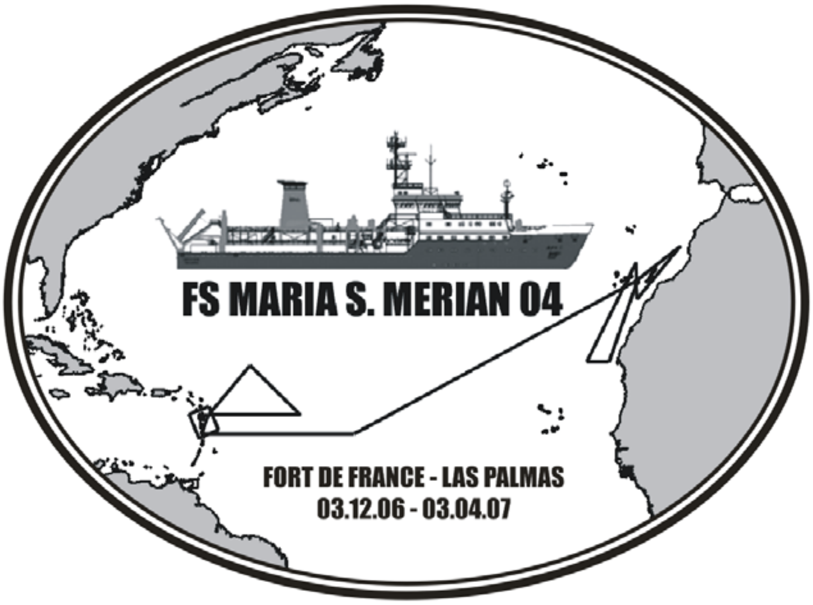
MARIA S. MERIAN-Berichte xx-x

Process studies in the hydro- and geosphere of the tropical/subtropical North Atlantic

Cruise No. 04

December 03, – April 03, 2006/2007, Fort de France (Martinique) – Las Palmas (Spain)



Thomas J. Müller, Ernst R. Flüh, Christian Borowski, Tim Freudenthal, Gerhard Fischer

Editorial Assistance:

Sonja-B. Löffler
Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven

Leitstelle METEOR
Institut für Meereskunde der Universität Hamburg

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Abstract

Four legs within three investigation areas (the Antilles region, mid-Atlantic Ridge, and continental margin of NW Africa) were conducted during MARIA S. MERIAN expedition MSM04 in the tropical/subtropical North Atlantic (Fig.1). During the **first leg** (MSM04/1) the variability of volume transport of North Atlantic Deep Water was measured at 16°N in the western subtropical Atlantic east of the Antilles. This campaign was conducted within the frame of the international Climate Variability Programme (CLIVAR). The main target of the **second leg** (MSM04/2) was the investigation of the role of water in the generation of earthquakes in the Antilles subduction zone. This research was conducted with international cooperation within the Thales EU FP6 project. A multidisciplinary approach within the DFG Special Priority Program SPP1144 was conducted during the **third leg** (MSM04/3) in order to investigate the biological, geochemical and geophysical variability in hydrothermal activity at the Logatchev hydrothermal vent field at the mid Atlantic ridge. The fourth leg (MSM04/4a+b) focused on the study of the high productivity region off NW Africa and was conducted within the frame of the EU project MERSEA and the DFG Research Center Ocean Margins. The study of environmental conditions influencing particle transport dynamics and the recovery of long sediment cores for the reconstruction of paleoenvironmental conditions were the major research targets of this leg that was separated in two sublegs for logistical reasons.

Zusammenfassung

Die MARIA S. MERIAN Reise MSM04 umfasst vier Fahrtabschnitte in drei Untersuchungsregionen (Antillen Region, Mittelatlantischer Rücken, Kontinentalrand vor NW Afrika) im tropisch-subtropischen Nordatlantik (Abb.1). Der **erste Fahrtabschnitt** (MSM04/1) konzentrierte sich auf die Untersuchung der Variabilität des Volumen-Transportes im Nordatlantischem Tiefenwasser zwischen den Antillen und dem mittelatlantischem Rücken bei 16°N und wurde im Rahmen des internationalen CLIVAR Projektes durchgeführt. Während des zweiten Fahrtabschnittes (MSM04/2) wurde im Rahmen des Thales EU FP6 Projektes im Bereich der Antillen-Subduktionszone die Rolle des Wassers bei der Auslösung von Erdbeben untersucht. Anschließend wurde während des dritten Fahrtabschnittes (MSM04/3) in einem multidisziplinärem Ansatz im Rahmen des DFG-Schwerpunkt-Programms SPP1144 die biologische, geochemische und geophysikalische räumliche und zeitliche Variabilität der hydrothermalen Aktivität im Logatchev-Hydrothermalfeld untersucht. Der vierte Fahrtabschnitt (MSM04/4a+b) führte in das Hochproduktionsgebiet vor NW Afrika. Hier wurden im Rahmen des EU Projektes MERSEA und des DFG Forschungszentrums Ozeanränder Partikeltransportprozesse in Abhängigkeit von den Umweltbedingungen im Hochproduktionsgebiet vor NW Afrika untersucht und lange Sedimentkerne für paläoklimatische Rekonstruktionen gewonnen. Dieser Fahrtabschnitt wurde aus logistischen Gründen in zwei Teilabschnitten durchgeführt.

Research Objectives

The tropical and subtropical North Atlantic was the research area of MARIA S. MERIAN-Cruise MSM04. Data and samples collected during the four legs of this expedition will serve as a basis to investigate several research themes within the international CLIVAR project, the EU projects Thales and MERSEA, the DFG Schwerpunktprogramm SPP1144 and the DFG Research Center Ocean Margins.

The goal of **Leg MSM04/1** was the investigation of the variability of volume transport of North Atlantic Deep Water (NADW) at 16°N in the western subtropical Atlantic east of the Antilles. An instrumental array that was initially set up by IFM-GEOMAR in 2000 within the experiment MOVE (*Meridional Overturning Variabilty Experiment*) was served during this leg. The collected data with geostrophic moorings with a number of self recording Conductivity-Temperature-Depth (CTD) instruments (MicroCat, MC) and acoustic tomography will allow to investigate transport fluctuations using cross basin integral methods. Surface elevations are measured using inverted echo-sounders in combination with high precision pressure sensors (PIES) which data are to be compared with gravity data from the GRACE satellite mission. Within the deep boundary current itself, recording current meters were moored to estimate directly transports. The main aim during cruise MSM04/1 was to recover or directly read out the instruments which were moored during a 2005 cruise on the French l'ATALANTE (Send, 2005), supplemented by an eddy-resolving CTD section along 16°N.

The main purpose of **Leg MSM04/2** was seismic monitoring of the Lower Antilles subduction zone. A dense seismological network of marine seismometers (OBS) was deployed in order to record and identify transient seismic signals, such as seismic tremors or silent earthquakes. This study was supplemented by the shooting of two dense refraction profiles across the island arc and the accretionary prism for the investigation of the structural inventory of this subduction zone. During the Sismantilles II experiment, on-board the R/V Atalante, deployment of some extra OBSs in the north of the area, shooting with a large seismic source and finally MCS data acquisition was conducted in February 2007. The OBS network will then be recovered from the R/V Antea (IRD) in April 2007 and in June from a rented vessel.

The research activities during **Leg MSM04/3** were related to the DFG priority program SPP 1144 "From Mantle to Ocean: Energy-, Material- and Life-cycles". It was the third in a series of SPP cruises to the Logatchev Hydrothermal Vent Field at 14°45'N on the Mid-Atlantic Ridge. The overall goal was to continue the investigations of spatial and in particular temporal variability patterns of the hydrothermal activity that started with RV METEOR cruises M 60/3 and M 64/2 in January 2004 and May 2005, respectively. The ROV Jason II from the Woods Hole Oceanographic Institution was used to recover and redeploy geophysical instruments and geochemical in-situ measurement devices, and for accurate sampling of hydrothermal fluids, sediments, macrofauna and microorganisms. Other instruments used were the CTD/Rosette water sampler, Miniature Automated Plume Recorders (MAPR, NOAA) and the Kongsberg EM 120 multi-beam echosounder.

The study of particle transport processes as well as the collection of sediments for the reconstruction of past environmental conditions in the upwelling area off NW Africa were the goals of **Leg MSM04/4**. These investigations included the recovery and redeployment of moored sensors and sediment traps, water sampling, in-situ pumps, and observation of in-situ particle distribution with a particle camera (ParCa) along three transects at the NW African continental slope between 31°N and 21°N and a mooring station north of the Canary Islands. The sea floor drill rig MeBo was deployed at two of the three profiles. At 31°N long sediment cores (up to 50 m) were recovered using push core technique for high resolution studies of the late quaternary climate variability. Plio-/Miocene sediments were sampled by rotary drilling at 26°N for the investigation of Neogen climate evolution.

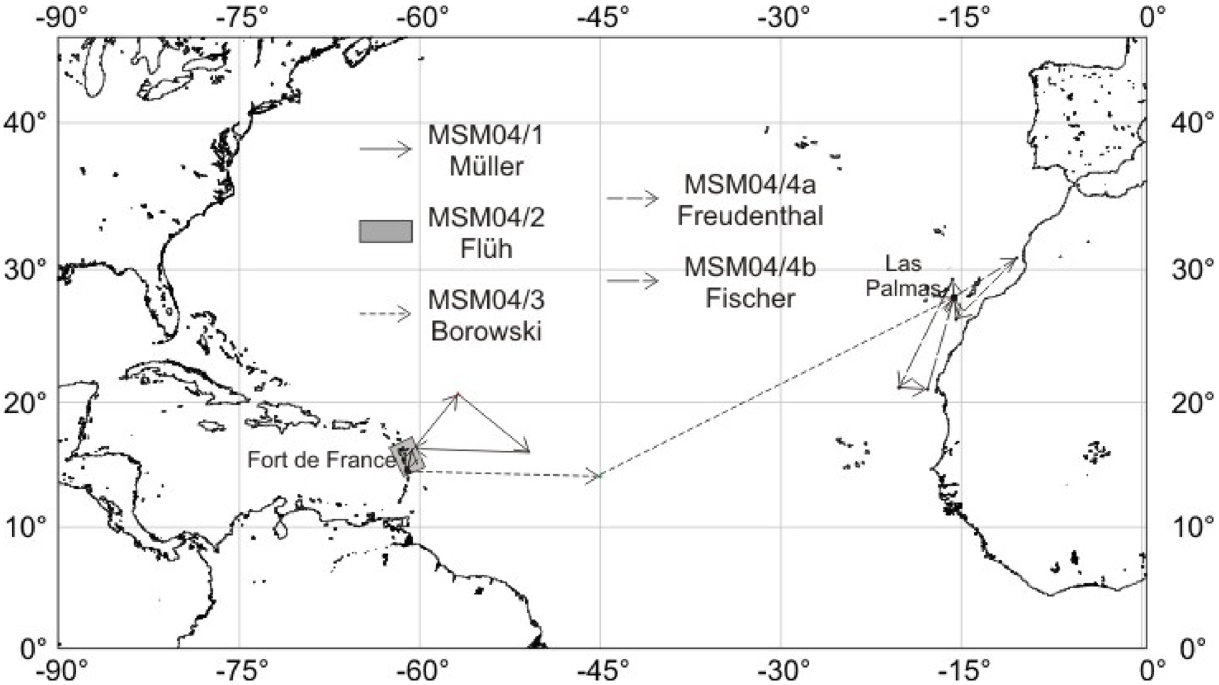


Fig. 1 Overview map of the research area of RV MARIA S. MERIAN expedition MSM04.

