A. Cruise Narrative

A.1 Highlights

WOCE AR15, AR04W and AR04E, R/V EDWIN LINK, Cruise ETAMBOT2

Expedition designation (EXPOCODE): 33 LKETAMBOTT2

Chief of Project: Claude Oudot
Chief Scientist: Yves Gouriou
Centre ORSTOM
B.P. 70
29280 Plouzané
France
Telephone: (33) 02 98 22 45 10
Telefax: (33) 02 98 22 45 14
e.mail:gouriou@orstom.fr

Ship: R/V EDWIN LINK

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

Cruises Date: April 15, 1996 to May 16, 1996

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_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°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

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. An other cruise, ETAMBOT1, 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, 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. 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 ETAMBOT2 cruise was similar to the track of the ETAMBOT1 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_2	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	CO2	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

By B.Bourlès

Navigation data (time, position, course and speed over ground, and fix quality information) were acquired every 15 seconds throughout the ETAMBOTT-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_2 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)

By 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^{-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 shipmounted 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. 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_2 system. The CTD-O_2/L-ADCP package was lowered and rised at about 1 m s^{-1}, 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^{-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 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^{-1} (***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^{-1}.

The L-ADCP perfectly worked during all the CTD-O_2 casts; hence, ninety-nine absolute velocity profiles were acquired during the Etambott-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

by 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 contamined 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 minutes 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_2 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

By B. Bourlès

Meteorological measurements were recorded at the beginning of every CTD-O_2 station. These measurements are the following: date, time, position, wind speed ($m\ s^{-1}$), wind direction (degrees from geographical north), sea level pressure (mbar), sea level temperature (°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

by P. Fournier and C. Oudot

Salinity analysis of samples collected during ETAMBOT2 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 (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

by P. Fournier and C. Oudot

Sampling and techniques

Oxygen samples were taken in calibrated clear glass bottles (capacity = 120 cm^3) 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 ± 1°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^{TM} Titrator^{TM} model 682 and a Dosimat^{TM} 665 burette (10 cm^3).

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

$$O_2\ [\mu mol\ kg^{-1}] = (44.660 / \rho_{sw}) * O_2\ [cm^3\ dm^{-3}]$$

where ρ_{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_2 concentration (µmol kg^{-1})	152.0	255.1	259.0	153.1
Maximum deviation (µmol kg^{-1})	0.7	0.6	0.3	1.7
Standard deviation (µmol kg^{-1})	0.7	0.2	0.4	0.6

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

Comparisons with historical data

Comparisons of ETAMBOT1 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

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 µmol 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 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

Silicate

Station number	32	42	72	87
Pressure (dbar)	1000	2000	2500	1000
Number of bottles	22	22	22	22
Mean silicate concentration (µmol kg^{-1})	27.32	18.85	23.28	27.19
Standard deviation (µmol 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 µmol kg^{-1})	0.11	0.06	0.07	0.29

Phosphate

Station number	32	42	72	87
Pressure (dbar)	1000	2000	2500	1000
Number of bottles	22	22	22	22
Mean phosphate concentration (µmol kg^{-1})	2.09	1.22	1.23	2.08
Standard deviation (µmol 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 µmol kg^{-1})	0.42	0.33	0.15	0.33

Nitrate

Station number	32	72	87
Pressure (dbar)	1000	2500	997
Number of bottles	22	22	22
Mean nitrate concentration (µmol kg^{-1})	31.10	19.00	31.45
Standard deviation (µmol kg^{-1})	0.08	0.03	0.05
Percent standard deviation	0.27	0.17	0.15
Percent standard deviation (vs full range, 40 µmol kg^{-1})	0.21	0.08	0.12

The standard deviation of the seventy-four sample pairs (duplicate) is 0.4 µmol kg^{-1} for silicate, 0.02 µmol kg^{-1} for phosphate and 0.1 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 ($R^2 = 0.9935$). The slope of the regression line (15.092) is in good agreement with the Redfield ratio.

Comparisons with historical data

Comparisons of ETAMBOT1 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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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, 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 ± 0.4& for F12 and ± 0.4& for F11, so better than for ETAMBOTT1.

The atmospheric mixing ratios were 524.5 ppt (±1.1%) for F12 and 267.1 ppt (±1.2%) for F11 so in the same order of magnitude than during ETAMBOTT1.
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 ETAMBOTT 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 pmol.kg^{-1} for F12 and 0.008 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 pmol.kg^{-1} for F12 and 0.025 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	32	42	72	87
Depth (dbar)	1000	2000	2500	1000
Number of bottles	21	22	17	22
TCO_2 (µmol kg^{-1})	2202.3	2215.9	2225.4	2201.6
Standard deviation (µmol kg^{-1})	9.1	14.2	7.7	6.1

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

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

where d_i = difference for pair ***i*** and n = number of pairs (76). For Etambot2 cruise S = 9.7 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	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):

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

with d_i = difference for pair ***i*** and n = number of pairs (76). For Etambot2 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:

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

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	32	42	72	87
Depth (dbar)	1000	2000	2500	1000
Number of bottles	21	21	17	21
A_T (µeql kg^{-1})	2308.7	2280.4	2397.2	2309.9
Standard deviation (µeq 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):

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

with d_i = difference for pair ***i*** and n = number of pairs (76). For Etambot2 cruise S = 10.8 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, $\boldsymbol{f}CO_2$, is related to the partial pressure, $\boldsymbol{p}CO_2$, by the relation (Weiss, 1974) to take into account the non-ideality of CO_2:

$$\boldsymbol{f}CO_2 = \boldsymbol{p}CO_2 \exp\{(B + 2\delta)\, p_{atm} / RT\}$$

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

$$\boldsymbol{p}CO_2 = \boldsymbol{x}CO_2\, p = \boldsymbol{x}CO_2\, (P - p_{H2O})$$

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 – 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_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 fCO_2 measurements was determined from statistical analysis of 86 pairs of duplicate results, according to the relationship (Dickson and Goyet, 1994):

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

where d_i = difference for pair ***i*** and n = number of pairs (86). For Etambot2 cruise S = 2.2 µatm.

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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 ±0.003°C. The solid line represents the 5th 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 ±0.001°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 that there is a bias between the two types of measurements: a bias of +0.017°C for the N°T_216 thermometer and +0.007°C for the N°T_707 thermometer. The laboratory calibrations point out an important drift at the 0°C temperature reference (+0.025°C for the N°T-216 thermometer and +0.015°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 figures 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 mmho cm^{-1} for 17% of the samples.
The difference is lower than 0.003 mmho cm^{-1} for 50% 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°26 and N°84).
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 ETAMBOT2 cruise

ETAMBOTT2 Station Number	ETAMBOTT2 Station Number	Salinity Difference
14	15	**0.0020**
15	16	**-0.0020**
16	17	0.0015
17	18	-0.0010
20	21	0.0015
34	35	0.0010
47	48	**-0.0020**
48	49	**0.0020**
57	58	-0.0010
58	59	**0.0020**
73	74	**-0.0020**
75	76	0.0010

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

2. During the ETAMBOT2 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 θ-S diagrams the salinity difference, for a given temperature, does not exceed 0.0010, below the potential temperature 1.9°C.

