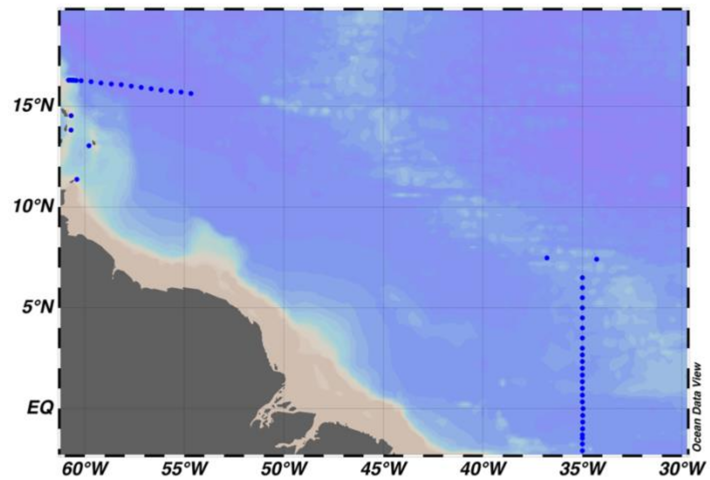
CRUISE REPORT: S-171

(*Updated: March 2026*)



Highlights

Cruise Summary Information

Section Designation	AR04
Expedition Designation (ExpoCode)	**06BE20030525**
Chief Scientist	**Prof. Dr. Monika Rhein**
Dates	25 May – 13 June 2003
Ship	R/V SONNE
Ports of Call	Recife, Brazil – Pointe a Pitre, Guadeloupe,France
Geographic Boundaries	16.29°N 60.82°"W 34.30°W 7.48°S
Stations	61
Floats and Drifters Deployed	4
Moorings Deployed and Recovered	8 deployed, 3 recovered

Contact Information:

Prof. Dr. Monika Rhein
Institut für Umweltphysik, Abt. Ozeanographie, Universität Bremen
28334 Bremen, Germany
Phone: +49 (0)421 218-62160 Email: mrhein@uni-bremen.de

*Summary page added and OxygenCal.pdf appended in March 2026

Report assembled by Savannah Lewis

Links to Selected Topics

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

Cruise Summary Information	**Hydrographic Measurements**
Description of Scientific Program	**CTD Data:**
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distribution (figure)	Conductivity Oxygen
Deployments	**Bottle Data**
Moorings Deployed or Recovered	Salinity
	Oxygen
Programs and Principal Investigators	Nutrients
Scientific Personnel	Total CO_2
	CFCs and SF_6
Problems and Goals Not Achieved	Total Alkalinity
	pH
Underway Data Information	Lowered Acoustic Doppler Current Profiler
Navigation Bathymetry	
Acoustic Doppler Current Profiler	
Thermosalinograph	
XBT and/or XCTD	
pCO_2	**Acknowledgements**
Atmospheric Chemistry Data	
Meteorological Observations	

CRUISE REPORT

RV SONNE: cruise S-171

by : Prof. Dr. Monika Rhein, chief scientist

Institut für Umweltphysik
Abt. Ozeanographie, Universität Bremen

from Recife, Brazil
to Pointe a Pitre, Guadeloupe, France

May 25 to June 13, 2003

With contributions from Christian Mertens, Reiner Steinfeldt and Maren Walter

Prof. Dr. Monika Rhein
Institut für Umweltphysik, Abt. Ozeanographie
Universität Bremen
28334 Bremen, Germany
Phon: ++49 421 218 2408
Fax : ++49 421 218 7018
Email : mrhein@physik.uni-bremen.de

Cruise report of RV SONNE cruise S-171

Introduction
The cruise S-171 is part of the german contribution to the international CLIVAR (Climate Variability and Predictability) program. The objective of the measurements is to estimate the climate relevant inflow of warm water masses from the South Atlantic into the Caribbean through the passages south of Guadeloupe and across the 16°N section east of Guadeloupe. The second aim of the cruise is to study the circulation of the deep water masses, forming the cold branch of the Atlantic meridional overturning. The transfer of deep water from the western into the eastern Atllantic through the 7°30 fracture zone is of special interest, since we will recover the moorings deployed in that fracture zone one year ago in June 2002 (METEOR cruise M53-3, chief scientist: M.Rhein). The measurements along 35°W continues the decadal long time series along that section, which is a crucial location for the interhemispheric exchange of the warm and the cold limb of the oceanic overturning.

The distribution of temperature, salinity and oxygen along 35°W and along 16°N were determined by CTDO measurements, using the SEABIRD instrument SBE9. On all stations water samples were taken from 10L Niskin bottles to calibrate the conductivity- and the oxygen sensors. As a means to estimate spreading times of deep water components from the formation region to the tropical Atlantic, CFC (Chlorofluorocarbon) concentrations are determined on water samples from the Niskin bottles. All oxygen, salinity and CFC analysis were done on board of RV SONNE.

The velocity distribution in the upper 800-900m of the water column was measured continually with a vessel mounted ADCP. Since the RV SONNE has no vm-ADCP installed, a 75kHz Ocean surveyor was kindly provided by the manufacturer RD-Instruments (San Diego, California) for the three cruises S170 to S172. The full water depth velocity profiles were determined at the location of the CTD stations by attaching a 150kHz NB-LADCP to the CTD-rosette system.

In order to obtain year long time series of the warm water inflow into the Caribbean, moorings east of St. Lucia, north of Tobago and east of Barbados were deployed. The three moorings form the Bremen Caribbean Inflow Array CARIBA. The moorings are equipped with several temperature, salinity, and pressure sensors allowing to calculate the vertical density stratification and thus the baroclinic geostrophic velocity. The barotropic fluctuations will be estimated with bottom pressure sensors, and Inverted Echosounders (PIES) will also be deployed. The CARIBA moorings are so called ‚end point' moorings, i.e. they will not give the transport through individual channels, but rather the integral transport fluctuations between Tobago and St. Lucia. In conjunction with the moorings at 16°N off Guadeloupe, the transport variations between St. Lucia and Guadeloupe will also be obtained.

During the L'Atalante cruise CARIBINFLOW (April, 2003, chief scientist: M.Rhein), one mooring was deployed east of Martinique. The mooring contained the Bremen CFC sampler, capable of collecting 52 uncontaminated water samples. The sampler is a prototype and moored for the first time. The mooring was recovered on cruise S-171. The mechanical construction and sample probes, both developed in Bremen, turned out to work well, but the step motor of the commercially available part of the system malfunctioned a short time after deployment.

Participants SONNE cruise S-171

1.	Monika Rhein, Prof.Dr.	chief scientist	IUP HB
2.	Gerd Fraas	moorings	IUP HB
3.	Oliver Huhn	CFC analysis	IUP HB
4.	Christian Mertens. Dr.	ADCP,moorings	IUP HB
5.	Reiner Steinfeldt, Dr.	CTD, Salinometry	IUP HB
6.	Maren Walter	LADCP	IUP HB
7.	Mario Barletta, Prof. Dr.	scientist	UFPE
8.	Paulo Roberto Costa Junior	observer	Brazil
9.	Heiko Dartsch	CTD/LADCP watch	IUP HB
10.	Alexander Moll	CFC sampling	IUP HB
11.	Kerstin Kirchner	CTD/LADCP watch	IFM HH
12.	Heike Hevekerl	CTD/LADCP watch	IUP HB
13.	Ismael Nunez-Riboni	floats, CTD watch	AWI
14.	Klaus Bulsiewicz	CFC analysis	IUP HB
15.	Giovanni Ruggiero	CTD/LADCP watch	IO/USP
16.	Oliver Beekmann	oxygen, CFCs	IUP HB
17.	Björn Schniedewind	oxygen	IUP HB

AWI : Alfred Wegener Institut für Polarforschung, Bremerhaven, Germany
IFM HH: Institut für Meereskunde, Hamburg, Germany
IO/USP: Instituto Oceanografico, Universidade de Sao Paulo, Sao Paulo, Brazil
IUP HB: Institut für Umweltphysik, Universität Bremen, Bremen, Germany
UFPE: Universidade Federal de Pernambuco, Recife, Brazil

Cruise narrative

The RV SONNE departed from Recife, Sunday, May 25, 2003, in the morning, under favorable weather conditions. After a short safety drill, the ‚SONNE‘ set course to the southern end of the 35°W section at 5°S. The vm-ADCP measurements began after leaving the 12nm zone. At 17 UTC, a CTD test station was carried out in order to check all instruments and measurement gear. CTDO and LADCP worked well.

The first station (CTD 2) at the 35°W section was on May, 26, 5:30 UTC at 5°04‘S. No CFC samples were taken since the signal from the GC/ECD system showed too much electronic noise disturbing the analysis of the ECD output. After excluding external sources, the internal electronic equipment was checked subsequently in order to find the failure. Due to this delay CFC concentrations could not be measured at the 35°W section south of 4°20‘S. After replacing the suspicious parts, the baseline was normal and calibration procedures began. When it was obvious, that the CFC analysis system would be working soon, 3-5 samples in the depth range of the upper NADW were taken at CTD stations CTD 6- CTD 11 (4°26‘S – 2°25‘S). Beginning with CTD 12 (2°05‘S) , the CFC sampling and analysis was back to normal.

The station spacing at the continental slope was between 7 and 14 miles and increased to about 20nm further offshore and was reduced to 10-17nm near the equator. In the core of the North Brazil Undercurrent, velocities higher than 1.30 m/s were measured with the lADCP and the vm-ADCP. Good vm-ADCP data were obtained down to 800-850m depth. At May, 28, 13:20 UTC, the scientific work was interrupted by a winch test, which was finished at 20:20 UTC. Afterwards, the station CTD 17 at 0°40.‘S, 35°W was carried out. At 0°20‘S (station CTD 18) and at 0°20‘N (station CTD 20) , RAFOS floats (No 492 and 495) were deployed. The CTD station work continued along the 35°W section, and the station spacing increased from 20nm to 30nm north of 3°N. At CTD 27 (2°40‘N), 5 MicroCats were attached to the rosette and lowered together with the CTD in order to get a calibration of the temperature and conductivity sensors before the deployment. After CTD 31 (4°30‘N) and CTD 32 (5°N), 2 RAFOS floats (No. 493 and 494) were launched. The work along 35°W was finished after CTD 35 at June, 1, 10 UTC.

