Cruise Report

SONNE cruise SO 151

KLIMAZIRKEL

Bridgetown - Recife

1. - 27. November 2000

Institut für Meereskunde
an der Universität Kiel
Düsternbrooker Weg 20
24105 Kiel - Germany

Zirkulation und Klimavariabilität des tropischen Atlantiks

Circulation and climate variability in the tropical Atlantic

Fahrtbericht
Cruise report

So 151

Klimazirkel

(BMBF Projekt 03G0151A)

Fahrtleiter/chief scientist:

Dr. Lothar Stramma
Institut für Meereskunde
an der Universität Kiel
Düsternbrooker Weg 20
24105 Kiel
Germany

Tel: 0431-597-3818
Fax: 0431-597-3821
e-mail:lstramma@ifm.uni-kiel.de

Zusammenfassung

Die Forschungsfahrt So151 des FS "SONNE" vom 1. bis 27. November 2000 von Bridgetown, Barbados nach Recife, Brasilien wurde vom Institut für Meereskunde an der Universität Kiel im Rahmen des internationalen CLIVAR (Climate Variability and Predictability) Projekts durchgeführt. Die Arbeiten waren ein Beitrag zum deutschen Ozean-CLIVAR (Teilprojekt "Tropisch-subtropische Wechselwirkung") Programm des Bundesministeriums für Bildung, Wissenschaft, Forschung und Technologie (BMBF). Ein Hauptziel des Teilprojekt ist die Fragestellung der Klimarelevanz der flachen tropisch-subtropischen Zirkulationszelle im äquatornahen Atlantik und deren Fokussierung im westlichen Randstrom vor Brasilien.

Die Hauptuntersuchungsaufgaben waren neben den CLIVAR-Fragestellungen im oberen Ozean Fragestellungen der Tiefseezirkulation. Im oberen Ozean geht es um die Ankopplung der tropischen Wasserzirkulation an den subtropischen Nordatlantik in der Spätphase der Zirkulation des Nordsommers. Einige Ziele dabei waren die Vermessung der Transporte des Warmwassers in Richtung Karibik entlang der Küste, die Existenz und Struktur des äquatorialen Unterstromes als Teil der nordhemisphärischen flachen Thermohalinen Zelle und deren Fokussierung im westlichen Randstrom. Bei der Tiefenzirkulation geht es um das Vordringen des Nordatlantischen Tiefenwassers (NADW) am und über den Äquator hinweg, sowie die Rezirkulation im Guyana-Becken, sowie um das vermutete Eintreffen des starken Pulses von Labradorsee-Wassers in Äquatornähe.

Messungen die durchgeführt wurden, waren hoch auflösende Messungen von Temperatur, Leitfähigkeit, Druck und Sauerstoff durch CTD-Profile, kontinuierliche Messungen der Strömungen in den oberen 500 m der Wassersäule mit dem im Schiff installierten Akustischen Doppler Strömungsprofiler (ADCP), Geschwindigkeitsprofile über die gesamte Wassersäule von einem an die CTD angebrachten ADCP, Freon-Verteilungen aus den Wasserschöpfern und kontinuierliche Aufnahme von Oberflächentemperaturen und Salzgehalten, meteorologischen Parametern und Tiefenmessungen. Ausserdem wurden 2 Verankerungen aufgenommen und wieder ausgelegt und 5 profilierende Floats ausgesetzt.

Die Fahrt stand im thematischen Zusammenhang mit der SONNE Reisen So152 (Prof. M. Rhein) und So153 (Prof. U. Send), die ebenfalls CLIVAR-Fragestellungen untersuchten. Die Schnitte senkrecht zur Küste sollen in Kombination mit den Schnitten von So152 für die grossräumigen Fragestellungen gemeinsam bearbeitet werden.

Summary

RV "SONNE" cruise So151, during 1 to 27 November 2000 from Bridgetown, Barbados to Recife, Brazil was carried out by the Institut für Meereskunde Kiel within the contect of the international CLIVAR (Climate Variability and Predictability) projects. The work was a contribution of the german ocean-CLIVAR (Sub-project "tropical-subtropical interaction") program of Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF). One main aim of the sub-project is the investigation of the climate relevance of the shallow tropical-subtropical circulation cell in the equatorial Atlantic and its focus in the western boundary current off Brazil.

The main objectives beneath the CLIVAR related research in the upper ocean were investigations of the deep sea circulation. In the upper ocean the interaction between the tropical water circulation an the subtropical North Atlantic in the late phase of the northern summer was one particular objective. Some goals of it were the measurements of transports of warm water off the coast towards the Caribbean, the existence and structure of the equatorial Undercurrent as part of the northern hemispheric shallow thermohaline cell and its focus in the western boundary current. Objectives of the deep circulation are the spreading of North Atlantic Deep Water (NADW) at and across the equator, as well as the recirculation in the Guyana-Basin and the expected arrival of a strong pulse of Labrador Sea Water at the equator.

Measurements carried out were high resolution measurements of temperature, conductivity, pressure and oxygen by CTD casts, continuous current profiling in the upper 500 m of the water column using shipboard Acoustic Doppler Current Profiler (ADCP), top to bottom velocity profiles from an ADCP lowered with the CTD, freon distribution from the Niskin bottles and continuous surface temperature and salinity distributions, meteorological parameters and depth soundings. In addition 2 moorings were recovered and redeployed and 5 profiling floats were deployed.

The cruise was carried out in close co-operation with So152 (Prof. M. Rhein) and So153 (Prof. U. Send) who also carried out CLIVAR investigations. The sections perpendicular to the coast will be worked up together with the ones from So152 to investigate large scale water mass and circulation distributions.

Table of contents

1. Narrative

Cruise So151 began with the arrival of SONNE in Bridgetown, Barbados on the morning of November 1. The official start of cruise So151 was on 28. October 2000 in Colon, Panama. However, Colon is a bad harbour to handle the logistic needs of the scientific container and person exchange and it was agreed upon a continuation of few scientists of the previous cruise So150 to Barbados as no scientific measurements were planned for the transfer from Colon to Bridgetown for So151 and the scientific start of So151 in Bridgetown. The advantage were reduced costs for air faires and container transports and more time for research in the investigation region of cruise So151 as SONNE had left the Panama Canal at the beginning of October 28, while otherwise the ship would have stayed in port in the Panama Canal in Colon.

During the stop in Bridgetown the container were unloaded and all laboratories and instruments were set up to be operational. 16 scientists and students of the Institute für Meereskunde in Kiel, Germany, one Brazilian scientist from the University of Pernambuco in Recife, Brazil and one Brazilian naval observer made up the scientific crew for SONNE cruise So151. SONNE left Bridgetown in the morning of 3 November and headed towards the coast of French Guyana. Due to the necessary mooring work at about 10°S off Brazil, we were not able to carry out measurements within the Economic Zones of Barbados and Tobago, which were originally planned. On the transfer to French Guyana one test CTD station was carried out successfully to the bottom at 9°34.5'N, 55°52.9'W at 3600 m water depth.

A typical CTD profile also contains a vertical velocity profile derived from a lowered ADCP connected to the CTD-rosette. Water samples were taken from the rosette for freon and nutrients measurements as well as for salinity and oxygen measurements, the latter only for the calibration of the CTD sensors. Continuous measurements were made from a new shipboard ADCP, the Ocean Surveyor given to us for testing by the manufacturer RD-Instruments, which after some days of testing provided good velocity distributions to 500 and sometimes even up to 600 m depth. This shipboard ADCP was operational with the beginning of the first CTD-section starting on 5 November. In addition continuous measurements were made for some meteorological and navigational data as well as sea surface temperature and sea surface salinity data.

On Sunday 5 November CTD profile 2 was the first station of the northeastward oriented section off the coast of French Guyana (Figure 1) which was carried out at the shelf break at 230 m water depth. This section ended with CTD/LADCP profile 24 (Table 1) at the Mid-Atlantic Ridge at 11°16'N 44°W; which was reached in the morning of 10 November. This profile marked also the beginning of a second CTD/LADCP section running southward along 44°W. The 44°W section was completed in the morning of 15. November with profile 48 at the Brazilian shelf break just north of the equator.

Within the eastward retroflection of the North Brazil Current on the 44°W section 3 profiling floats were deployed (Table 2), 2 of them at 200 m depth and one at 400 m depth on 12 and 13 November. These floats stay for 10 days at their nominal depth, than sink to 1500 m and on its way back upwards to the surface sample a hydrographic profile, which is transmitted via satellite to the Institut für Meereskunde in Kiel and then returns to its nominal depth for another cycle. These floats might work for up to 100 cycles.
After completion of the 44°W section the ship sailed to the northeast corner of Brazil. At 18.

November at 17:00 local time a CTD/LADCP station was carried out at the Brazilian shelf break at 5°39'S, 34°57'W to start another hydrographic section**.** 13 CTD/LADCP profiles were carried out at a section along about 5°S to finish the section in the afternoon of 19. November at 5°07'S, 32°10'W. Two more profiling floats were deployed at the eastern end of this section, one for a nominal depth of 200 m and one for 400 m.

A last hydrographic section was made along about 11°S. After about one day of transfer from the last CTD/LADCP station of the 5°S section, the easternmost CTD/LADCP profile 62 was made at 11°30'S, 31°48'W in the late evening of 20. November. The CTD/LADCP data were first carried out westward along 11°30'S to 34°13'W and then northwestward to cross the shelf break perpendicular. The CTD/LADCP section work had to be interrupted 4 times for mooring work and hence the locations of the taken profiles sometimes move back and forth in the western half of the section (see Table 1).The westernmost CTD/LADCP profile was made at 600 m water depth at 10°15.8'S, 35°53.0'W. In total 83 CTD/LADCP profiles were taken during the Sonne cruise 151.

Five moorings were deployed along the so-called 11°S section in March 2000 for a two year period. However, it will take more than 2 years until a ship is available for recovery and therefore 2 of the moorings were recovered on 22. and 23. November and redeployed at the same locations on 24. und 25. November. The mooring K4 at 10°56.5'S, 34°59.5'W was recovered on 22. November and redeployed on 24. November, the mooring K2 at 10°22.8'S 35°40.8'W was recovered on 23. November and redeployed on 25. November 2000. The redeployment of mooring K2 was the last station work carried out before the ship sailed towards the port of Recife.

In the morning of 26. November 2000 RV Sonne called port in Recife, Brazil. The same day Prof. Monika Rhein, the chief scientist of the next cruise and several persons of the scientific group of Sonne cruise 152 visited the ship for an information exchange, as most of the instruments used during Sonne 151 will be also used during the next cruise. In the afternoon of 26, November 3 faculty members of the University of Pernambuco in Recife visited the ship to discuss the possibilities of future joint work. The scientific crew of cruise Sonne 151 left the ship in the morning of 27. November to fly back to Germany, and Sonne cruise 151 ended in Recife on 27. November 2000.

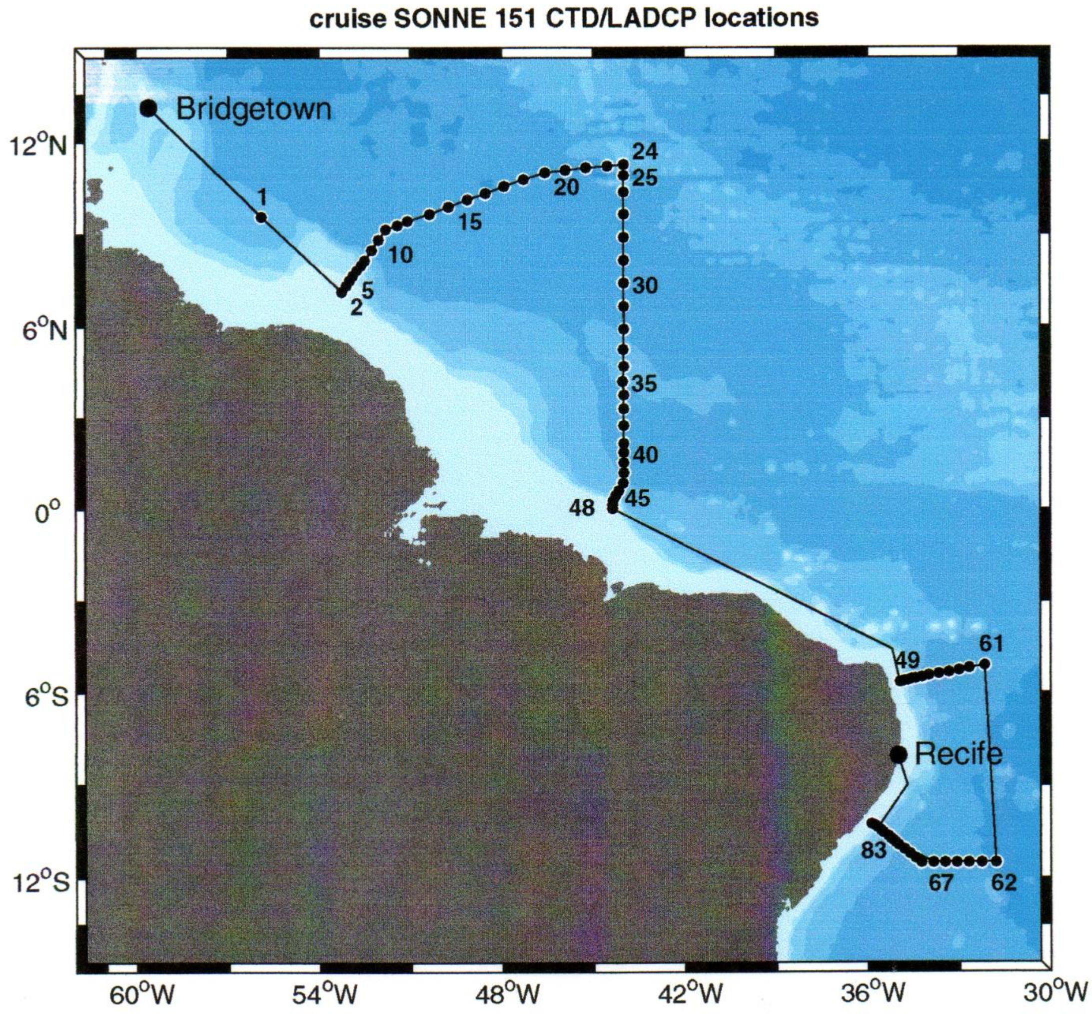

Figure 1: *Location of the CTD/LADCP stations (dots) during cruise So151.*
Abbildung 1: *Lage der CTD/LADCP Stationen (Punkte) während der Reise So151.*

2. Cruise participants

SONNE cruise So151 was planned, coordinated and led by the Institut für Meereskunde at the University of Kiel.