3. The ETAMBOT2 cruise exactly repeats the cruise track of the ETAMBOT1 cruise and the western part of the CITHER 1 cruise (WHP A6 and A7 lines).

Omitting the shallow stations, 80 θ-S diagrams of the ETAMBOTT1 and ETAMBOTT2 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 ETAMBOT1 and ETAMBOT2 profiles

ETAMBOT2 Station Number	ETAMBOT1 Station Number	Salinity difference
15	15	**-0.0020**
20	20	0.0010
24	24	-0.0010
33	33	0.0010
36	36	0.0010
43	42	**-0.0020**
49	48	-0.0010
51	50	0.0010
69	68	**0.0020**
73	71	0.0010
74	72	**0.0020**
75	73	0.0010
86	84	**-0.0020**

Likewise 40 θ-S diagrams of the ETAMBOT2 and CITHER 1 cruise have been compared. The salinity differences are reported in the following table.

TABLE 12: Salinity comparison between ETAMBOT2 and CITHER 1 profiles

ETAMBOT2 Station Number	CITHER1 Station Number	Salinity difference
15	133	**-0.0030**
19	137	-0.0010
20	138	0.0010
33	151	**0.0020**
34	153	0.0010
43	114	-0.0010
48	110	0.0010
52	106	0.0010

The difference observed at the ETAMBOT2 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]

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**.

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) µmol 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 µmol kg^{-1}, between the oxygen samples and the down-cast CTD measurements.
The difference is lower than 1 µmol kg^{-1} for 27% of the samples .
The difference is lower than 2 µmol kg^{-1} for 65% of the samples .

CONTROL

As for the salinity profiles, the comparison with the oxygen profiles of the ETAMBOT1 have been made.

TABLE 14: Oxygen comparison between ETAMBOT1 and ETAMBOT2 profiles

N° de station ETAMBOT2	N° de station ETAMBOT1	Oxygen difference µmol 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.

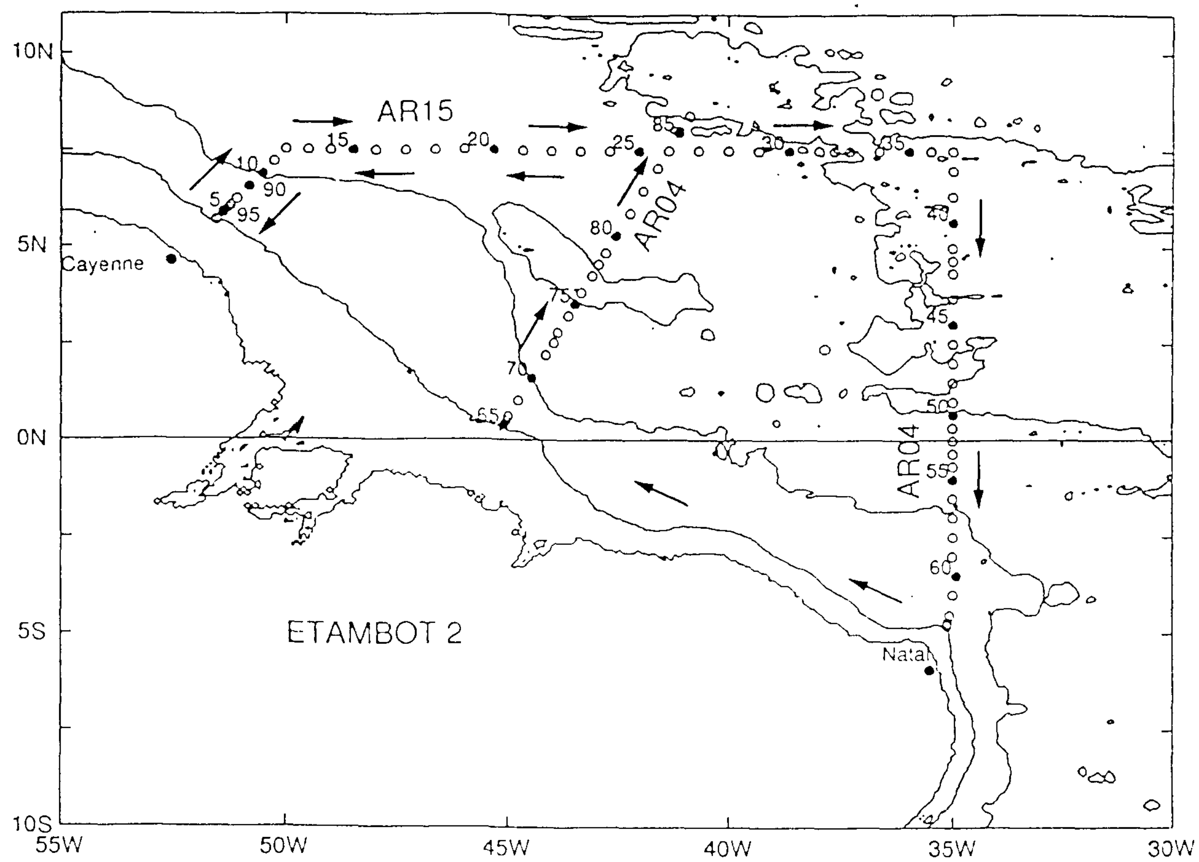


Figure 1: Cruise track and station position.