Acknowledgements

The scientific parties aboard R/V MARIA S. MERIAN cruise MSM04 gratefully acknowledge the friendly cooperation and efficient technical support of Captains F. von Staa and L. Holtschmidt and their crew. We are indepted to the Federal Foreign Ministry (Auswärtiges Amt) in Berlin and the German diplomatic representatives of the visited countries, who helped to clear necessary allowances from national authorities. Thanks to Captain Berkenheger at the Leitstelle METEOR / MARIA S. MERIAN (Hamburg), K. Bohn at VTG – Lehnkering AG (Hamburg), I. Weigert at Contiways (Hamburg), the Briese Schiffahrts GmbH (Leer) and the Senatskommission für Ozeanographie for logistical and administrative support. This cruise was funded by the Deutsche Forschungsgemeinschaft (DFG).

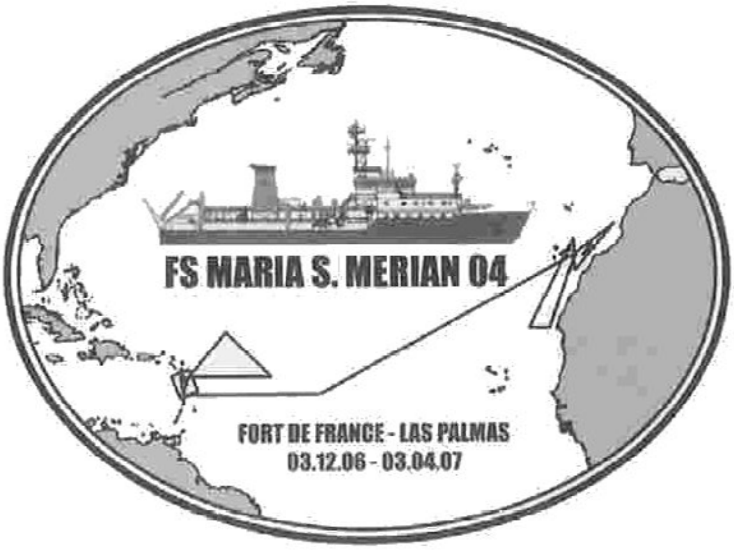
MARIA S. MERIAN-Berichte xx-2

Process studies in the hydro- and geosphere of the tropical/subtropical North Atlantic

PART 1

Cruise No. 04, Leg 1

December 3 – December 19, 2006, Fort de France (Martinique) – Fort de France



T. Müller, C. Begler, W. Böke, G. Chavez, C. Denker, F. Karbe, J. Karstensen, G. Krahmann, R. Link, G. Niehus, M. Nielsen, U. Neumann, P. Neves-Silva, G. Passalacqua, A. Pinck, T. Semingson

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1.1 Participants

Name	Discipline	Institution
Müller, Dr. Thomas J.	Principal Scientist	IFM-GEOMAR
Begler, Christian, Dipl.-Oz.	Physical Oceanography	SIO
Böke, Wolfgang	Technician	IUPUHB
Chavez, Gabriela	Student	SIO
Denker, Claudia	Student	IFM-GEOMAR
Karbe, Fritz	Student	IFM-GEOMAR
Karstensen, Dr. Johannes	Physical Oceanography	IFM-GEOMAR
Krahmann, Dr. Gerd	Physical Oceanography	IFM-GEOMAR
Link, Rudolf	Technician	IFM-GEOMAR
Niehus, Gerd	Technician	IFM-GEOMAR
Nielsen, Martina	Technician	IFM-GEOMAR
Neumann, Uta	Student	IFM-GEOMAR
Neves-Silva, Pericles	Student	INDP
Passalacqua, Gino	Technician	SIO
Pinck, Andreas	Technician	IFM-GEOMAR
Semingson, Taylor	Technician	SIO

IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften, Kiel, Germany
IUPUHB	Institut für Umweltphysik, Universität Bremen, Germany
INDP	Fishery Research Institute of the Cape Verde Islands
SIO	Scripps Institution of Oceanography, La Jolla, CA, USA

Contact
Dr. Thomas J. Müller
Leibniz-Institut für Meereswissenschaften
IFM-GEOMAR
Geb. Westufer
24105 KIEL, Germany
Düsternbrooker Weg 20
phone: +49-(0)431-600-4161
fax: +49-(0)-431-600-4152
e-mail: tmueller@ifm-geomar.de

1.2 Research Program

The southward transported North Atlantic Deep Water (NADW) is the most important cold water branch of the world's oceanic thermohaline circulation, and it is expected from numerical modelling that fluctuations or, in the worst, a break-down would have significant impact on climate (Clarke et al., 2001; Johns et al., 2005). It is well known that the strongest signal of associated currents within NADW transports can be observed in the deep western boundary current off the Americas. However, within the large deep basins, recirculation cells can induce large transport fluctuations even when currents are weak. IFM-GEOMAR in 2000 initially set up an instrumental array along 16°N in the western basin within the experiment MOVE (*Meridional Overturning Variabilty Experiment*) to measure such fluctuations using cross-basin integral methods, namely geostrophic moorings with a number of self recording Conductivity-Temperature-Depth (CTD) instruments (MicroCat, MC) and acoustic tomography (Kanzow et al., 2004). Surface elevations are measured using inverted echo-sounders in combination with high precision pressure sensors (PIES) which data are to be compared with gravity data from the GRACE satellite mission. Within the deep boundary current itself, recording current meters were moored to estimate directly transports. The geographical distribution of mooring sites and CTD stations during this cruise is shown in figure 1.1.

The main aim during cruise MSM04/1 was to recover or directly read out the instruments which were moored during 2005 cruise on the French l'ATALANTE (Send, 2005), supplemented by a final an eddy-resolving CTD section along 16°N. The moored component of MOVE from MSM04/1 on is continued in the western basin by the Scripps Institution of Oceanography (SIO, La Jolla, CA, U.S.A.), and is complemented in the eastern basin by IFM-GEOMAR through its new time series station off the Cape Verde Islands. The scientific party during MSM04/1 consisted of 11 scientists and technicians from IFM-GEOMAR, three from SIO, one participant from the University of Bremen, and a guest from the Fishery Research Institute of the Cape Verde Islands (INDP).

1.3 Narrative of the Cruise

The ship sailed on 03rd December 2006 at 09:00 local time from Fort de France, Martinique, for cruise MSM04/1. Outside territorial waters, scientific work started with underway meteorological and physical surface data recording. After a CTD test station later the same day, on 4th December we reached shortly after midnight the site of PIES 123 (Fig. 1.1) within the western mooring arrays M3 and M4. The instrument was still in site, however data could not be read out acoustically. Before deciding whether to pick up this instrument when returning to Fort de France later at the end of the cruise or to leave it in site, we wanted to check the other four instruments for possible systematic malfunction in the *read-out* mode.

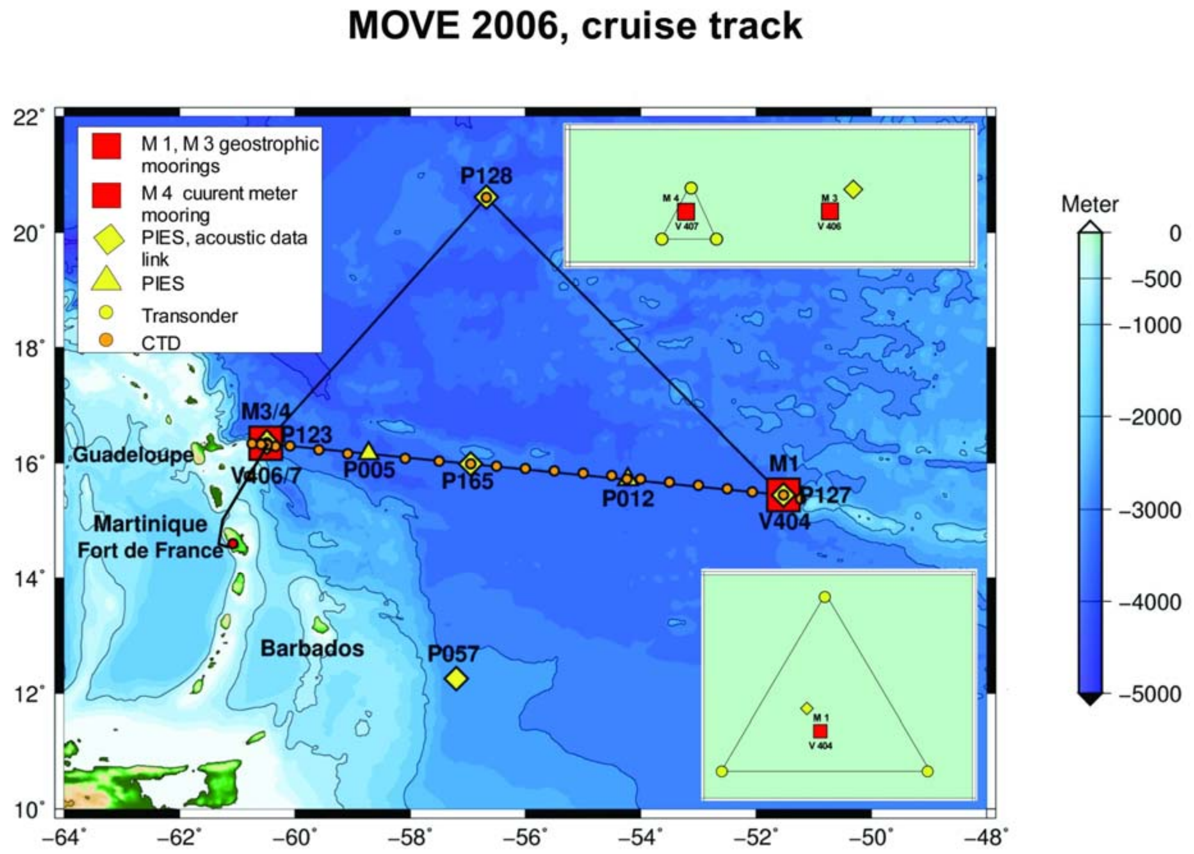

Fig. 1.1 Track of R/V MARIA S. MERIAN, cruise MSM04/1, 03 - 21 December 2006, Fort de France – Fort de France, Martinique, France. Track clockwise along the triangle. Moorings at sites M1, M3 and M4 including 4 transponders recovered; 2 transponders at M4 lost; moorings at M1, M3 and M4 redeployed with less instrumentation. All PIES along the cruise track recovered. PIES 057 was to be recovered later early 2007 with a different ship.