The shipboard scientific party included 17 scientists, technicians and students and one Brazilian Navy Observer.

Dr. Lothar **Stramma**	IfM Kiel
Karina **Affler**	IfM Kiel
Dr. Peter **Brandt**	IfM Kiel

Dr. Carlos **de Sena Martins**	IfM Kiel
Uwe **Dombrowsky**	IfM Kiel
Dr. Jürgen **Fischer**	IfM Kiel
Meike **Hamann**	IfM Kiel
Sigrun **Komander-Hoepner**	IfM Kiel
Frank **Malien**	IfM Kiel
Jorge Luiz **Mesquita de Medeiros**	Brazilian Navy
Geber **Moura**	UFPE
Mario **Müller**	IfM Kiel
Uwe **Papenburg**	IfM Kiel
Dr. Olaf **Plähn**	IOW/IfM Kiel
Uwe **Richter**	IfM Kiel
Helena **Schlüter**	IfM Kiel
Hauke **Schmidt**	IfM Kiel
Martina **Schütt**	IfM Kiel

IfM Kiel:
Institut für Meereskunde
an der Universität Kiel
Düsternbrooker Weg 20
24105 Kiel
Germany
Tel.: +49-431-597-3818
Fax: +49-431-597-3821

IOW:
Institut für Ostseeforschung Warnemünde
Seestr. 15
18119 Rostock
Germany
Tel.: 0381 51 97 0
Fax: 0381 51 97 480

UFPE:
Universidade Federal de Pernambuco
Departamento de Oceanografia
Campus Universitario
50.679-901 Recife-PE
Brazil
Tel.: 81 271 8225
Fax: 81 271 8227

The officers and crew of RV SONNE consisted of 30 members of the Reedereigemeinschaft Forschungsschiffahrt, Bremen, Germany.

3. Instrumentation

3.1 LADCP

At all stations a narrow band ADCP (NBADCP 301) was attached to the CTD-Rosette (see station list in table 1). At the beginning some of the profiles suffered from large tilts of the CTD near the surface where the currents were rather strong (about 1m/s). Later, with the deep sea winch and sufficiently more weight at the Rosette tilt angles were small and no data drop outs were observed. External data used for the LADCP processing were obtained from a standard GPS receiver, that has high enough accuracy after the SAV has been switched off in May 2000. It should be mentioned that the CTD package rotated more than experienced during previous cruises, but the reason for that behavior remained unclear. However, a stabilizing fin was welded to the Rosette, and in fact the number of rotations per profile was significantly reduced. The LADCP data set served as the primary source for evaluating the quality of the Ocean Surveyor data.

3.2 Ocean Surveyor

A 75KHz Phased Array ADCP, named Ocean Surveyor (OS) was mounted in the front sea chest of the ship. The transducer levels with the ships bottom and there was no acoustic window in front of it. This instrument was kindly provided by the manufacturer RD-Instruments, San Diego, California for the three Sonne cruises SO151 to SO153. Almost no experience with this new instrument exists (except some test cruises) and we therefore will describe the procedure how to use this instrument in detail.

The OS needs several navigation data to be stored with the raw acoustic data, namely ships heading (from the gyro compass) and various GPS strings containing position data and attitude data from the Ashtec receiver. While the gyro heading was used to perform the transformation of the raw OS-data to currents in the earth coordinate system (east/north/vertical), the position information is stored with the data for later use in the post-processing.

The OS was set up to send out acoustic pulses (pings) every four seconds and store the data as single ping profiles and as averages over 5 minutes of data (short averaging) and 20 minutes of data (long averages). The data were collected using a bin length of 16 m and a blank length of 8 m. However, whenever the VMDAS control program was started and the first short averaging interval should be written into a new file it came to a fatal WINDOWS error message. The only way to proceed with the measurements was to ignore this message, as the only consequence was to loose the 5-minute data. The high temporal resolution (single ping profiles) led to an enormous amount of data, but allows for maximum flexibility in the data screening and post-processing as we will show later.

***Calibration**:*All shipboard ADCPs have to be calibrated for possible misalignments between the ADCP axis (usually the line between beams 3 and 4) and the ships axis (which of course is aligned with the gyro). This misalignment has two sources, a mechanical source due to inaccurate mounting of the transducer head in the ships well and an unknown offset in the synchro-connection to the OS board unit. Furthermore there are other compass dependent errors that are not perfectly corrected; typical is a dependence on the latitude as well as on the heading of the ship.

Due to several circumstances the misalignment angle changed three times during the cruise. Thus the misalignment angle had to be calibrated for the resulting four separated data sets. For each data set a water track calibration was carried out, which results in standard deviations of the calculated angle offset comparable to standard deviations of angle offset calibrations obtained from other cruises with the same gyro system. As known from other cruises, the gyro heading showed a heading dependence. Here a correction of the gyro heading with the Ashtech heading was only possible for the largest data set out of the four data sets as only for this data set the dependence between Ashtech and gyro heading could be established sufficiently enough. Thus the data of this data set were processed, using the Ashtech - gyro heading differences whenever available and using a polynomial fit to these differences with respect to the ship's heading whenever Ashtech was not available.

The ADCP worked well throughout the cruise apart from a 20 hours gap in the data due to a storage error of the VMDAS control program. In most of the surveyed area, good data (50 % good criterion) were obtained to a depth range of 600 m during day-time and to a depth range of 500 m during night-time. The range decreased slightly due to low scatter layers in the measurements close to the continental shelf of Brazil, in parts including the region of the North Brazil Current (NBC).

3.3 APEX - Floats

During the cruise we launched 5 APEX floats programmed to a 10 day duty cycle and with parking depths of 200 m (3 floats) and 400 m (2 floats). Table 2 gives an overview about their deployment.

Float 194 was launched on **station 33**, and we had a very strong current that just reached the parking depth of the float. At the surface the flow was about 1.5 m/s. The float was started approximately one hour before deployment, such that it would drift for about 5 hours at the surface and then descend to its parking depth. This is one of the 4 floats with only small holes in the rear end and we hope that this helps when floats drift over shallow water and sink into the mud.

Float 120 was launched on **station 37**, where we waited until the station was finished and the LADCP data were processed (which took about 10 minutes). The currents showed a strong undercurrent core near 200 m and a deeper core with about 20 - 25 cm/s eastward flow at 400 m depth. The float should sink about 5 hours after launch.

Float 195 was launched on **station 38**, about 10 minutes after the CTD was on board. Surface currents show first signs of a current reversal (towards west) at this place, while at 200 m there is an eastward undercurrent.

Float 123 was launched on **station 60** immediately after the CTD was on board. This location was outside the boundary current regime with weak eastward currents in the parking depth of the float.

Float 196 was launched on **station 61** immediately after the CTD. This was the outermost station on the 5°S section.

3.4 Mooring work:

At the end of cruise So151 two moorings deployed in March 2000 during METEOR cruise M47/1 were recovered and redeployed just 2 days later.

K4_1 recovery:
During the morning of the 22. November we recovered mooring K4_1. We used different hydrophones and Mors deck-units to talk to the releases from a distance of 0.5 to 0.2 nautical miles, but without success. We decided to release both units and a few minutes later the mooring was seen at the surface. Some floatation packages were tangled, as there was almost no current at the surface. One Benthos group could not be seen and it later turned out that four out of six glass-spheres imploded. This implosion happened already during the deployment, as the nearby Aanderaa current meter lost its rotor at that time (presumably caused by the imploding glass balls).

Visual inspection of the upper mooring components showed almost no bio-fouling and all instruments had full data sets of about 8 months duration (one Aanderaa had only temperature).

K2_1 recovery:
The recovery of mooring K2_1 began in the afternoon of November 23 at 17:35 UTC. It took about 10 minutes after the release command and the first visualization of some Benthos floats at the surface. The top element could not be detected. Therefore we began to recover the first group of Benthos floats. On top of this group we recovered the ADCP, a Microcat and a Temperature/Depth probe, all other components (another Microcat, and the top float were lost). It could only be speculated what caused this loss (fishery, corrosion etc.). Below, all instruments were savely recovered. Inspection of the uppermost pressure sensor showed that this happened already May 26, 2000 about two months after deployment.

K4_2 deployment:
The top element of this mooring was launched 15:02 UTC on November 24. The mooring deployment began at 10°56.49' S, 34°59.06' W, a little more than 2.5 nm west of the tentative anchor drop position (in fact very similar conditions as during the first deployment in March 2000). The deployment went very smooth and at 15:02 UTC the anchor was dropped at exactly the planned position. For the first time a new program was used to estimate the initial position and the anchor drop location.

K2_2 deployment:
The deployment of K2_2 began in the morning of November 25 with the usual deployment simulation; easterly winds were weak at 2-3 Bft. The duration of the deployment was planned to be 2 hours 20' which turned out to be rather long, and we had to steam for half an hour to reach the anchor launch position. The deployment went very smooth and the final position of the mooring is estimated to be the same as for K2_1. Water depth at the mooring position was 2325 m and no wire length adjustment had to be done.

3.5 CTD measurements

Hydrographic parameters, i.e. temperature, conductivity and pressure as well as oxygen were measured using a Seabird 9 11 plus CTD instrument attached to a 24 bottle rosette sampler. Only 22 samplers were used because an ADCP (to be described below) was attached to the rosette in the place of two samplers. Five of the samplers were also equipped with electronic deep sea reversing thermometers and pressure sensors for calibration purposes. Water samples were taken at most stations and analyzed for CFCs, CCl4, for salinity with a Guildline Autosal, for oxygen with a titration stand using Winkler titration and for nutrients with an Autoanalyzer. The CTD worked well during the cruise. At stations 3 single spikes occurred in pressure and on following stations also on other sensors, becoming more frequent to station 6. Therefore, station 6 was run again with the ship-owned Seabird instrument, in order to check the correct transmission of the signals through the cable. This data were transmitted well without any spikes. A substitution of the cable adapter between the IfM Kiel rosette and the cable removed the problem. During the following deeper stations the winch showed some problems, therefore another winch was used. This did not affect in any aspect the quality of the CTD data. A total of 83 profiles were achieved. The accuracy of the data after calibration with in situ water samples is 3 dbar, 0.001 K, 0.002 and 0.04 ml/l for pressure, temperature, salinity and dissolved oxygen content, respectively. The positions of the CTD stations are listed in Table 1 and shown in Figure 1.

3.6 Tracer (CFC-11, CFC-12 und CCl4) measurements

During the cruise Sonne 151 the two systems for CFC-11/CFC-12 and CCl4 worked continuously without major technical or contamination problems. After sampling, about 20 mL of water were transferred from precleaned 10 L Niskin bottles to a purge and trap unit. The CFCs were then separated on a gaschromatographic packed stainless steel column and detected with an Electron Capture Detector (ECD). To separate CCl4 from other gases a capillary column was used on the second analysis system. The carrier gas in both system is ECD pure Nitrogen, which was additionally cleaned by molsieves. Two different standard gases were used to convert the ECD signals in concentrations. The efficiency of both ECDs was stable in time, the observed temporal variations were about 10% for the CFCs and more than 20% for CCl4. To correct for the temporal drift of the ECD, a calibration curve with five to seven different gas volumes was taken before and after each station assuming that the temporal change between two calibration curves is linear in time.

All 'O'-rings and valves as well as the nylon stopcocks (of the syringes) were removed and washed in isopropanol and baked in a vacuum oven prior the cruise. The personnel for all water sampling and handling procedures at the bottles wore one-way gloves to protect the valves from grease.