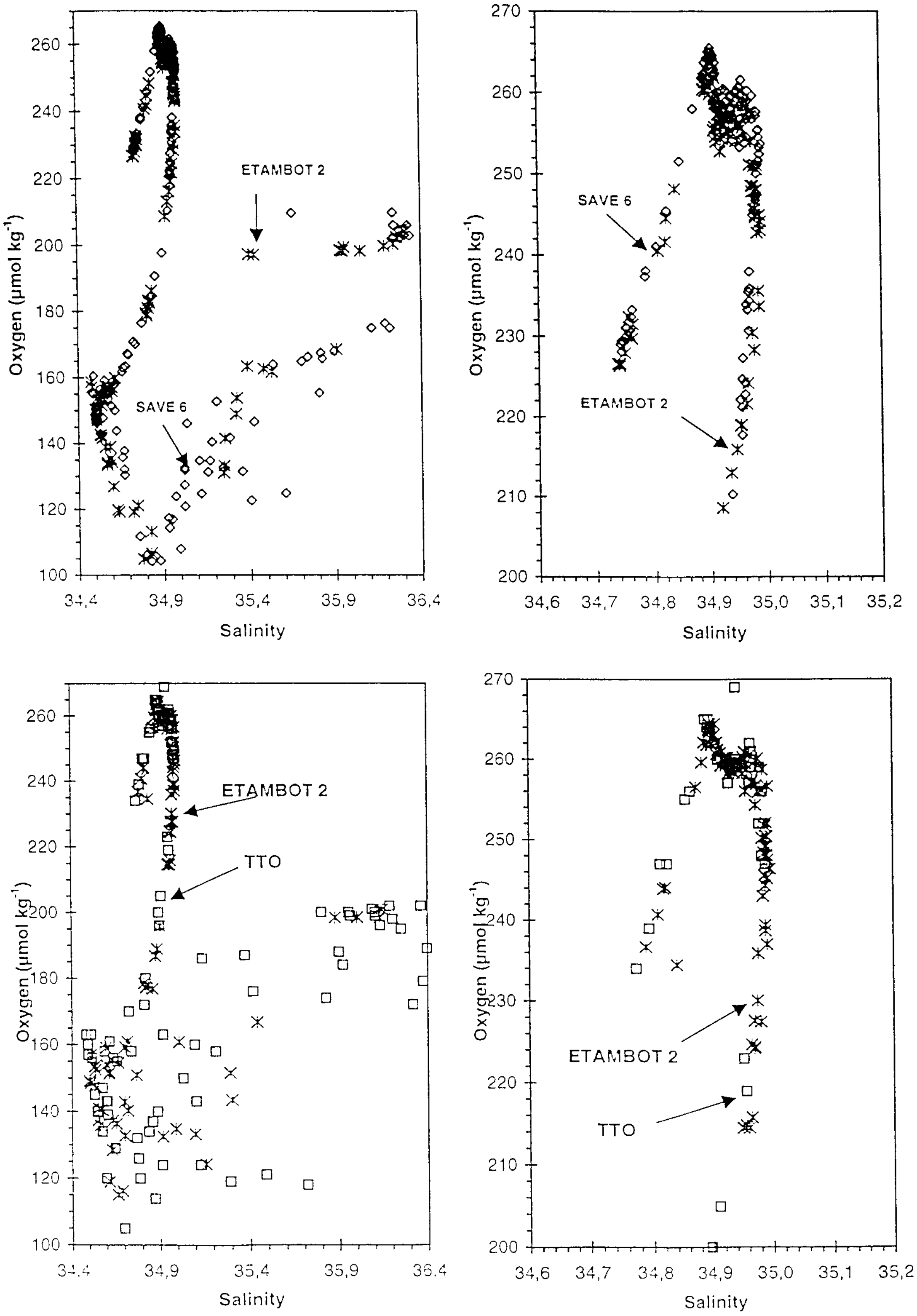


Figure 2: Oxygen versus salinity for ETAMBOT2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S], and TTO-TAS [45°W-1°N to 41°W-7°30’N]).

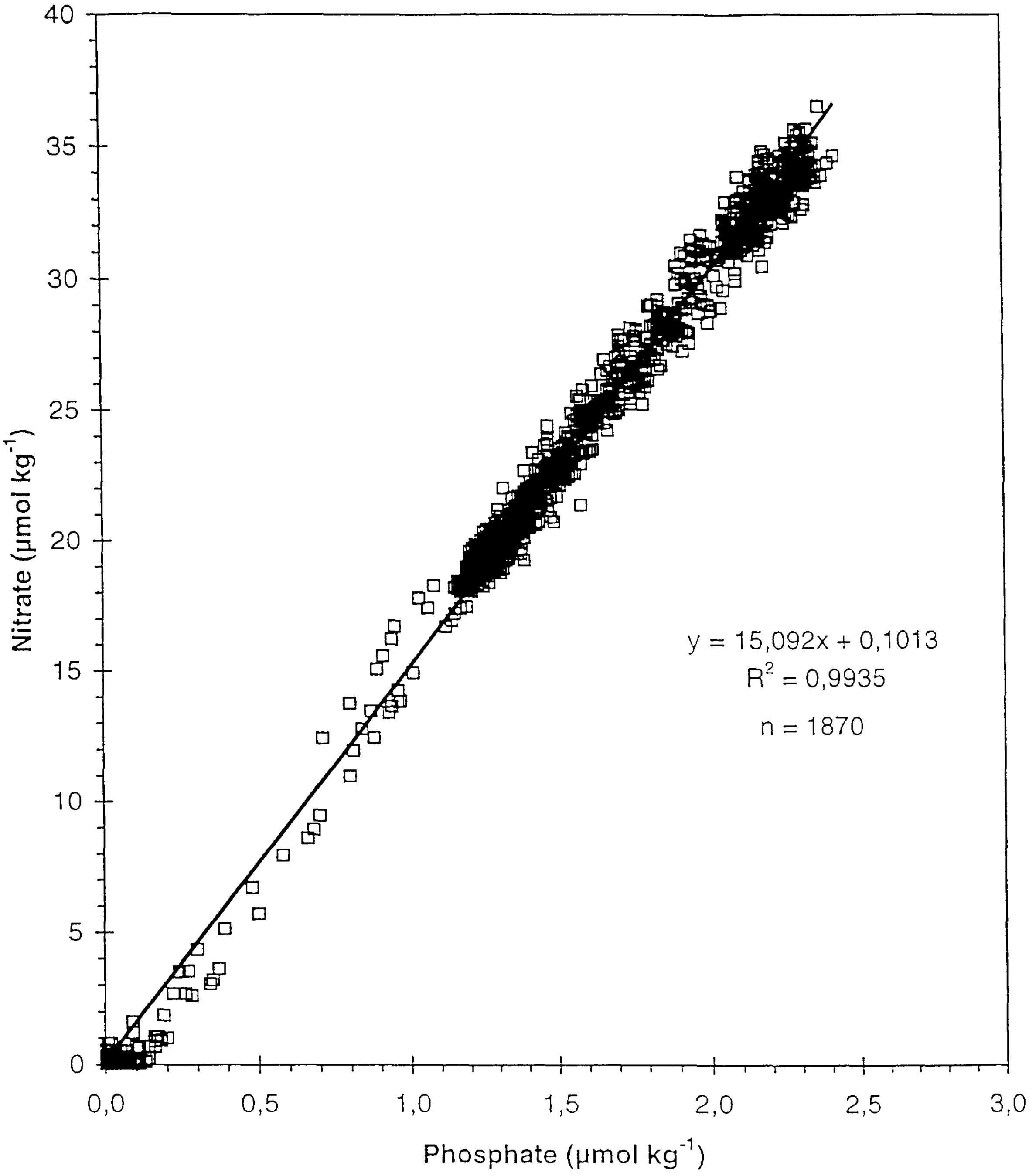


Figure 3: Nitrate – phosphate correlation for ETAMBOT2 cruise data.