On the 4th and the 5th December both, the combined current meter and tomography mooring arrays at M4 and the geostrophic mooring at M3 at the western edge of the deep basin were recovered successfully besides two of three transponders. The current meters and all but one MC show good data. The tomograph transceiver in M4 had transmitted all the time. Moorings M4 and M3 were re-launched by SIO on 5th and 6th December with less instruments. Several CTD casts were taken in between the mooring work for calibration purposes.

When leaving sites M3 and M4 towards the site of PIES 128 in the north, the multibeam echo-sounding and the ship mounted 75 kHz OCEAN SURVEYOR ADCP were switched on. The site of PIES 128 was reached on 9th December. As we faced the same problems in *data read out mode* as before, PIES 128 was released and recovered. Technical inspection showed that the main batteries had ceased 18 months after deployment in 2004. As turned out later during the cruise and was confirmed by the manufacturer, this was a general instrumental problem.

On 11th December, we reached the eastern array M1 where the geostrophic mooring with tomography receiver, all three transponders and PIES 127 were recovered. The telemetry on top of the mooring had transmitted deep sea data *via* satellite ashore for all the time. With less instrumentation, the geostrophic mooring M1 was launched by SIO on 12th December.

After having finished the mooring work, the CTD section along ca. 16°N started on 13th December (locations see map in *Fig. 1.1*). Most casts were down to 5000 m. Many casts also were used to calibrate *in-situ* some instruments recovered from moorings. On the way the remaining PIES 012, 165, 005 and 123 were recovered. Scientific work was finished after completion of the section off Guadeloupe on 19th December.

Overall data are complete and of high quality with the following exceptions: two MCs showed malfunction; all PIES records are incomplete (ca. 18 of 33 months); data in the tomography receiver from the deep ray lack correlation with the theoretical eigen-rays. For logistic reasons PIES 057 off Barbados in the south was not recovered. Before the cruise SIO has agreed that work at this site would be performed later in early 2007 by SIO with a different ship.

1.4 Preliminary Results

(J. Karstensen, C. Begler, G. Krahmann, T.J. Müller)

1.4.1 Hydrography and Upper Ocean Currents along 16° N

The zonal section along approximately 16°N from Guadeloupe to the Midatlantic Ridge (Fig. 1.1 for location) of potential temperature, salinity and dissolved oxygen could only be obtained down to 5000 dbar, thus missing the deepest part of the western basin; also one station on the continental break reaches down to only 3500 dbar. Nevertheless, the section shows the well known general water mass structrure of the subtropical western North Atlantic (Fig. 1.2a-c): Warm (θ>27°C) and saline (S~36 psu) surface water; the core of the subtropical salinity maximum (S>36.5 psu) at ca. 150 dbar; the core of Antarctic Intermediate water (S<34.8 psu, O_2<130 µmol/kg) at 800 dbar; the core of upper North Atlantic Deep Water (S>35.0) at 1200 dbar with the layer thinning and deepening towards the east; the thick layer of North Atlantic Deep Water (O_2> 260 µmol/kg) from 1500 dbar to more than 4000 dbar, and below finally Antarctic Bottom Water (θ<1.8.0°C, S<34.9 psu) with its coldest component (θ<1.5°C) at the Midatlantic Ridge.

Spatial variability off Guadeloupe and in the eastern part of the deep basin (Fig. 1.2) are indicated. Off the coast of Guadeloupe on the continental break, the upper thermocline water is slightly colder and less saline than further east. In the deep basin with more than 3000 m water depth between however, the water is warmer, more saline and has higher dissolved oxygen, indicating clockwise circulation which is also confirmed in the upper thermocline by direct current measurements from the OCEAN SURVEYOR ADCP (Fig. 1.3). Further east and centred at about 54°W (distance 850 km), salinity and dissolved oxygen distribution indicate strong baroclinic eddy flow, again supported by the ADCP measurements.

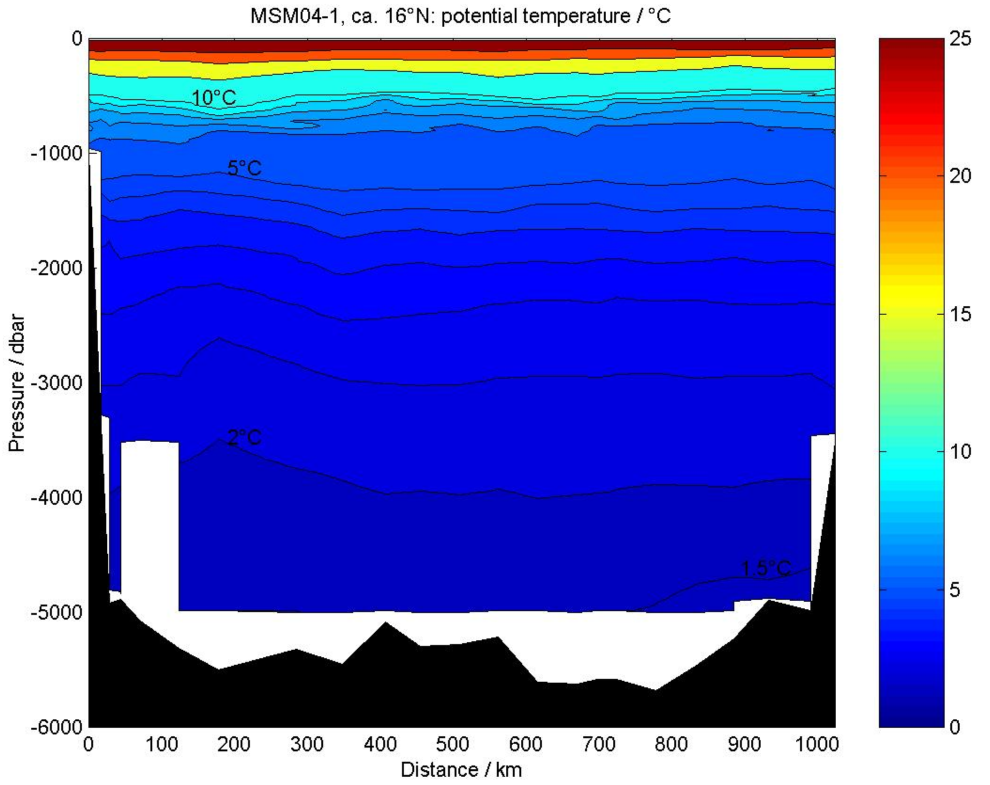

Fig. 1.2a MSM04/1, potential temperature along 16° N between the shelf break off Guadeloupe in the East (left) and the rise of the Mid Atlantic Ridge in the West (right); isoline spacing 1 K between 2°C and 10°C, and 5 K for temperature >10°C

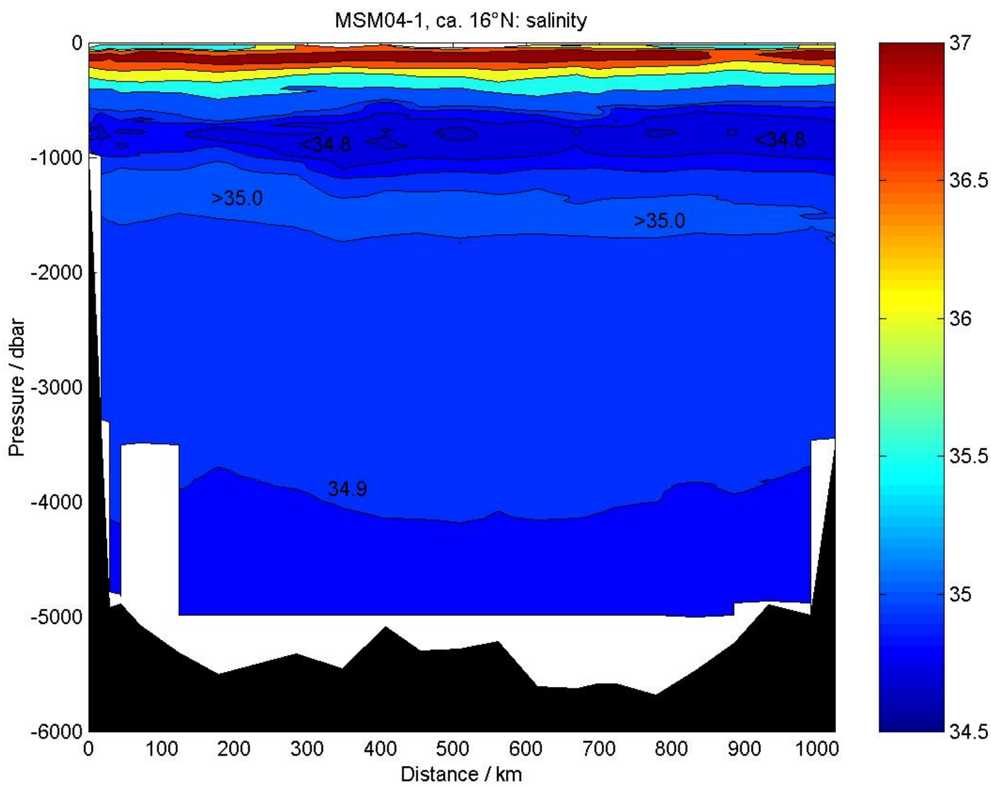

Fig. 1.2b MSM04/1, as Fig. 1.2a for salinity S; for S>35.0 psu, isolines at 0.5 psu spacing

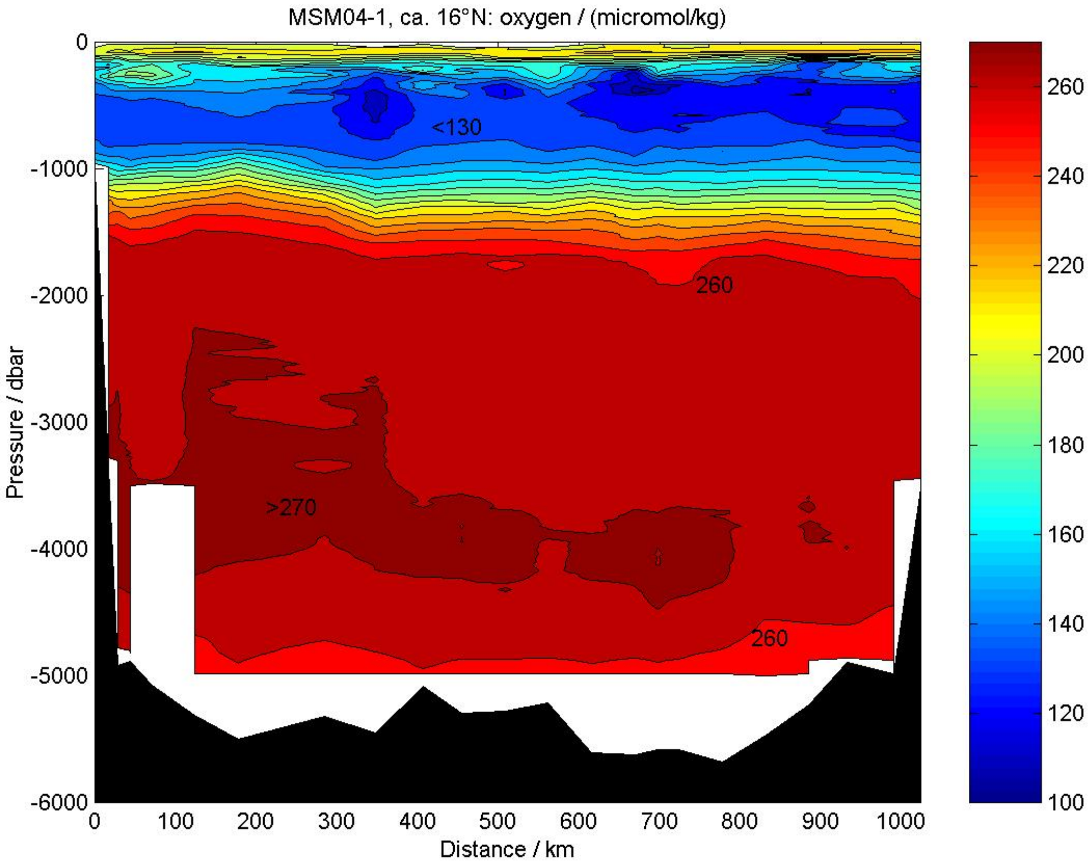

Fig. 1.2c MSM04/1, as Fig. 1.2a for dissolved oxygen; isoline spacing 10 µmol/kg.