The RV SONNE then set course to the location of the Bremen mooring B2 (7°24.70‘N, 34°17.30‘W). B2 was reached at June, 1, 14:30, and the mooring released. The mooring only covers the deep water below 3800m and the first elements surfaced 45 minutes after the release. The retrieval of the mooring ended at 16 UTC. All instruments had good data, except one pressure record in the current meter at 4300m depth. After a CTD cast at the location of the mooring (CTD 36), the RV SONNE headed to the Bremen mooring B1 further west in the 7°30N fracture zone. The course was set to follow the center of the fracture zone throughout the 140nm distance, and the topography of the fracture zone was monitored with the SIMRAD EM12 system. The horizontal range of the SIMRAD was about 20km, covering most of the fracture zone. The mooring location B1 was reached at June,2, 7 UTC. After a CTD station (CTD 37), the mooring B1 at 7°28.40‘N, 36°50.00‘W was recovered. The mooring surfaced at 12:10 UTC and was on board 40 minutes later. All instruments sampled good data.

The RV SONNE then set course to the easternmost station of the 16°N section at 15°38‘N, 54°40‘W. On the way, on June,3, another winch test was carried out, from 9 to 13 UTC, where the speed of RV SONNE was reduced to 7kn. 3 SOLO drifters from S. Garzoli, (NOAA, Miami, USA) were deployed at 9°52‘N, 42°W, (No 208, June,3, 18:10) 12°10‘N, 47°W (No 191, June 5, 18UTC) and at 13°59‘ N, 51°W, (No 220, June, 5, 14:10 UTC) respectively.

At June,6, 8 UTC the CTD work along the 16°N section began with CTD 38 at 54°40‘W. The lADCP was removed from the rosette, since the water depth is below 5500m and the lADCP is pressure resistant only to 500bar. Moreover, due to our experience from the last cruises, the lADCP signals are very weak at 16°N below 3000m due to lack of a sufficient number of backscatterers. After CTD 43, a releaser test at 1000m depth was successfully carried out. At arriving at the very steep continental slope, at June, 9, the LADCP was again attached to the rosette beginning with CTD 50. The spacing between the CTD station decreased to about 3 miles, and the difference in the water depth between two adjacent stations was about 500-700m. The 16°N section was finished at June, 9, 23 UTC with CTD 57.

The remaining time of the cruise was dedicated to the study of the inflow into the Caribbean by vm-ADCP measurements and by mooring activities. The RV SONNE headed to the Guadeloupe – Dominica Channel to obtain an ADCP velocity section along the passage, starting at 16°00.0‘N, 61°34.50‘W and ending at 15°39.40‘N, 61°26.30‘W. This and the following passage was repeatedly sampled during our former cruises (Meteor M53-3, June 2002, and L’Atalante cruise CARIBINFLOW, April 2003). After passing Dominica leeward, the Dominica – Martinique Channel was surveyed with the vm-ADCP from 15°14,10‘N, 61°17.70‘W to 14°55.20‘N, 61°08.35‘W.

On June, 10, 13:30 UTC the mooring position B4 at 14°32.75‘N, 60°41.22‘W east of Martinique was reached. The mooring consists of only one instrument, the Bremen CFC-sampler. The mooring was deployed (750m depth) in April 2003 with the french research vessel L’Atalante. For the CFC sampler, it was the first deployment and thus a relatively short deployment period was chosen. After a CTD station (CTD 58), the mooring was relased and surfaced 10 minutes later. The instruments were recovered without any problems.

The next deployment took place east of St. Lucia (mooring B7) at 13°48.25'N, 60°41.29'W in 993m depth. The mooring contains 5 MicroCats with temperature and salinity sensors as well as 3 acoustic current meters. B7 ist the easternmost mooring of the Bremen Caribbean Inflow Array (CARIBA). Additionally an Inverted Echosounder with a high precision pressure sensor (PIES) was deployed further south at 13°38.01'N, 60°41.52'W. The deployment was finished at June 10, 21:30 UTC and after CTD 59 the SONNE headed to the southern end of the CARIBA array off Tobago at 11°21.70'N, 60°24.00'W. Here at June 11, from 13 UTC to 18 UTC, a mooring with 3 current meters and 6 Microcats (mooring B5) was deployed in 1100m water depth at 11°21.70'N, 60°24.00'W followed by a PIES half a mile further east and a CTD cast (CTD 60) . The Sonne left for the third CARIBA mooring (B6) off Barbados and reached the B6 position at June 12, 3:30 UTC. The mooring with 5 Microcats and 2 current meters was deployed in 1030m depth at 13°01.77'N, 59°47.62'W. After the CTD cast 61 at the same position, all mooring – and CTD work of the cruise was finished at 7 UTC. On the way to Pointe a Pitre, the velocity distribution of the upper 900m in the channels between the islands St. Vincent , St. Lucia, Martinique, Dominica and Guadeloupe was measured with the vessel mounted Ocean Surveyor from RD Instruments. The cruise S-171 accomplished all objctives successfully and ended on June 13. RV Sonne arrived in Pointe a Pitre at 12 UTC.

Technical Aspects

CTD-O_2 (Reiner Steinfeldt)
During the cruise a SEABIRD SBE9 system with pressure, temperature, conductivity and an additional oxygen sensor (SBE 43) is used. 61 CTD profiles have been taken during the cruise, and all sensors worked correctly. Difficulties with the bottle release unit occurred at a few stations, so that not all bottles were closed correctly. Bottle number three often did not close due to mechanical problems. For calibration of the conductivity and oxygen sensors, water samples have been taken from most stations. Bottle salinities were determined using a Guildline Autosal salinometer (IfM Kiel). An automatic Sensoren Instrumente Systeme (SIS) DO (dissolved oxygen) analyser based on Winkler titration was used for the oxygen measurements. About 240 samples were analysed both for the conductivity and the oxygen calibration. The conductivity of the CTD-sensor was found to be too low for all profiles and depths. By adding an offset to the CTD-conductivity, the rms-difference between the bottle and CTD salinities could be reduced to 0.0029 (0.0021 for samples below 1000 m).
The oxygen samples had been taken in glass bottles which are normally used for salinity measurements. Some of these bottles cracked because of the expansion of the cold water samples. The remaining glass bottles have to be volume calibrated in the home lab. The error estimated from repeated sampling is in the order of one percent. The preliminary calibration is based on a bottle volume approximated by the saturation of near surface samples and calibration from S-170. Correcting the CTD-oxygen sensor with respect to pressure, temperature and oxygen current resulted in a rms-error of 0.06 ml/l. The original Seabird Calibration of the sensor gives too low oxygen concentrations below 2000 m.
Thermosalinograph. The instrument recorded continually temperature and salinity of the ocean surface during the cruise. The data were calibrated against the CTD data at the locations of the CTD stations.

LADCP (Maren Walter)
On 48 of the 61 CTD stations a Lowered ADCP profile was obtained parallel to the CTD cast. Of the remaining 13 stations, 12 were deeper than 5000m and therefore not accessible with

the ADCP (5000dbar pressure housing), and one station was lost due to battery failure. The measurements were taken with a RDI 150kHz narrow-band ADCP (S/N 301) attached to the water sampler. The sampling frequency was 12 pings per 8 seconds, with a bin length of 16m. The instrument used was the same as on the previous cruise (S170, IFM Kiel). During S170, it turned out that two of the beams were not working properly, resulting in a reduction of range, especially at high depths. It will be send back to the manufacturer for repair directly after the cruise.

On this cruise, the impact of the range reduction was worst on the 16°N section, where scatterers are scarce at all depth, but especially below 3000m . The range was reduced to 4-5 bins, resulting in less than 10 shear estimates per depth bin, and thus large incertainties in the velocity. However, the use of an inverse solution with the inclusion of the bottom track velocity provided reasonable velocity profiles, while the "classical" post-processing (integration of shear) resulted in profiles with large first-baroclinic-mode errors or large shifts below the bottom reflection gap. During the 35°W section across the equator, the range was somewhat higher with a minimum of 5 to 6 good bins for depth below 4000 m.
For the shallower parts of the profiles, the range was not greatly reduced, but the weak beams caused a higher occurrance of single "bad" bins in the middle of ensembles. However, this did not aversely affect the postprocessing, so the resulting profiles were all in all satisfying. At a few stations the data quality was diminished by the strong currents, which resulted in momentary instrument tilts larger than 17 degrees. These tilt events were luckily only very shortlived and occurred not at depths where the data were already scarce, so the remaining ensembles had enough overlap to not inhibit the generation of a full depth profile.

Vm ADCP (Christian Mertens)

A 75 kHz phased array Acoustic Doppler Current Profiler (ADCP), called Ocean Surveyor, had been mounted into the well of the ship at the beginning of the previous cruise (SO 170). The instrument was generously provided by the manufacturer RD Instruments (San Diego, California) for the three cruises SO 170 to SO 172. The instrument worked flawless throughout the entire cruise.

The instrument setup used on this cruise was similar to that on SO 170. To maximize the range the OS was operated in narrowband mode with a depth cell size of 16 m and a blank behind the transducer of 8 m. With a transducer depth of 6 m this resulted in a depth of about 30 m for the center of the first bin. The interval between successive pings was set to two seconds, thus forcing the intrument to ping as fast as possible. The resulting ping interval was of about 2.3 s.

Position from the GPS receiver, Ashtech attitude measurements, and heading from the gyrocompass were provided via the ship's data distribution system (with a time delay of about 2 seconds) and recorded together with the velocities. A synchro input of gyrocompass heading was not used, because of possible interruptions that would change the heading bias, making a new calibration necessary. Instead, the data were stored in ship coordinates and rotated to earth coordinates during the postprocessing using the digital heading data from Ashtech. The about 13% of missing Ashtech data were replaced by gyrocompass data that had been corrected for an offset of 0.8 degrees.

A watertrack calibration for the misalignment angle had already been carried out on the previous cruise. The calibration resulted in a misalignment angle of -45.23 degrees and an amplitude factor of 1.0036. No changes were necessary on this cruise. The ship's Doppler log, that transmits at a frequency of 78 kHz, is known to cause a considerable reduction in data quality. A comparison between Doppler log on and off on SO 170 showed a reduction of reliable data of about 25% and a reduction in range by about 15%. The Doppler log was therefore turned off during most of the cruise except for the mooring station. During the mooring stations, with running Doppler log, the same interferences as on the previous cruise were observed.

The range of the instrument was largest in the equatorial region, where more than 25% of good data were obtained down to 850 m. Along the 16 N section the range was a bit reduced to 820 m, while on the southward section towards Tabago 25% of good data were obtained only to about 740 m. Here the ship had to steam against rougher sea.

