METEOR CRUISE M53-3

Circulation in the Tropical – Subtropical Atlantic

RECIFE – POINTE A PITRE

June 7 -- July 4, 2002

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Short Cruise Report of Meteor cruise M53/3, June 7 – July 4, 2002

Recife – Pointe a Pitre

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Introduction

The global meridional overturning of the ocean plays an important role for climate and climate change. In the Atlantic, the overturning consists of a northward transport of warm water in the upper ocean, and a southward transport of cold water in the deep ocean. The objectives of the cruise M53/3 are for the cold-water limb:

- to study pathways and mean speed of the cold-water limb as well as the interactions between boundary currents and the oceans interior, including the export of deep water (lower North Atlantic Deep Water, lNADW) between the western and the eastern tropical Atlantic.

for the warm water limb:

- to study the main path of the South Atlantic water which remains in the North Atlantic and becoming part of the Gulf Stream, i.e. the warm inflow into the Caribbean through passages south of Guadeloupe.

Cruise Narrative

In Recife, several meetings and events took place on RV Meteor between, June 3 – June 6, which were related to the ‚Jahr der Geowissenschaften‘ (Year of the Geosciences) in Germany. The Meteor left Recife on June 7, 12 UTC and headed north and then northwest to reach the southern end of the 40°W section at 2°07‘S, 40°00‘W. Due to favourable winds and the North Brazil Current NBC, the speed of the Meteor was about 13kn. A test station was carried out successfully on June 8.

Station work began on June 9, 13 UTC at 2°07‘S, 40°00‘W, water depth: 1200m. The CTD measures the vertical profile of pressure, temperature, conductivity and oxygen. Conductivity and oxygen are calibrated on board by analysing water samples taken with 21 10liter bottles. Oxygen was analysed by automatic titration and with two optical frequencies, and the salinity was determined with an Autosal. Samples taken from the water bottles were also analysed on board for the chlorofluorocarbon components CFC-11 and CFC-12 by an automatic GC-ECD system designed at the University Bremen. The CFCs are a major tool to estimate time scales of spreading of deep and intermediate water masses and to follow the spreading paths. A 150kHz narrow band lADCP is attached to the CTD-rosette system and measures the velocity profile from the surface to the bottom. The current field in the upper 1400m was continuously measured by two ADCPs: a 75 kHz and a 38 kHz ADCP Ocean Surveyor, located in the ship’s hull and the well, respectively. The vertical resolution was 16m for both instruments. The thermosalinograph records continuously the surface salinity, and was calibrated on station against the CTD values.
Besides the shipboard measurements, the RV Meteor will deploy two moorings in the 7°30‘N passage to estimate the transport of lower North Atlantic Deep Water (lNADW) and Antarctic Bottom Water (AABW) from the western into the eastern basin.

The distance between the CTD/lADCP stations were 5 miles at the continental slope to resolve the deep current field and increased to 25 miles north of 1°16‘S, 40°N. The RV METEOR left the 200nm zone of Brazil at 0°30‘N, 40°00‘W on June 11, 1 UTC. At 2°30‘N, 40°W, the station spacing increased to 30 miles. At 6°N, 40°W on June 13, 17UTC the Meteor headed towards the eastern entrance of the 7°30‘N fracture zone at the Midatlantic Ridge at 38°20‘W. After CTD/lADCP station 22, the 4 releasers for the passage moorings were successfully tested after lowering them to 1000m depths.

In the fracture zone, CTD/lADCP work continued along 7°30‘N roughly every 30 miles. On CTD/lADCP station 25, 7°26‘N, 38°19.3‘W, at June 14, 16 out of 21 water bottles didn't close. Despite several attempts to repair and/or to exchange part of the equipment, the malfunction could not be found. The following stations 26-29 were run without water bottles and thus without CFC samples. On CTD/lADCP station 29, June 15, 12:30UTC, no CTD data were transferred due to malfunctions of the electric cable and the SBE assembly board. After repairing both, the system was back to function normal.
On June 15, 9:30UTC the topography around the mooring location at 7°28‘N, 36°52‘W was surveyed with Hydro sweep. The Bremen mooring B1 was deployed at the sill in the 7°30‘N passage at 7°28.40‘N, 36°50.00‘W, at 16:06 UTC. The mooring is equipped with pressure, temperature and conductivity sensors (Micro Cats) and acoustic current meters (Aanderaa), and encompasses the lNADW from the bottom to about 3600m depths. The water depth at the sill turned out to be 200m deeper (4500m) than anticipated from the Sandwell-Topography (2min resolution).