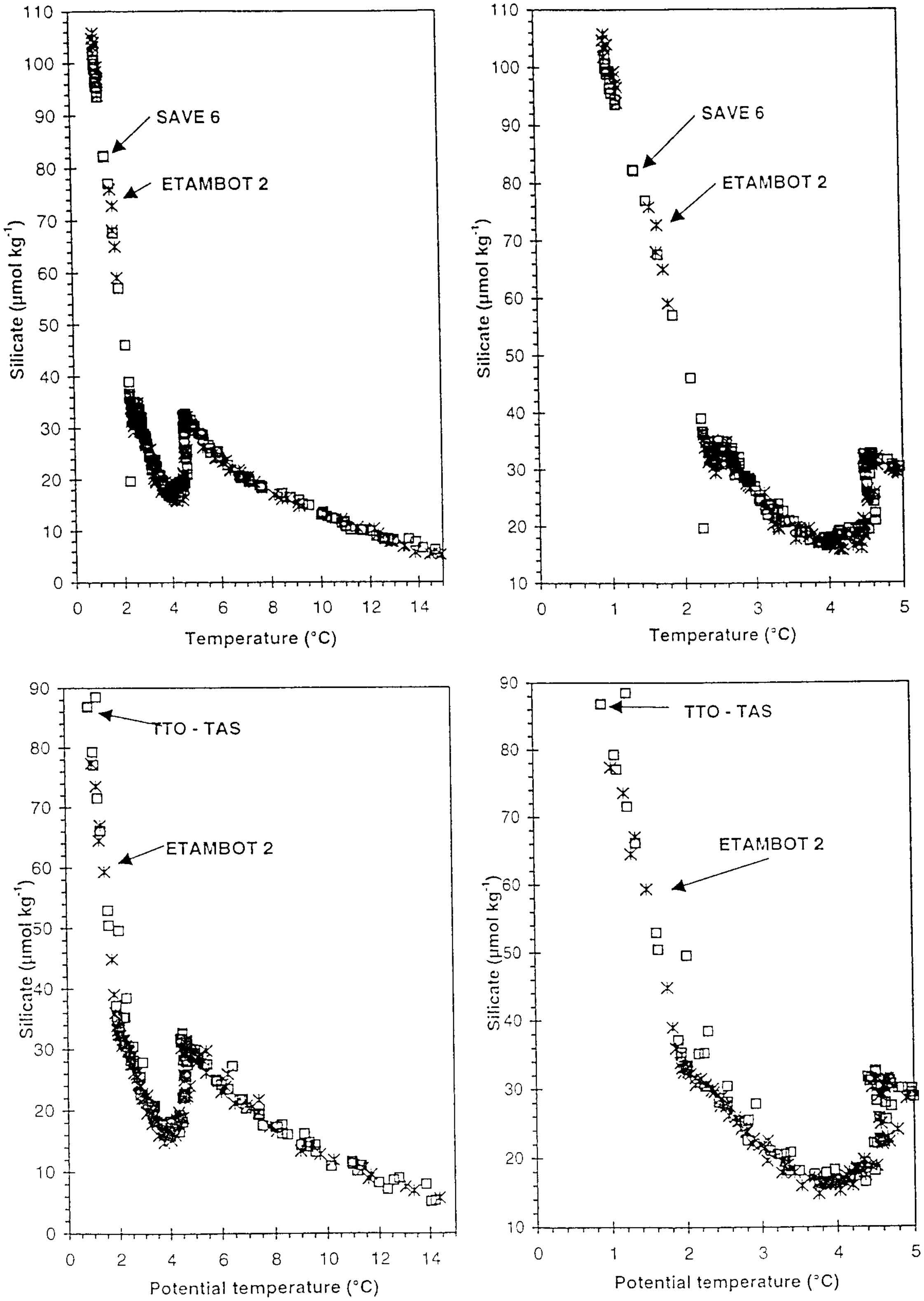


Figure 4: Silicate versus temperature for ETAMBOT2 and historical data (SAVE Leg 6 [35°W, 1°N to 1°S] and TTO-TAS [45°W-1°N to 41°W-7°30'N]).

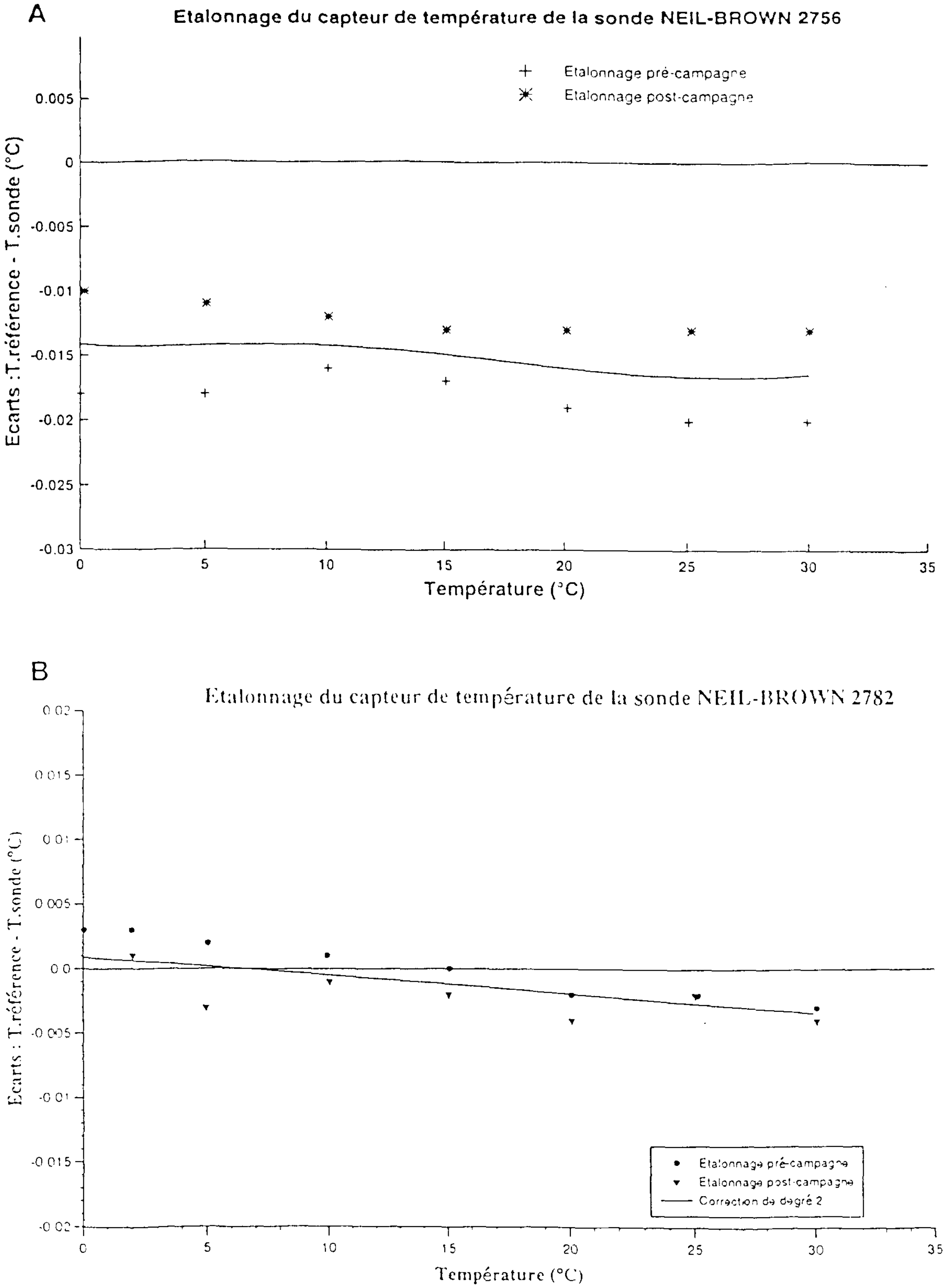


Figure 5: Temperature difference , in °C, between the laboratory reference temperature and the temperature measured by the probe. The solid represent the 5th order polynomial minimizing the differences.