Moorings: Location, Water depths, Dates

Name	Latitude	Longitude	Depth	Deployment Date	Retrieval Date
B1	7°28.40‘N	36°50.00‘W	4510m	15.6.2002, 16:05	**2.6..2003,11:30**
B2	7°24.70‘N	34°17.30‘W	4690m	16.6.2002, 17:27	**1.6.2003,14:31**
B4	14°32.75‘N	60°41.22‘W	1000m	24.4.2003, 13:20	**10.6.2003,14:00**
B5	11°21.79‘N	60°24.04‘W	1105m	**11.6.2003, 18:30**	
PIES	11°21.73‘N	60°23.50‘W	1120m	**11.6.2003, 18:58**	
B6	13°01.77‘N	59°47.70‘W	1030m	**12.6.2003, 5:50**	
B7	13°48.25‘N	60°41.29‘W	1002m	**10.6.2003, 21:20**	
PIES	13°48.01‘N	60°41.52‘W	993m	**10.6.2003, 22:54**	

PIES: Inverted Echo Sounder with Pressure sensor
Bold dates: work done during S-171 cruise

Mooring B1

Instrument	Number	Depth	Comments
Releaser	SN798	4455m	ok
Releaser	SN 517	4455m	ok
RCM11	94	4449m	data stop April, 2,2003
MicroCat C,T	1888	4448m	record length 351 days, T,C ok
MicroCat C,T	1915	4147m	record length 351 days, T,C, ok
RCM11+P	93	4145m	data stop April,12,2003
MicroCat C,T	1931	3839m	record length 351 days, T,C ok
RCM11+P	92	3838m	data stop April,21,2003

Sampling rate for all instruments : 30min.
RCM: Anderaa Acoustic Current Meter, +P: with pressure sensor
MicroCat C,T : SBE, measurement of temperature and conductivity
Radio frequency: 160.785 MHz signal received
Time from release to surface : 40minutes (upward w 1.6m/s)

Mooring B2

Instrument	Number	Depth	Comments
Releaser	AR810	4655m	ok
Releaser	RT238	4655m	not released
RCM11	97	4654m	data stop May,6,2003
MicroCat C,T	1936	4648m	record length 349 days, T,C ok
MicroCat C,T	1934	4347m	record length 349 days, T,C ok
RCM11+P	91	4345m	data stop March, 22, 2003
MicroCat C,T	1932	4039m	record length 349 days, T,C ok
RCM11+P	89	4033m	no press. record, data stop March,27 2003

Sampling rate for all instruments: 30min
Radio frequency: 160.725 MHz signal received
Time from release to surface 45min (1.6m/s)

Mooring B4 / CFC Sampler

Instrument	Number	Depth	Comments
Releaser	SN529	695m	ok
Releaser	SN52 1	695m	ok
CFC-Sampler	1	640m	no data

Time from release to surface : 10minutes

Mooring B7/St. Lucia

Instrument	Number	Depth	Comments
Releaser	SN521	955m	
Releaser	SN520	955m	
RCM11	89	954m	
MicroCat C,T	1932	947m	
MicroCat C,T	1931	547m	
MicroCat C,T	2050	346m	
RCM11	94	344m	
MicroCat C,T	2015	188m	
RCM11	93	86m	
MicroCat C,T	2052	70m	

Sampling rate for all instruments : 30min.
RCM: Anderaa Acoustic Current Meter, +P: with pressure sensor
MicroCat C,T : SBE, measurement of temperature and conductivity
Radio frequency: 160.785 MHz

Mooring B5/Tobago

Instrument	Number	Depth	Comments
Releaser	SN517	1055m	
Releaser	SN798	1055m	
MicroCat C,T	2476	953m	
RCM11	98	951m	
MicroCat C,T	2454	549m	
MicroCat C,T	2438	348m	
RCM11	97	346m	
MicroCat C,T	2377	194m	
MicroCat C,T	1934	93m	
RCM11	92	91m	
MicroCat C,T	1933	75m	

Sampling rate for all instruments : 30min.
RCM: Anderaa Acoustic Current Meter, +P: with pressure sensor
MicroCat C,T : SBE, measurement of temperature and conductivity
Radio frequency: 160.725 MHz

Mooring B6/Barbados

Instrument	Number	Depth	Comments
Releaser	SN531	985m	
Releaser	SN826	985m	
MicroCat C,T	2277	953m	
MicroCat C,T	1943	551m	
MicroCat C,T	1936	350m	
RCM11	95	349m	
MicroCat C,T	1915	193m	
RCM11	91	92m	
MicroCat C,T	1888	75m	

RCM: Anderaa Acoustic Current Meter, +P: with pressure sensor
MicroCat C,T : SBE, measurement of temperature and conductivity
Radio frequency: 160.725 MHz

Figure 1a,b Cruise track of cruise S-171, 25.5. to 13.6. 2003, a) part 1 and b) part 2

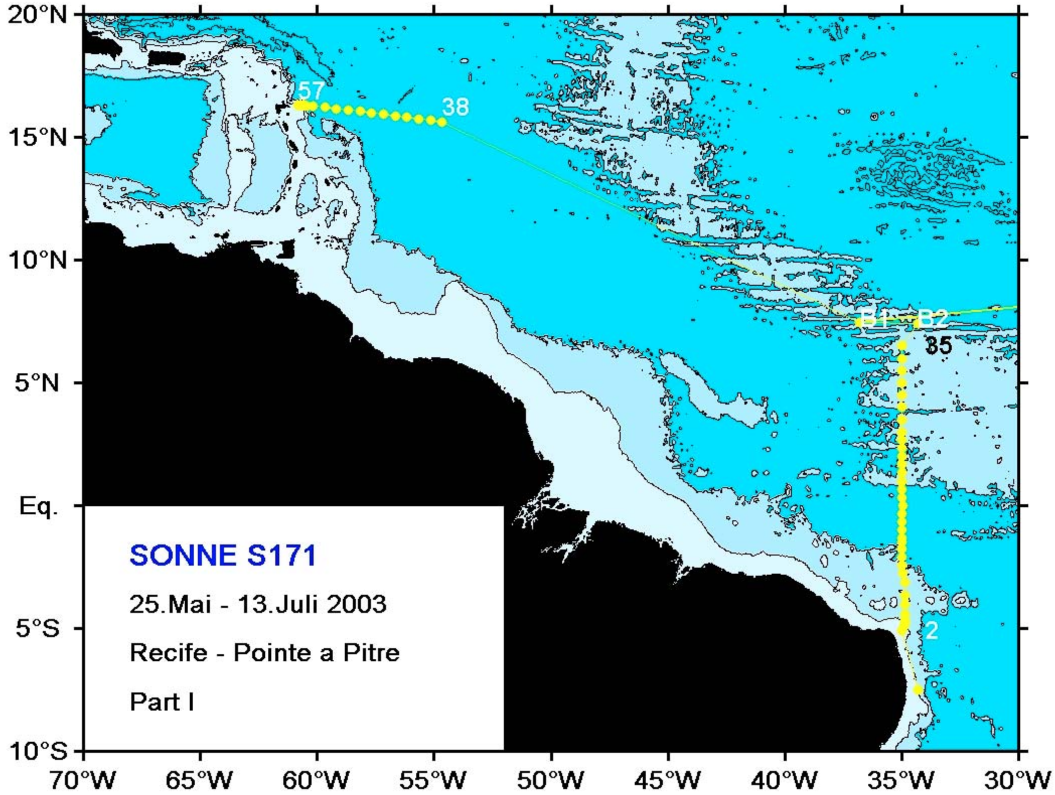
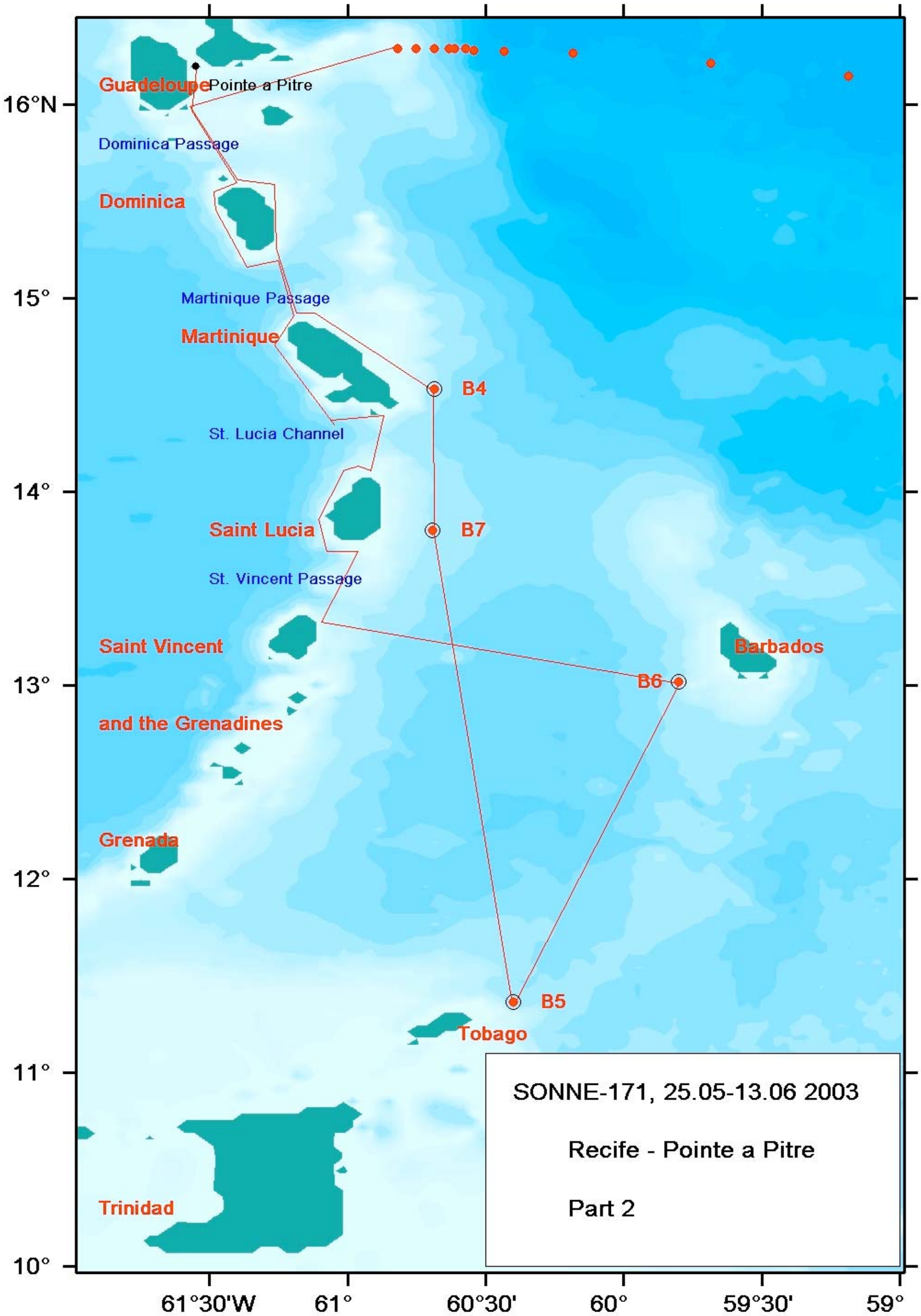