On June 15, 19 UTC the ‚Meteor‘ arrived in the area, where the 2nd deployment was planned (8°00‘N, 36°00‘W). The topography of the area was surveyed with Hydro sweep. The deep passage (4300m depth) present in the Sandwell topography was only 3900m deep, too shallow for a substantial lNADW export. Thus we continued to follow the deep passage towards the east till 7°24.85‘N, 34°19.84‘W, and the easternmost exit of the 7°30' N passage to the eastern Atlantic. On June, 16, 9UTC, Hydro sweep showed, that the sill was located about 2 miles further east than found in the map and was deeper (sill depth: 4660m instead of 4200m) and the passage was wider than found in the Sandwell topography. After a CTD/lADCP station near the allocated mooring position at the sill, the Bremen mooring B2 was deployed at 7°24.70‘N, 34°17.30‘W at 15 UTC. At 16:30 UTC, the Bremen CFC sampler was tested for the first time by putting the device in 2000m depths for 6 hours. The moored sampler was developed in Bremen by modifying a commercially available nutrient sampler for the measurements of CFCs in deep water. The main purpose is to obtain yearlong time series of CFC concentrations in deep water. At 23:30, the sampler was retrieved and the METEOR headed northwestward towards the easternmost station of the 16°N section. On the way, at June 18, 17UTC the CFC sampler was lowered to 10m depth for 90 minutes for another test. In both tests, the sampler showed no contamination affecting the analysis of CFCs.

The METEOR arrived at the eastern starting point of the 16N section (15°14'N, 51°21'W) on June 21, 2UTC. Since the lADCP can only be lowered to 5000m depths, and the bottom of the ocean is deeper than 5000m west of 52°W, two different CTD/rosette systems were used alternatively. One system (S1) with the lADCP attached was only lowered to 5000m, and on the next station, the second CTD/rosette system without lADCP (S2) was used and lowered to the bottom. The CTD station spacing is 20miles, i.e. a lADCP profile is obtained every 40 nautical miles. On CTD station 36 (15°27'N, 53°07'W, June, 22, 0UTC), the measurements were aborted in 1800m depths due to a malfunction of the conductivity sensor in S1, and the profile was repeated with S2. The conductivity sensor in S1 was replaced. On June 24, another CFC sampler test was carried out by lowering the sampler to 2500m depths for 8 hours. After recovery, the sampler was still working.

On 17 UTC, we began with the recovery of the tomography mooring m2, located at 16°02'N, 56°55'W. Both releasers responded, and were hauled on deck at 20:30 UTC. Then the RV Meteor continued CTD station work at 15°54'N, 57°00'W. The distance between the stations 54 and 56 increased to 30 miles. On June 26, the tomography mooring m3 at 16°23'N, 60°28'W was recovered successfully. After reaching the steep continental slope off Guadeloupe, the CTD station spacing between profiles 57-63 were reduced from 15 miles to roughly 2 to 3 miles, so that the bottom depths between subsequent stations did not differ by more than 600m. The tomography mooring m5-sara at 16°22'N, 60°42'W was recovered without any problems on June 27, 18UTC.

The last task of the cruise is to measure the properties of the water masses flowing into the Caribbean Sea and to estimate their transport. The 'Meteor' headed south of Guadeloupe to the 100m isobaths at 16°00.0'N, 61°34.5'W and crossed the Guadeloupe-Dominica Passage to the 100m isobaths north of Dominica at 15°39'40'N; 61°26.3'W in order to measure the velocity distribution with the two vessels mounted Ocean Surveyors. It turned out that the increasing winds (Bft 8) and the waves decreased the data quality of the 38kHz system, the quality of the 75kHz ADCP mounted in the ship's hull was not affected and had good data down to 750m depth. At June 28, on the way back to Guadeloupe, 5 CTD stations (CTD 64-68) were carried out and on the way south, the ADCPs recorded the velocity distribution in the passage for the third time. Dominica was passed leeward and the Dominica – Martinique passage was surveyed after the same fashion as the Guadeloupe-Dominica passage starting at 15°14.10'N, 61°17.70'W till 14°55.20'N, 61°08.35'W at the northern tip of Martinique (CTD stations 69-72). At the centre of the passage, the water depth exceeded 2000m, and the CFC sampler was lowered for 9 hours to about 2000m to test some parameter settings. The test confirmed, that the sampler was free of contamination. At cold temperature and pressures of 2000dbar, however, the sample ampoules were not rinsed sufficiently, probably due to different expansion coefficients of the plunger materials. On June, 29, 16 UTC, the Meteor headed south to the Martinique – Saint Lucia passage to the northern starting location of the ADCP section at 14°22.35'N, 60°52.30'W. After finishing the ADCP section off Saint Lucia at 14°10.00'N, 60°54.30'W, 5 CTD stations (CTD stations 73-79) were carried out along this section on the way north. After repeating the ADCP section southward, the work continued in the Saint Lucia – Saint Vincent passage with an ADCP section (13°39.40'N, 60°54.00'W to 13°21.60'N, 61°07.00'W. Since we expected the largest transport here, the ADCP section was repeated 4 times. 6 CTD stations (81-85) were carried out in the passage starting at June 30, 10 UTC. The work in the Saint Lucia - Saint Vincent passage was finished at 20 UTC. The water mass characteristic and the inflow into the Caribbean south of Saint Vincent were measured on the way from Saint Vincent to Tobago. Station spacing was 15 miles. The data quality of the 38kHz Ocean Surveyor was deteriorated severely during that section.