a) calibration results for the N°2756 CTD probe

b) calibration results for the N°2782 CTD probe

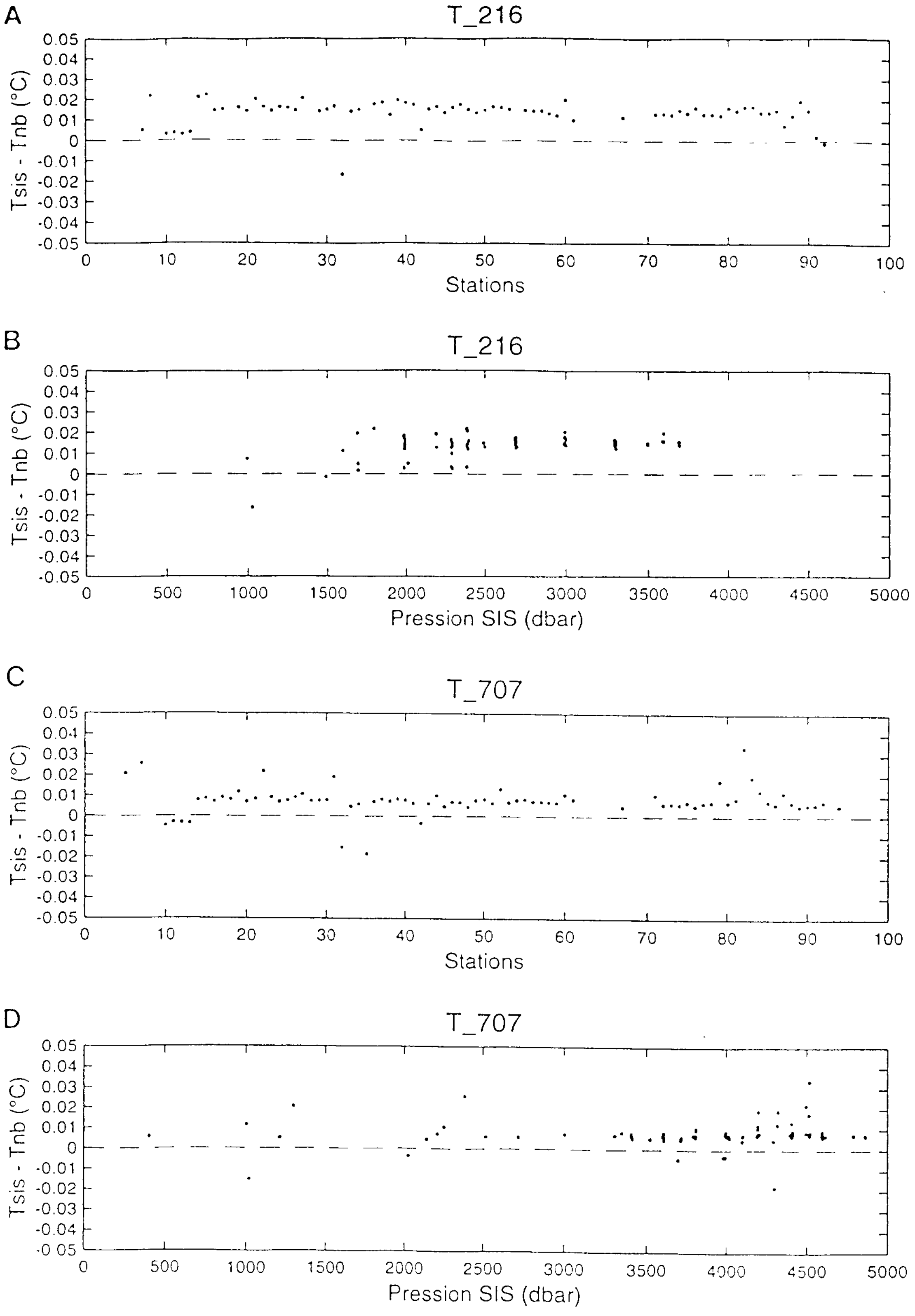


Figure 6: Temperature difference, in °C, between SIS and CTD measurements (after calibration).

