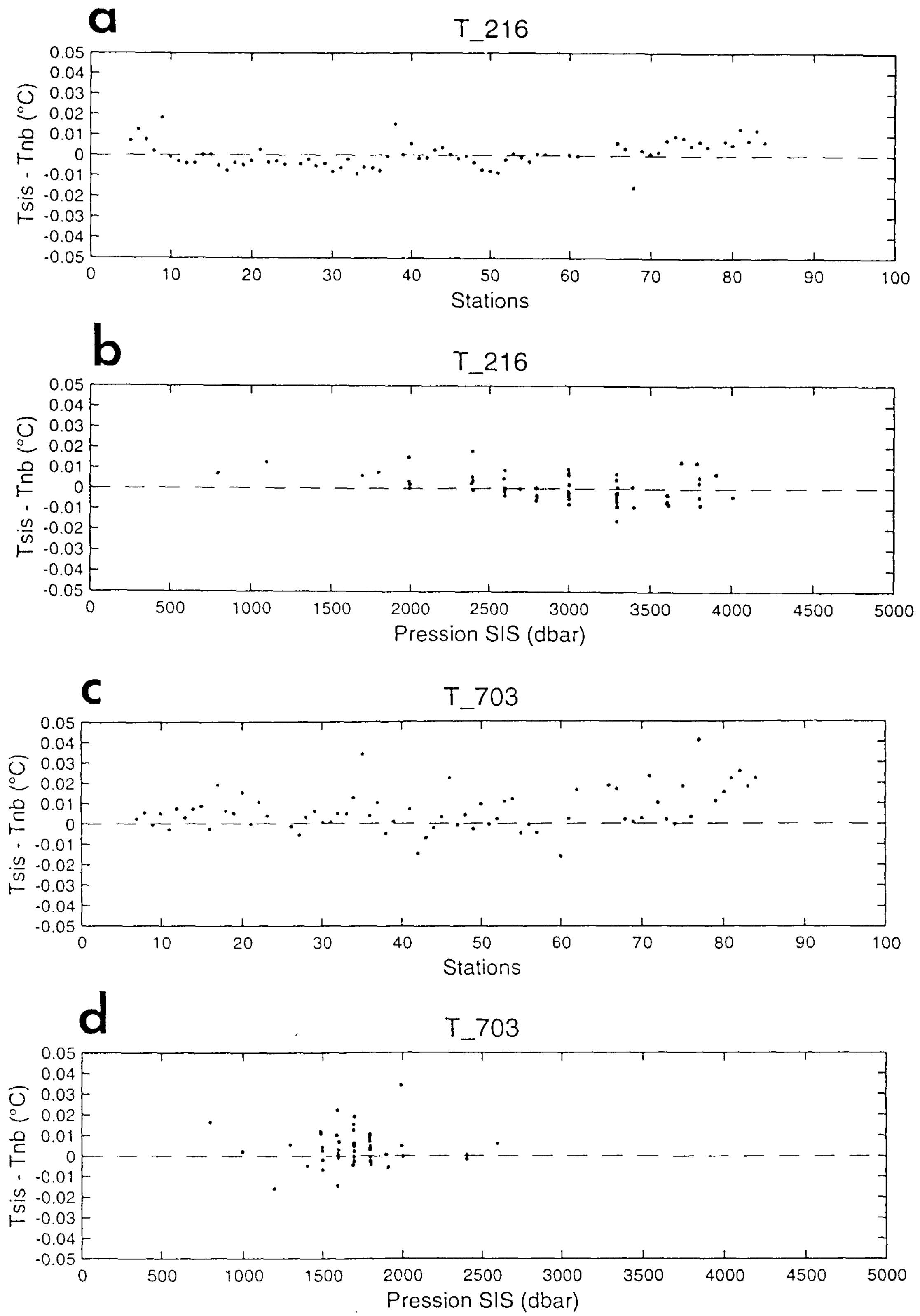


Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

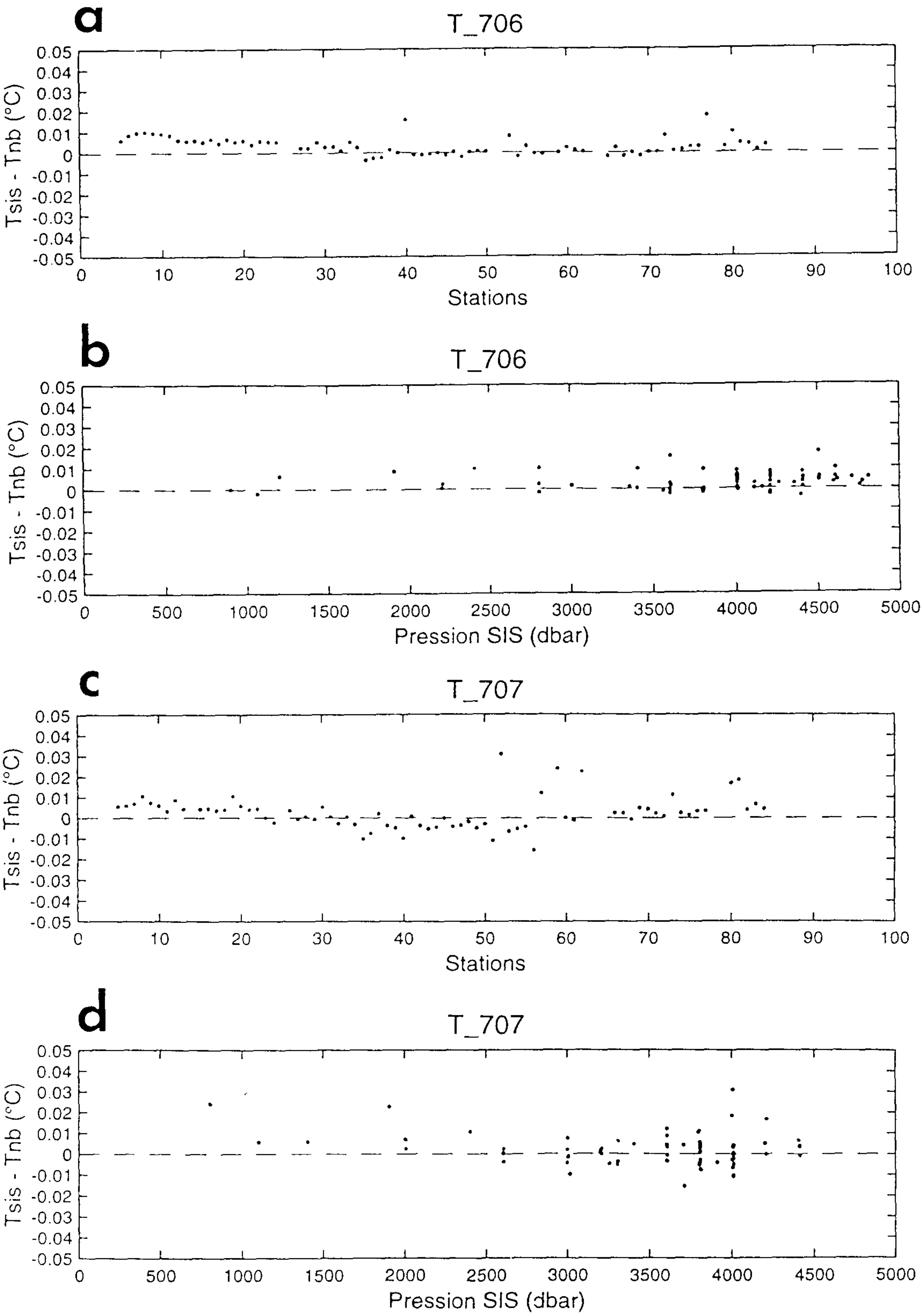


Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

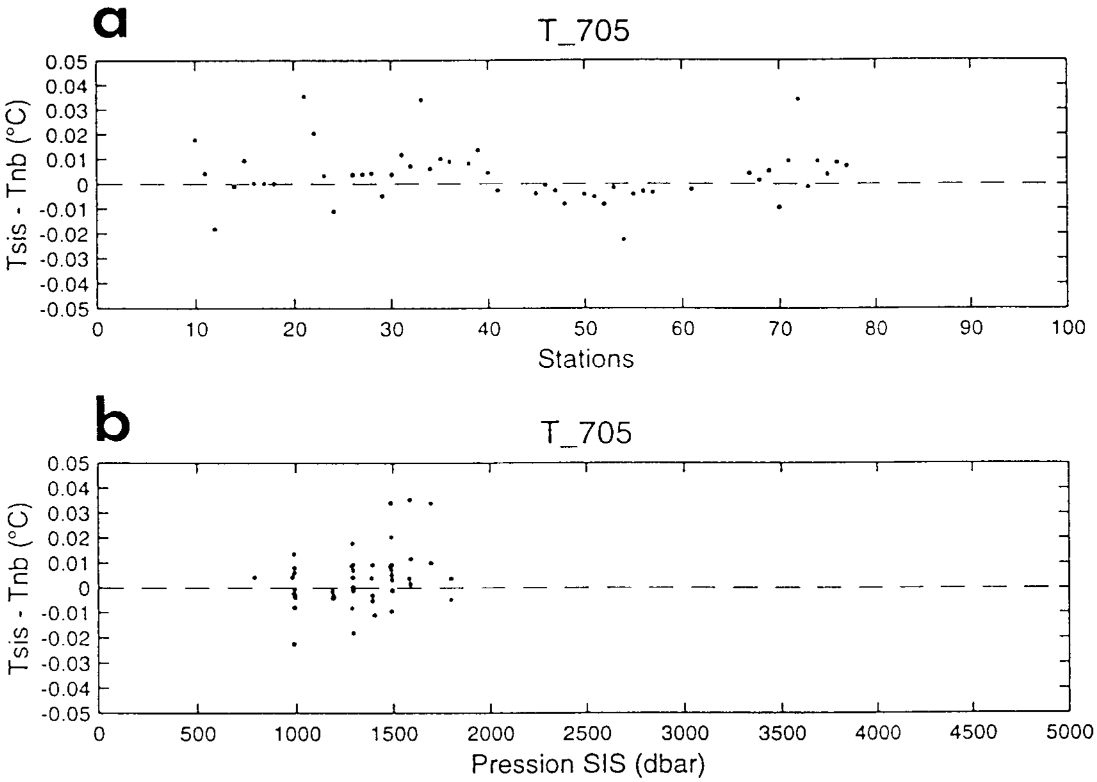


Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