The stations 88 – 93 were done with the lADCP attached to the rosette. The Meteor reached the 1000m isobaths off Tobago at July 15 UTC. The stations on the way north towards Guadeloupe were about 15 miles apart. The last CTD station was done at 16°N, 60°41'W on July 3. The remaining time was used to repeat with ADCP measurements the 16°N boundary current section to 59°30'W in order to have another transport estimate. The research cruise M53-3 ended in Pointe a Pitre at July 4, 13 UTC. On July 5, a reception on RV Meteor was given to present the research vessel and the science to the public.

Measurements

CTD-O_2 The measurements as well as the calibration of the conductivity and the oxygen sensors were successful, despite the various sensors used. Temperature and pressure have been calibrated before the cruise. The finalized data set will be finished soon.

CFCs The components CFC-11 and CFC-12 were analysed during the cruise. Calibration was done with standard gas. The finalized data set will be soon available

LADCP The 150kHz NB ADCP worked well during the cruise. Since the 38kHz vessel-mounted ADCP measured the velocity distribution down to 1400m depths, a comparison between the two instruments could be carried out at the station locations. It showed that both instruments agree well.

Underway Measurements
Ocean Surveyor 38kHz and 75kHz. Both instruments worked continually during the cruise. The vertical range of the 38kHz ADCP was mostly to 1200-1400m depths. In the Caribbean passages, however, the data quality was reduced and the vertical range restricted to about 700m, the 75kHz instrument was not affected.

Thermosalinograph The temperature and salinity surface data have been calibrated with the CTD data.

Figures

Figure 1 a) Overview cruise track of research cruise M53-3. The moorings B1 and B2 located in the 7°30’N passage are shown with red marks. **b)** Cruise track, Caribbean passages and the regions east.

Figure 2 Zonal velocity component u (cm/s) along the 40°W section, from the 38kHz Ocean Surveyor. Left side: continental slope off Brazil, right side: Mid Atlantic Ridge. +: eastward velocity --: westward velocity. The various equatorial currents with their transports (in Sv = 10^6 m^3/s) are indicated. NBC: North Brazil Current; SEC: South Equatorial Current; EUC: Equatorial Undercurrent; NECC: North Equatorial Counter Current; NEUC: North Equatorial Undercurrent. EIC: Equatorial Intermediate Current. The isopycnals separating the Tropical Surface Water from the central water masses and the AAIW are also shown

Figure 3 Zonal velocity component u (cm/s) from lADCP measurements along 40°W, the locations of the profiles are indicated on top. Orientation, see Figure 2. Red: eastward velocity, blue: westward velocity. Compare the upper 1400m with Figure 2. The black lines denote the limits of the deep-water masses. The upper LSW (uLSW) is bounded by $sigma\_{1500}$ = 34.42 and 34.70, the LSW by $sigma\_{1500}$ = 34.70 and 34.755, the middle NADW by $sigma\_{1500}$ = 34.755 and $sigma\_{4000}$ = 45.83, the lower NADW by $sigma\_{4000}$ = 45.83 and 45.90, and below 45.90 the Antarctic Bottom Water AABW is found.

Figure 4 CFC-11 concentrations (pmol/kg) along 16°N, from 1000m to the bottom. Left side: Guadeloupe, right side: Mid Atlantic Ridge. The high CFC concentrations at 1500-1800m depths and at about 3600-4000m depths reflect the recent ventilation of the upper North Atlantic Deep Water (NADW) in the Labrador Sea and of the overflow water, spilling over the sill between Greenland and Iceland (lower NADW). These deep-water masses flow south, mainly in the Deep Western Boundary Current (DWBC), but with substantial recirculation in the ocean's interior.