Figure 1b Cruise track S-171, part 2



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Sonne S171		**CTD Stations**						**Page 1**
Profile	Station	Date	Time	Latitude	Longitude	Water Depth	Profile Depth	Comment
1	1	2003/05/25	16:41	7° 28.80' S	34° 18.10' W	2417	2297	
2	2	2003/05/26	05:23	5° 4.71' S	34° 59.40' W	540	536	
3	3	2003/05/26	06:46	4° 56.08' S	34° 55.40' W	803	714	
4	4	2003/05/26	08:20	4° 48.61' S	34° 52.74' W	983	972	
5	5	2003/05/26	09:54	4° 40.64' S	34° 52.64' W	2451	2399	
6	6	2003/05/26	12:54	4° 26.59' S	34° 52.40' W	3331	3305	
7	7	2003/05/26	17:34	4° 0.53' S	34° 52.49' W	3568	3549	
8	8	2003/05/26	21:49	3° 38.96' S	34° 52.94' W	3420	3407	
9	9	2003/05/27	02:43	3° 7.93' S	34° 52.89' W	3828	3811	
10	10	2003/05/27	07:00	2° 45.23' S	34° 57.05' W	3867	3843	
11	11	2003/05/27	11:18	2° 25.07' S	35° 0.30' W	3923	3899	
12	12	2003/05/27	15:28	2° 5.01' S	35° 0.08' W	4051	4033	
13	13	2003/05/27	19:56	1° 45.03' S	35° 0.02' W	4112	4090	
14	14	2003/05/28	00:00	1° 27.98' S	35° 0.00' W	4315	4296	
15	15	2003/05/28	03:37	1° 18.08' S	35° 0.00' W	4362	4345	
16	16	2003/05/28	08:07	1° 0.02' S	34° 59.49' W	4283	4266	
17	17	2003/05/28	20:15	0° 40.00' S	34° 59.00' W	4473	4430	
18	18	2003/05/29	00:31	0° 20.09' S	34° 59.04' W	4515	4493	
19	19	2003/05/29	05:18	0° 0.02' S	34° 57.99' W	4549	4526	
20	20	2003/05/29	09:43	0° 20.05' N	34° 59.96' W	4543	4527	
21	21	2003/05/29	14:16	0° 40.04' N	35° 0.00' W	4551	4530	
22	22	2003/05/29	18:45	1° 0.00' N	35° 0.03' W	3589	3577	
23	23	2003/05/29	22:30	1° 20.03' N	34° 59.98' W	4065	4049	
24	24	2003/05/30	02:38	1° 39.98' N	34° 59.93' W	4048	4037	
25	25	2003/05/30	06:49	1° 59.98' N	35° 0.03' W	4196	4185	
26	26	2003/05/30	11:07	2° 20.05' N	35° 0.02' W	4145	4127	
27	27	2003/05/30	15:20	2° 40.02' N	35° 0.04' W	4004	3990	
28	28	2003/05/30	19:38	3° 0.00' N	35° 0.00' W	3815	3792	
29	29	2003/05/31	00:19	3° 30.04' N	34° 59.97' W	3965	3946	
30	30	2003/05/31	05:14	3° 59.99' N	34° 59.98' W	3495	3481	
31	31	2003/05/31	10:07	4° 30.07' N	34° 59.97' W	3884	3865	
32	32	2003/05/31	15:05	4° 59.98' N	34° 59.99' W	3724	3708	
33	33	2003/05/31	20:08	5° 30.06' N	35° 0.01' W	3876	3816	
34	34	2003/06/01	01:06	6° 0.03' N	35° 0.00' W	4230	4211	
35	35	2003/06/01	06:23	6° 29.95' N	35° 0.11' W	3794	3780	

Sonne S171		**CTD Stations**						**Page 2**
Profile	Station	Date	Time	Latitude	Longitude	Water Depth	Profile Depth	Comment
36	36	2003/06/01	16:29	7° 24.58' N	34° 17.17' W	4723	4705	
37	37	2003/06/02	07:42	7° 28.36' N	36° 46.98' W	4674	4724	
38	38	2003/06/06	08:43	15° 37.97' N	54° 39.99' W	5503	5487	
39	39	2003/06/06	14:45	15° 42.04' N	55° 10.00' W	5500	5496	
40	40	2003/06/06	20:52	15° 43.99' N	55° 40.05' W	5497	5489	
41	41	2003/06/07	02:47	15° 48.07' N	56° 10.10' W	5359	5350	
42	42	2003/06/07	08:26	15° 51.95' N	56° 40.00' W	5287	5268	
43	43	2003/06/07	14:01	15° 55.98' N	57° 10.07' W	5173	5166	
44	44	2003/06/07	20:42	16° 0.02' N	57° 40.05' W	5410	5398	
45	45	2003/06/08	03:15	16° 4.04' N	58° 10.10' W	5385	5375	
46	46	2003/06/08	08:46	16° 5.99' N	58° 40.02' W	5666	5645	
47	47	2003/06/08	14:31	16° 9.05' N	59° 11.09' W	5294	5299	
48	48	2003/06/08	20:11	16° 13.05' N	59° 41.03' W	4954	4908	
49	49	2003/06/09	01:26	16° 15.97' N	60° 11.02' W	5034	4992	
50	50	2003/06/09	06:04	16° 16.49' N	60° 26.03' W	4829	4753	
51	51	2003/06/09	09:46	16° 17.03' N	60° 32.66' W	4092	4082	
52	52	2003/06/09	12:48	16° 17.50' N	60° 34.46' W	3445	3404	
53	53	2003/06/09	15:22	16° 17.50' N	60° 36.71' W	2895	2988	
54	54	2003/06/09	17:38	16° 17.49' N	60° 38.06' W	2465	2561	
55	55	2003/06/09	20:02	16° 17.53' N	60° 41.18' W	1691	1671	
56	56	2003/06/09	21:36	16° 17.51' N	60° 45.19' W	1024	991	
57	57	2003/06/09	22:53	16° 17.55' N	60° 49.20' W	521	515	
58	58	2003/06/10	13:37	14° 32.10' N	60° 41.17' W	779	757	
59	59	2003/06/10	21:45	13° 49.03' N	60° 41.56' W	974	962	
60	60	2003/06/11	12:56	11° 22.25' N	60° 24.08' W	1155	1157	
61	61	2003/06/12	06:17	13° 2.47' N	59° 47.58' W	959	956	

RESULTS

Transport sections , 35°W

Mean transports of 13 realizations along 35°W have been summarized in Schott et al. 2002. Most of the features found in May-June 2003 do fit the mean zonal current distribution of the latter (Fig.2). Exceptions are that the SEUC (South Equatorial Undercurrent) is missing. And the EIC bound by 1°S and 1°N is restricted to the depth range between 500 and 900m and transports 6.1 Sv towards the east, not reflecting the seasonal signal proposed by Schott et al. (2002). Between 3°N and 5°N, the flow is everywhere westward between sigma_th= 24.6 (80m depth) and sigma_1000=32.15, and that part of the SEC alone transports 32.7Sv, much more than the mean of Schott et al. (7.7 Sv). The velocity core exceeding 40cm/s is located in the central water range between sigma_th=25.6 and sigma_th=26.8. Between 5°N and 7°N, the NEUC centered at the same density interval but with maximum velocities above 70cm/s transports 29 Sv to the east.

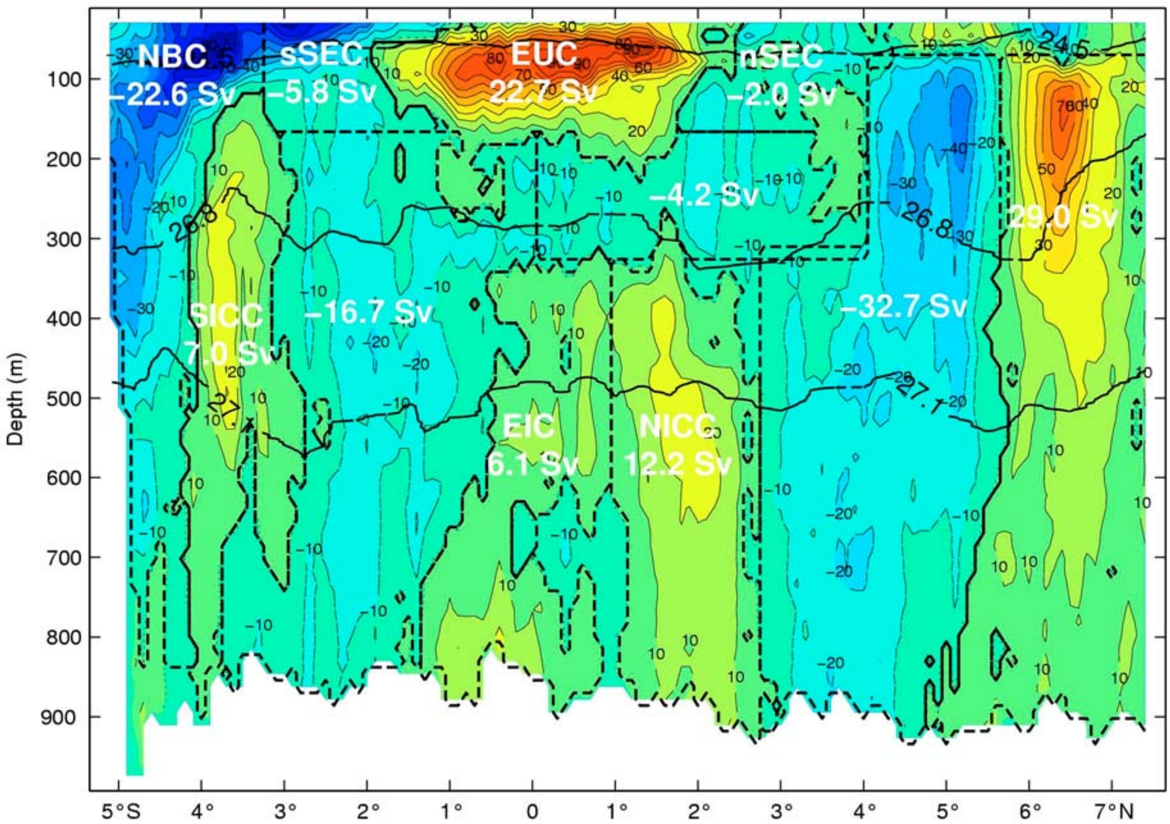


Figure 2 Zonal velocity component from the vessel mounted Ocean Surveyor (75kHz). NBC: North Brazil Current, SEC: South Equatorial Current, EUC: Equatorial Undercurrent, SICC: Southern Intermediate Counter Current, NICC: Northern Intermediate Counter Current. The bold black lines are isopycnals separating the upper water mass components . The isopycnals sigma_th = 24.50 delineates the subtropical salinity maximum water within the Tropical Surface Water TSW. Sigma_th=25.6 and 26.8 limit the upper central water masses , and sigma_th=26.8 and 27.1 the lower central water. The Antarctic Intermediate Water AAIW is found between sigma_th=27.1 and sig_1000=32.15.