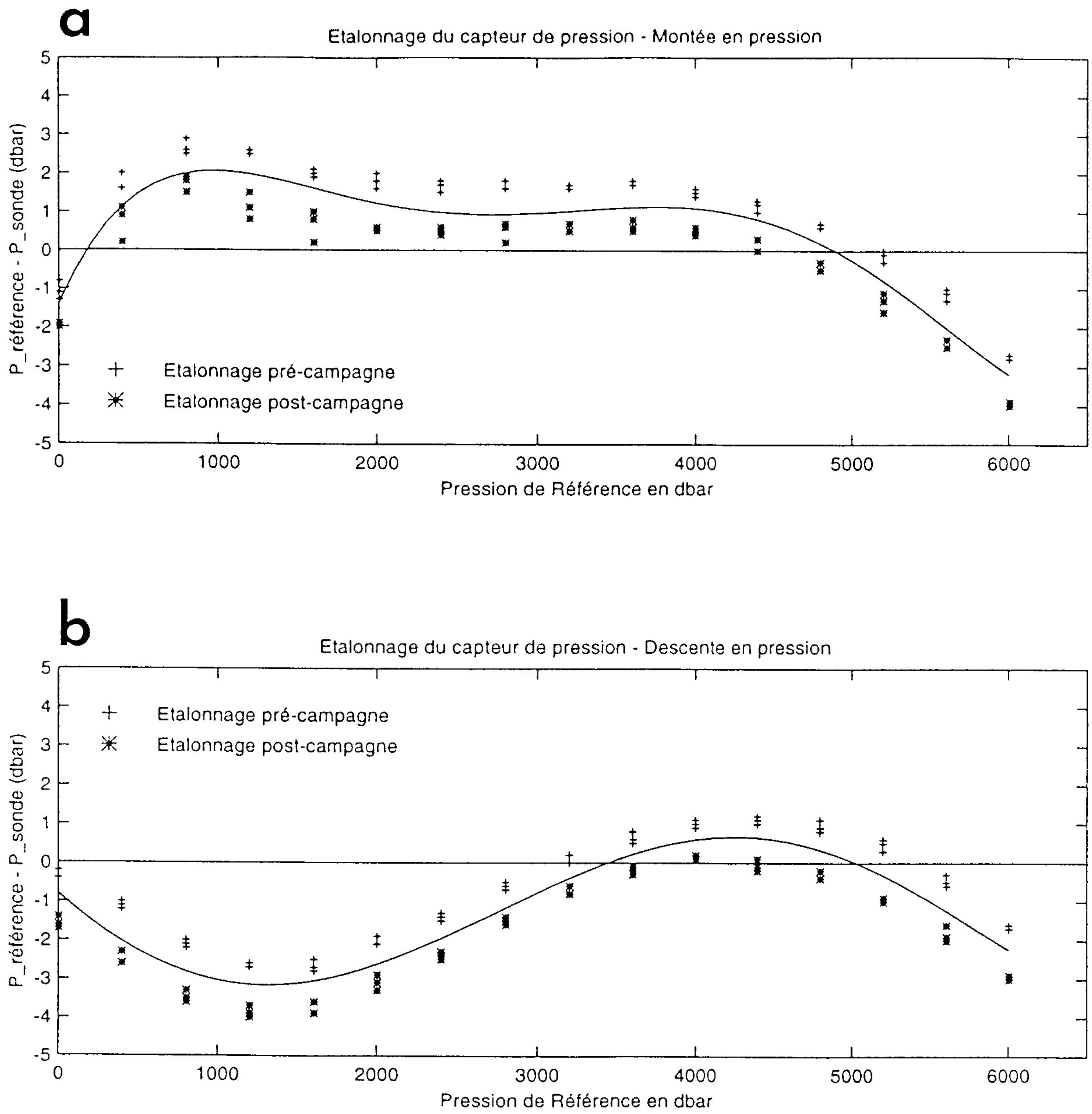


Figure 7: Pressure difference, in dbar, between the laboratory reference pressure and the pressure measured by the probe. The solid represent the 5th order polynomial minimizing the differences.
a) calibration for increasing pressure at a 20°C temperature (down cast).