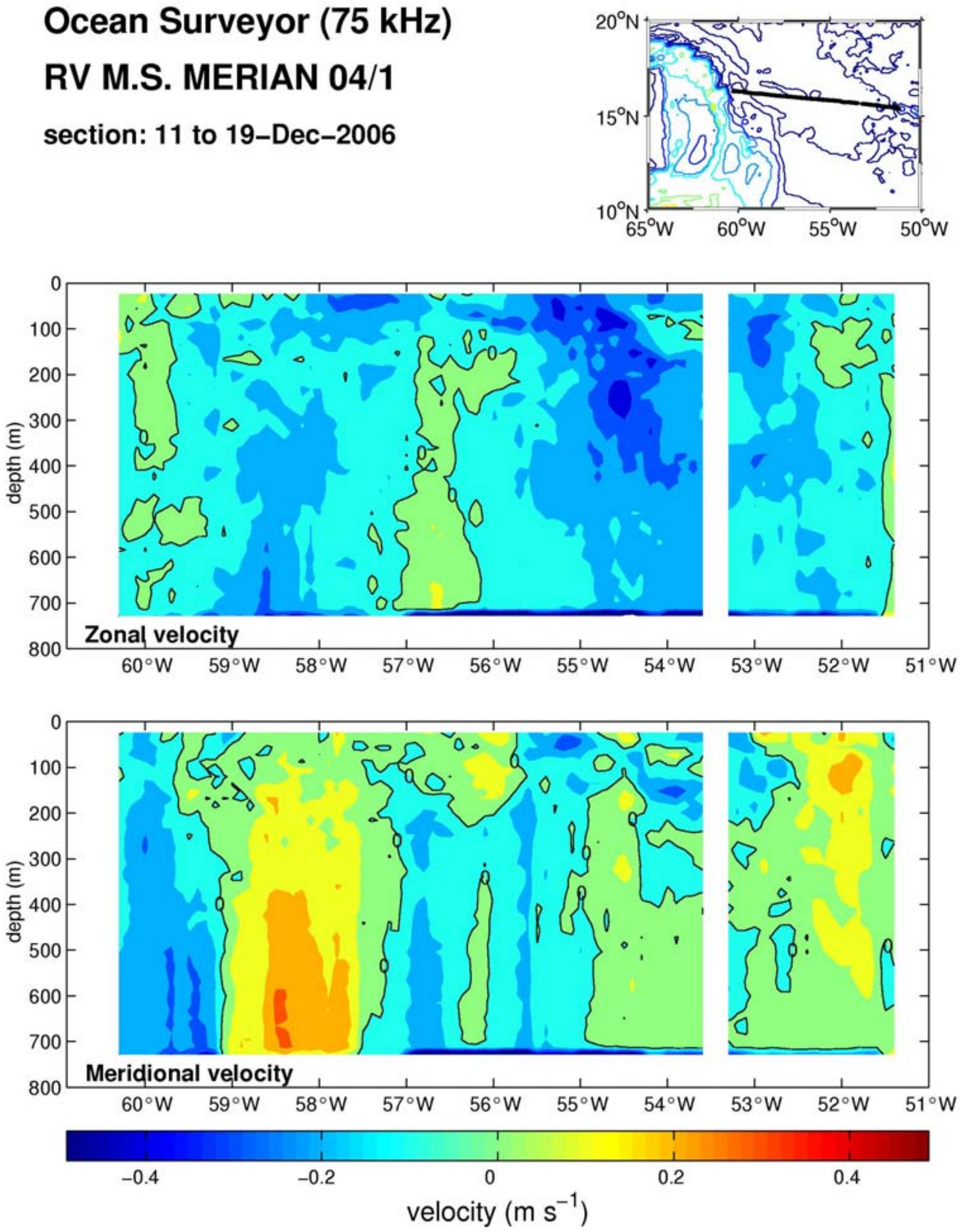

Fig. 1.3 MSM04/1, currents along 16° N from the OCEAN SURVEYOR 75 kHz ADCP.

1.4.2 Variability of Currents and Hydrography in 2005 to 2006

Direct currents were measured over much of the whole water column at the western boundary (sites M4 and M3) and at the eastern flank of the deep basin (M1). Starting in the west (M4, Fig. 1.4a), the vertical flow clearly shows the southward deep western boundary current between 810 m and 2243 m with the core at 1437 m. In the core the average speed is 14 cm/s directed to 152° while above and below the mean flow is weaker and more variable.

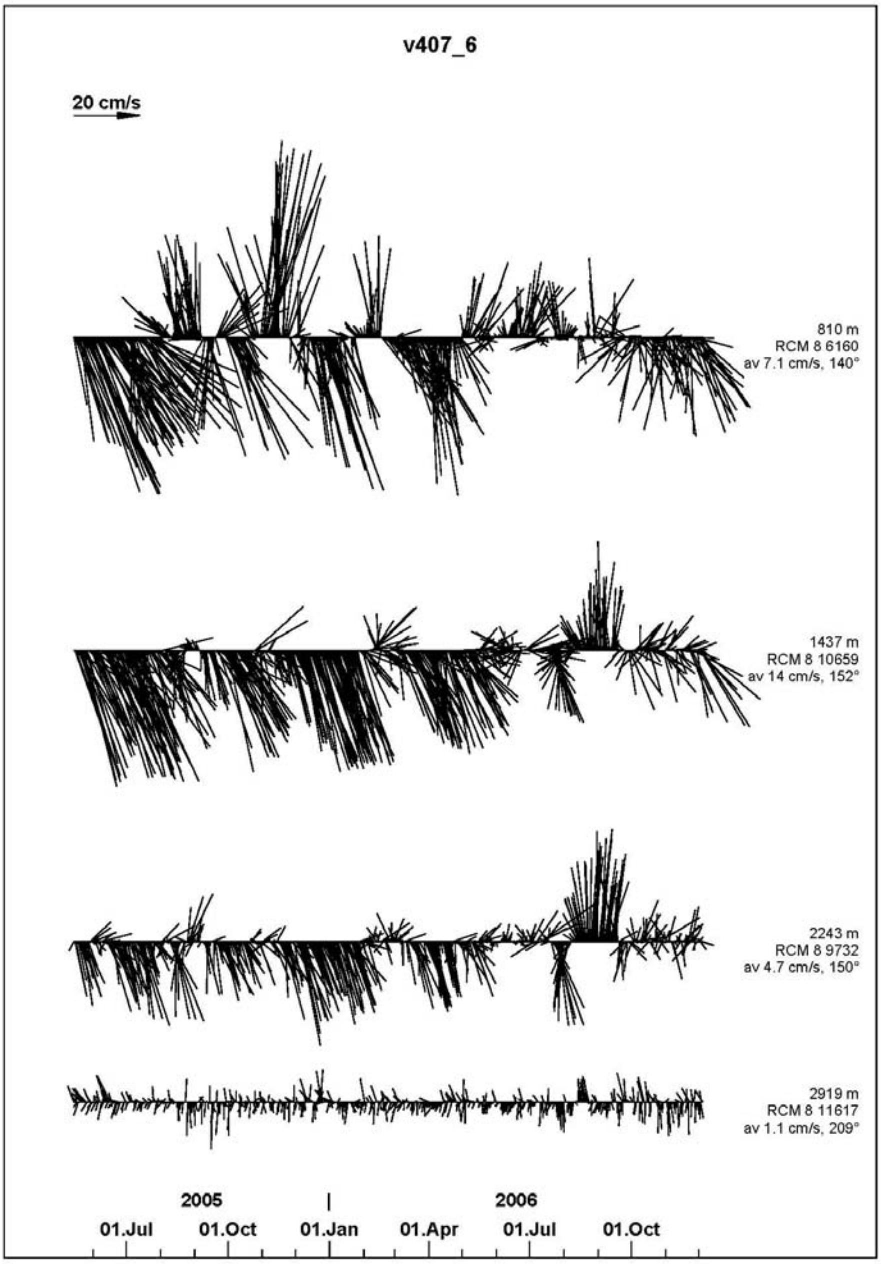

Fig. 1.4a site M4, western boundary current mooring V407-6, currents; low pass filtered daily averages; up is north direction; depths and average currents indicated.

At the western flank of the deep basin (site M3, Fig. 1.4b), the deep western boundary is even stronger with a maximum average of more than 20 cm/s between 1424 m and 2125 m and directed to 150° along the local topography. Close to the bottom at 4863 m, the flow reverses direction to 349° at an average of 1.2 cm/s; this indicates weak mean flow of Antarctic Deep Water towards the north. In the upper ocean at 172 m the flow is highly variable, at an average of 5.5 cm/s towards the north indicated the outer range of the Antilles Current. Note, that at the end of the record, the flow is to the southeast which is congruent with the ship's ADCP measurements during the cruise (Fig. 1.3).