The DWBC south of 4°S (Fig. 3) is relatively strong compared to other cruises (9.7 Sv), Another main eastward current in the upper NADW is found between 3°S and 2°S , and between 1°30‘N and 2°30‘N, with transports of 19.8 Sv and 9.4 Sv, repsectively. Between 1°30‘S and 1°30‘N, coherent deep equatorial jets are found in the range of uNADW, a westward current between 1400 and 1600m (16.5 Sv) is bound by eastward flow (14.9 Sv). The net eastward transport of uNADW is 37.3 Sv south of 4°N, much higher than the mean of Schott et al. (2.9 Sv). The transport of mNADW and lNADW to the east in the velocity core north of the Paranaiba ridge at 1°40‘S amounts to 14.8 Sv, and 5.2 Sv AABW (mean 2Sv) are flowing through the equatorial channel towards the west.

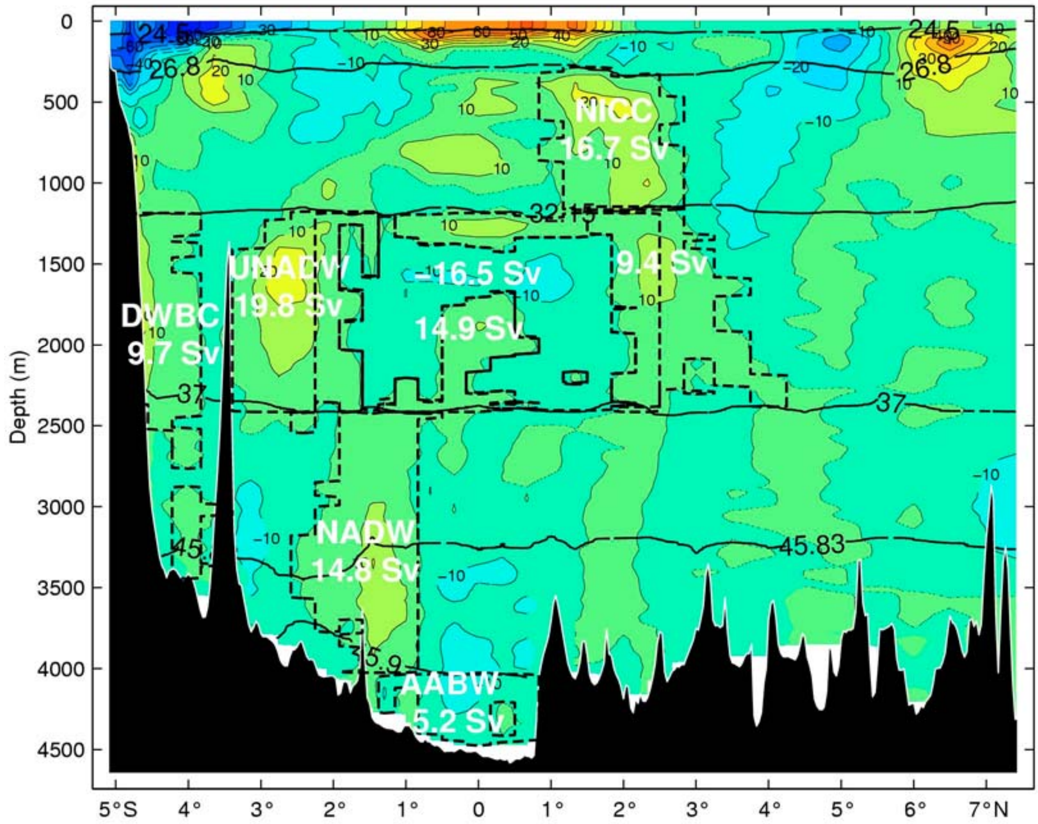


Figure 3 The zonal velocity distribution along 35°W, from the 150kHz NB LADCP attached to the rosette. DWBC: Deep Western Boundary Current, uNADW: upper North Atlantic Deep Water, AABW: Antarctic Bottom Water. The transports are in Sverdrup (1Sv = 1million cubicmeter per second) The bold black lines are isopycnals separating the deep water components uNADW, mNADW and lNADW and near the bottom AABW.

Hydrograpic Distributions : The upper water column , 35°W, May-June 2003

The most striking feature in the oxygen distribution (Fig. 4a) is the difference between the oxygen rich water in the NBC, originating from the NBUC at the South American coast and the oxygen poor water in the SEC, coming from the tropical eastern Atlantic. 2 very low oxygen cores exist. One is located in the upper central water (sigma_th=25.6 – sigma_th=26.9) at 3°S – 1°S, and the other one north of the equator at 4°N in the lower central water (sigma_th=26.8 – sigma_th=27.1).

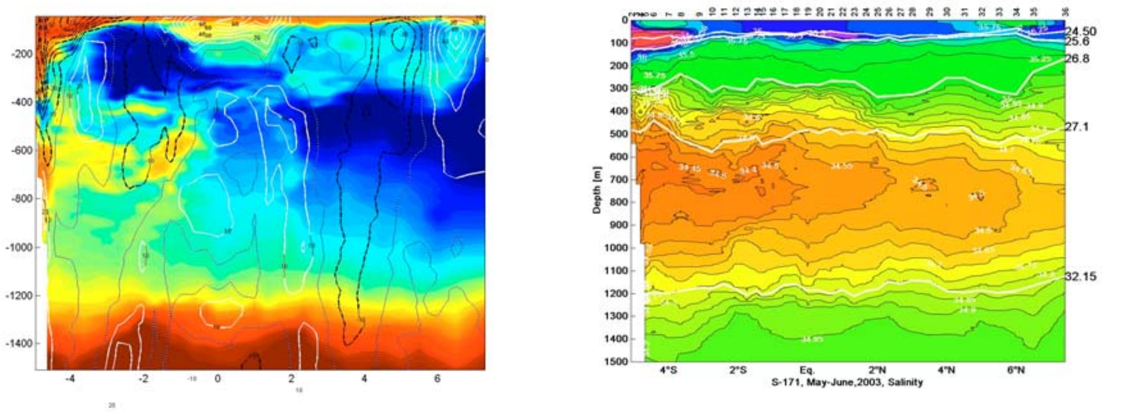


Figure 4 a) oxygen distribution (coloured) along 35°W, overlaid by velocity contours. Black: westward velocity, white: eastward velocity, contour interval 10cm/s. b) Salinity distribution along 35°W, from the surface to 1500m depth. The bold white lines are isopycnals.

Below the surface, the water in the EUC has moderate oxygen concentrations, the values in the EIC are lower. The oxygen maximum at 600-800m depth south of the equator characterizes the Antarctic Intermediate Water (AAIW) and is colocated with a salinity minimum. Both features are strongest in the boundary current.

The two main extrema in the salinity dstribution (Fig. 4b) are the maximum in 100m depth in the NBC (Subtropical Maximum Salinity Water with S>37.0) and the broad salinity minimum around 600m depth. The lattes is a signature of the AAIW and the salinity is lowest in the western boundary current. The salinity minimum weakens towards the north. The bold white lines are isopycnals.

Salinity and CFC distribution, deep water at 35°W

uNADW

The most conspicuous feature in the upper NADW is the deepening of the salinity maximum from about 1600m to 1800m depth compared to other cruises (Fig.6). There is no deepening of the isopycnals, so that the density of the salinity maximum increased from sigma_1500=34.62-34.63 to sigma_1500 =34.68. The salinity values are lower by 0.01 (1600m) to 0.005 (2000m). This distribution is found in the equatorial region between 2°S and 3°N north of 4°N. The CFC profiles correspond to the salinity distribution by a deepening of the maximum (Fig.5). The biggest changes compared to May 2002 and November 2000 thus occured in the density range sigma_1500 = 34.67-34.70, (increase from 0.3 pmol/kg to 0.4 pmol/kg) the concentrations at sigma_1500 = 34.63 (0.37pmol/kg) ,however, did not change.

This peculiar distribution corresponds nicely with the velocity distribution in the NADW with strong westward flow in the depth range of the former salinity maximum and strong eastward currents below 1600m depth. The westward flow recirculates relatively fresh and CFC poor uNADW from the eastern Atlantic and the eastward flow transports relatively saline and CFC rich water downstream from the formation region.

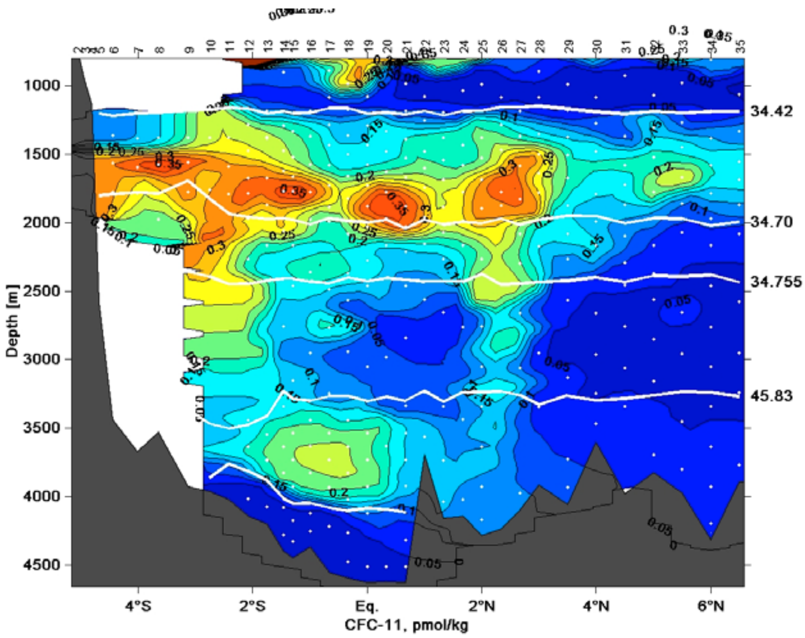


Figure 5 CFC-11 distribution below 1000m depth along 35°W. Data gaps are due to mafunctioning of the CFC analysis system, and only a few samples could be stored until the system was running.The white bold lines are isopycnals separating the deep water masses. Upper Labrador Sea Water (ULSW) is bound by sigma_1500 = 34.42 and 34.70 and in the tropical Atlantic characterized by a CFC maximum and a salinity maximum (see next figure). The LSW stretches from sigma_1500=34.70 to 34.755, and both water masses together are also called upper NADW. The mNADW is limited by sigma_1500=34.755 and sigma_4000=45.83. The lNADW is located between sigma_4000=45.83 and 45.90, and also characterized by an intermediate CFC maximum, although weaker than the ULSW. Below sigma_4000=45.90 the AABW (Antarctic Bottom Water) is observed with the lowest CFC concentrations in this section. Note the deepening of the uLSW maximum around the equator (1°30‘S to 2°N).