b) calibration for decreasing pressure at a 15°C temperature (up cast).

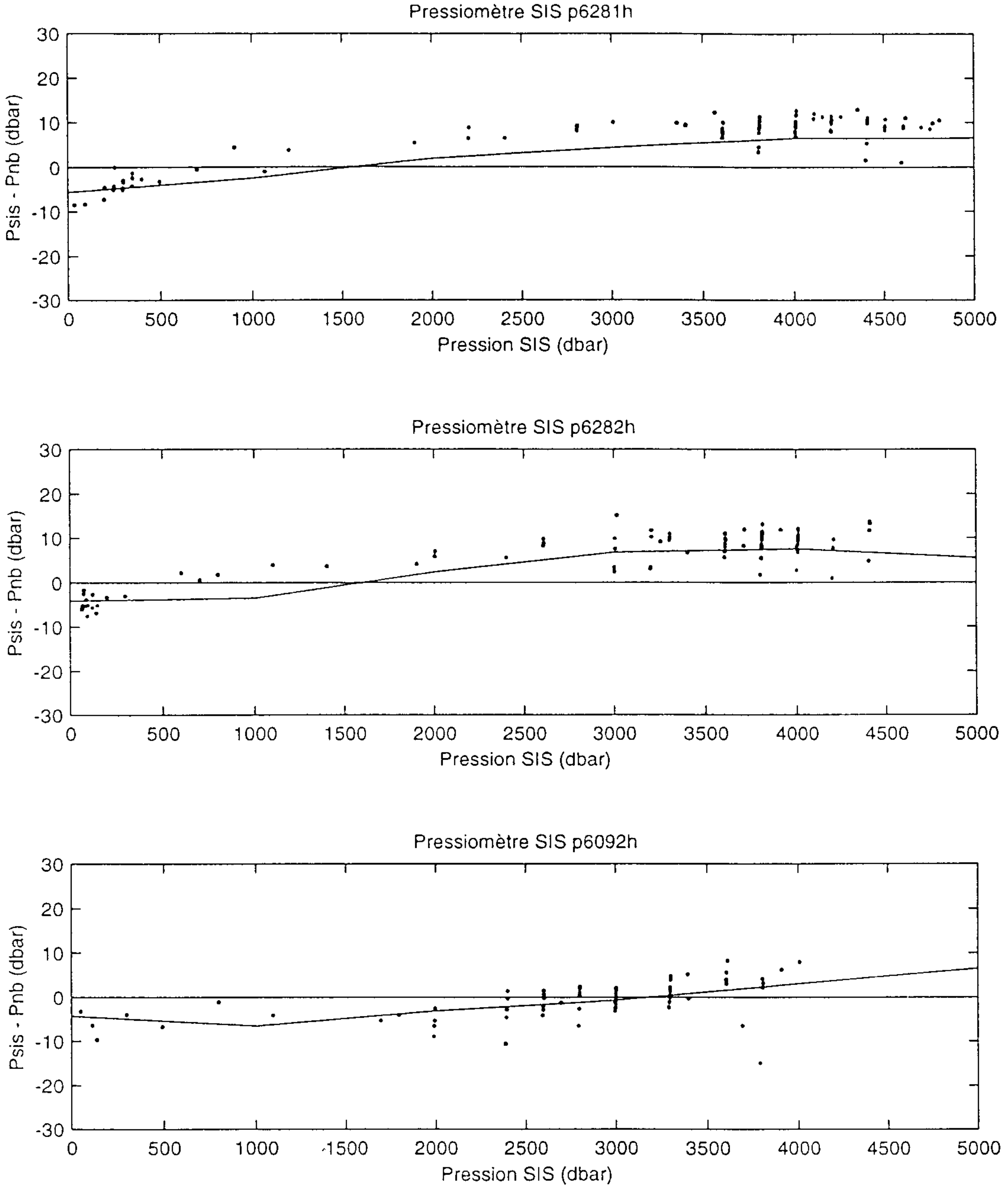


Figure 8: Pressure difference, in dbar, between SIS and CTD measurements (before calibration). The solid line represents the sum of the SIS and CTD pressure correction to add to the pressure difference.