During the cruise, more than 1000 water samples for CCl4, and about 1100 water samples for CFC from 73 CTD stations along 10°S, 5°S, 44°W and 53°W were analysed. The survey was dedicated to the circulation of the deep and bottom water masses. In order to get a sufficient vertical resolution in the deep water masses with the 22 available bottle samples, thus measurements were restricted to the water column beneath 900 m depth. Precision was checked by analysing about 10% of the water samples at least twice. It was found to be +/- 0.003 pmol/kg for CFC-12, and +/- 0.004 pmol/kg for CFC-11. The precision for CCl_4 was better than 1%. In addition, air samples were taken regularly and analysed.

4. Listings of station positions, float deployments and mooring work

Table 1: List of CTD/LADCP stations

R/V SONNE Cruise So151 CTD-stations

SHIP EXPOCODE	WOCE SECT	Station Number	Cast Number	CAST TYPE	DATE mmddyy	UTC TIME	CODE	POSTION LATITUDE			LONGITUDE			Uncorr. DEPTH	HT ABOVE BOTTOM	MAX PRESS	NO. OF BOTTLES	PARAMETERS
06BE151	AR15	1	1	ROS	110400	1321	BE	9	34,45	N	-55	52,94	W	3623			22	
06BE151	AR15	1	1	ROS	110400	1439	BO	9	34,45	N	-55	52,94	W	3623	20	3648	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	1	1	ROS	110400	1611	EN	9	34,46	N	-55	52,94	W	3622			22	
06BE151	AR15	2	1	CTD	110500	1009	BE	7	8,04	N	-53	15,05	W	218			0	
06BE151	AR15	2	1	CTD	110500	1011	BO	7	8,04	N	-53	15,04	W	219	20	208	0	
06BE151	AR15	2	1	CTD	110500	1022	EN	7	8,04	N	-53	15,04	W	219			0	
06BE151	AR15	3	1	ROS	110500	1153	BE	7	20,02	N	-53	6,01	W	537			5	
06BE151	AR15	3	1	ROS	110500	1213	BO	7	20,04	N	-53	6,01	W	537	20	525	5	1,2,3,4,5,6,7,8,28
06BE151	AR15	3	1	ROS	110500	1232	EN	7	20,03	N	-53	6,01	W	537			5	
06BE151	AR15	4	1	ROS	110500	1335	BE	7	30,14	N	-53	0,10	W	872			6	
06BE151	AR15	4	1	ROS	110500	1401	BO	7	30,14	N	-53	0,07	W	873	20	863	6	1,2,3,4,5,6,7,8,28
06BE151	AR15	4	1	ROS	110500	1427	EN	7	30,14	N	-53	0,10	W	872			6	
06BE151	AR15	5	1	ROS	110500	1531	BE	7	40,04	N	-52	53,01	W	1200			6	
06BE151	AR15	5	1	ROS	110500	1601	BO	7	40,13	N	-52	53,01	W	1188	20	1188	6	1,2,3,4,5,6,7,8,28
06BE151	AR15	5	1	ROS	110500	1633	EN	7	40,26	N	-52	53,04	W	1203			6	
06BE151	AR15	6	1	ROS	110500	1741	BE	7	49,89	N	-52	45,00	W	1388			9	
06BE151	AR15	6	1	ROS	110500	1814	BO	7	50,39	N	-52	45,05	W	1396	20	1379	9	1,2,3,4,5,6,7,8,28
06BE151	AR15	6	1	ROS	110500	1850	EN	7	50,28	N	-52	45,26	W	1404			9	
06BE151	AR15	7	1	ROS	110500	2158	BE	7	59,84	N	-52	36,92	W	2318			12	
06BE151	AR15	7	1	ROS	110500	2252	BO	8	0,62	N	-52	37,11	W	2345	20	2337	12	1,2,3,4,5,6,7,8,28
06BE151	AR15	7	1	ROS	110500	2352	EN	8	1,52	N	-52	37,39	W	2367			12	
06BE151	AR15	8	1	ROS	110600	0049	BE	8	9,59	N	-52	29,83	W	3022			17	
06BE151	AR15	8	1	ROS	110600	0202	BO	8	10,42	N	-52	30,01	W	3065	20	3065	17	1,2,3,4,5,6,7,8,28
06BE151	AR15	8	1	ROS	110600	0315	EN	8	11,26	N	-52	29,64	W	3101			17	
06BE151	AR15	9	1	ROS	110600	0502	BE	8	29,23	N	-52	15,84	W	4014			22	
06BE151	AR15	9	1	ROS	110600	0638	BO	8	30,35	N	-52	15,68	W	4059	20	4541	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	9	1	ROS	110600	0829	EN	8	31,35	N	-52	15,47	W	4014			22	
06BE151	AR15	10	1	ROS	110600	1033	BE	8	49,80	N	-52	1,69	W	4682			22	
06BE151	AR15	10	1	ROS	110600	1207	BO	8	49,98	N	-52	0,63	W	4690	20	4753	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	10	1	ROS	110600	1358	EN	8	50,02	N	-52	0,44	W	4688			22	
06BE151	AR15	11	1	ROS	110600	1606	BE	9	10,01	N	-51	48,10	W	4768			22	

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS	WOCE	Station	Cast	CAST	DATE	UTC		POSTION						Uncorr.	HT ABOVE	MAX	NO. OF	
EXPOCODE	SECT	Number	Number	TYPE	mmddyy	TIME	CODE	LATITUDE			LONGITUDE			DEPTH	BOTTOM	PRESS	BOTTLES	PARAMETERS
06BE151	AR15	11	1	ROS	110600	1743	BO	9	10,16	N	-51	46,56	W	4765	20	4834	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	11	1	ROS	110600	1958	EN	9	9,79	N	-51	45,10	W	4756			22	
06BE151	AR15	12	1	ROS	110600	2146	BE	9	17,92	N	-51	25,43	W	4778			22	
06BE151	AR15	12	1	ROS	110600	2323	BO	9	17,63	N	-51	24,36	W	4775	20	4851	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	12	1	ROS	110700	0109	EN	9	17,17	N	-51	23,02	W	4775			22	
06BE151	AR15	13	1	ROS	110700	0256	BE	9	26,40	N	-51	5,56	W	4791			22	
06BE151	AR15	13	1	ROS	110700	0432	BO	9	26,13	N	-51	5,12	W	4774	20	4859	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	13	1	ROS	110700	0646	EN	9	25,99	N	-51	4,58	W	4787			22	
06BE151	AR15	14	1	ROS	110700	1057	BE	9	39,94	N	-50	22,15	W	4790			22	
06BE151	AR15	14	1	ROS	110700	1231	BO	9	40,01	N	-50	21,93	W	4791	20	4861	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	14	1	ROS	110700	1426	EN	9	40,02	N	-50	22,04	W	4791			22	
06BE151	AR15	15	1	ROS	110700	1826	BE	9	54,00	N	-49	44,99	W	4800			22	
06BE151	AR15	15	1	ROS	110700	1954	BO	9	54,01	N	-49	45,02	W	4842	20	4916	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	15	1	ROS	110700	2125	EN	9	53,99	N	-49	45,02	W	4840			22	
06BE151	AR15	16	1	ROS	110800	0128	BE	10	7,97	N	-49	7,13	W	4862			22	
06BE151	AR15	16	1	ROS	110800	0253	BO	10	8,03	N	-49	7,03	W	4866	20	4947	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	16	1	ROS	110800	0423	EN	10	8,16	N	-49	7,16	W	4864			22	
06BE151	AR15	17	1	ROS	110800	0755	BE	10	19,82	N	-48	31,91	W	4877			22	
06BE151	AR15	17	1	ROS	110800	0922	BO	10	19,90	N	-48	31,96	W	4877	20	4956	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	17	1	ROS	110800	1057	EN	10	19,88	N	-48	31,95	W	4874			22	
06BE151	AR15	18	1	ROS	110800	1422	BE	10	34,03	N	-47	55,02	W	4845			22	
06BE151	AR15	18	1	ROS	110800	1549	BO	10	34,03	N	-47	54,97	W	4846	20	4869	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	18	1	ROS	110800	1715	EN	10	34,09	N	-47	54,89	W	4841			22	
06BE151	AR15	19	1	ROS	110800	2040	BE	10	46,99	N	-47	17,10	W	4841			22	
06BE151	AR15	19	1	ROS	110800	2207	BO	10	47,03	N	-47	16,97	W	4841	20	4923	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	19	1	ROS	110800	2339	EN	10	47,00	N	-47	16,66	W	4782			22	
06BE151	AR15	20	1	ROS	110900	0323	BE	11	0,01	N	-46	35,09	W	4915			22	
06BE151	AR15	20	1	ROS	110900	0450	BO	10	59,95	N	-46	34,84	W	4914	20	5003	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	20	1	ROS	110900	0619	EN	11	0,09	N	-46	34,48	W	4923			22	
06BE151	AR15	21	1	ROS	110900	0939	BE	11	4,96	N	-45	55,03	W	4990			22	
06BE151	AR15	21	1	ROS	110900	1109	BO	11	4,88	N	-45	54,93	W	4995	20	5075	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	21	1	ROS	110900	1245	EN	11	4,87	N	-45	55,04	W	4990			22	
06BE151	AR15	22	1	ROS	110900	1618	BE	11	9,96	N	-45	14,04	W	4095			22	
06BE151	AR15	22	1	ROS	110900	1733	BO	11	9,98	N	-45	14,01	W	4097	20	4142	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	22	1	ROS	110900	1846	EN	11	10,01	N	-45	14,01	W	4119			22	
06BE151	AR15	23	1	ROS	110900	2223	BE	11	13,03	N	-44	31,99	W	3774			21	
06BE151	AR15	23	1	ROS	110900	2332	BO	11	12,99	N	-44	32,00	W	3740	20	3754	21	1,2,3,4,5,6,7,8,28

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS	WOCE	Station	Cast	CAST	DATE	UTC		POSTION						Uncorr.	HT ABOVE	MAX	NO. OF	
EXPOCODE	**SECT**	**Number**	**Number**	**TYPE**	**mmddyy**	**TIME**	**CODE**	**LATITUDE**			**LONGITUDE**			**Depth**	**BOTTOM**	**PRESS**	**BOTTLES**	**PARAMETERS**
06BE151	AR15	23	1	ROS	111000	0043	EN	11	13,11	N	-44	32,00	W	3762			21	
06BE151	AR15	24	1	ROS	111000	0329	BE	11	16,06	N	-44	0,08	W	3025			22	
06BE151	AR15	24	1	ROS	111000	0427	BO	11	16,06	N	-43	59,97	W	3010	20	3052	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	24	1	ROS	111000	0526	EN	11	15,96	N	-43	59,98	W	3120			22	
06BE151	AR15	25	1	ROS	111000	0717	BE	10	54,99	N	-44	0,00	W	5130			22	
06BE151	AR15	25	1	ROS	111000	0844	BO	10	55,00	N	-44	0,02	W	5131	130	5094	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	25	1	ROS	111000	1011	EN	10	55,04	N	-44	0,00	W	5132			22	
06BE151	AR15	26	1	ROS	111000	1249	BE	10	22,99	N	-44	0,04	W	4933			22	
06BE151	AR15	26	1	ROS	111000	1415	BO	10	23,00	N	-44	0,00	W	4935	20	5016	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	26	1	ROS	111000	1540	EN	10	23,01	N	-44	0,99	W	4935			22	
06BE151	AR15	27	1	ROS	111000	1922	BE	9	40,05	N	-44	0,03	W	4383			22	
06BE151	AR15	27	1	ROS	111000	2043	BO	9	40,01	N	-44	59,99	W	4369	20	4427	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	27	1	ROS	111100	0342	EN	9	40,02	N	-44	0,00	W	4348			22	
06BE151	AR15	28	1	ROS	111100	0734	BE	8	55,06	N	-44	0,04	W	4815			22	
06BE151	AR15	28	1	ROS	111100	0902	BO	8	55,01	N	-43	59,99	W	4818	20	4893	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	28	1	ROS	111100	1028	EN	8	54,97	N	-44	0,02	W	4813			22	
06BE151	AR15	29	1	ROS	111100	1417	BE	8	10,01	N	-44	0,01	W	4773			22	
06BE151	AR15	29	1	ROS	111100	1539	BO	8	9,99	N	-44	0,03	W	4760	20	4843	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	29	1	ROS	111100	1706	EN	8	10,09	N	-43	59,96	W	4772			22	
06BE151	AR15	30	1	ROS	111100	2058	BE	7	25,05	N	-43	59,99	W	4681			22	
06BE151	AR15	30	1	ROS	111100	2221	BO	7	24,99	N	-43	59,99	W	4678	20	4746	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	30	1	ROS	111100	2346	EN	7	25,06	N	-44	0,02	W	4679			22	
06BE151	AR15	31	1	ROS	111200	0327	BE	6	39,93	N	-43	59,98	W	4649			22	
06BE151	AR15	31	1	ROS	111200	0454	BO	6	39,98	N	-44	0,00	W	4632	20	4713	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	31	1	ROS	111200	0620	EN	6	39,98	N	-43	59,93	W	4652			22	
06BE151	AR15	32	1	ROS	111200	0955	BE	5	54,88	N	-43	59,84	W	4164			22	
06BE151	AR15	32	1	ROS	111200	1110	BO	5	54,92	N	-43	59,67	W	4163	20	4200	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	32	1	ROS	111200	1231	EN	5	55,07	N	-43	59,80	W	4157			22	
06BE151	AR15	33	1	ROS	111200	1552	BE	5	14,99	N	-44	0,95	W	3342			22	
06BE151	AR15	33	1	ROS	111200	1705	BO	5	15,11	N	-43	59,95	W	3475	20	3443	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	33	1	ROS	111200	1809	EN	5	14,92	N	-43	59,42	W	3526			22	
06BE151	AR15	34	1	ROS	111200	2109	BE	4	41,56	N	-43	59,54	W	3190			21	
06BE151	AR15	34	1	ROS	111200	2206	BO	4	41,72	N	-43	59,26	W	3159	20	3185	21	1,2,3,4,5,6,7,8,28
06BE151	AR15	34	1	ROS	111200	2306	EN	4	41,70	N	-43	58,90	W	3135			21	
06BE151	AR15	35	1	ROS	111300	0157	BE	4	11,73	N	-44	2,40	W	4206			22	
06BE151	AR15	35	1	ROS	111300	0156	BO	4	11,86	N	-44	2,35	W	4204	20	4246	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	35	1	ROS	111300	0312	EN	4	12,00	N	-44	2,21	W	4205			22	