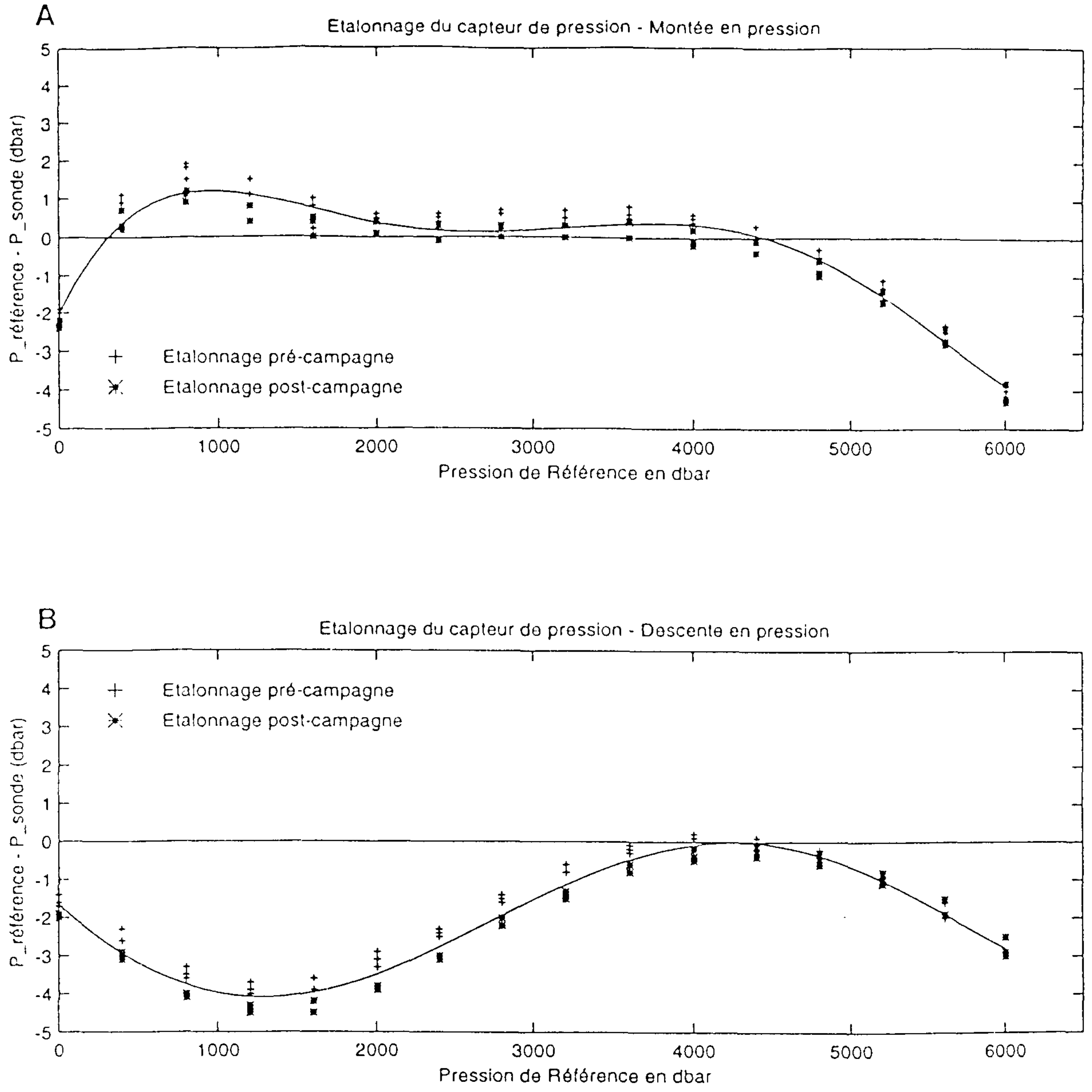


Figure 7: Pressure difference, in dbar, between the laboratory reference pressure and the pressure measured by the N°2756 probe. The solid represent the 5th order polynomial minimizing the differences.

a) calibration for increasing pressure at a 20°C temperature (down cast).

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

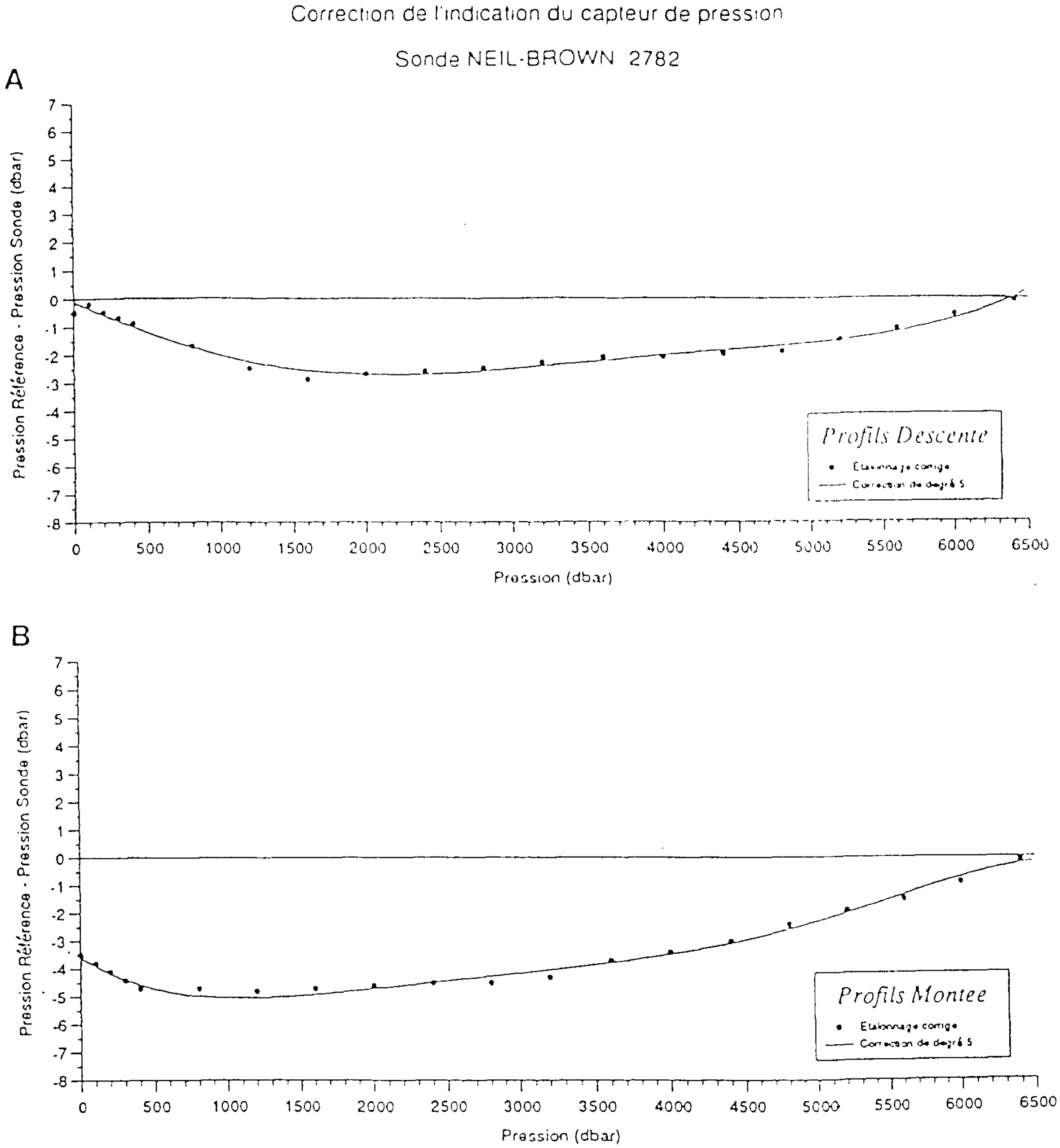


Figure 8: Calibration curve for the pressure sensor of the N°2782 CTD probe
a) calibration for increasing pressure (down cast).
b) calibration for decreasing pressure (up cast).