The flow of LNADW is commonly found just north of the Parnaiba ridge at 1°40‘S (Rhein et al., 1995). The CFC maximum is colocated with Tpot=2.0-2.05°C, and the maximum concentrations increased from 0.18pmol/kg (Nov.2000) to 0.21pmol/kg (May 2002) and to 0.24pmol/kg. (May 2003).

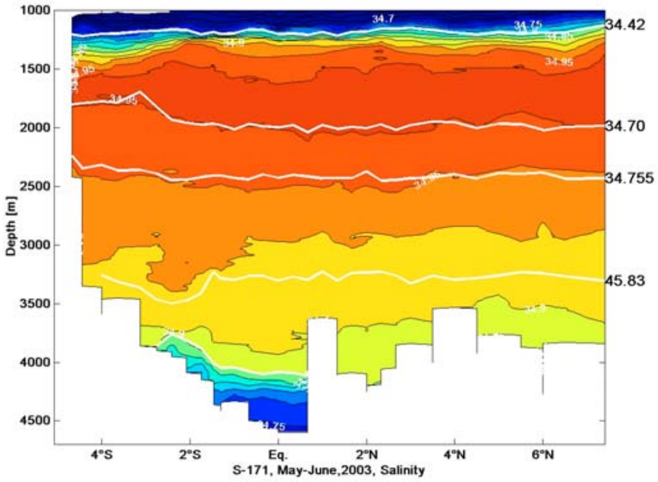


Figure 6 Salinity distribution along 35°W, for the deep water. The white bold lines are isopycnals separating the deep water masses. Upper Labrador Sea Water (ULSW) is bound by sigma_10005=34.42 and 34.70 and in the tropical Atlantic characterized by a salinity maximum. The LSW stretches from sigma_10005=34.70 to 34.755, and both water masses together are also called upper NADW. The mNADW is limited by sigma_10005=34.755 and sigma_40000=45.83. The lNADW is located between sigma_4000=45.83 and 45.90, and below this isopycnal, the AABW (Antarctic Bottom Water) is observed by decreasing salinities.

The 16°N section

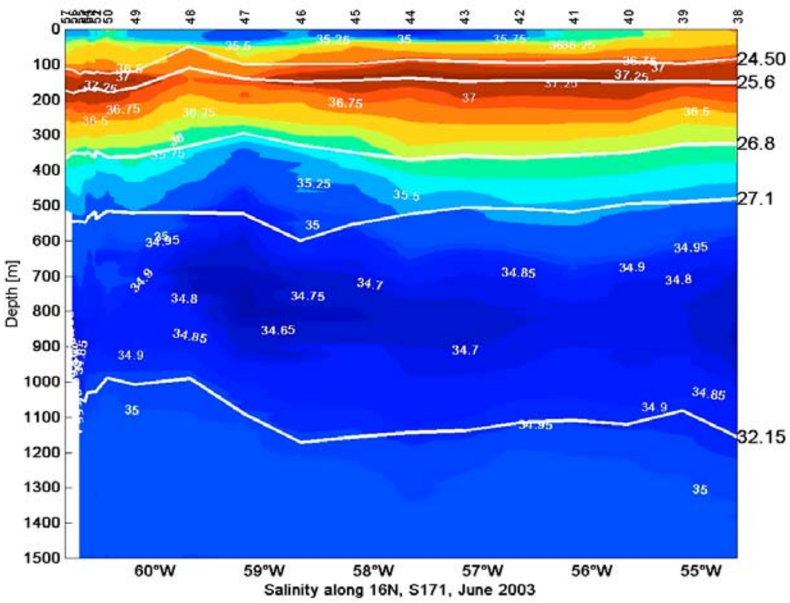


Figure 7 Salinity distribution along 16°N, cruise S171, June 2003. The bold black lines are isopycnals separating the upper water mass components . The isopycnals sigma_th = 24.50 delineates the subtropical salinity maximum water within the Tropical Surface Water TSW. Sigma_th=25.6 and 26.8 limit the upper central water masses , and sigma_th=26.8 and 27.1 the lower central water. The Antarctic Intermediate Water AAIW is found between sigma_th=27.1 and sigma_1000=32.15.

Upper Ocean

Due to lack of time, the 16°N section could not be sampled from the Midatlantic Ridge to Guadeloupe, but started further west at 55°40'W. In the TSW (Fig. 7), the salinity maximum is centered around sigma_th=25.6, i.e. at slightly higher densities than the salinity maximum originating from the South Atlantic (Fig.4b). The salinity maxima are higher than S=37.25 everywhere except between 60°W-59°W, where a strong northward flow prevailed (Fig. 8). The northward flowing water presumably carries a higher contribution of fresher southern hemispheric water This velocity feature was surface intensified, but reached at least down to 850m depth, the lower limit of the velocity section (Fig. 8). Another indication that the northward flow carries more southern hemispheric water is observed in the salinity minimum of the AAIW between sigma_th=27.1 und sigma_1000=32.15, with the lowest values found in the northward flow. The flow west of 60°W and east of 59°W was towards the south in the upper 900m, but southward velocities higher than 10cm/s were only found west of 60°W near the continental slope.

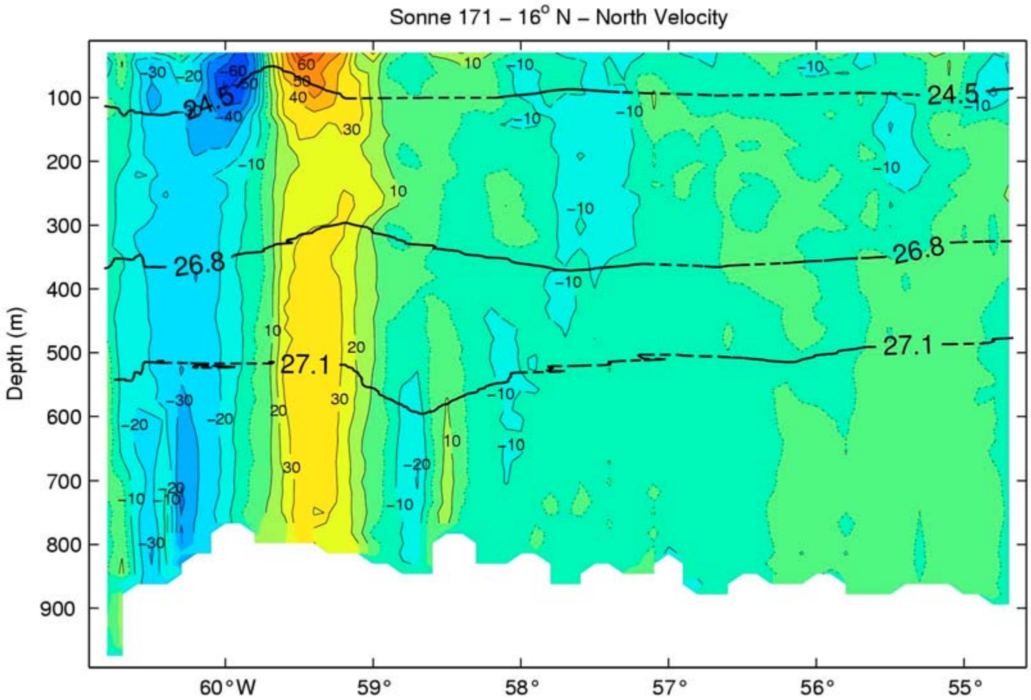


Figure 8 Meriodional velocity component from the Ocean Surveyor along 16°N, positive : flow to the north, negative: flow to the south, units: cm/s. , cruise S171, June 2003.

Deep Ocean

The deep velocity distribution was only measured west of 60°W at the continental slope. Further offshore, the number of backscatterers in the deep water is low and therefore the LADCP data have poor quality. As another backdraw, the LADCP is only pressure resistant to 500bar, preventing the CTD to be lowered to the bottom (5700m) in the deep basin. At the time of the survey, no deep western boundary current (DWBC) could be observed (Fig.11). In the depth range from 1500m to 2500m, i.e. the upper NADW, the flow was even northward. A weak southward core was found between 3000 and 3500m, and the mean flow below this core was also to the south. Both velocity distributions from our cruises in June 2002 (with RV Meteor, cruise M53-3) and April 2003 (with RV L'Atalante, cruise CARIBINFLOW), however, do show a significant southward DWBC as expected, but it was also absent during our first survey in December 2000 (with RV Sonne, cruise 152).

The deep salinity distribution shows clearly the salinity maximum of uNADW at 1400m (Fig. 9a). In contrast to 35°W, it does not correlate with the CFC Maximum, which is located several 100m deeper in the water column. The salinity maximum above the CFC max gets eroded by mixing with fresh uCDW (the lower oxygen poor part of the AAIW, Fig. 9b) while traversing downstream. Another striking contrast between these two sections ist the thickness differerence of the AABW layer: about 500m at 35°W and more than 1000m at 16°N, although the depth of this isopycnal has decreased from 4000m at 35°W to 4500m at 16°N. The thickness increase is thus caused by the deepening of the topography reaching more than 5700m at 16°N, 55°W. The coldest AABW, however, warmed from 0.65°C in the equatorial channel at 35°W to 1.35°C at 16°N, indicating the prominent role of vertical mixing for the AABW water mass changes.

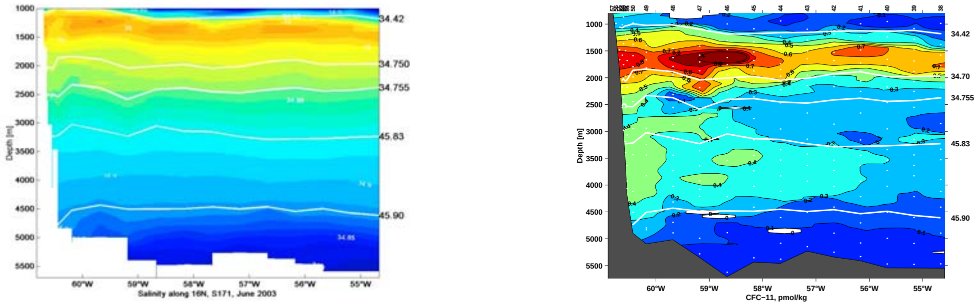


Figure 9 a) Deep Salinity distribution along 16°N, June 2003. The white lines are isopycnals, similar to the ones shown in the 35°W sections. B) the CFC distribution along 16°N. The CFC maximum of the upper NADW is at the same densities than further downstram at 35°W.