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS	WOCE	Station	Cast	CAST	DATE	UTC		POSTION						Uncorr.	HT ABOVE	MAX	NO. OF	
EXPOCODE	SECT	Number	Number	TYPE	mmddyy	TIME	CODE	LATITUDE			LONGITUDE			Depth	BOTTOM	PRESS	BOTTLES	PARAMETERS
06BE151	AR15	36	1	ROS	111300	0701	BE	3	45,09	N	-44	0,04	W	4229			22	
06BE151	AR15	36	1	ROS	111300	0817	BO	3	45,17	N	-43	59,83	W	4232	20	4277	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	36	1	ROS	111300	0938	EN	3	45,21	N	-43	59,91	W	4232			22	
06BE151	AR15	37	1	ROS	111300	1209	BE	3	18,10	N	-43	59,98	W	4212			22	
06BE151	AR15	37	1	ROS	111300	1324	BO	3	18,21	N	-44	0,03	W	4211	20	4260	21	1,2,3,4,5,6,7,8,28
06BE151	AR15	37	1	ROS	111300	1442	EN	3	18,09	N	-44	0,16	W	4214			21	
06BE151	AR15	38	1	ROS	111300	1752	BE	2	44,90	N	-43	59,93	W	4205			22	
06BE151	AR15	38	1	ROS	111300	1912	BO	2	44,97	N	-43	59,82	W	4206	20	4250	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	38	1	ROS	111300	2028	EN	2	44,88	N	-43	59,78	W	4208			22	
06BE151	AR15	39	1	ROS	111300	2338	BE	2	10,12	N	-44	0,11	W	4165			22	
06BE151	AR15	39	1	ROS	111400	0053	BO	2	10,12	N	-44	0,19	W	4162	20	4209	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	39	1	ROS	111400	0213	EN	2	10,08	N	-44	0,24	W	4163			22	
06BE151	AR15	40	1	ROS	111400	0357	BE	1	51,96	N	-43	59,99	W	4244			22	
06BE151	AR15	40	1	ROS	111400	0515	BO	1	51,99	N	-44	0,06	W	4143	20	4183	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	40	1	ROS	111400	0631	EN	1	52,04	N	-44	16,00	W	4145			22	
06BE151	AR15	41	1	ROS	111400	0826	BE	1	31,95	N	-43	59,88	W	4122			22	
06BE151	AR15	41	1	ROS	111400	0940	BO	1	31,99	N	-43	59,99	W	4120	20	4162	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	41	1	ROS	111400	1056	EN	1	31,99	N	-44	0,12	W	4120			22	
06BE151	AR15	42	1	ROS	111400	1247	BE	1	12,07	N	-43	59,59	W	4126			22	
06BE151	AR15	42	1	ROS	111400	1359	BO	1	12,05	N	-43	59,99	W	4123	20	4164	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	42	1	ROS	111400	1515	EN	1	12,13	N	-44	0,28	W	4119			22	
06BE151	AR15	43	1	ROS	111400	1704	BE	0	51,99	N	-44	2,53	W	4033			22	
06BE151	AR15	43	1	ROS	111400	1817	BO	0	52,06	N	-44	2,01	W	4031	20	4064	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	43	1	ROS	111400	1929	EN	0	52,11	N	-44	2,27	W	4032			22	
06BE151	AR15	44	1	ROS	111400	2056	BE	0	36,94	N	-44	9,53	W	3668			22	
06BE151	AR15	44	1	ROS	111400	2202	BO	0	37,10	N	-44	9,96	W	3676	20	3701	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	44	1	ROS	111400	2308	EN	0	37,27	N	-44	10,17	W	3679			22	
06BE151	AR15	45	1	ROS	111500	0014	BE	0	26,88	N	-44	15,86	W	3401			21	
06BE151	AR15	45	1	ROS	111500	0118	BO	0	27,12	N	-44	16,09	W	3401	20	3413	21	1,2,3,4,5,6,7,8,28
06BE151	AR15	45	1	ROS	111500	0225	EN	0	27,20	N	-44	16,21	W	3402			21	
06BE151	AR15	46	1	ROS	111500	0327	BE	0	16,97	N	-44	20,56	W	3024			15	
06BE151	AR15	46	1	ROS	111500	0426	BO	0	17,45	N	-44	21,01	W	3045	20	3037	15	1,2,3,4,5,6,7,8,28
06BE151	AR15	46	1	ROS	111500	0523	EN	0	17,80	N	-44	21,45	W	2974			15	
06BE151	AR15	47	1	ROS	111500	0618	BE	0	8,70	N	-44	22,67	W	1088			5	
06BE151	AR15	47	1	ROS	111500	0648	BO	0	9,18	N	-44	23,08	W	1129	20	1117	5	1,2,3,4,5,6,7,8,28
06BE151	AR15	47	1	ROS	111500	0711	EN	0	9,39	N	-44	23,40	W	1100			5	
06BE151	AR15	48	1	CTD	111500	0803	BE	0	1,67	N	-44	22,63	W	287			0	

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS EXPOCODE	WOCE SECT	Station Number	Cast Number	CAST TYPE	DATE mmddyy	UTC TIME	CODE	POSTION LATITUDE			LONGITUDE			Uncorr. Depth	HT ABOVE BOTTOM	MAX PRESS	NO. OF BOTTLES	PARAMETERS
06BE151	AR15	48	1	CTD	111500	0820	BO	0	1,93	N	-44	23,05	W	290	20	281	0	
06BE151	AR15	48	1	CTD	111500	0831	EN	0	2,11	N	-44	23,42	W	289			0	
06BE151	AR15	49	1	CTD	111700	1959	BE	5	39,08	S	-34	56,98	W	715			0	
06BE151	AR15	49	1	CTD	111700	2019	BO	5	39,00	S	-34	57,06	W	615	20	596	0	
06BE151	AR15	49	1	CTD	111700	2033	EN	5	38,87	S	-34	57,08	W	535			0	
06BE151	AR15	50	1	ROS	111700	2103	BE	5	38,27	S	-34	53,10	W	2121			12	
06BE151	AR15	50	1	ROS	111700	2142	BO	5	37,95	S	-34	53,00	W	2144	20	2144	12	1,2,3,4,5,6,7,8,28
06BE151	AR15	50	1	ROS	111700	2222	EN	5	37,64	S	-34	53,11	W	2079			12	
06BE151	AR15	51	1	ROS	111700	2318	BE	5	37,35	S	-34	48,08	W	2780			15	
06BE151	AR15	51	1	ROS	111800	0009	BO	5	36,48	S	-34	48,17	W	2748	20	2755	15	1,2,3,4,5,6,7,8,28
06BE151	AR15	51	1	ROS	111800	0103	EN	5	36,83	S	-34	48,54	W	2721			15	
06BE151	AR15	52	1	ROS	111800	0157	BE	5	35,32	S	-34	40,68	W	3143			16	
06BE151	AR15	52	1	ROS	111800	0255	BO	5	34,92	S	-34	41,07	W	3081	20	3104	16	1,2,3,4,5,6,7,8,28
06BE151	AR15	52	1	ROS	111800	0355	EN	5	34,55	S	-34	41,30	W	3059			16	
06BE151	AR15	53	1	ROS	111800	0445	BE	5	33,38	S	-34	34,73	W	3528			16	
06BE151	AR15	53	1	ROS	111800	0553	BO	5	33,08	S	-34	33,81	W	3535	20	3556	16	1,2,3,4,5,6,7,8,28
06BE151	AR15	53	1	ROS	111800	0705	EN	5	33,38	S	-34	34,73	W	3528			16	
06BE151	AR15	54	1	ROS	111800	0751	BE	5	32,21	S	-34	25,92	W	3752			17	
06BE151	AR15	54	1	ROS	111800	0900	BO	5	31,98	S	-34	25,98	W	3761	20	3796	17	1,2,3,4,5,6,7,8,28
06BE151	AR15	54	1	ROS	111800	1006	EN	5	32,01	S	-34	26,05	W	3761			17	
06BE151	AR15	55	1	ROS	111800	1121	BE	5	29,99	S	-34	13,07	W	4079			21	
06BE151	AR15	55	1	ROS	111800	1235	BO	5	29,96	S	-34	13,01	W	4079	20	4121	21	1,2,3,4,5,6,7,8,28
06BE151	AR15	55	1	ROS	111800	1350	EN	5	29,98	S	-34	12,99	W	4079			21	
06BE151	AR15	56	1	ROS	111800	1508	BE	5	25,99	S	-34	0,03	W	4216			22	
06BE151	AR15	56	1	ROS	111800	1625	BO	5	25,98	S	-34	0,03	W	4216	20	4258	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	56	1	ROS	111800	1744	EN	5	26,02	S	-34	0,03	W	4215			22	
06BE151	AR15	57	1	ROS	111800	1936	BE	5	23,00	S	-33	40,01	W	4406			22	
06BE151	AR15	57	1	ROS	111800	2053	BO	5	22,99	S	-33	40,02	W	4407	20	4460	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	57	1	ROS	111800	2213	EN	5	22,96	S	-33	40,04	W	4409			22	
06BE151	AR15	58	1	ROS	111900	0004	BE	5	19,98	S	-33	19,97	W	4497			22	
06BE151	AR15	58	1	ROS	111900	0125	BO	5	19,98	S	-33	20,04	W	4497	20	4552	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	58	1	ROS	111900	0249	EN	5	20,00	S	-33	20,02	W	4497			22	
06BE151	AR15	59	1	ROS	111900	0441	BE	5	16,00	S	-33	0,03	W	4559			22	
06BE151	AR15	59	1	ROS	111900	0603	BO	5	16,00	S	-33	0,02	W	4555	20	4612	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	59	1	ROS	111900	0728	EN	5	16,00	S	-32	59,99	W	4554			22	
06BE151	AR15	60	1	ROS	111900	0917	BE	5	12,12	S	-32	40,08	W	4589			22	
06BE151	AR15	60	1	ROS	111900	1210	BO	5	11,98	S	-32	40,03	W	4592	20	4649	22	1,2,3,4,5,6,7,8,28