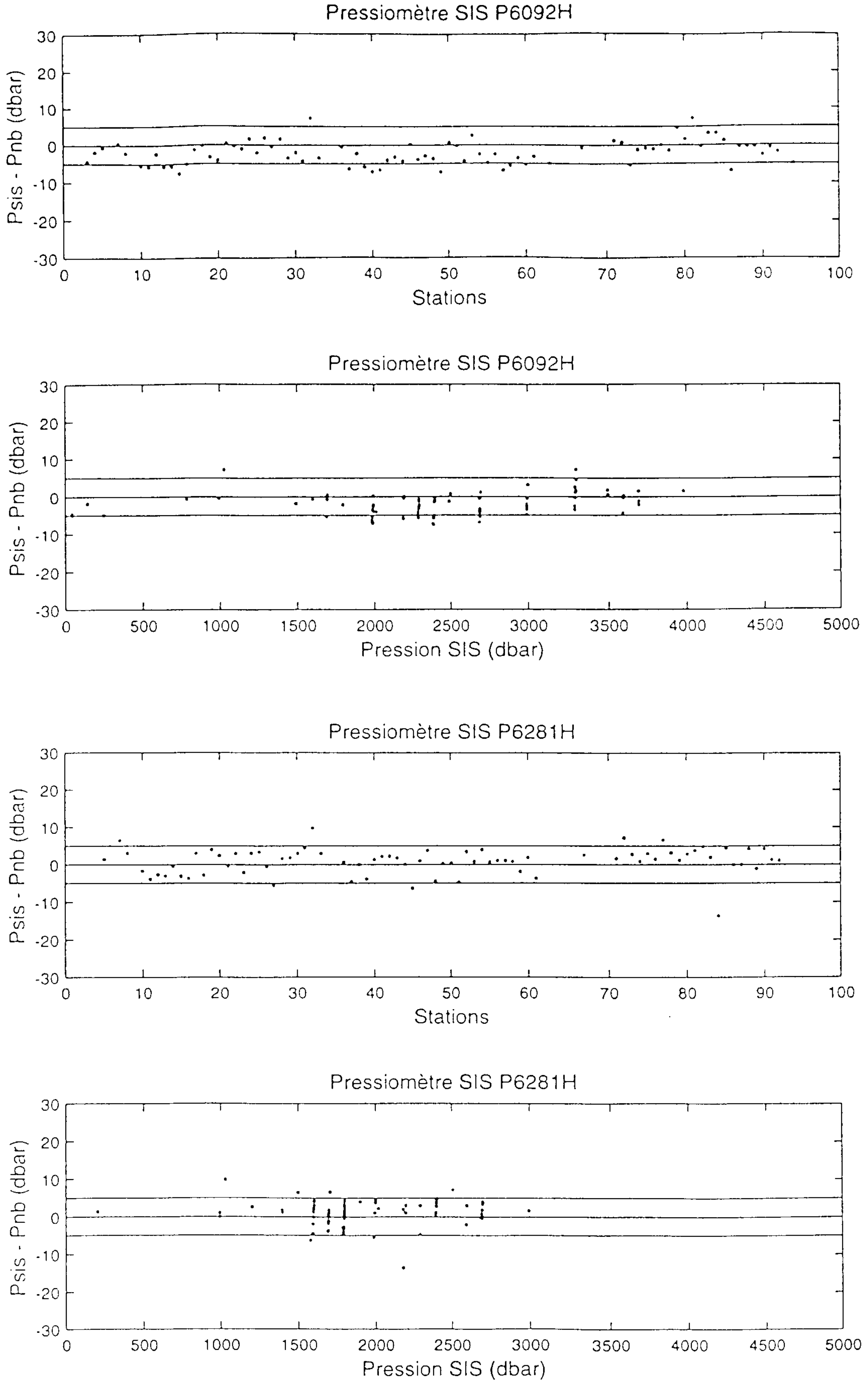
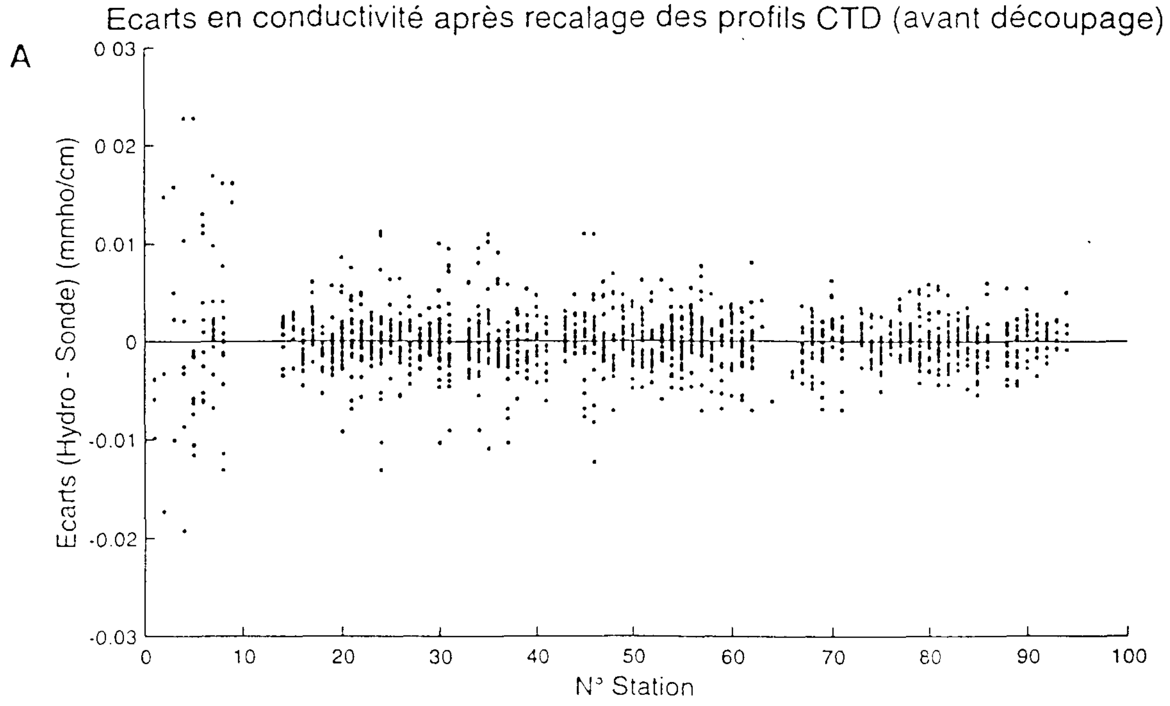


Figure 9: Pressure difference, in dbar, between SIS and CTD measurements (after calibration).



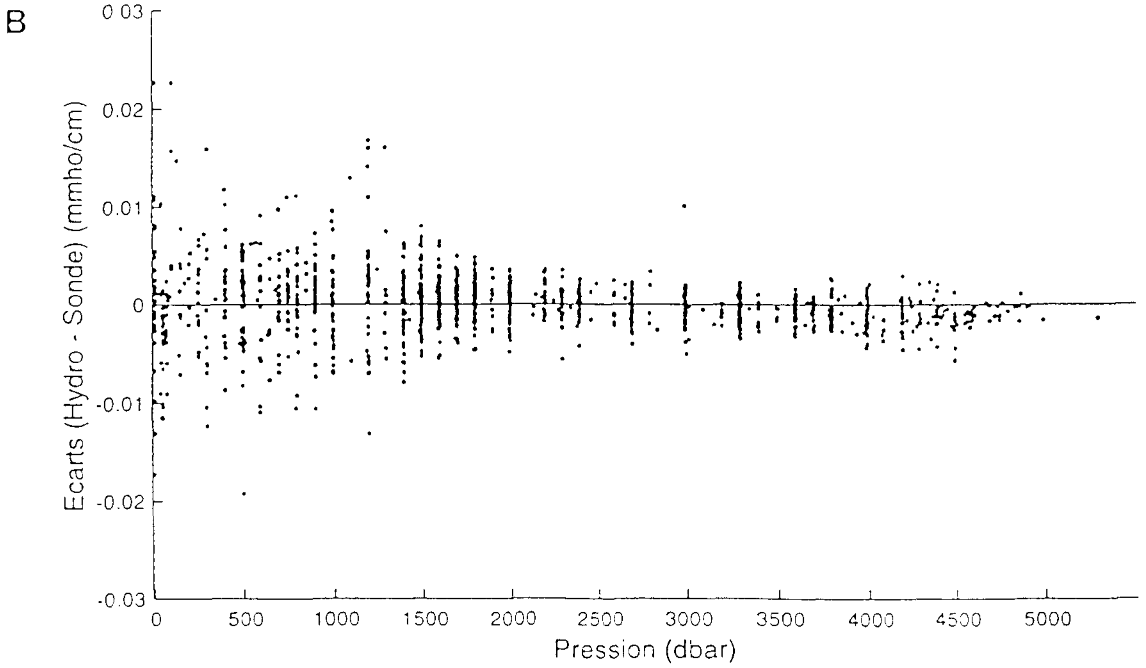


Figure 10: Conductivity difference, in mmho/cm, between water sample and CTD measurements, after calibration.
a)difference as a function of station number.
b)difference as a function of pressure.