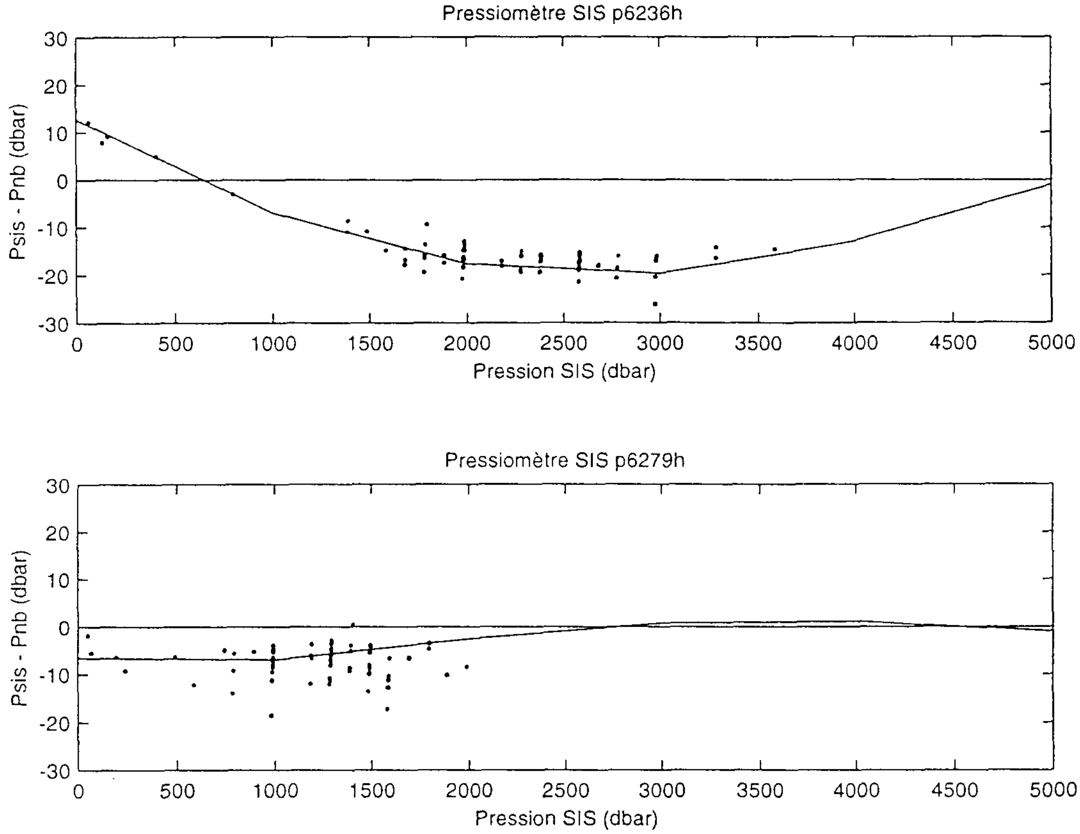


Figure 8: Pressure difference, in dbar, between SIS and CTD measurements (before calibration). The solid line represents the sum of the SIS and CTD pressure correction to add to the pressure difference.

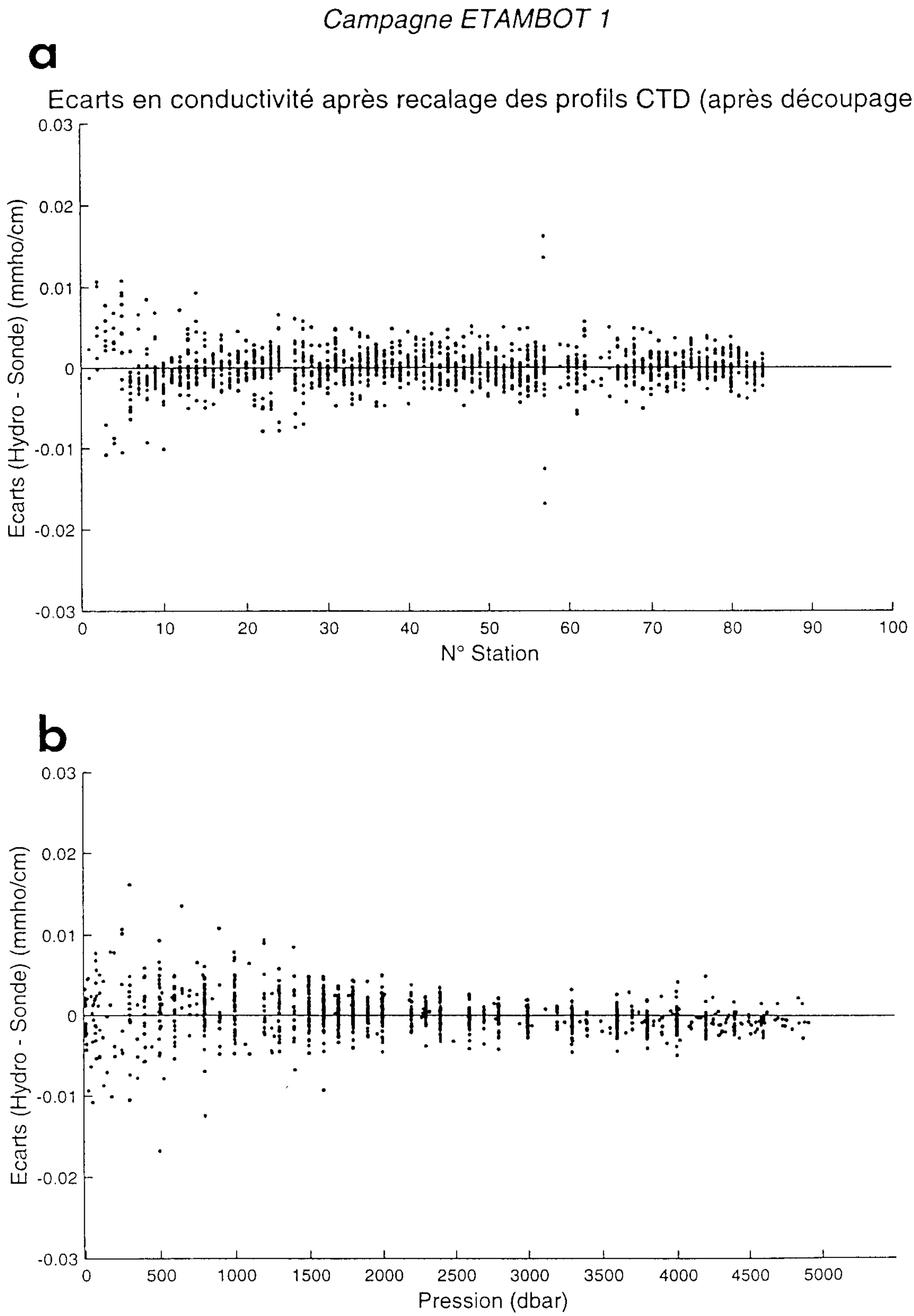


Figure 9: Conductivity difference, in mmho/cm, between water sample and CTD measurements, after calibration.

a) difference as a function of station number.

b) difference as a function of pressure.