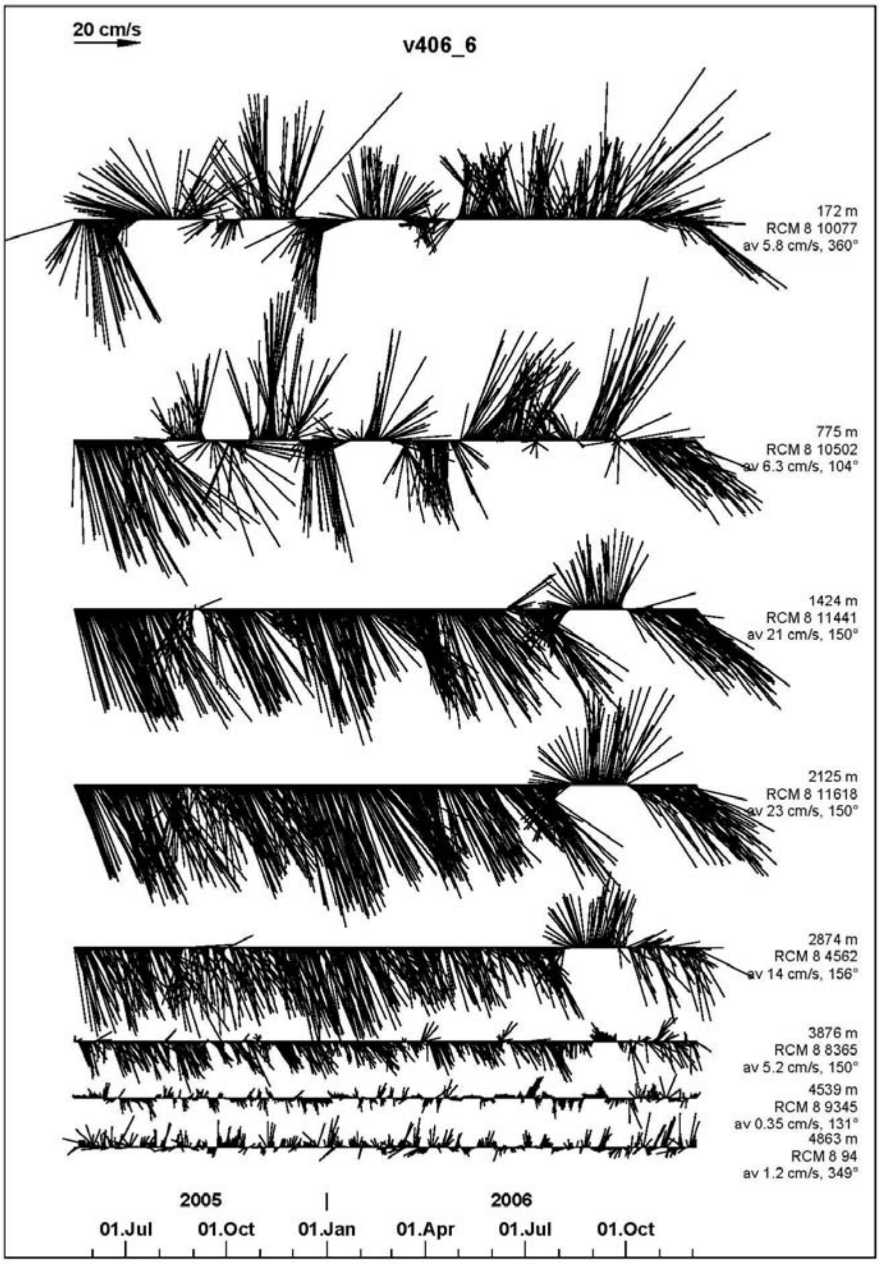

Fig. 1.4b site M3, western geostrophic mooring V406-6, currents; low pass filtered daily averages; up is north direction; depths and average currents indicated

At the eastern flank of the deep basin (site M1, Fig. 1.4c), direct currents were measured only between 1000 m depth and close to the bottom. As expected, the flow is highly variable with weak means throughout this depth range.

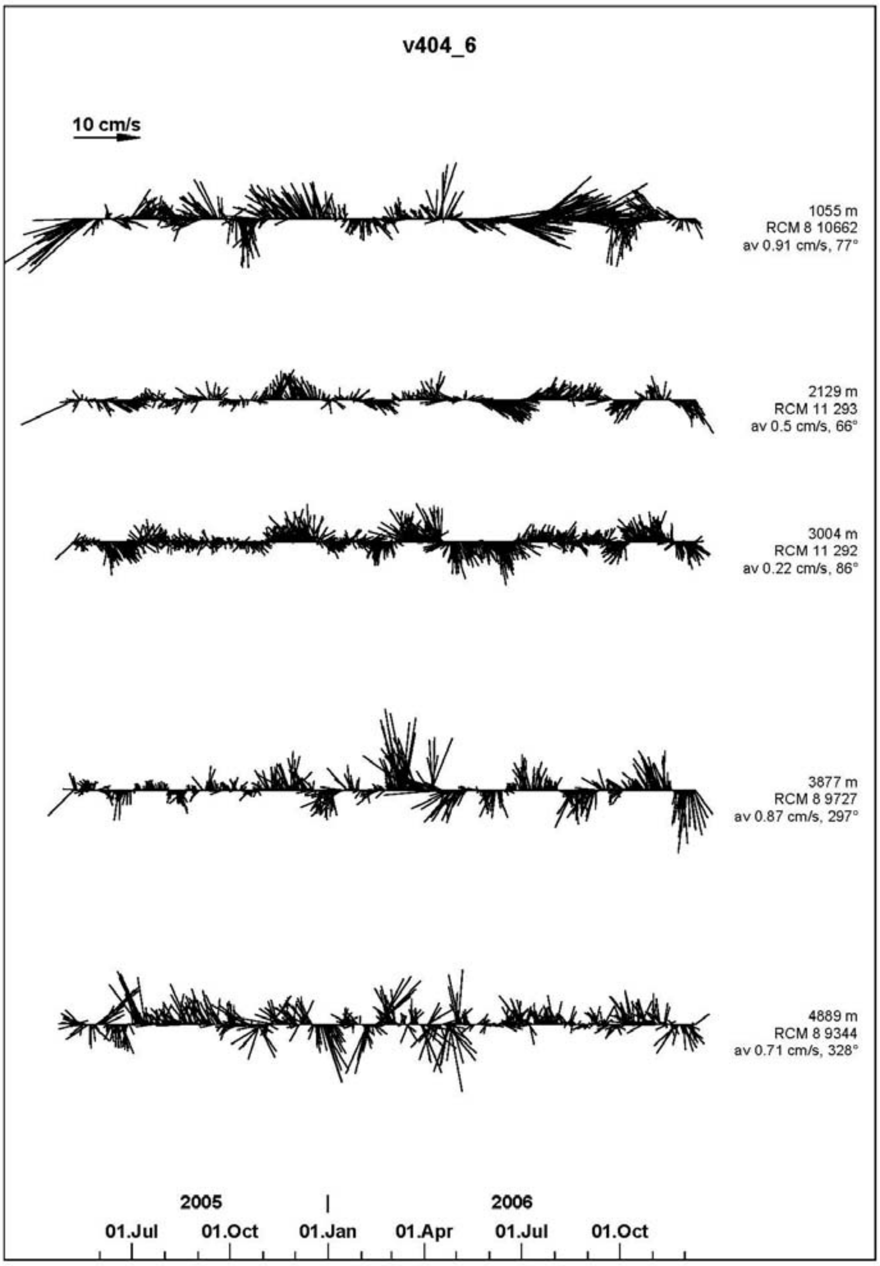

Fig. 1.4c site M1, eastern geostrophic mooring V404-6, currents; low pass filtered daily averages; up is north direction; depths and average currents indicated

Interesting, and a surprise for us is the occurrence of a near surface fresh water lens far offshore at mooring site M1/V404-6 in June 2005; a possible source maybe is water freshened by Amazon (or Orinoco) run off. The fresh water in combination with high temperature increases the density gradient, i.e. it forms a barrier layer, which in turn decreases heat and salt exchange with the colder and saltier water below resulting in higher near surface layer temperatures than usual at that time of the year and keeping the fresh water isolated.

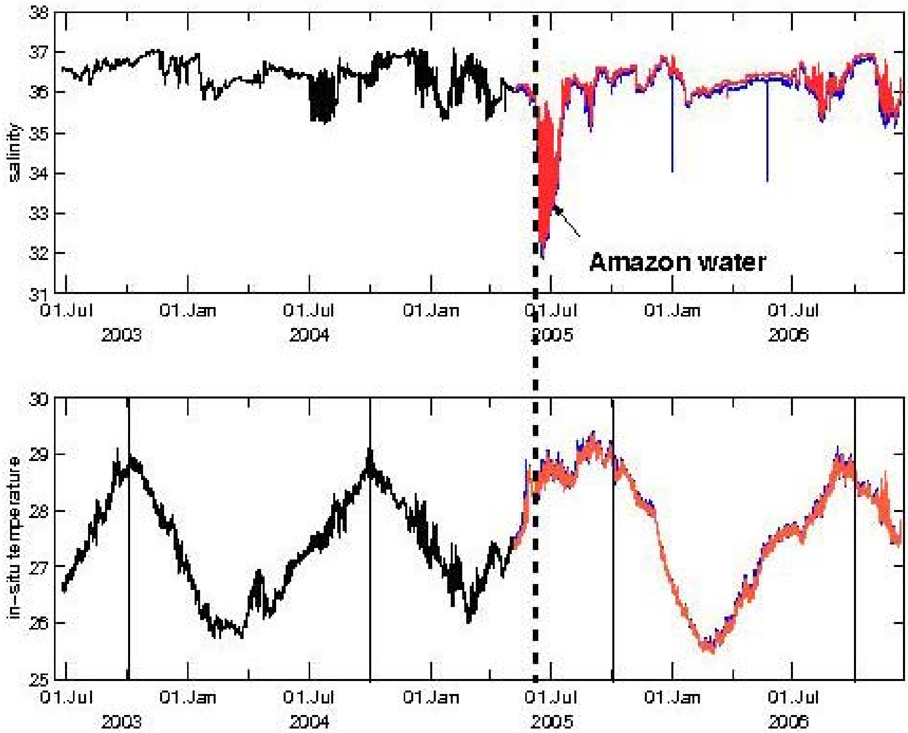

Fig. 1.5 site M1, mooring V404-6, time series of salinity (upper panel) and temperature (lower panel) in the upper 50 m, 2003 - 2006. The vertical lines in the lower panel indicates timing of peak temperatures in late summer. The broken line indicates extremely fresh water which maybe associated with a lens of Amazon (or Orinoco) run river off.

1.4.3 Tomography

To enable integral measurements of deep flow variability using tomography, a low frequency acoustic transmitter was installed at site M4 on mooring V407-06, and a receiver at site M1 on mooring V404-6. The transmitter for several months worked well until April 2006, and so did the receiver. Clock drifts could be determined by comparison with GPS time after recovery. Correlations were good with predicted eigen-rays in the upper levels, but correlation decreased with depth due to the extremely long distance of 1000 km between source and receiver (example for channel 1 in Fig. 1.6).