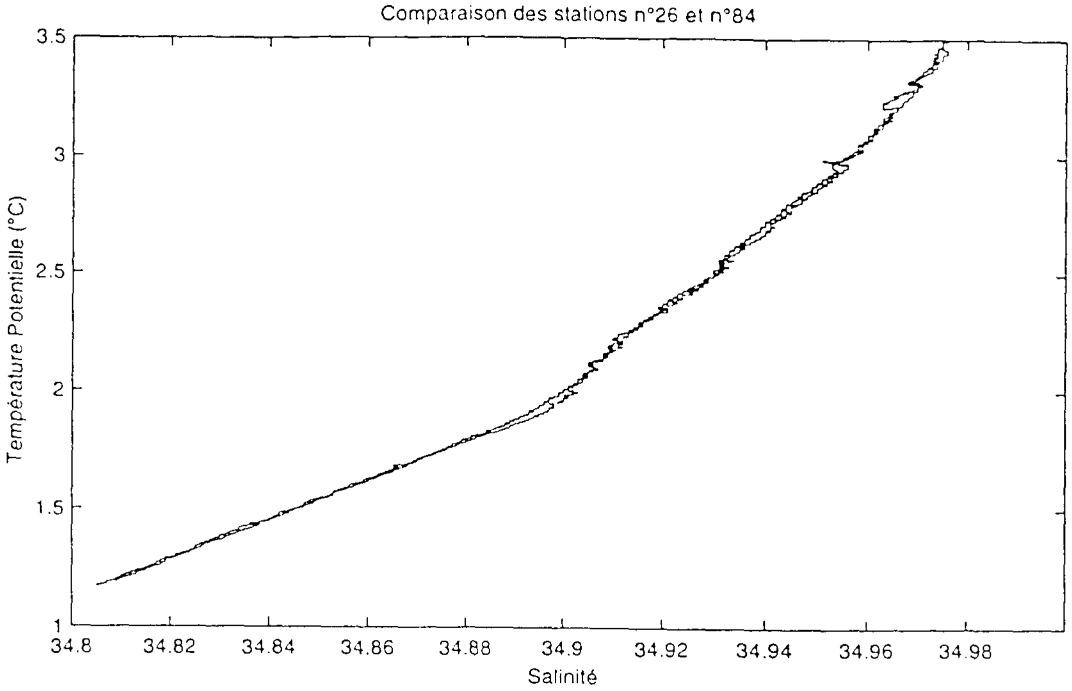


Figure 11: θ-S diagram of repeated ETAMBOT2 stations N°26 and N°84 (41°40'W-7°30'N).

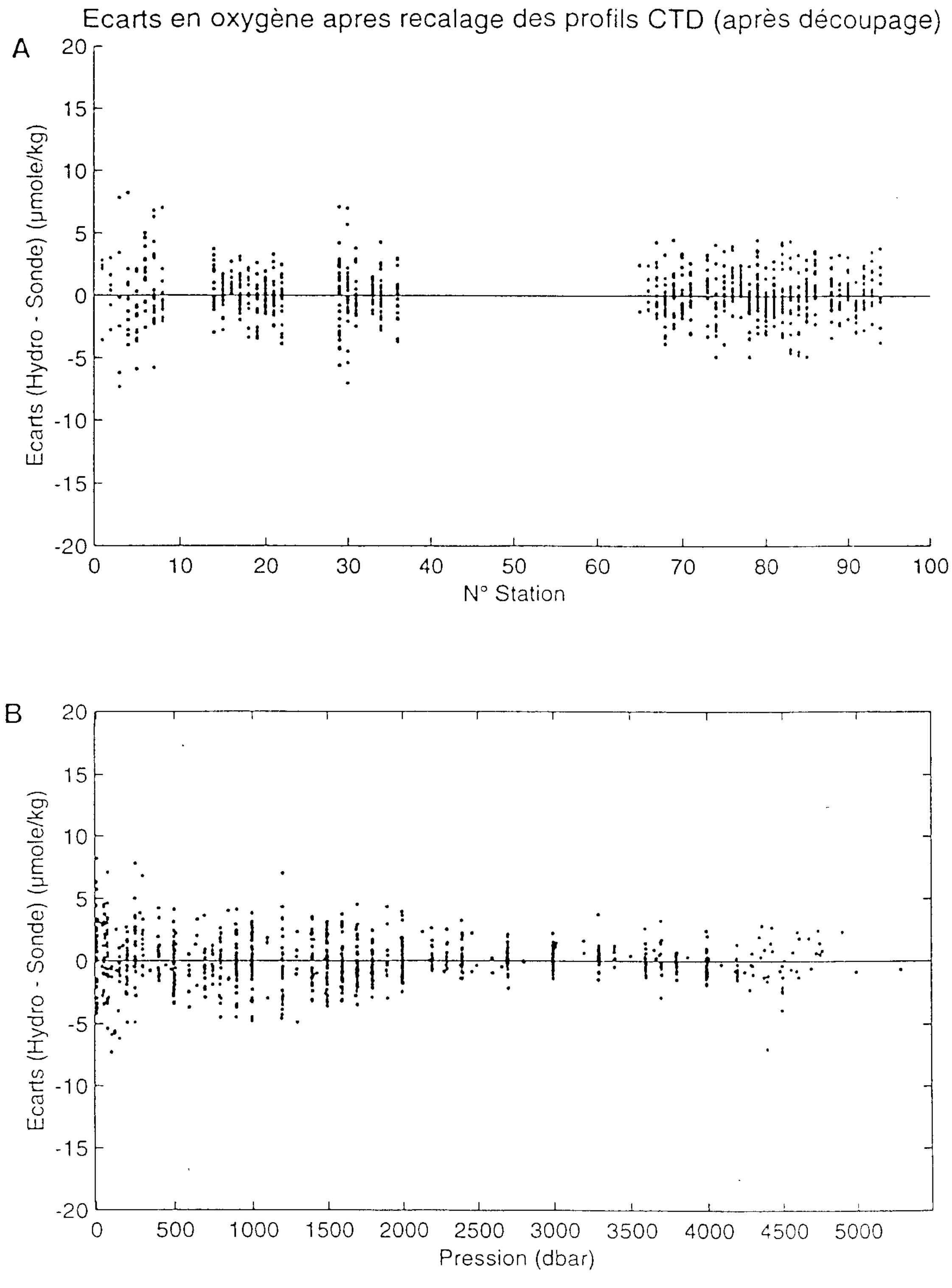


Figure 12: Dissolved oxygen difference, in µ mol kg^{-1}, between water sample and CTD measurements.

a) difference as a function of station number.

b) difference as a function of pressure.