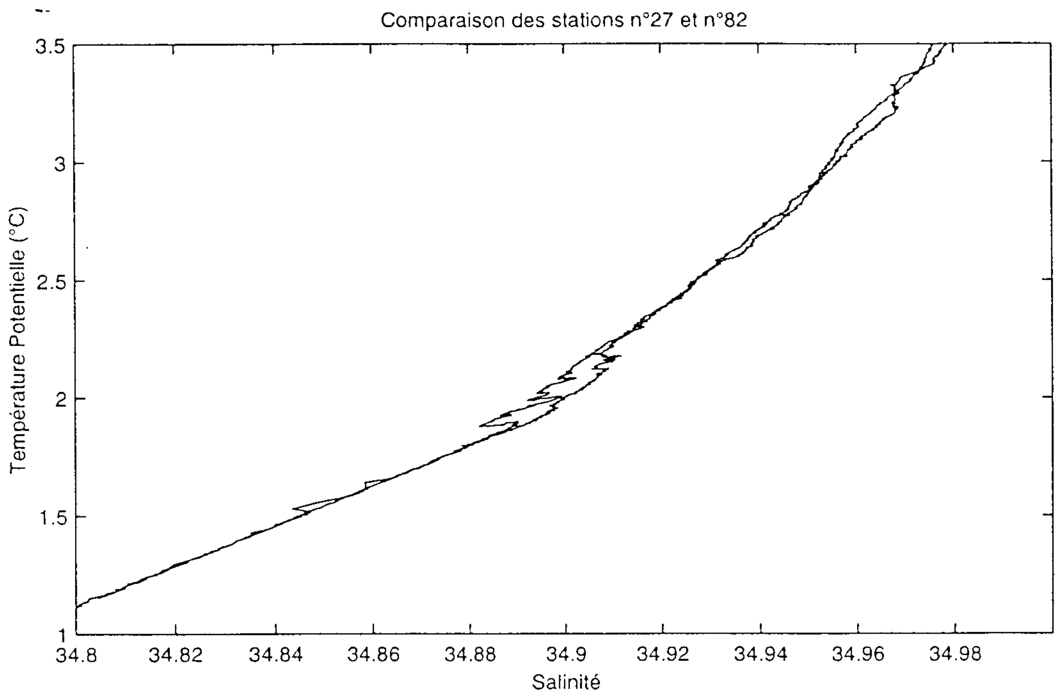


Figure 10: θ-S diagram of repeated ETAMBOT 1 stations N°27 and N°82 (41°20'W-7°30'N).

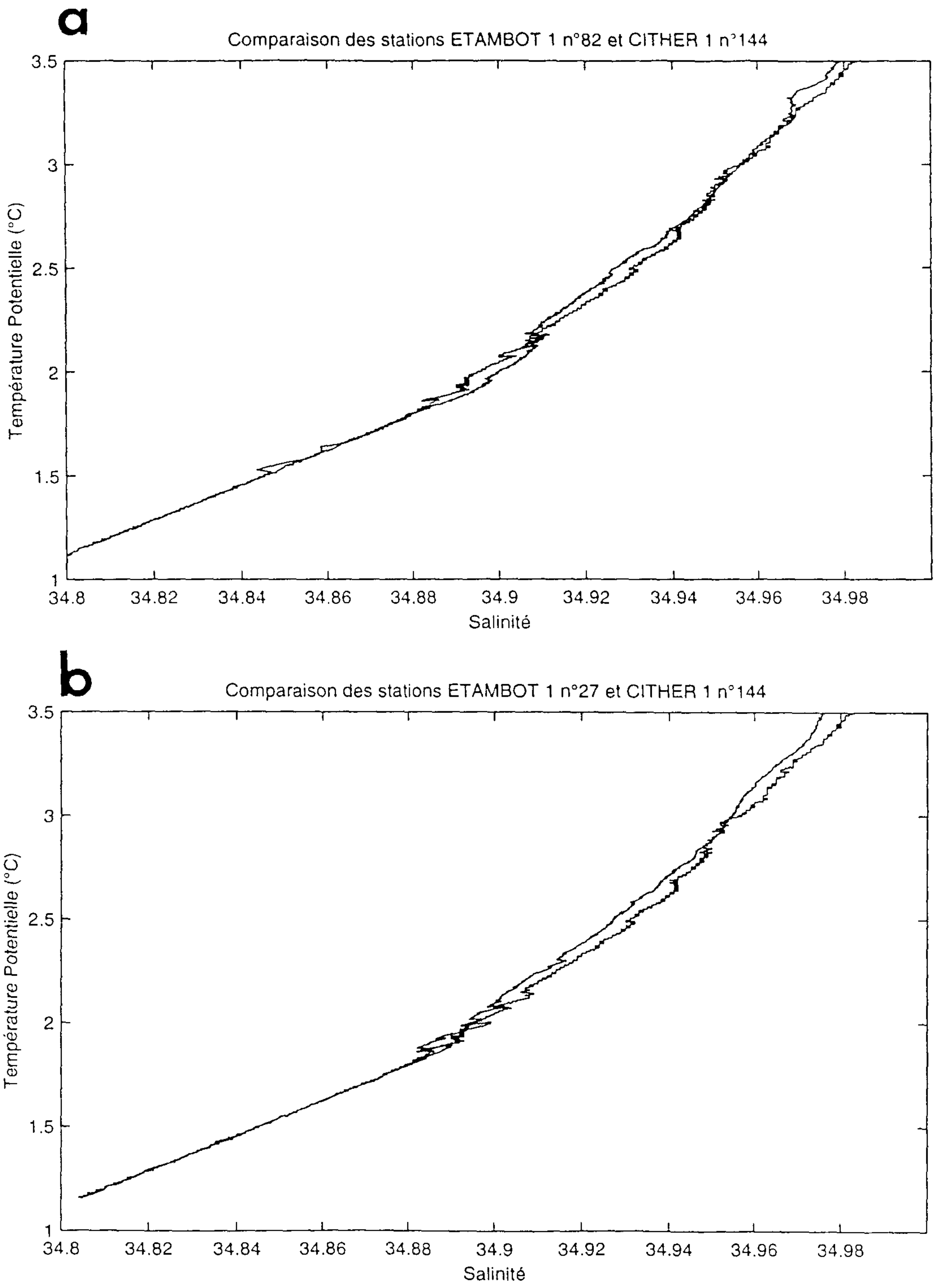
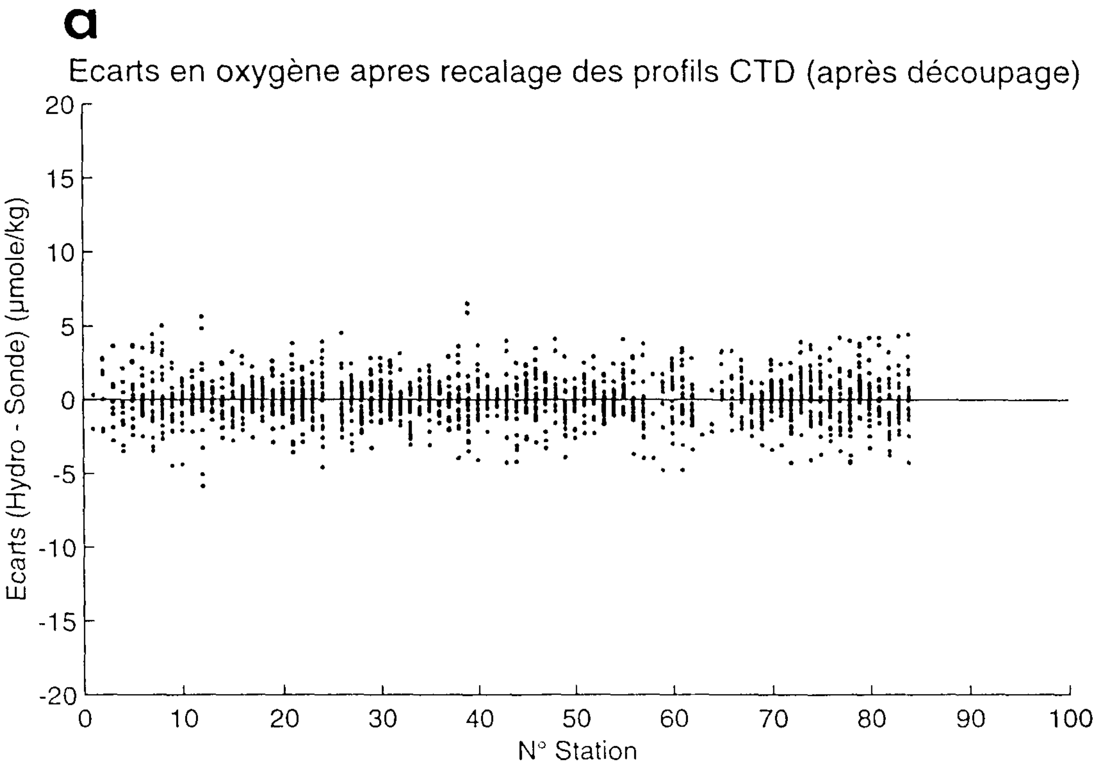