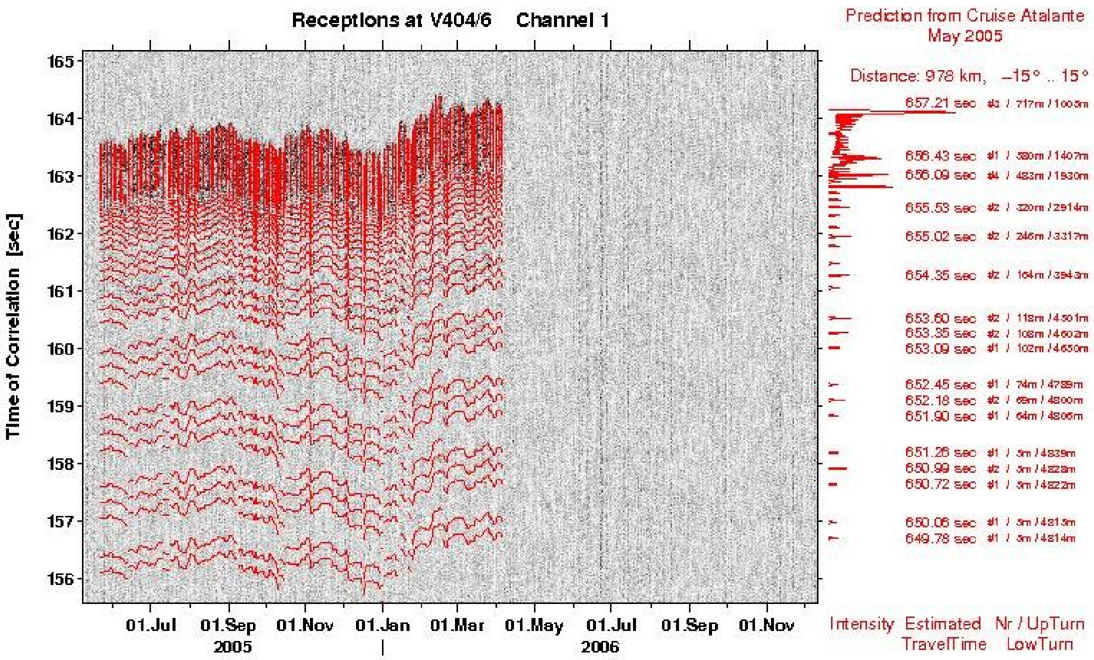

Fig. 1.6 Correlation of received signal f channel 01 with eigen-rays as calculated from hydrographic data of the preceding MOVE cruise in 2005 (Send, 2005). Correlation decreases significantly with depth due to the large distance between the source at M4 and the receiver at M1.

1.4.4 Pressure Sensor Inverted Echo-Sounder (PIES)

Seven PIES were in site since the l'ATALANTE MOVE cruise in 2005 (Send, 2005). Six of them should be read out or recovered and serviced during MSM04/1. For the 7th, PIES 057 off Bermuda, SIO has agreed to service it later in early 2007 during a different cruise in order to save transit times during MSM04/1. Four of the six remaining had a built-in feature that enables them to be read out acoustically without recovery (PIES123, 128, 127 and 165). This feature would enable these PIES to stay at the sea bed and thus avoid an offset in pressure reading after re-deployment, be it for a different water depth or for hysteresis of the pressure sensor. Unfortunately due to a manufacturing failure, the main batteries voltage of the four PIES dropped down ca. 18 months of recording which did not allow any acoustic read-out. The same holds for the two PIES005 and PIES012 which were to be recovered for read out, anyway.

The pressure records of all six PIES (Fig. 1.7a) show long-term drifts. However, the travel time data (Fig. 1.7b) apparently were quite stable. Near-bottom temperature data as measured by the PIES showed some expected short time variability, but rather good long term stability, besides the record of PIES005 (Fig. 1.7c).

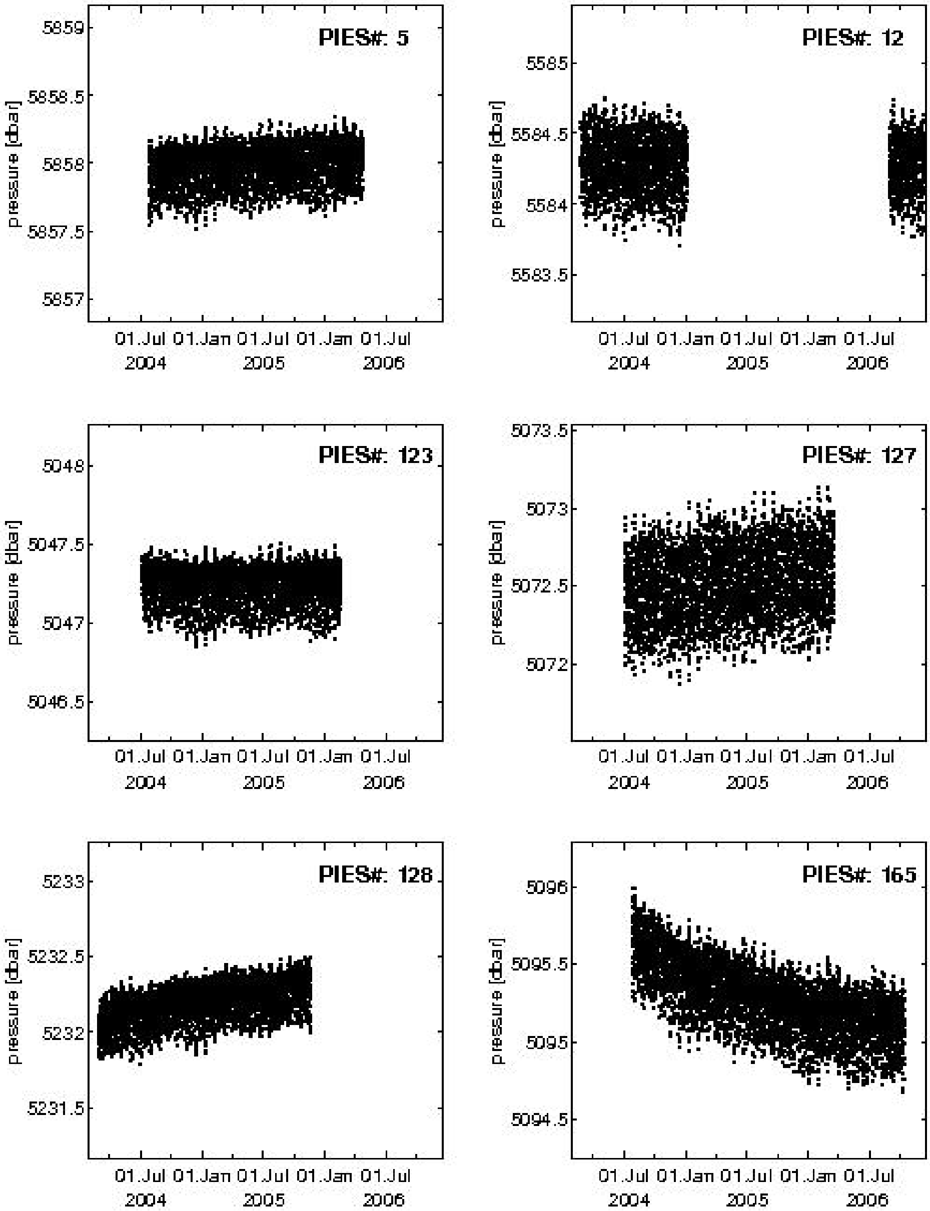

Fig. 1.7a PIES pressure records after recovery during MSM04/1 All records show significant record drift. The data gap in the PIES012 record is due to non-anted reset commands during that period of time.

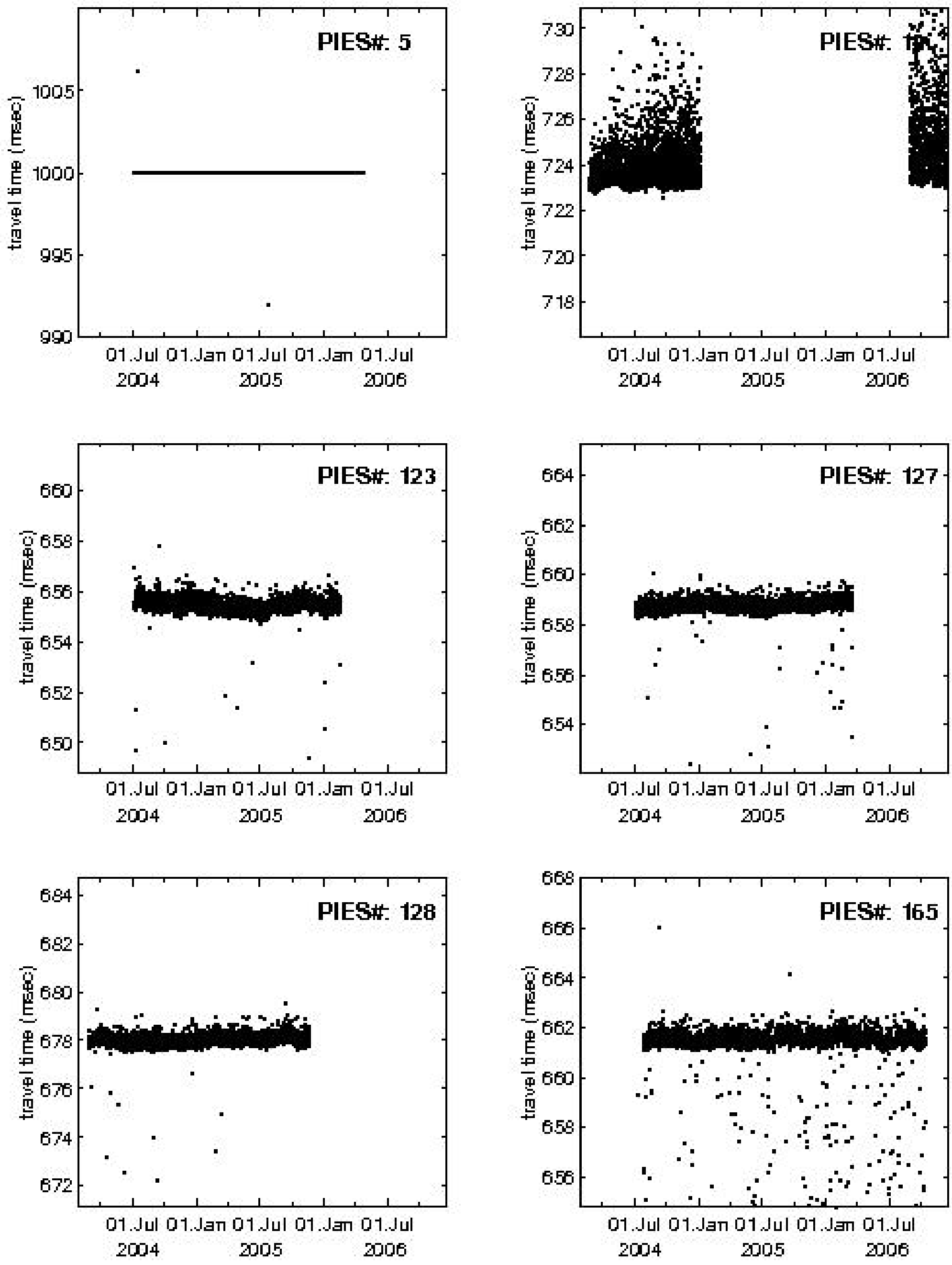

Fig. 1.7b PIES echo-sounder travel times, no data for PIES005.