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS EXPOCODE	WOCE SECT	Station Number	Cast Number	CAST TYPE	DATE mmddyy	UTC TIME	CODE	POSTION LATITUDE			POSTION LONGITUDE			Uncorr. Depth	HT ABOVE BOTTOM	MAX PRESS	NO. OF BOTTLES	PARAMETERS
06BE151	AR15	60	1	ROS	111900	1336	EN	5	11,99	S	-32	40,00	W	4592			22	
06BE151	AR15	61	1	ROS	111900	1620	BE	5	7,01	S	-32	10,03	W	4593			22	
06BE151	AR15	61	1	ROS	111900	1744	BO	5	6,99	S	-32	10,02	W	4593	20	4648	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	61	1	ROS	111900	1910	EN	5	7,00	S	-32	10,01	W	4592			22	
06BE151	AR15	62	1	ROS	112100	0106	BE	11	29,96	S	-31	47,98	W	5124			22	
06BE151	AR15	62	1	ROS	112100	0240	BO	11	30,01	S	-31	48,04	W	5124	130	5091	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	62	1	ROS	112100	0412	EN	11	29,99	S	-31	48,04	W	5124			22	
06BE151	AR15	63	1	ROS	112100	0622	BE	11	29,99	S	-32	16,02	W	4939			22	
06BE151	AR15	63	1	ROS	112100	0751	BO	11	29,98	S	-32	10,02	W	4937	20	5007	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	63	1	ROS	112100	0918	EN	11	29,98	S	-32	16,03	W	4940			22	
06BE151	AR15	64	1	ROS	112100	1126	BE	11	29,99	S	-32	42,06	W	4517			22	
06BE151	AR15	64	1	ROS	112100	1246	BO	11	30,01	S	-32	42,02	W	4520	20	4558	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	64	1	ROS	112100	1409	EN	11	30,04	S	-32	42,04	W	4523			22	
06BE151	AR15	65	1	ROS	112100	1606	BE	11	30,03	S	-33	5,02	W	4309			22	
06BE151	AR15	65	1	ROS	112100	1727	BO	11	30,00	S	-33	5,02	W	4305	20	4356	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	65	1	ROS	112100	1845	EN	11	30,01	S	-33	5,04	W	4296			22	
06BE151	AR15	66	1	ROS	112100	2040	BE	11	30,02	S	-33	28,02	W	4686			22	
06BE151	AR15	66	1	ROS	112100	2203	BO	11	29,99	S	-33	27,99	W	4690	20	4749	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	66	1	ROS	112100	2330	EN	11	29,97	S	-33	28,03	W	4689			22	
06BE151	AR15	67	1	ROS	112200	0130	BE	11	30,08	S	-33	51,15	W	4621			22	
06BE151	AR15	67	1	ROS	112200	0252	BO	11	30,01	S	-33	51,02	W	4622	20	4681	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	67	1	ROS	112200	0416	EN	11	29,99	S	-33	51,03	W	4620			22	
06BE151	AR15	68	1	ROS	112200	1358	BE	10	56,62	S	-34	59,80	W	4105			22	
06BE151	AR15	68	1	ROS	112200	1518	BO	10	56,49	S	-34	59,53	W	4104	20	4137	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	68	1	ROS	112200	1631	EN	10	56,49	S	-34	59,50	W	4104			22	
06BE151	AR15	69	1	ROS	112200	2123	BE	11	29,98	S	-34	15,17	W	4583			22	
06BE151	AR15	69	1	ROS	112200	2243	BO	11	29,97	S	-34	15,02	W	4578	20	4640	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	69	1	ROS	112300	0009	EN	11	30,01	S	-34	15,03	W	4581			22	
06BE151	AR15	70	1	ROS	112300	0125	BE	11	21,41	S	-34	26,18	W	4653			22	
06BE151	AR15	70	1	ROS	112300	0248	BO	11	21,45	S	-34	26,08	W	4651	20	4717	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	70	1	ROS	112300	0414	EN	11	21,48	S	-34	26,06	W	4652			22	
06BE151	AR15	71	1	ROS	112300	0526	BE	11	12,96	S	-34	37,01	W	4395			22	
06BE151	AR15	71	1	ROS	112300	0646	BO	11	12,98	S	-34	36,99	W	4402	20	4450	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	71	1	ROS	112300	0805	EN	11	12,98	S	-34	37,05	W	4392			22	
06BE151	AR15	72	1	ROS	112300	0922	BE	11	4,44	S	-34	48,01	W	4260			22	
06BE151	AR15	72	1	ROS	112300	1036	BO	11	4,55	S	-34	48,01	W	4260	20	4304	22	1,2,3,4,5,6,7,8,28
06BE151	AR15	72	1	ROS	112300	1154	EN	11	4,48	S	-34	48,01	W	4261			22	

R/V SONNE Cruise So151 CTD-stations

SHIP/CRS	WOCE	Station	Cast	CAST	DATE	UTC		POSTION						Uncorr.	HT ABOVE	MAX	NO. OF	
EXPOCODE	**SECT**	**Number**	**Number**	**TYPE**	**mmddyy**	**TIME**	**CODE**	**LATITUDE**			**LONGITUDE**			**Depth**	**BOTTOM**	**PRESS**	**BOTTLES**	**PARAMETERS**
06BE151	AR15	73	1	ROS	112300	1924	BE	10	22,78	S	-35	40,82	W	2328			16	
06BE151	AR15	73	1	ROS	112300	2009	BO	10	22,66	S	-35	40,65	W	2331	20	2319	16	1,2,3,4,5,6,7,8,28
06BE151	AR15	73	1	ROS	112300	2054	EN	10	22,46	S	-35	40,46	W	2326			16	
06BE151	AR15	74	1	ROS	112300	2354	BE	10	44,24	S	-35	15,04	W	3787			21	
06BE151	AR15	74	1	ROS	112400	0101	BO	10	44,31	S	-35	14,92	W	3786	20	3807	21	1,2,3,4,5,6,7,8,28
06BE151	AR15	74	1	ROS	112400	0214	EN	10	44,35	S	-35	14,86	W	3784			21	
06BE151	AR15	75	1	ROS	112400	0259	BE	10	47,99	S	-35	10,36	W	3918			17	
06BE151	AR15	75	1	ROS	112400	0409	BO	10	48,13	S	-35	10,32	W	3922	20	3952	17	1,2,3,4,5,6,7,8,28
06BE151	AR15	75	1	ROS	112400	0520	EN	10	48,25	S	-35	10,27	W	3922			17	
06BE151	AR15	76	1	ROS	112400	0602	BE	10	51,94	S	-35	5,14	W	3992			18	
06BE151	AR15	76	1	ROS	112400	0716	BO	10	51,98	S	-35	5,07	W	3993	20	4027	18	1,2,3,4,5,6,7,8,28
06BE151	AR15	76	1	ROS	112400	0833	EN	10	52,02	S	-35	5,01	W	3997			18	
06BE151	AR15	77	1	CTD	112400	0919	BE	10	56,45	S	-34	59,58	W	4106			0	
06BE151	AR15	77	1	CTD	112400	1031	BO	10	56,50	S	-34	59,54	W	4102	20	4137	0	
06BE151	AR15	77	1	CTD	112400	1145	EN	10	56,53	S	-34	59,51	W	4099			0	
06BE151	AR15	78	1	ROS	112400	1748	BE	10	38,73	S	-35	20,11	W	3621			19	
06BE151	AR15	78	1	ROS	112400	1854	BO	10	38,80	S	-35	20,05	W	3623	20	3643	19	1,2,3,4,5,6,7,8,28
06BE151	AR15	78	1	ROS	112400	2000	EN	10	38,75	S	-35	19,98	W	3627			19	
06BE151	AR15	79	1	ROS	112400	2107	BE	10	31,98	S	-35	29,98	W	3198			17	
06BE151	AR15	79	1	ROS	112400	2208	BO	10	32,00	S	-35	30,03	W	3201	20	3213	17	1,2,3,4,5,6,7,8,28
06BE151	AR15	79	1	ROS	112400	2312	EN	10	32,01	S	-35	30,02	W	3196			17	
06BE151	AR15	80	1	ROS	112500	0001	BE	10	28,00	S	-35	34,87	W	2904			15	
06BE151	AR15	80	1	ROS	112500	0054	BO	10	28,01	S	-35	34,98	W	2899	20	2900	15	1,2,3,4,5,6,7,8,28
06BE151	AR15	80	1	ROS	112500	0154	EN	10	27,92	S	-35	34,99	W	2898			15	
06BE151	AR15	81	1	ROS	112500	0327	BE	10	18,93	S	-35	45,99	W	1765			11	
06BE151	AR15	81	1	ROS	112500	0408	BO	10	18,63	S	-35	45,94	W	1739	20	1734	11	1,2,3,4,5,6,7,8,28
06BE151	AR15	81	1	ROS	112500	0446	EN	10	18,32	S	-35	45,87	W	1763			11	
06BE151	AR15	82	1	CTD	112500	0533	BE	10	15,79	S	-35	53,05	W	676			0	
06BE151	AR15	82	1	CTD	112500	0554	BO	10	15,78	S	-35	53,03	W	687	20	659	0	
06BE151	AR15	82	1	CTD	112500	0610	EN	10	15,79	S	-35	53,06	W	675			0	
06BE151	AR15	83	1	CTD	112500	0754	BE	10	22,76	S	-35	40,82	W	2326			0	
06BE151	AR15	83	1	CTD	112500	0839	BO	10	22,74	S	-35	40,70	W	2329	20	2317	0	
06BE151	AR15	83	1	CTD	112500	0923	EN	10	22,65	S	-35	40,69	W	2319			0	

Cast-type: CTD = CTD without bottles, ROS = CTD including bottle samples
Code: BE = begin, BO = bottom, EN = end
Parameters: 1= salinity, 2 = oxygen, 3 = silicate, 4 = nitrate, 5 = nitrite, 6 = phosphate, 7 = CFC-11, 8 = CFC-12, 28 = CCl_4

Table 2: Apex float deployments

S/N	*ID*	*Date*	*Time (UT)*	*Depth (m)*	*Latitude*	*Longitude*
194	3833	11.12.00	18:16:00	200	5 14.91' N	43 59.26' W
195	3835	11.13.00	20:38:00	200	2 44.95' N	43 59.93' W
196	3834	11.19.00	19:16:19	200	5 07.01' S	32 09.99' W
120	26673	11.13.00	14:57:00	400	3 18.12' N	44 00.22' W
123	16277	11.19.00	13:43:21	400	5 11.99' S	32 40.01' W

Table 3: Mooring recovery and deployment

Mooring	*Date*	*Time (UT)*	*Latitude*	*Longitude*	*Comment*
K4_1	11.22.00	13:32:00	10 56.50' S	34 59.50' W	recovery
K2_1	11.23.00	19:02:00	10 22.80' S	35 40.80' W	recovery
K4_2	11.24.00	15:02:00	10 56.51' S	34 59.52' W	deployment
K2_2	11.25.00	13:26:00	10 22.80' S	35 40.80' W	deployment

5. Preliminary results

5.1 Currents measured during SO151

The warm water circulation and its variability in the western tropical Atlantic is of primary interest for the German Clivar Program. Current measurments during SO151 were carried out by two methods, underway with a new shipboard ADCP called Ocean Surveyor (OS) and on station current profiling by lowered ADCP. In addition, 5 profiling floats were deployed during the cruise and their regularly updated trajectories identified by the S/N numbers of Table 2 can be seen together with trajectories from earlier deployments in March 2000 at URL: http://www.ifm.uni-kiel.de/general/clivar/floats.html

5.1.1 Upper Layer Flow

The near surface flow field is best illustrated by the OS-data, and for discussing the major current branches we subdivided the upper layer flow in two layers, 0 to 150 m and 200 to 300 m.

Following the North Brazil Current (NBC) from 11°S northward we see the Western Boundary Current changing its character from an undercurrent at 11°S (the North Brazil Undercurrent, NUBC) that is weak near the surface (Figure 2) and shows a clear current maximum in the layer 200 to 300 m depth (Figure 3). At 5°S this signature is still visible. Maximum current speeds are around 1 m/s. Farther along the Brazilian coast the surface flow intensifies to the fully developed NBC meandering along the shelf break northwestward. While the near surface flow continues across 44°W, a part of the deeper flow appears to retroflect already near 44°W. The northern section off French Guyana then shows the NBC retroflection in both layers, feeding the North Equatorial Countercurrent (NECC) confined to the upper layer and another eastward branch in the 200 - 300 m depth level that becomes the Equatorial Undercurrent (EUC) and an even deeper branch, presumably developing into the North Equatorial Undercurrent (NEUC).

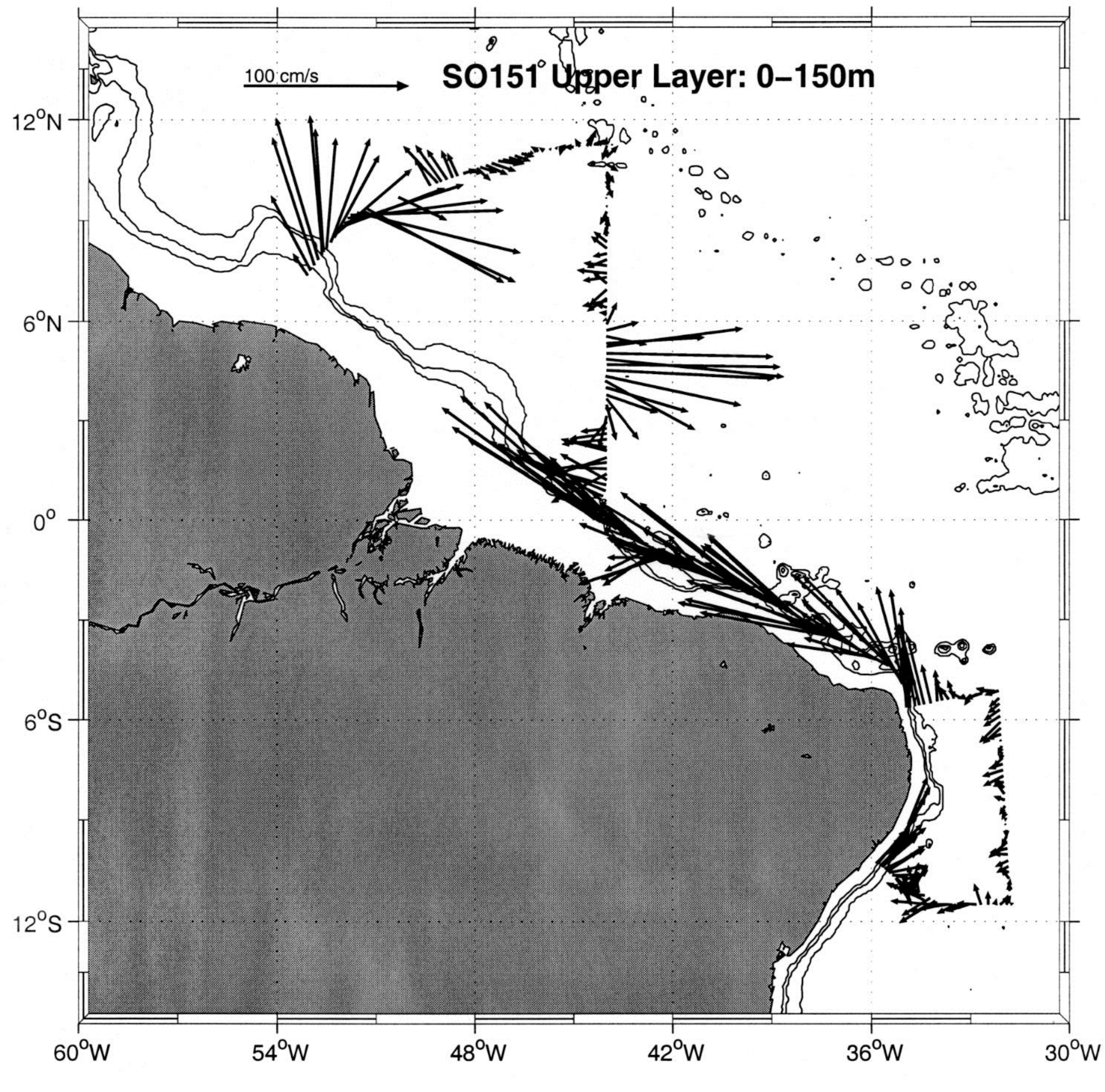

Figure 2: *Vector map of the near surface flow (0 to 150 m), in November 2000 as measured by the Ocean Surveyor. For vector scaling see labelled arrow in the upper left corner.*