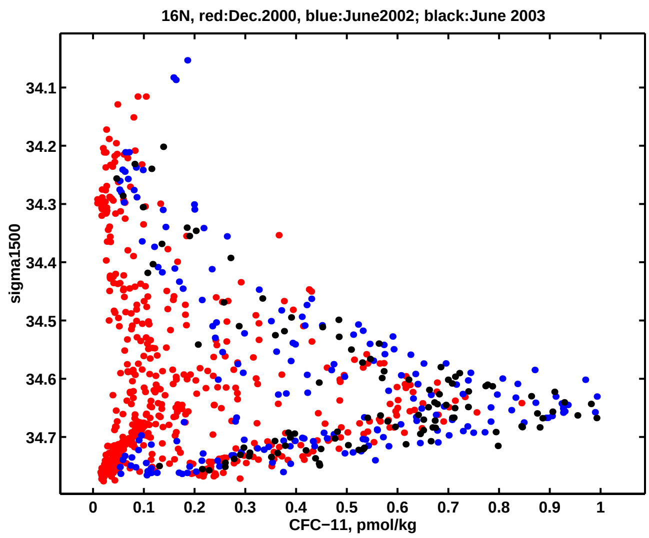


Figure 10 CFC-11 vs sigma_1500 , 16°N: red: December 2000, cruise S-152; blue: June 2002, cruise M53/3, black: June 2003, cruise S-171.

The CFC distribution along 16°N shows basically the same pattern than at 35°W Fig. 9b): The CFC maximum is located at 1600m depth and identifies the upper NADW, the deep maximum is the DSOW. Note the difference in the color scale between the 35°W and the 16°N section. Since 16°N is upstream of 35°W, and the uNADW gets diluted with CFC poorer water flowing downstream, the concentrations decrease downstream. In general, the CFC maxima of both deep water cores at 35°W are about 35-40% of the values found at 16°N.
The atmospheric increase in the CFC concentrations is mirrored in the temporal CFC increase at every location in the boundary current. Fig.xx compares the CFC values in the upper NADW from December 2000 to June 2003. At first, the remarkable increase in the maximum concentrations from 0.7pmol/kg in Dec. 2000 to 1pmol/kg in June 2002 was thought to mark the arrival of the vigorously ventilated vintages of LSW formed in the early 1990s.

One would expect that the CFCs increase from now on. In contrast to that, they remained constant. One explanation could be the local variability in the DWBC flow. In June 2003, the DWBC was flowing to the NORTH, presumably carrying older NADW, which had passed that site already some time ago.

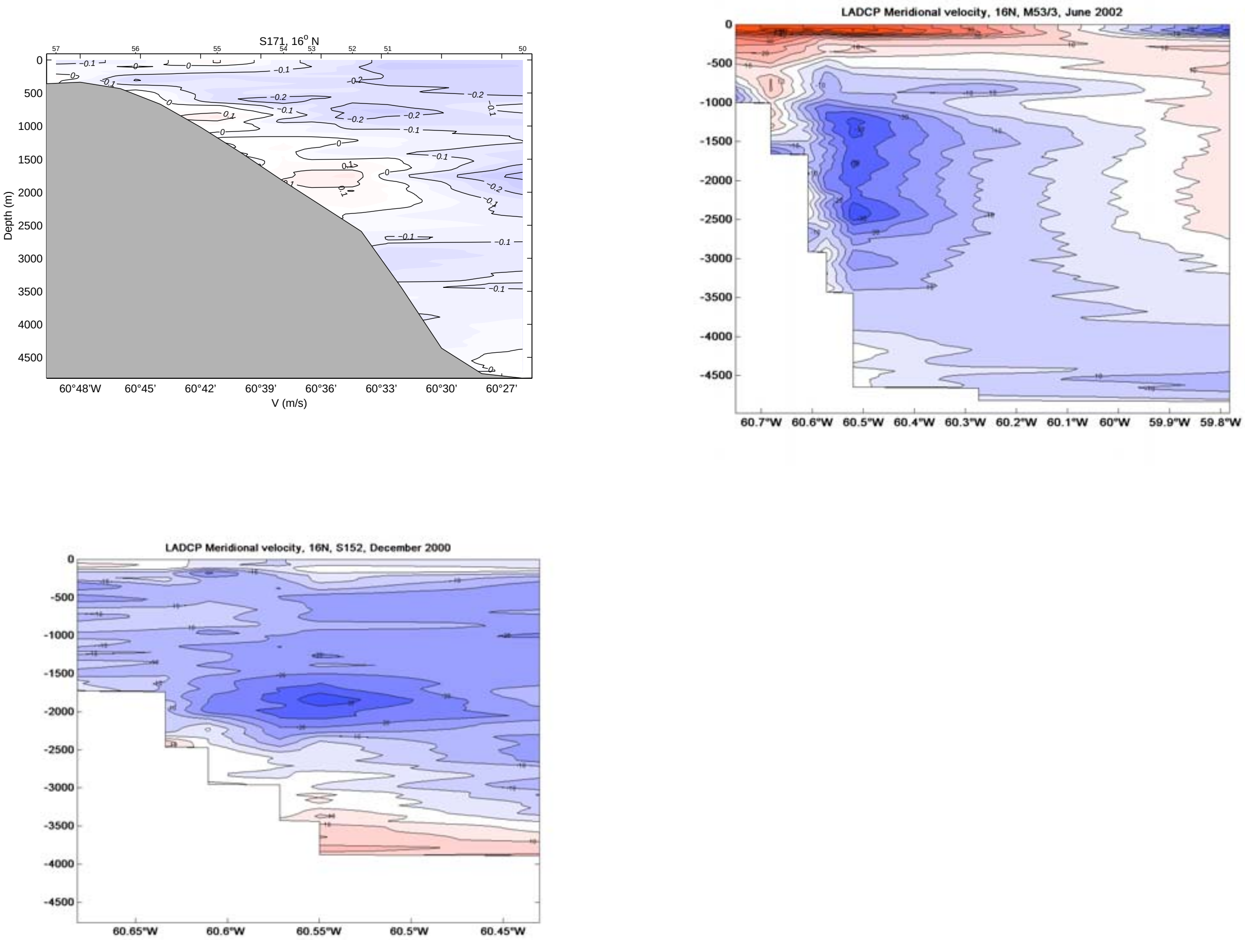


Figure 11 Meridional velocity component from the LADCP, Deep Western Boundary Current at 16°N. red: northward flow, blue: southward flow. A) June 2003, cruise S-171, B) June 2002, Cruise M 53/3, C) December 2000, cruise S-152 . red: flow to the north; blue: flow to the south.

In June 2002, however, flow direction of the DWBC between 1000 and 3000m depth was to the south, bringing water which had nor recirculated before. In December 2000, the flow was also to the south. We hope that our next surveys in 2004 and 2005 will enhance the tracer and velocity time series sufficiently to make the interpretation more clear.

Moored CFC sampler

The prototype of a moored CFC sampler, capable of collecting 52 water samples was moored for the first time. The recovery was without any problems, but the sampler was malfunctioning and was sent back to the manufacturer for repair of the step motor/ valve system.

Lower NADW transport through the 7°30'N fracture zone

During cruise S-171, we recovered the two moorings which were deployed in the 7°30'N fracture zone in May 2002. Earlier LADCP shipboard measurements led us believe that this fracture zone might by an export path for lower NADW into the eastern Atlantic. This turned out not to be the case. There was an inflow in to the fracture zone on the western entrance with annual mean eastward velocities of 20-30cm/s (Fig. 12)

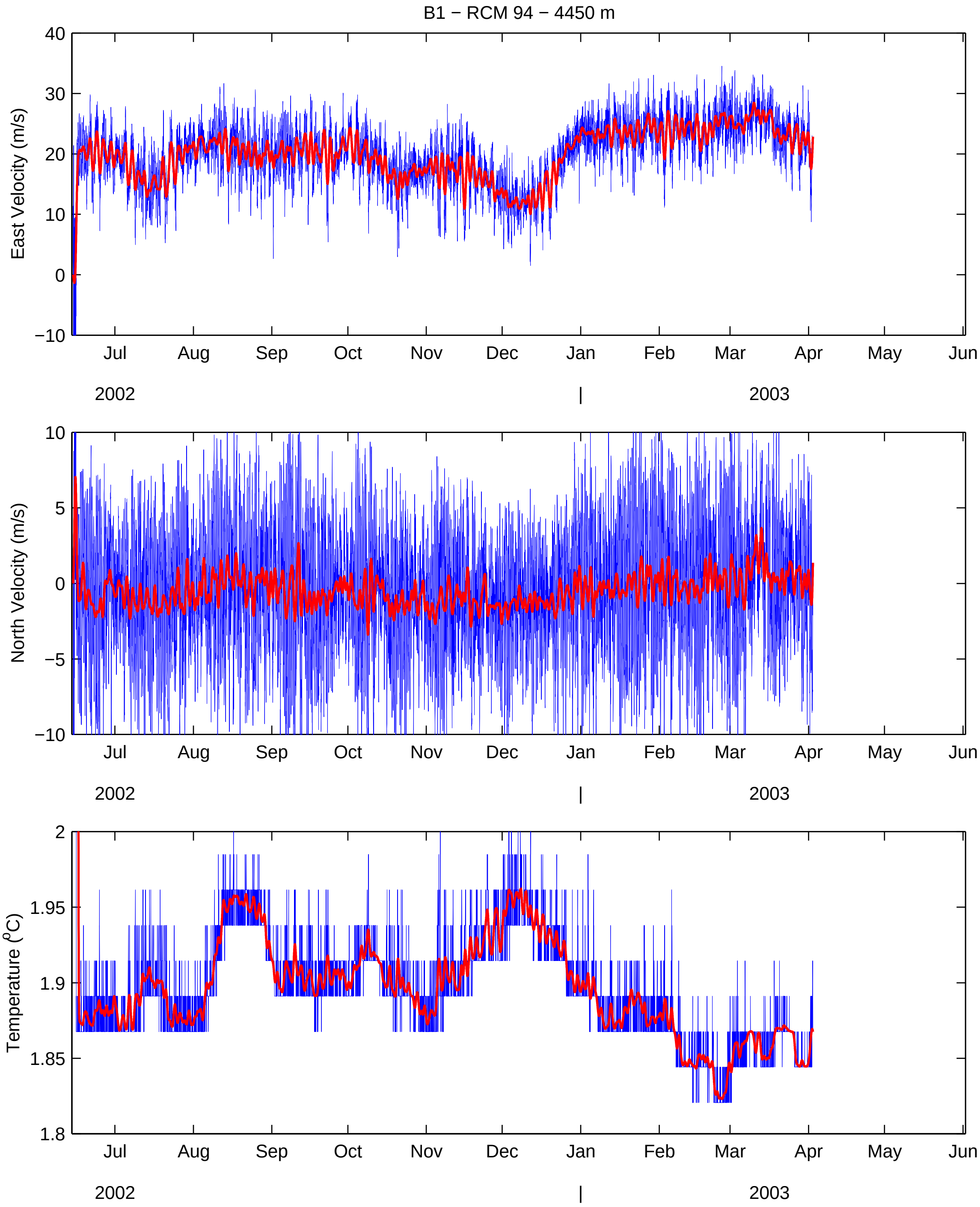


Figure 12 Velocity (a: zonal, b: meridional) and c) temperature record of the acoustic currentmeter (Aanderaa) deployed at the bottom of the western entrance of the 7°30'N fracture zone. Note the different y-axis in 12a) and 12b). The increase in the eastward velocity in January 2003 is accompanied by a decrease in temperature, indicating an increase in the AABW fraction. Blue: original data, red: low pass filtered.

but the inflowing water was AABW, since the fracture zone was deeper than expected from the charts available. Further up, the mean velocties decreased. We were able to survey the whole fracture zone with a SIMRAD echosounder recently installed at SONNE and obtained the topography of the fracture zone and could therefore determine the inflow area very well.