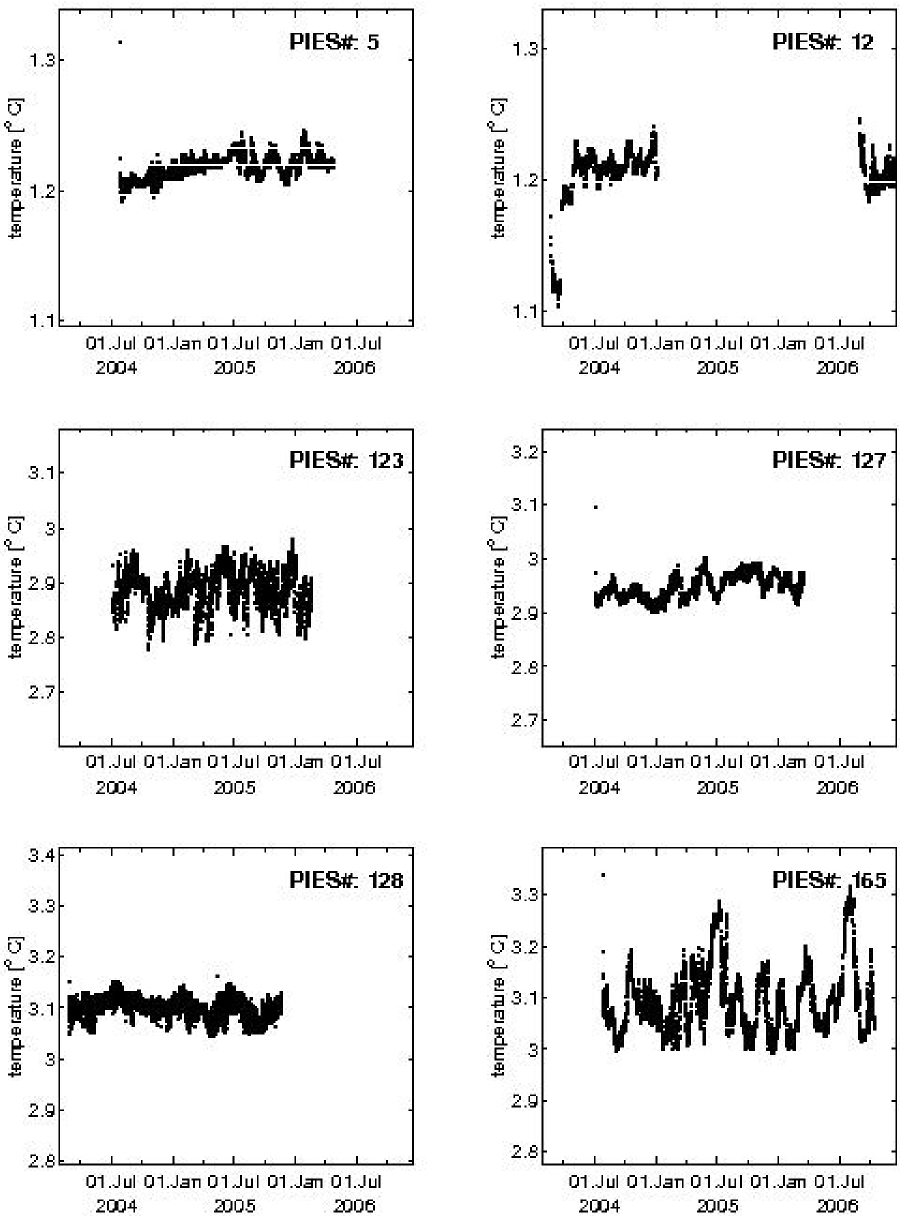

Fig. 1.7c PIES near-bottom temperature records; non-stable record for PIES0005.

1.4.5 Instrument Calibration and Data Processing

1.4.5.1 Ship borne CTD

The CTD used during MSM04/1 was a SeaBird 911 with pressure, temperature, conductivity and oxygen sensors. The pressure and temperature sensor were calibrated before the cruise at IFM-GEOMAR's calibration lab to WOCE standard (WOCE, 1991). A 24x10 l bottle rosette (22 bottles attached only to have space of a lowered ADCP) served to sample water for in-situ calibration of conductivity (salinity) and dissolved oxygen. For salinity, an AUTOSAL 8400 Guildline salinometer was used with standard sea water batch P145, K15=0.99981, S=34.9926. The calibration and processing procedures followed that of the WOCE Hydrographic Office (WOCE, 1991; Müller, 1999). After applying pre-cruise laboratory calibrations for corrections and *in-situ* calibration with samples, we estimate the following accuracies of processed data interpolated to 1 dbar pressure intervals:

- Temperature: 0.002 K
- Pressure: 0.1% of full range
- Salinity: 0.003 psu
- Dissolved oxygen: 5 µmol/l

1.4.5.2 Ship Borne ADCP

The hull mounted ship-borne ADCP is an RDI OCEAN SURVEYOR, 75 kHz. Several steps in processing were applied: first, raw data were converted for a convenient format. Next, navigational data were merged to ADCP data on the same time basis. The ship's speed was estimated by differentiating GPS positions, and as a preliminary correction a first guess misalignment of 48° with a refined correction of 1.000° was determined using time periods while the ship was 'on station', i.e. no large ship speeds are expected. Using this misalignment, data were converted to estimated true North and East components. Further correction is left to final users.

1.4.5.3 Lowered ADCP

From the beginning of the cruise on, two RDI WORKHORSE ADCP, 300 kHz, were mounted onto the rosette frame, one downward and one upward looking to measure the current profile on station (Fischer and Visbeck, 1993). Unfortunately the rosette during casts twisted extensively, and therefore and because of the lack of backscatter in the 'blue' ocean far offshore, no reliable data could be obtained. Only the last 5 casts, when the mechanical problems were overcome and the ship approached waters near the coast with better backscatter conditions, data quality increased and gave reliable data.

1.4.5.4 Moored CTD (MicroCats) and Temperature-Depth Recorders (MTD)

Instruments used are SeaBird made MicroCats (MC) and IFM-GEOMAR developed cheap and small Temperature-Depth-Recorder (MTD). Only three of all MCs had a non-complete data return. Data processing included to add artificial pressure records to those which lacked a pressure sensor *a priori* or had no reliable pressure measurements; all neighbouring instruments were used. Furthermore, all MCs and MTDs calibrations were corrected linearly using pre- and post-deployment calibration casts when attached to a CTD/rosette. At pre-determined pressure levels, the up-cast CTD was stopped for approximately 6 minutes allowing the MCs and MTDs sensors' to adapt and thus allow data comparison at the chosen pressure level. Comparisons between pre- and post-cruise MC calibration casts show rather stable offsets which in return confirms the method.

1.4.5.5 Moored Current Meters (Aanderaa RCM8)

Aanderaa current meters RCM8 and the new generation RCM9 in addition to current speed and direction measure temperature (standard) and pressure (optional). In case of speed measurements with the RCM8, much of achievable accuracy depends on how the rotor movement is free of basic offset and trends due to fouling. As not much is known about the sensor's behaviour during deployment, generally, the calibration sheets of the manufacturer were used to transfer 10-bit raw data to physical units. Nevertheless, experience shows that data are consistent in the vertical and therefore reliable. The same holds for current direction. For temperature measurements, no laboratory calibration is available; instead, measurements at the start and at the end of the record are checked by comparing them with those from CTD casts close to the mooring.

1.4.6 Underway data

1.4.6.1 Ship's Meteorological Station (DWD)

The ship's meteorological station is automated and non-manned. The station provides data to the underway data acquiring system DVS by WERUM and on an 2-hourly basis via METEOSAT into the Global Telecommunication System, GTS. The station is served and maintained by the German Weather Service (DWD) regularly on annual intervals. Sensors installed are

- Wind direction, located in the mast, 31 m above sea level, resolution 2.5 °
- Wind speed, location in the mast, 31 m above sea level, range 0 – 40 m/s.
- Air pressure, mounted in the main box of the automated weather station on the 1st superstructure, separate inlet to sensor, temperature corrected, 0.5 hPa accuracy
- Air temperature, Pt-100 temperature sensor, located on the observational deck, 20 m above sea level
- Humidity, mounted in a shielded box close to the air temperature sensor, 20 m above sea level, electric sensor
- Water temperature, Pt-100 temperature sensor, located in the tank deck, 2 m below sea level

For more technical details see the ship's handbook.

1.4.6.2 Radiation

Radiation is measured by three sensors: within the SMS-1A combined system made by MessSen Nord, Germany. Calibration and maintenance is surveyed by the Institut für Ostseeforschung, IOW, Warnemünde, Germany. The sensors are installed on the signal mast, 19.5 m above sea level in a hydraulically damped cardan suspension thus minimizing effects of pitch and roll in detecting the skyward looking spheric angle 180°. The sensors are

- Downward incoming global radiation (GS, shortwave)
- Infrared radiation (IR, long-wave)
- Photosysntetic available radiation (PAR)

1.4.6.3 Rain-meter

The rain-meter SRM 450/H is made by Eigenbrodt, Germany. It consists of a standard rain collecting funnel and a mass defining droplet counter (RAIN1). It is combined with a second cylindrical catching area including a second droplet counter (RAIN2). From RAIN2, the liquid water content can be estimated which gives a correction for systematic errors in the RAIN1 measurement. The precipitation rate is then estimated from the guideline in the manual.

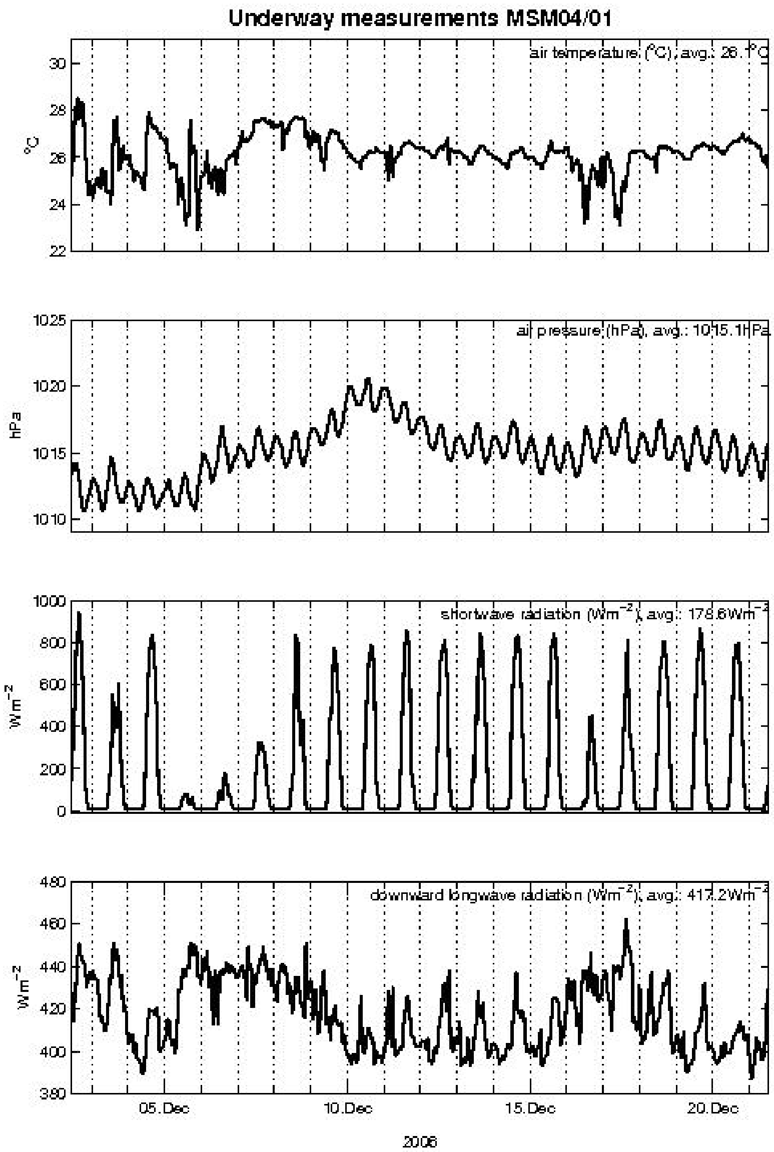

Fig.1.8a Time series from the ship's automated meteorological station, from top to bottom: air temperature, air pressure, short- and long-wave radiation