Figure 11: Comparison of the θ-S diagram of ETAMBOT 1 and CITHER 1 stations.

a) ETAMBOT 1 station N°82 (41°20'W-7°30'N) and CITHER 1 station N°144 (41°20'W-7°30'N)

b) ETAMBOT 1 station N°27 (41°20'W-7°30'N) and CITHER 1 station N°144 (41°20'W-7°30'N)



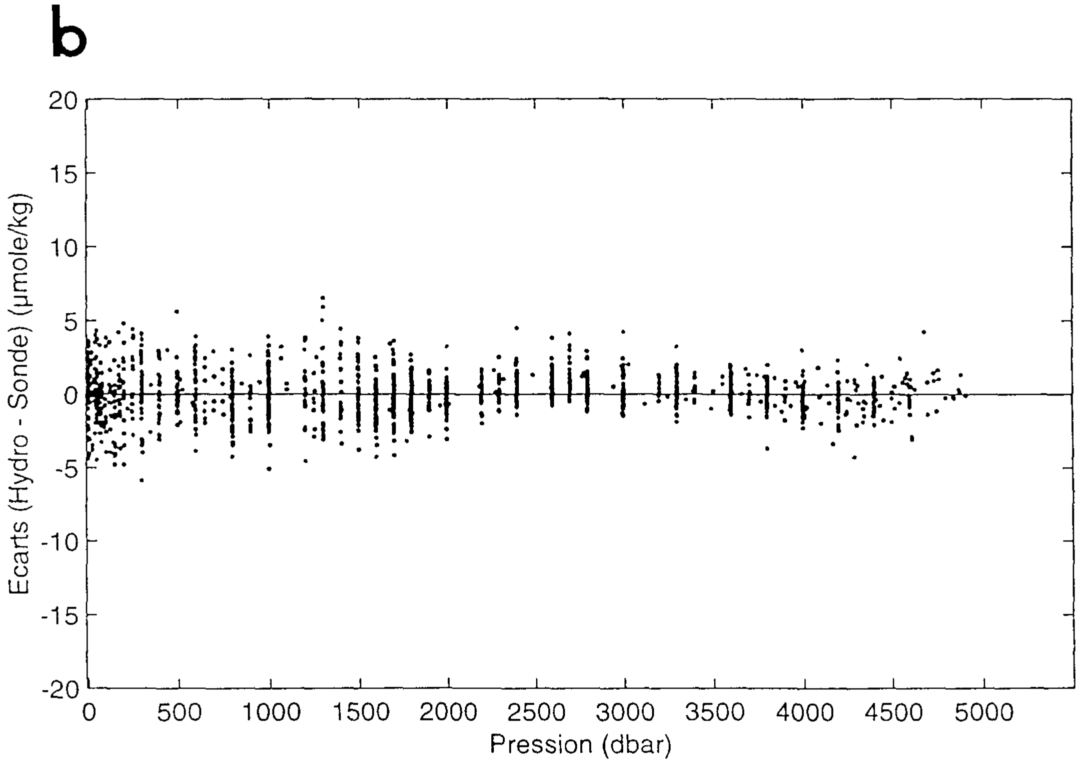


Figure 12: Dissolved oxygen difference, in µ mol kg^{-1}, between water sample and CTD measurements.
a) difference as a function of station number.
b) difference as a function of pressure.