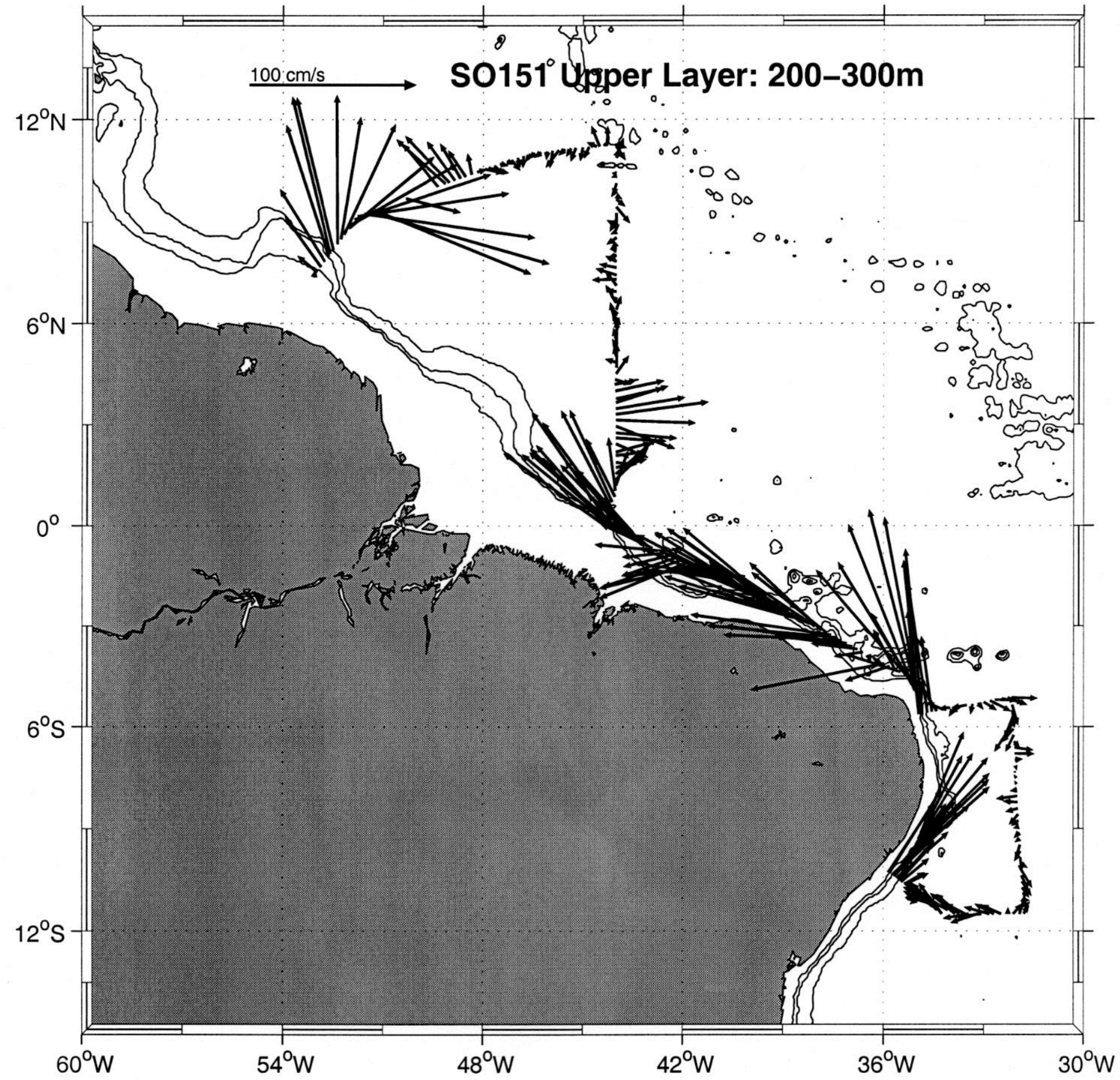

Figure 3: *As in Figure 2, but for depth layer 200 to 300 m.*

The vertical structure of the flow at 44°W is more clearly seen in the section plot (Figure 4) of the zonal (U) component. Near the coast we observed the NBC extending beyond the measurement range of the OS and a clear surface maximum of about 0.8 m/s. Offshore we see the NECC that is even swifter with a surface maximum of about 1.5 m/s. At depth levels below 200 m the NBC is much narrower, and at this depth level the reverse flow is nearly 200 km nearer to the coast. North of the NECC the currents are rather weak and unorganized.

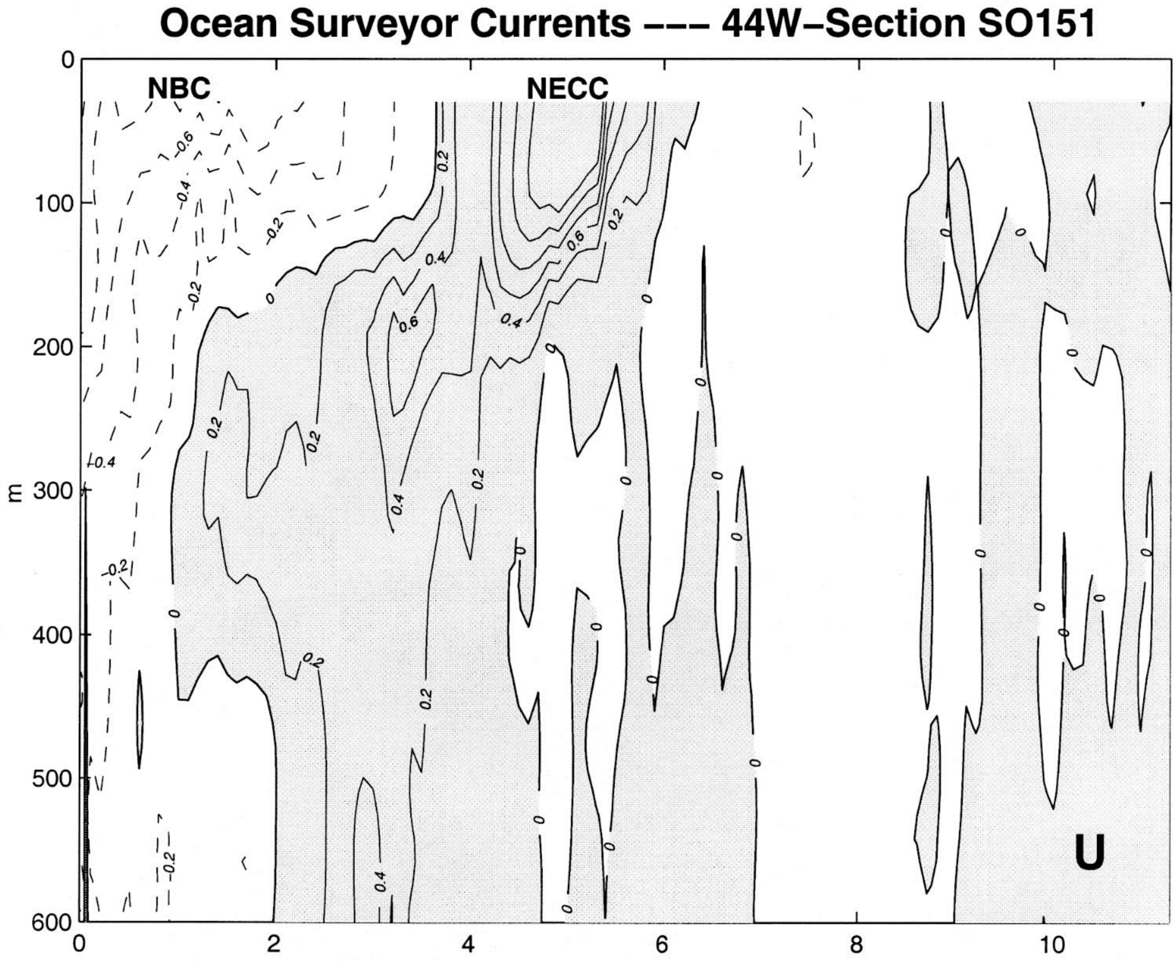

Figure 4: *Vertical section of the zonal current at 44°W, in November 2000 as measured by the OS. Currents are in m/s.*

Comparing the transport values of the NBC at 11°S and 5°S measured during S151 by a combination from the Ocean Surveyor (OS) and the lowered ADCP (Figure 5) with those measured during M47/1 in March 2000, we found that they are very similar: during M47/1 the transport between σ_θ=24.5 and 26.8 isopycnals was 9.9 Sv at 11°S and 15.4 Sv at 5°S, while during S151 it was 8.4 Sv at 11°S and 14.3 Sv at 5°S. In particular, almost the same strong increase of the transport between the isopycnals from 11°S to 5°S was observed during M47/1 and S151.

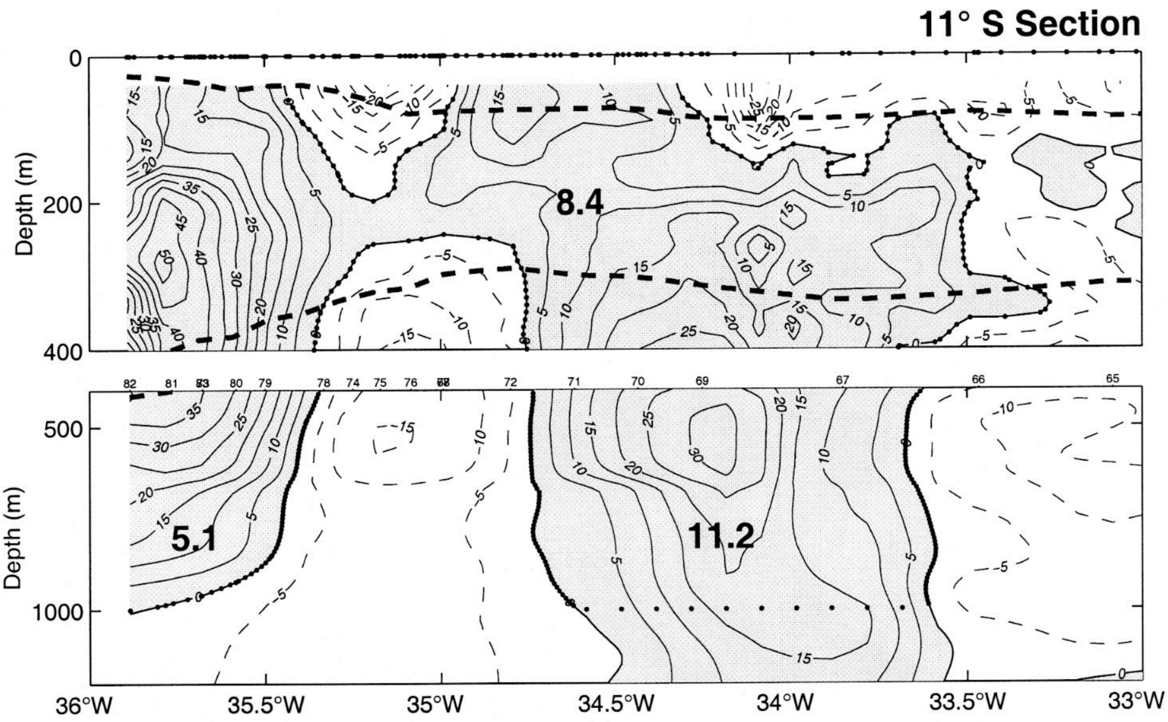

Figure 5a: *Meridional currents in the upper 1200 m at the 11°S section as calculated from a combination of OS and LADCP data; positive flow is shaded. Also included are the isopycnals σ_θ=24.5 and 26.8 (thick dashed lines) and transport values in Sv.*