Figure 5 Velocity distribution (cm/s) across the Saint Lucia – Saint Vincent Passage, 75 kHz Ocean Surveyor. Left side: Saint Vincent, right side Saint Lucia. +: eastward, -- : westward, i.e. into the Caribbean. The mean transport into the Caribbean Sea through the St. Vincent Passage was 4 Sv.

Figure 6 Salinity distribution across the Saint Vincent Passage, orientation see Figure 5.

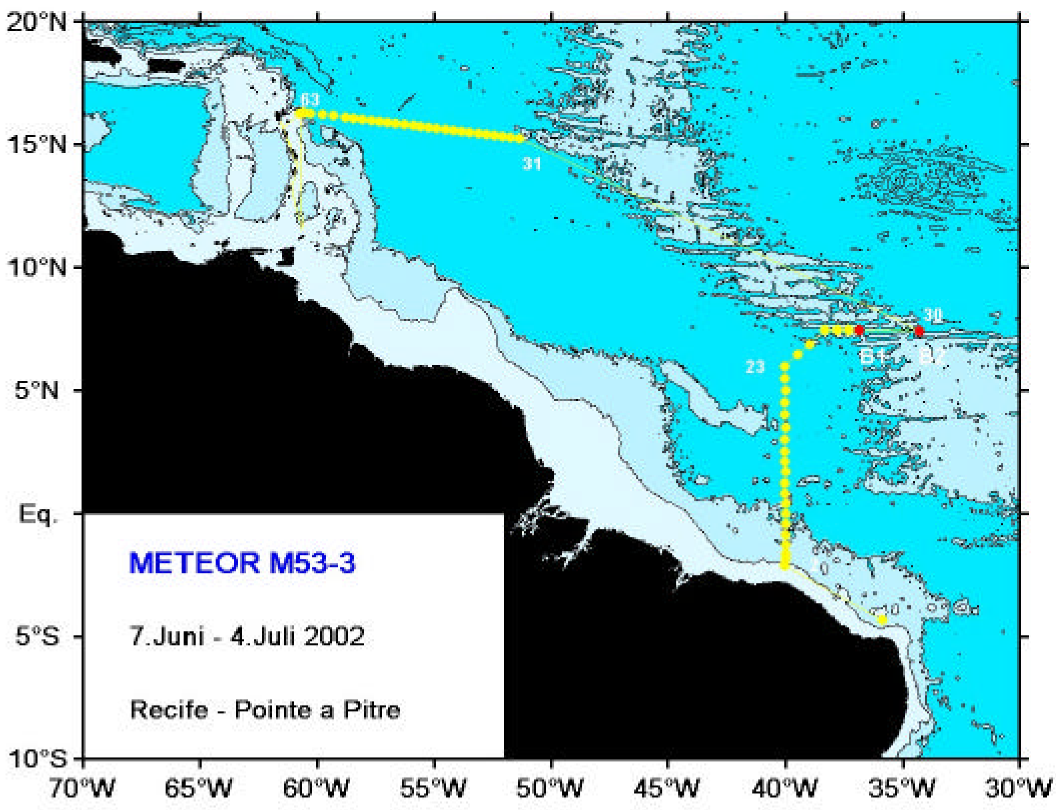


Figure 1a

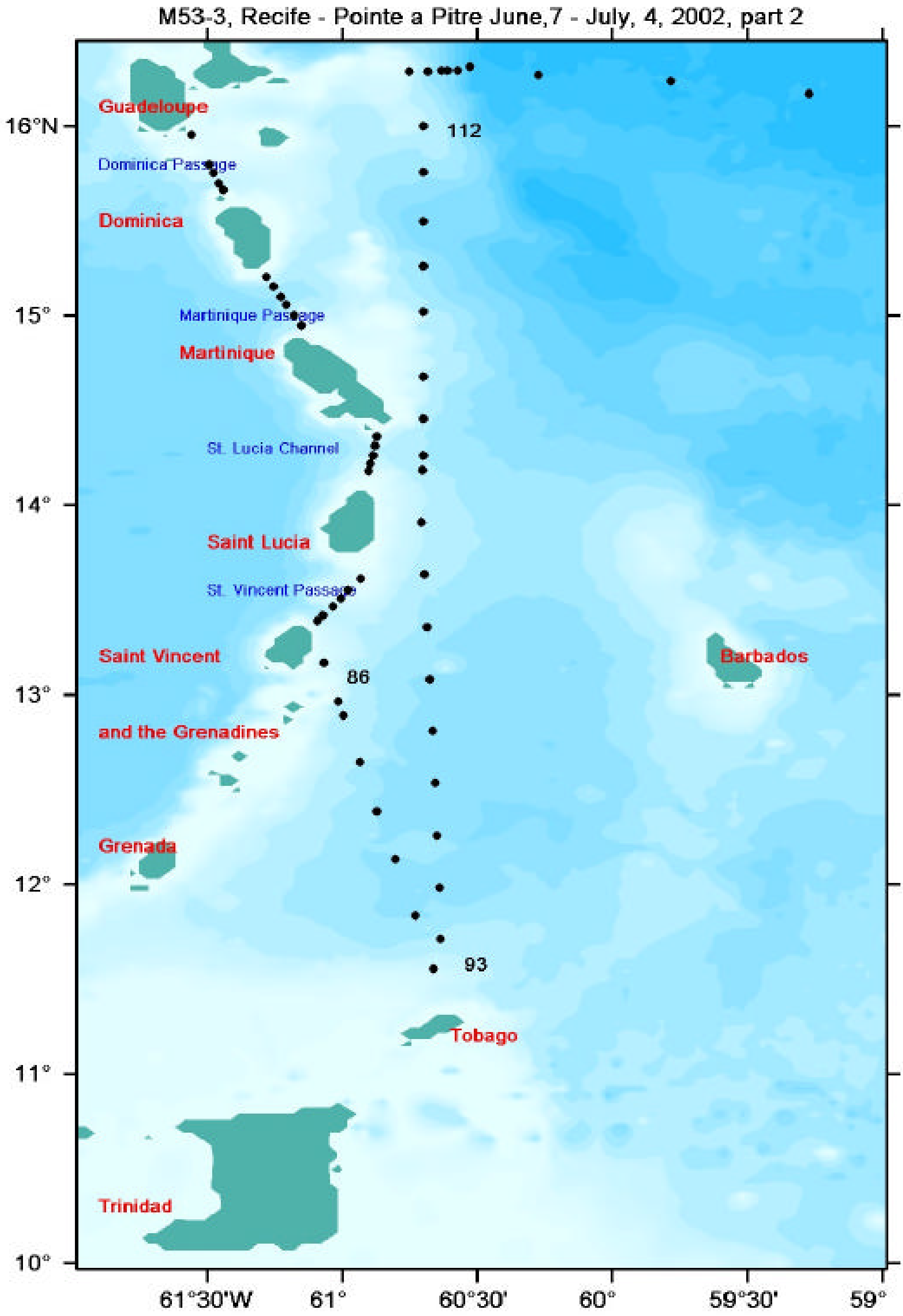
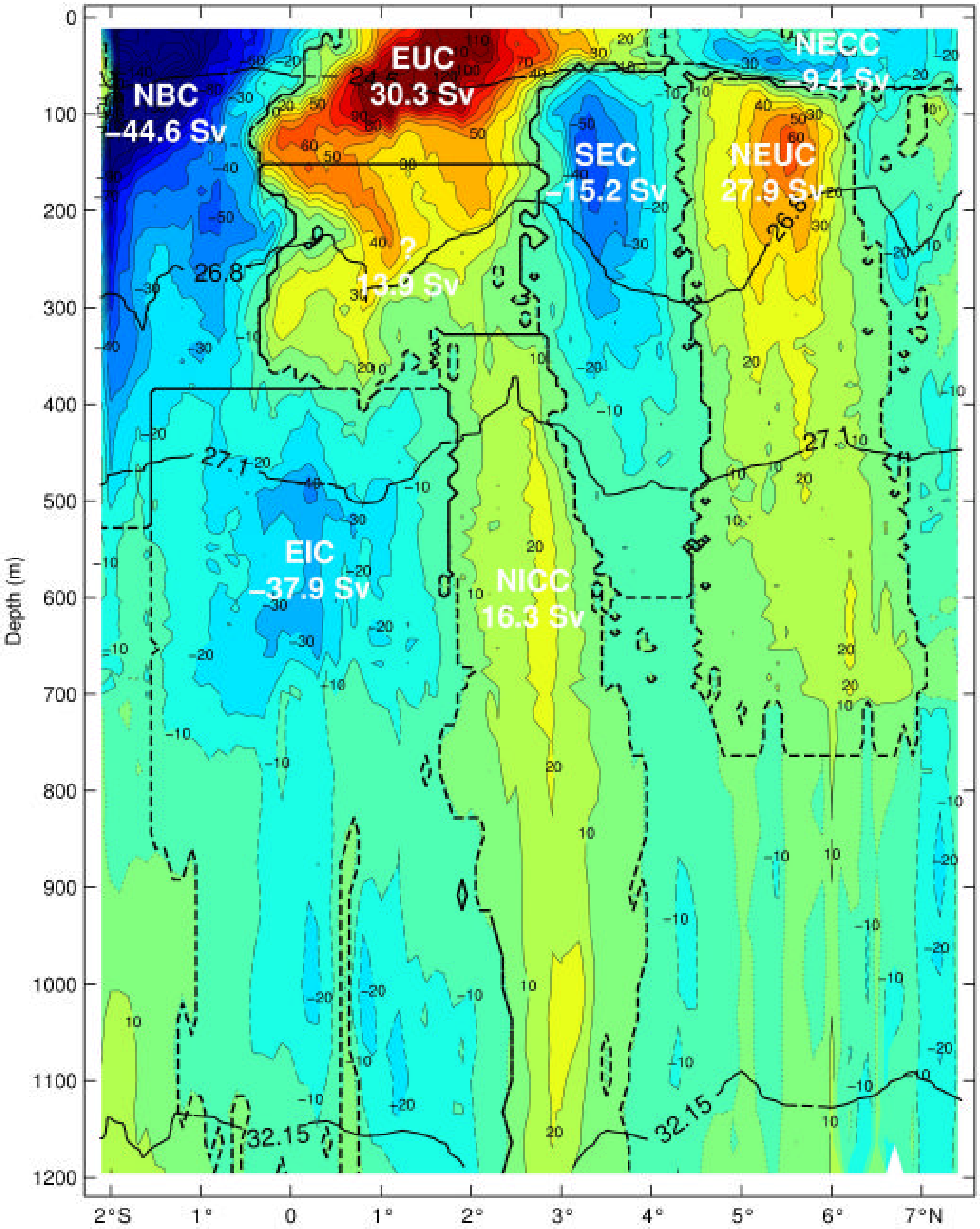