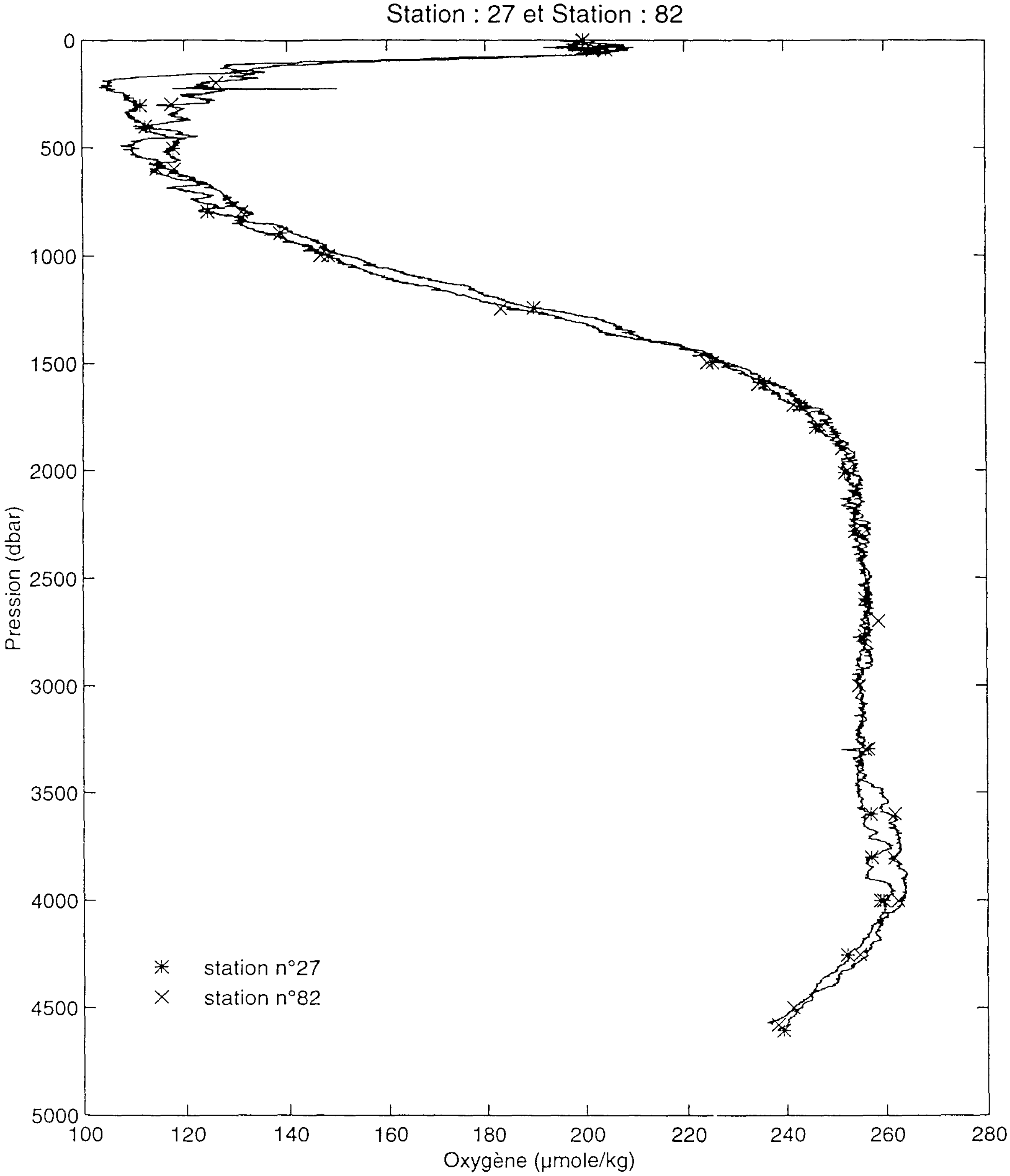


Figure 13: Dissolved oxygen profiles, in µ mol kg^{-1}, of repeated stations N°27 and N°82 (41°20'W-7°30'N).
*: water sample measurement of station N°27
x: water sample measurement of station N°82