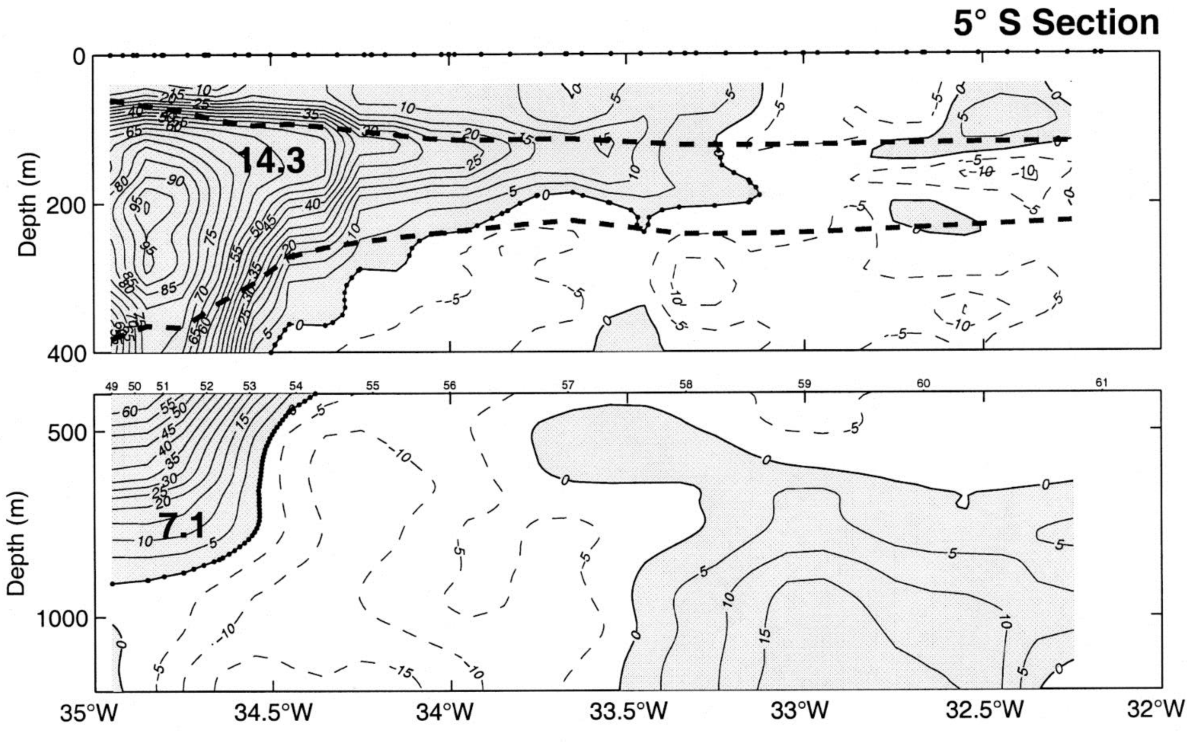

Figure 5b: *Meridional currents in the upper 1200 m at the 5°S section as calculated from a combination of OS and LADCP data; positive flow is shaded. Also included are the isopycnals σ_θ=24.5 and 26.8 (thick dashed lines) and transport values in Sv.*

5.1.2 Deep Currents

Deep current were directly measured by LADCP at each station and there are data from the four major sections showing the top to bottom flow. Here we show preliminary results from the 5°S section (meridional component, Figure 6). The NBUC located at the shelf break extends down to about 1000 m depth. At the depth of the current maximum (200 m depth) the NBUC extends more than 150 km off the shelf break, while below 500 m depth in the Antarctic Intermediate Water layer it is only some 10 kilometers wide. The Deep Western Boundary Current (DWBC) appears to be detached from the topography. The current core of the DWBC shows more than 20 cm/s southward flow at the typycal depth of Upper North Atlantic Deep Water. However, offshore of the DWBC the flow is in opposite direction thereby reducing the net southward transport of NADW considerably.

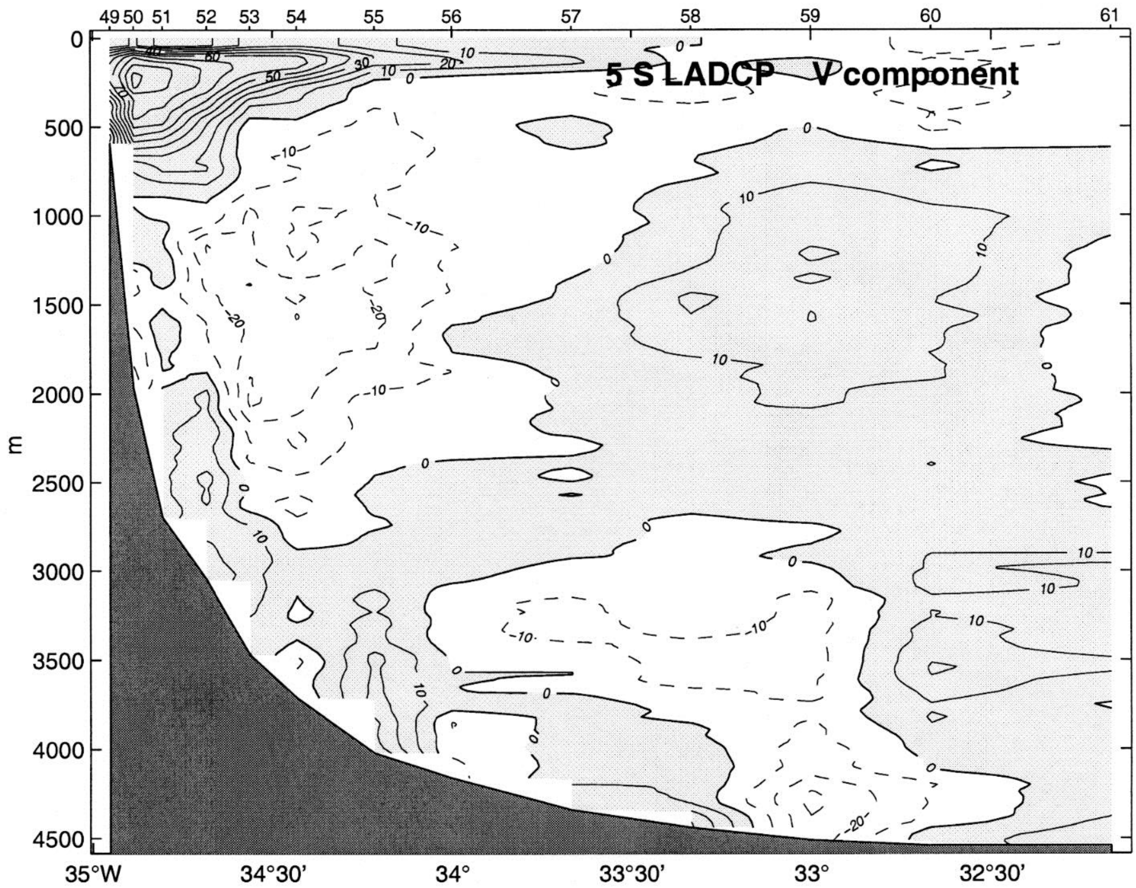

Figure 6: *Meridional flow (cm/s) across 5° S as measured by LADCP in November 2000 on 13 deep stations. Grey areas are for northward flow and white areas for southward directions.*

5.2 Variability in the CTD data

The major point of interest of the CTD investigations is the variability in time. During earlier Meteor cruises the 44°W sections was measured 4 times and the 5°S section 5 times, hence these are the ideal sections for comparisons. Here the comparison for the 5°S section is presented. First, the salinity distribution at 5°S is presented in Figure 7 as example of the

CTD-sections and the water mass distribution reflected in the sections. The well-known water masses described already from earlier cruises with METEOR to the western tropical Atlantic are for the upper ocean the Tropical Surface Water near the surface in which a salinity maximum called Subtropical Underwater is imbedded, below it the South Atlantic Central Water (SACW) layer, the Antarctic Intermediate Water (AAIW) with a salinity minimum at about 700 m depth and the northern reaches of the upper Circumpolar Deep Water (uCDW) with phosphate and silica maxima and a weak temperature minimum. The salinity distribution along 5°S in November 2000 in Figure 7 shows the salinity maximum of the Subtropical Underwater near 120 m depth and the salinity minimum of the AAIW near 700 m. The maximum and minimum are restricted on the western side within the region of the Western Boundary Current.

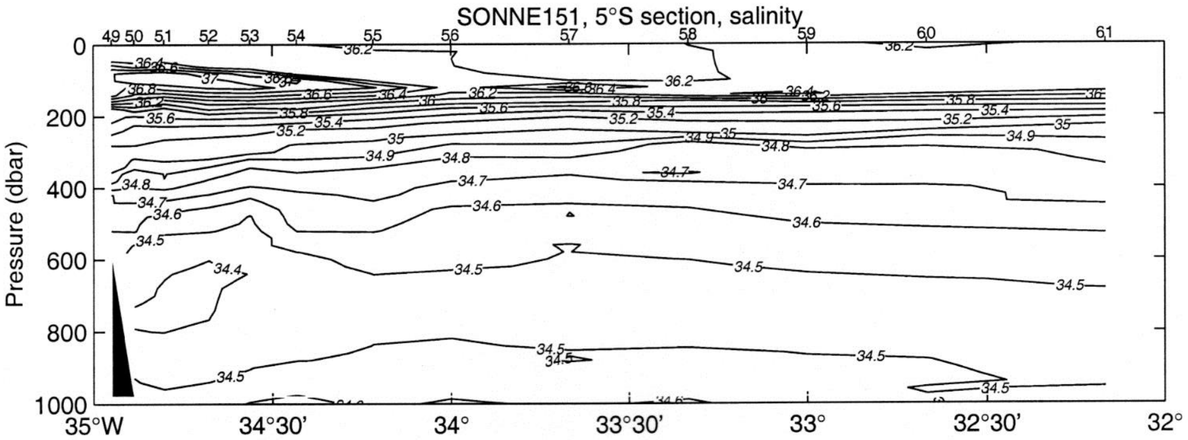

__Figure 7:__ Salinity distribution along 5°S, 17 to 19 November 2000 for the upper 1000 m. Contour interval is 0.2 for salinity higher as 35.0 else 0.1.

Plotting the parameter distribution along a section hardly gives indications for differences between different sections. However, if ones presents the differences as done in Figure 8 for the 5°S section changes become obvious. Earlier cruises with Meteor had been in October 1990, June 1991, November 1992, March 1994 and March 2000. An earlier investigation for the March 2000 survey showed that in the upper ocean in the region of the North Brazil Undercurrent the surface water, the Subtropical Underwater and the upper South Atlantic Central Water (SACW) were warmer and more saline in March 2000 compared to March 1994 as well as compared to the other cruises in the 90's. To investigate a possible continuation of these trends the temperature difference in Figure 8 is presented as the temperature distribution in March 2000 (M47/1) minus the one in November 2000 (S151). It can be seen that in the upper 300 m in the North Brazil Current (located west of about 34°W in the upper 300 m and west of 34°30'W between 400 m and 1000 m) the water in March 2000 was warmer and more saline (Figure not shown) than in November 2000, which means that the high temperature and salinity water observed in March 2000 has passed across 5°S and the water returns to values as in the observations during the 90's.

A different situation is found for the Antarctic Intermediate Water (AAIW). At depth of 400 to 800 m the water in March 2000 was colder and less saline than during the cruises in the

90's. In the range 400 to 600 m the water in March 2000 compared to November 2000 (Figure 8) is colder and less saline, which indicates also a return to regular values, however in the core of the AAIW at 700 to 800 m the water on the western side is warmer and more saline in March 2000 compared to November 2000, which shows that the temperature and salinity decrease even continued from March to November 2000. To investigate whether this decrease is present in the mean values of the entire AAIW Figure 9 shows the thickness of the AAIW layer as well as the mean temperature and mean salinity for the 6 cruises along 5°S. First it becomes obvious that the described decrease is present only in the region of the North Brazil Undercurrent (west of 34°30'W) while to the east there is even indication of an increase during the two cruises in 2000 compared to the 90's. The described decrease from March 2000 to November 2000 is slightly indicated in the mean temperature and mean salinity, however it is quite variable.

A more detailed investigation of the differences between the different cruises and a correlation to climate changes in the region of the water formation is needed to get a better insight into the causes of the variability. Nevertheless, there seems to be the potential to observe climate induced changed in the water masses away from its formation region.