Figure 1b

Next page: Figure 2


EUC
30.3 Sv
NECC
9.4 Sv
NBC
−44.6 Sv
SEC
−15.2 Sv
NEUC
27.9 Sv
?
13.9 Sv
EIC
−37.9 Sv
NICC
16.3 Sv
Depth (m)
2°S
1°
0
1°
2°
3°
4°
5°
6°
7°N

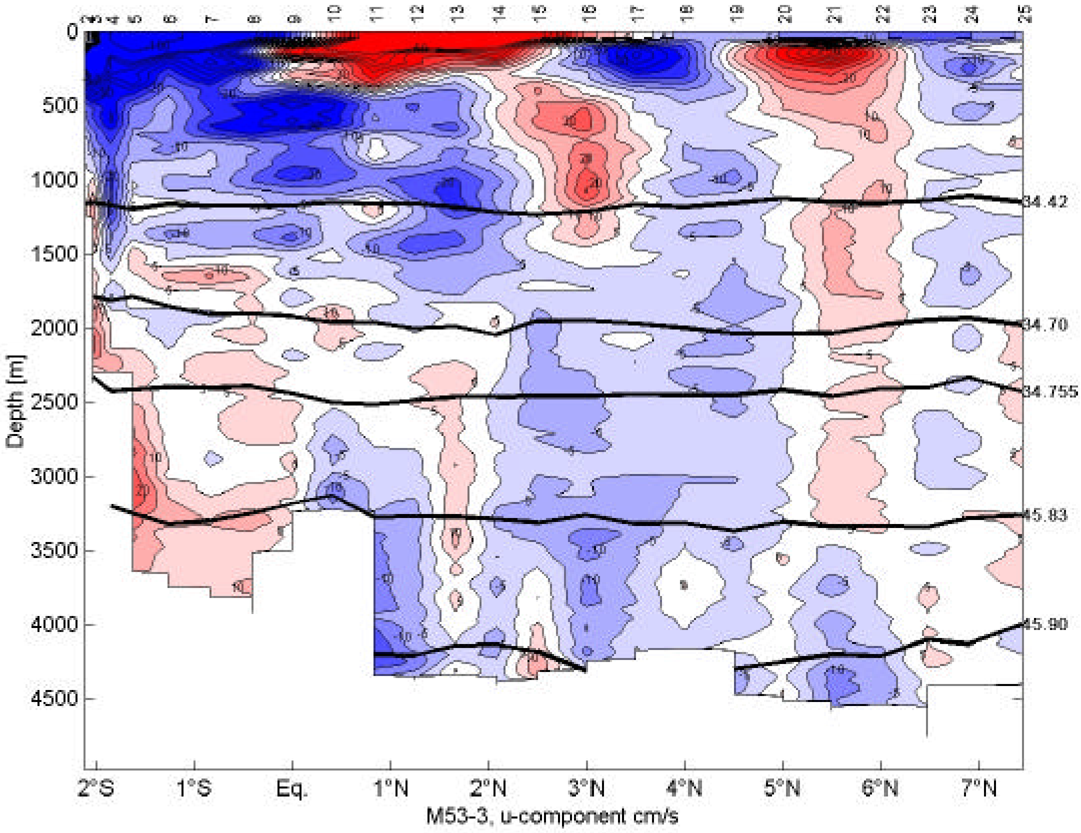

Depth [m]
0
500
1000
1500
2000
2500
3000
3500
4000
4500
2°S 1°S Eq. 1°N 2°N 3°N 4°N 5°N 6°N 7°N
M53-3, u-component cm/s
34.42
34.70
34.755
45.83
45.90