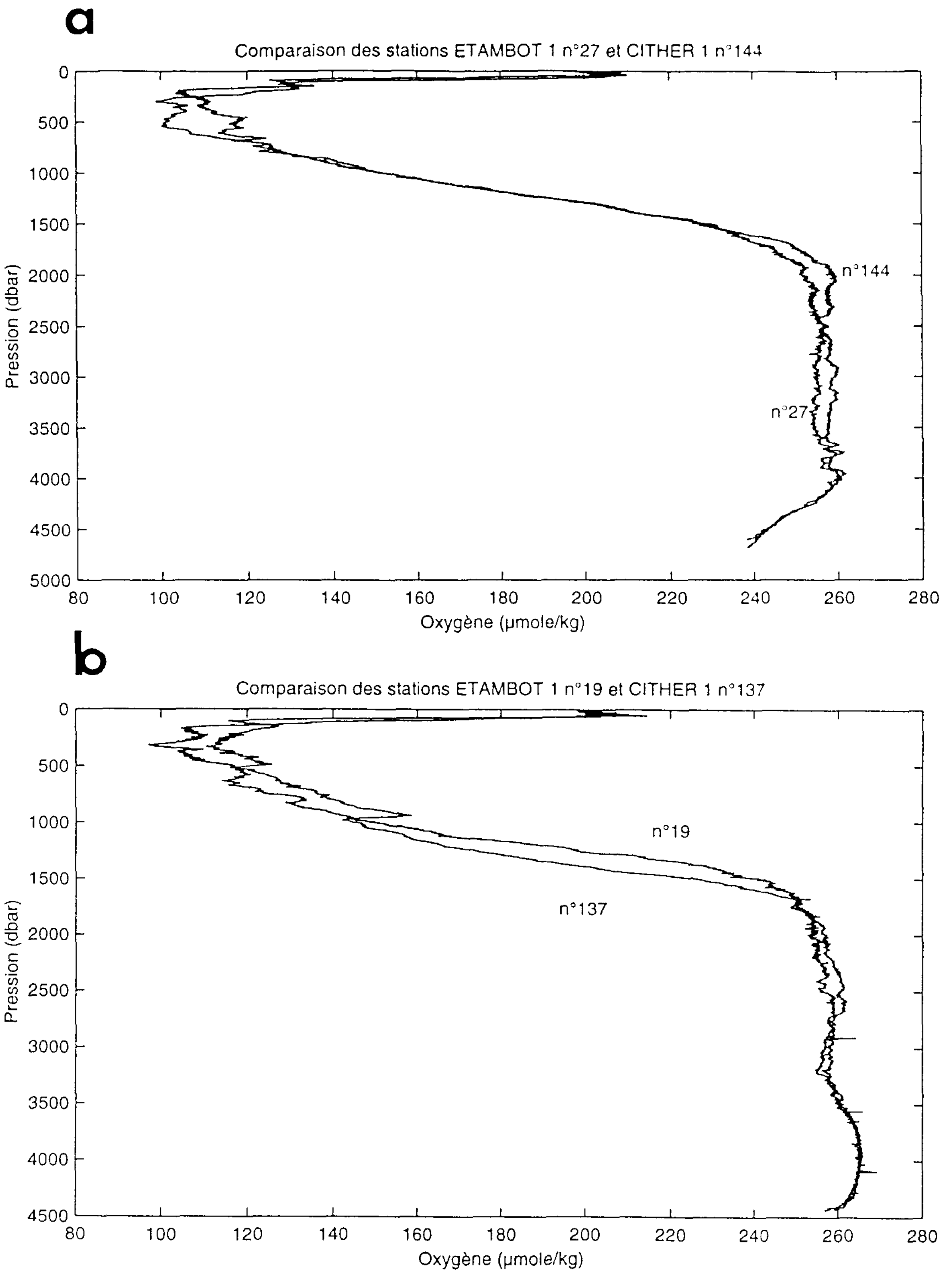


Figure 14: Dissolved oxygen profiles, in µ mol kg^{-1}.

a) ETAMBOT 1 station N°27 (41°20’W-7°30’N) and CITHER 1 station n°144 (41°20’W-7°30’N).

b) ETAMBOT 1 station N°19 (46°W-7°30’N) and CITHER 1 station n°137 (46°W-7°30’N).

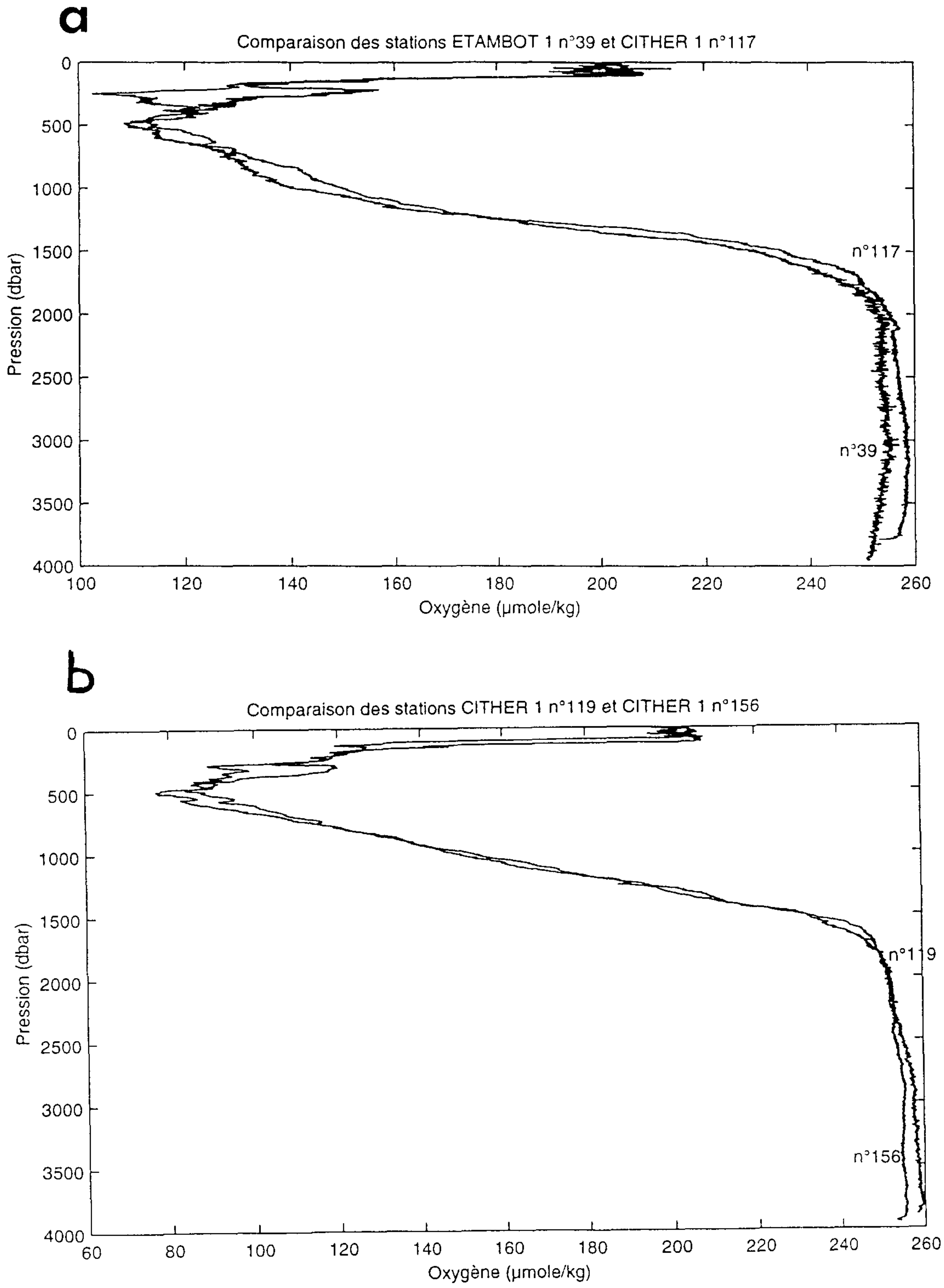


Figure 15: Dissolved oxygen profiles, in µ mol kg^{-1}.

a) ETAMBOT 1 station N°39 (35°W-7°N) and CITHER 1 station n°117 (35°W-7°N).

b) CITHER 1 station N°119 (35°W-7°30'N) and CITHER 1 station n°156 (35°W-7°30'N).