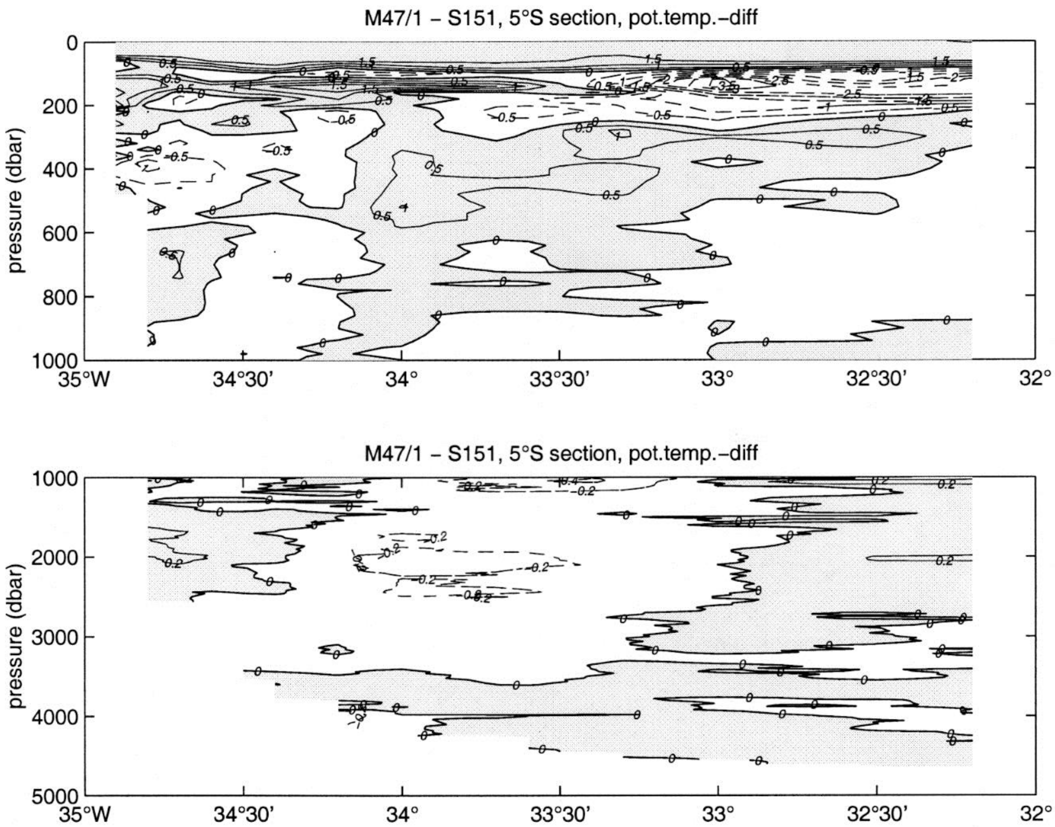

Figure 8: *Temperature differences between March 2000 (M47/1) and November 2000 (S151) along the 5°S section for the upper 1000 m (top) and the depth range 1000 to 5000 dbar (bottom), shaded is positive.*

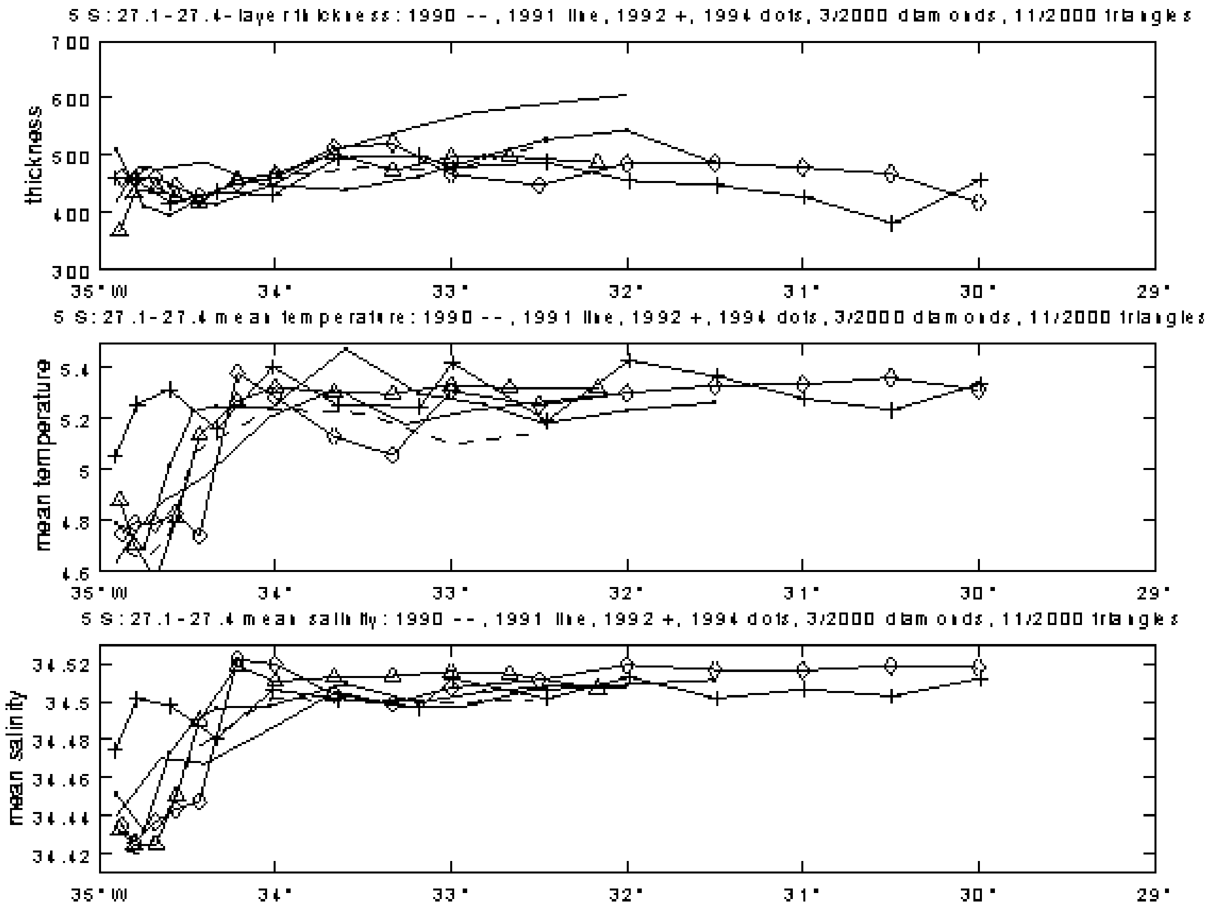

Figure 9: *Thickness (top), mean temperature (middle) and mean salinity (bottom) for the Antarctic Intermediate Water layer defined by the isopycnals Sigma-Theta= 27.1 and Sigma-Theta= 27.4 as boundaries at 5°S for October 1990 (dashed line) June 1991 (solid line), November 1992 (line with plus signs), March 1994 (line with dots), March 2000 (line with diamonds) and November 2000 (line with triangles).*

5.3 Analysis of Chlorofluorocarbons (CFC-11, CFC-12) and Carbontetrachloride (CCl4)

The CFC and CCl4 measurements in the tropical Atlantic make it possible to analzyse the development of different water mass characteristics between 53°W and 10°S. Figure 10 shows the CFC-11 concentration along the westernmost section.

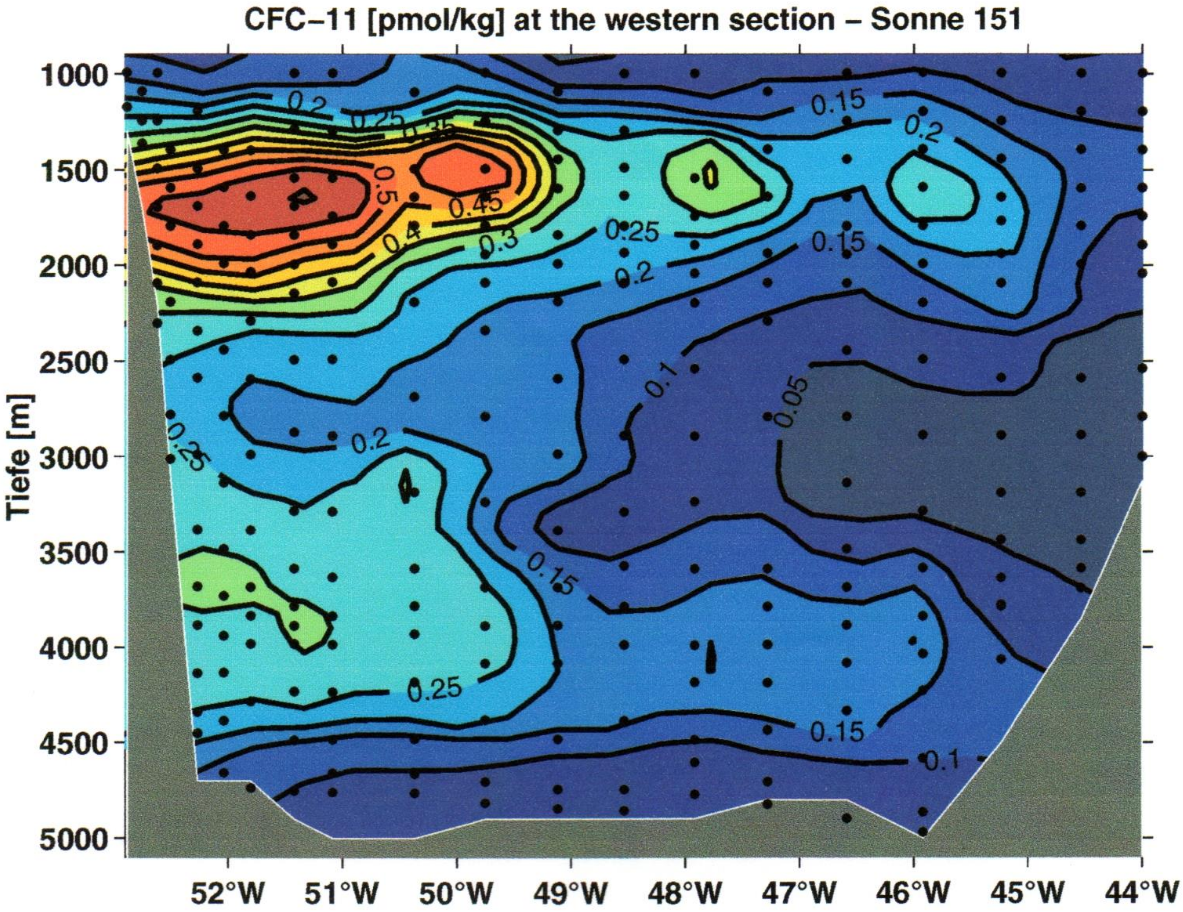

Figure 10: *CFC-11 concentration in pmol/kg at the section fron French Guyana to the Mid-Atlantic Ridge.*

At the bottom the concentrations are small (<0.1 pmol/kg) caused by the CFC-poor Antarctic Bottom Water. The deepest part of the North Atlantic Deep Water (NADW) exhibits a distinct tracer maximum (>0.25 pmol/kg) at about 3800 m depth at the continental slope. This maximum reflects the convective renewal of Denmark Strait Overflow Water. Towards the Mid-Atlantic-Ridge the maximum strongly decreases. Above this tracer maximum the water column is characterized by CFC-poor water, at about 2600 m depth, the level of Gibbs Fracture Zone Water. The upper maximum (>0.5 pmol/kg at about 1700 m depth) indicates a separate water mass in the NADW. It presumably is formed in the southern Labrador Sea rather than being a modified form of the classical Labrador Sea Water. During the cruise some sub-maxima of high concentrations were observed, too. Along the 44°W section the CFC concentrations are lower than along the western-most section, but the CCl4 concentration are similar at both sections.

Flowing along the northern continental slope of south America, the Deep Western Boundary Current crosses the equator at about 35°W. Then it is separated into two parts. One part flows eastward along the equator and the other part follows the continental slope. Both parts are marked by high tracer concentrations, which were found along the 23°W-section during the cruise Meteor 47/1 in March 2000 and near the coast along the 5°S and 10°S-section. During the cruise in March 2000, it was found that the mean concentration at 23°W is much smaller than the values measured along the continental slope. The main part of the DWBC flows southward, but the eastward transport of ventilated water towards the east Atlantic is not negligible. The first rough analysis shows no strong differences to the Meteor data-set along 10°S and 5°S.

In comparison with measurements collected between 1990 and 1994 in the same region, a strong increase of CFC concentrations is recognized in the deep water masses. However, a signal of the strong convection events in the Labrador was not observed, as the CFC concentration of the LSW show no positive anomaly.

6. Acknowledgements

It is our particular pleasure to thank Captain Henning Papenhagen and his crew for the flexible, friendly and helpful attitude and professional assistance during the entire cruise and especially during the mooring work. We also thank our Brazilian participants Geber Moura from the University of Pernambuco as well as the Brazilian Navy Observer, Jorge Luiz Mesquita de Medeiros, for joining us on the cruise So151, which allowed us to carry out research in the Brazilian EEZ.

Financial support for this study was given by the Bundesminister für Bildung, Wissenschaft, Forschung und Technologie under grant 03G0151A.