Figure 3

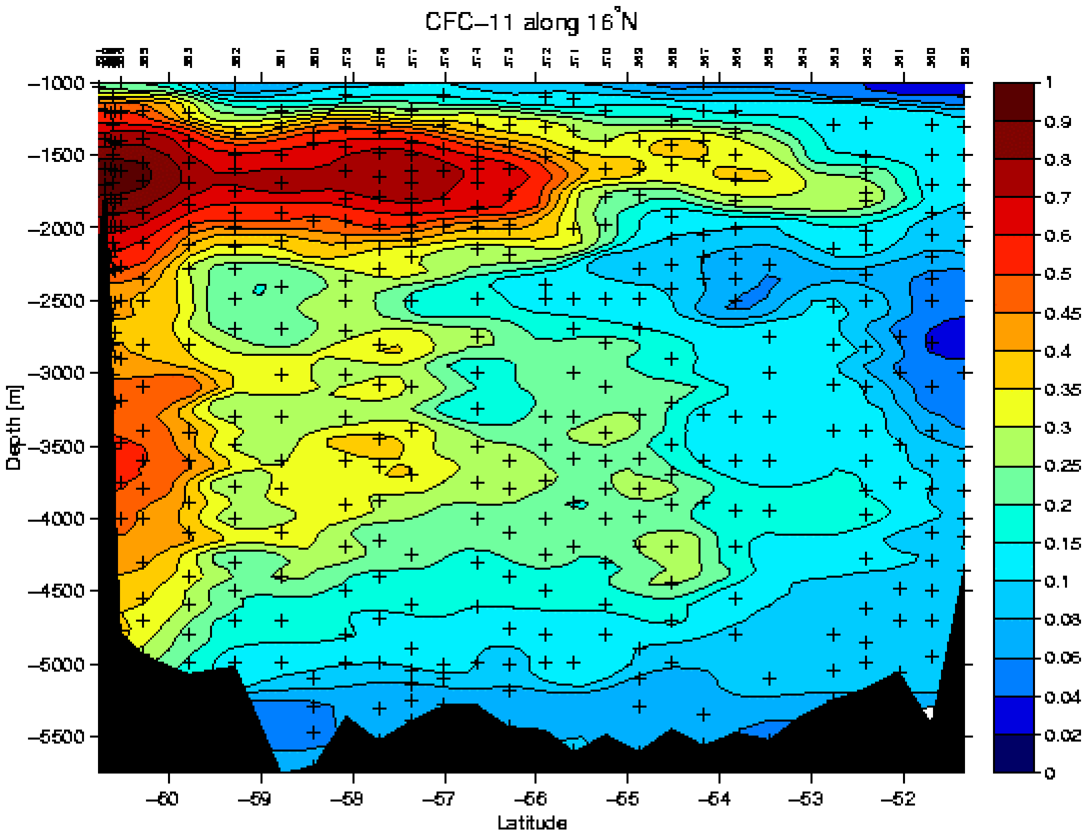
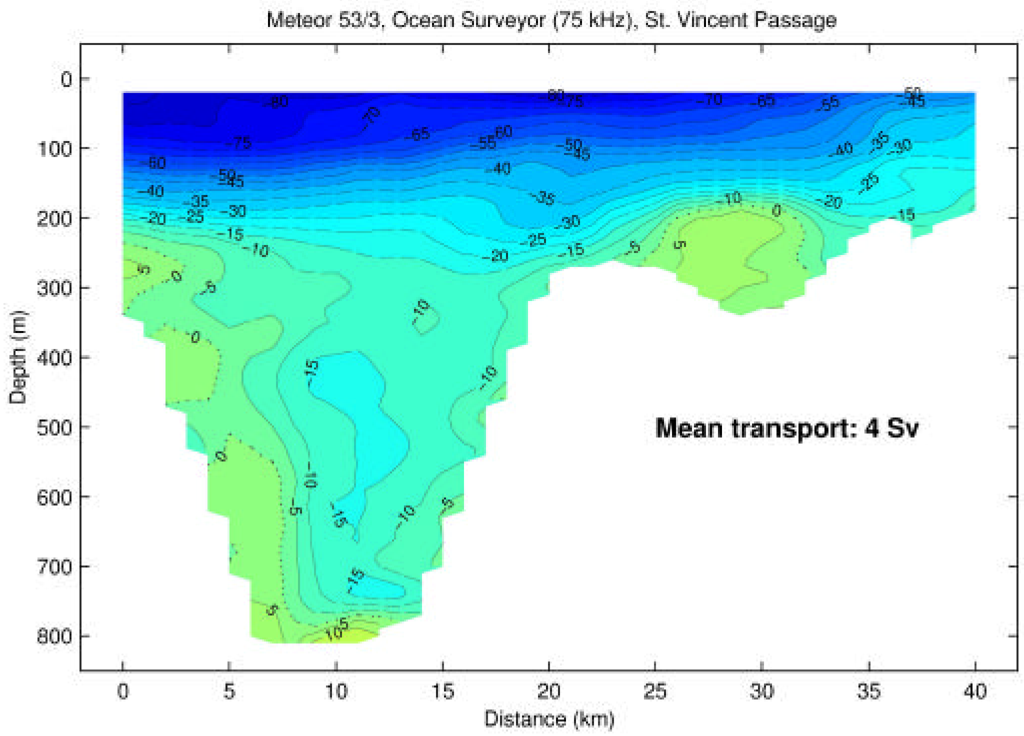
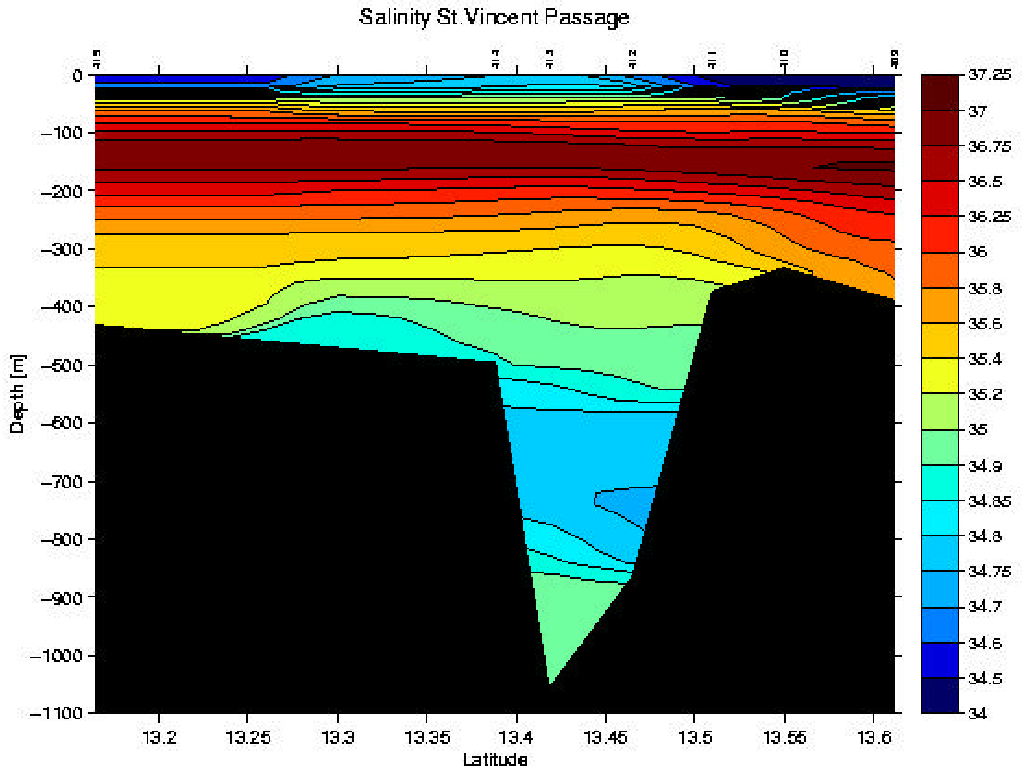


Figure 4

Next page: Figures 5 and 6


Meteor 53/3, Ocean Surveyor (75 kHz), St. Vincent Passage
Mean transport: 4 Sv
Depth (m)
Distance (km)


Salinity St.Vincent Passage
Depth [m]
Latitude

Participants METEOR 53

Leg M53/3

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