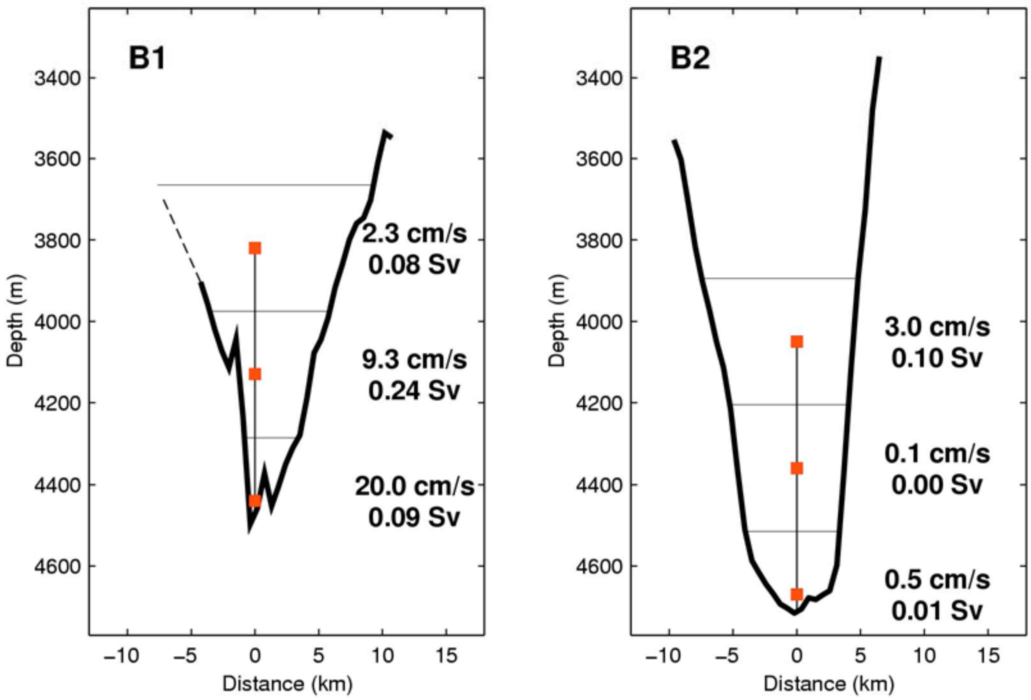
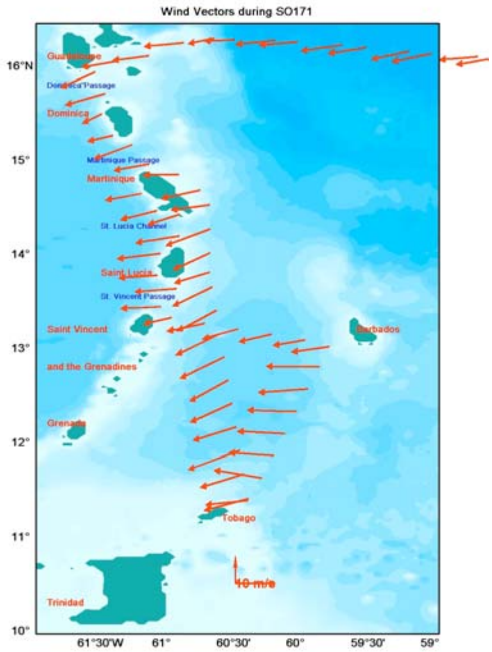


Figure 13: cross area of the western entrance (right) and the eastern exit of the 7°30'N fracture zone. Embedded are the locations of the moored acoustic current meter and the mean velocities (cm/s) for the deployment period. Also included are the mean transports for the respective areas. The deep water entering the fracture zone below 4000m contains a significant fraction of AABW.

The mean transport into the fracture zone was 0.2 Sv, and no outflow of any deep water occurred at the eastern exit, where all 5 moored ADCPs showed high variability in the velocities due to tidal and inertial flow, but the average was zero. Assuming vertical mixing rates like estimated for the Romanche Fracture Zone, the inflow could be mixed away instead of exported. The importance of the 7°30'N Fracture zone thus seems more to act as a mixing agent for AABW and lower NADW than an export highway .

Weather conditions



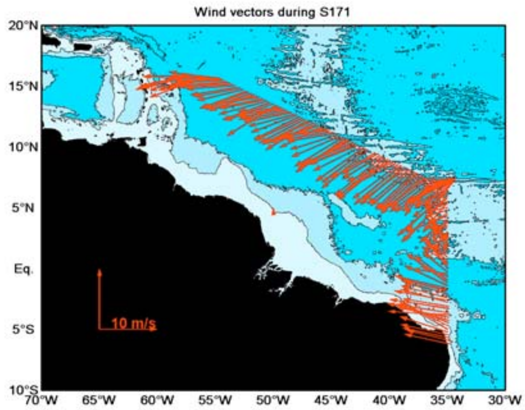


Figure 14. Mean winds during cruise S-171 . They were as expected very continuous and moderate. At the first few days off Brazil, the wind direction was almost parallel to the coast (SE Trades). After crossing the ITCZ, the NE trades were present throughout the entire time period. The winds were slightly higher and aligned to the topography in the passages south of Guadeloupe due to orographic effects.

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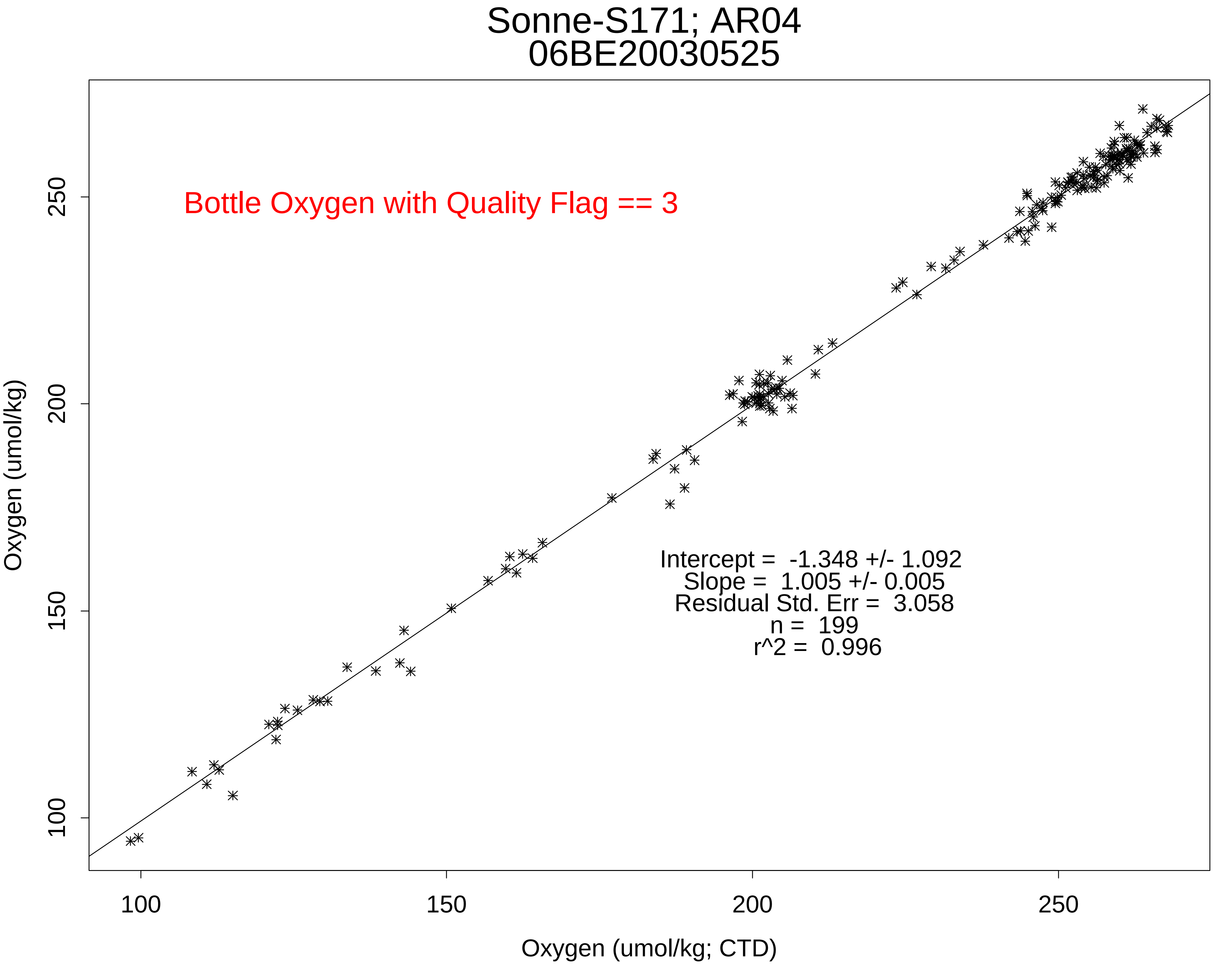

Sonne-S171; AR04
06BE20030525
Bottle Oxygen with Quality Flag == 3
Intercept = -1.348 +/- 1.092
Slope = 1.005 +/- 0.005
Residual Std. Err = 3.058
n = 199
r^2 = 0.996
Oxygen (umol/kg)
Oxygen (umol/kg; CTD)
100
150
200
250