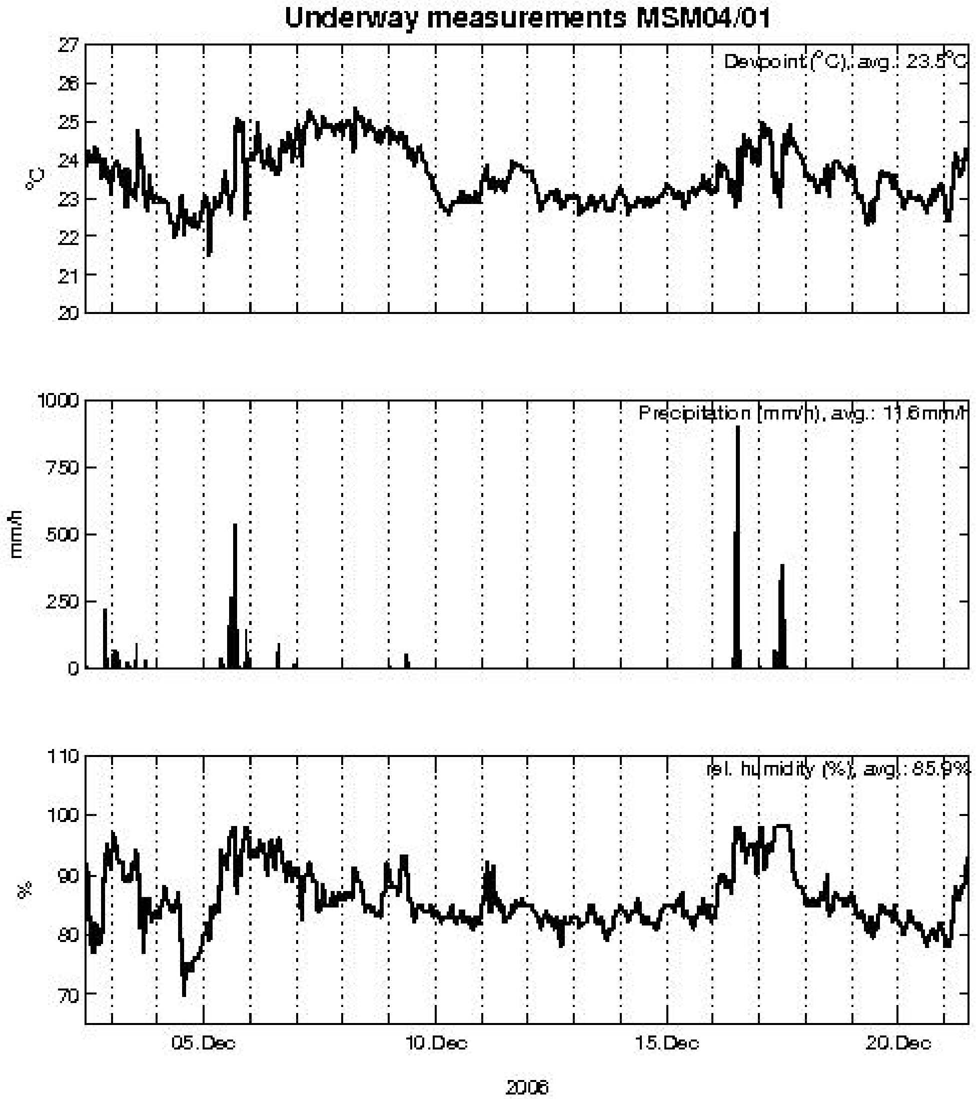

Fig.1.8b Time series from the ship's automated meteorological station, from top to bottom: dew-point, precipitation, relative humidity

1.4.6.4 Thermosalinograph (TSG)

The continuous flow thermosalinograph (TSG) is derived from the multi-parameter measuring system CT48 made by Sea&Sun, Trappenkamp, Germany. Sensors usually are located in the echo sounding room, 2m below the sea surface. Sensors are

- Pt-100 for outside temperature, located at the water inlet in the ship's hull
- Pt-100 for inside temperature close to the conductivity cell
- Conductivity cell, located in the TSG main body within the pipe flow

From bottle samples, the salinity correction is +0.135 psu with an error of 0.02 psu for cruise MSM04/1; no correction was applied to temperature measurements.

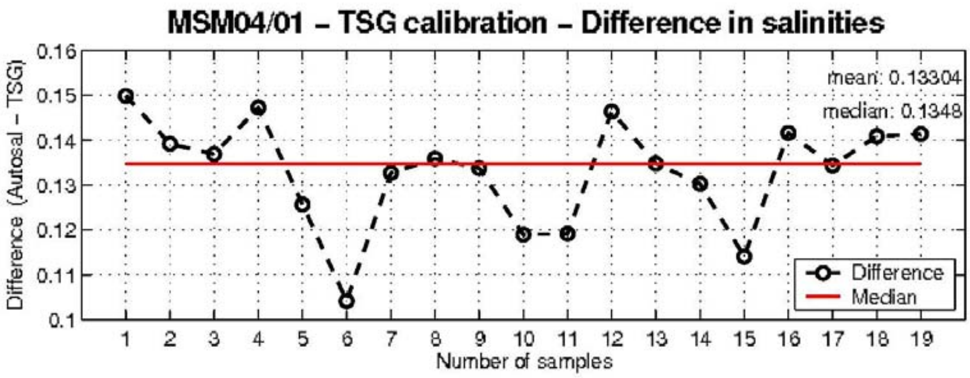

Fig.1.9 Calibration of the thermosalinograph salinity using bottle samples from the seawater inlet at the ship's bow.

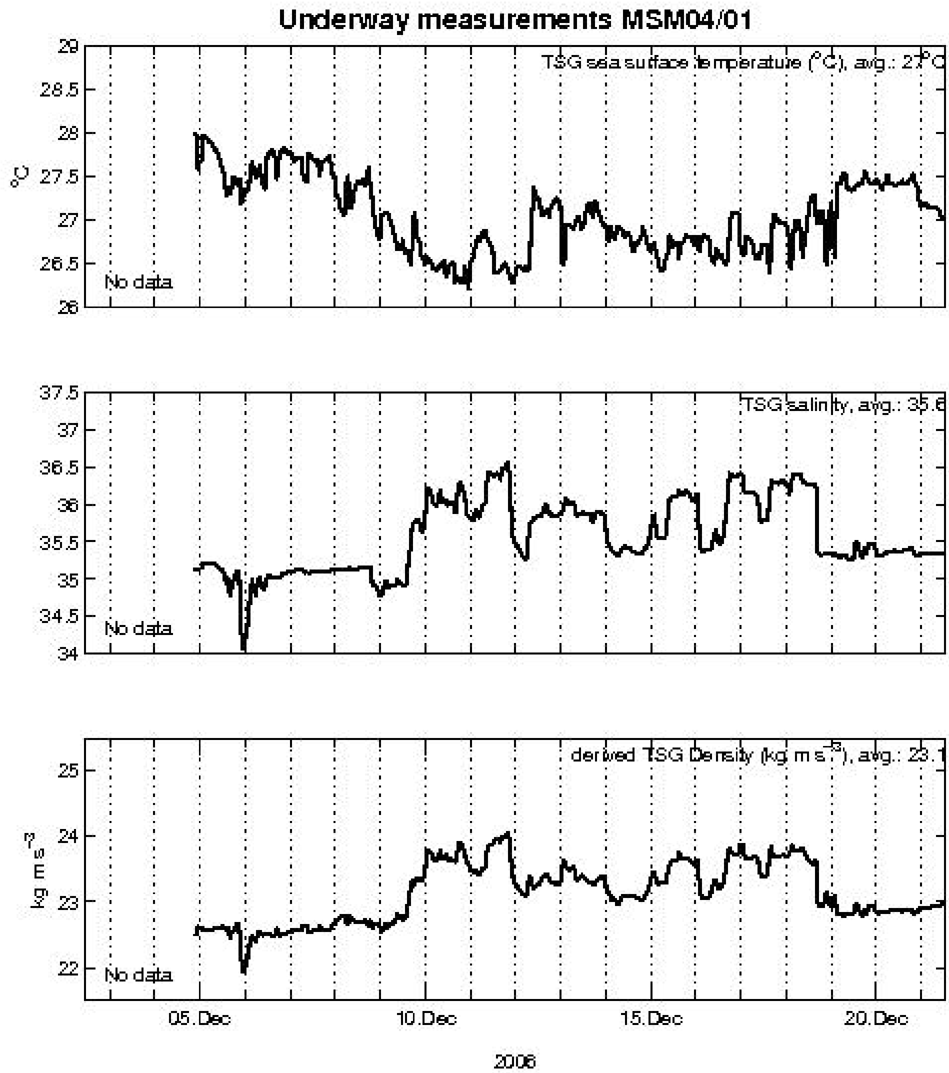

Fig. 1.10: Thermosalinograph time series, temperature (upper panel), salinity (middle), and density (lower)

1.6 Station List MSM04/1

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
967-1	03.12.2006	20:53	15° 46.11'	60° 47.49'	1705.8	CTD/rosette	at surface	Test station, start CTD cast
967-1	03.12.2006	21:37	15° 46.11'	60° 47.49'	1705.9	CTD/rosette	at depth	
967-1	03.12.2006	21:37	15° 46.11'	60° 47.49'	1705.9	CTD/rosette	Information	vmADCP on for testing
967-1	03.12.2006	22:02	15° 46.11'	60° 47.49'	1705.7	CTD/rosette	on deck	
968-1	04.12.2006	01:51	16° 21.30'	60° 29.25'	4959.4	PIES123	start reading	
968-1	04.12.2006	07:27	16° 21.25'	60° 29.35'	45.1	PIES123	finish reading	no signal data
968-2	04.12.2006	12:10	16° 20.26'	60° 30.86'	42.3	Mooring M3/V406-6	release command	start recover mooring
968-2	04.12.2006	20:49	16° 16.14'	60° 26.27'	328.5	Mooring M3/V406-6	mooring on deck	finish recover
970-1	04.12.2006	23:54	16° 20.30'	60° 30.30'	4953.2	CTD/rosette	at surface	start CTD cast
970-1	04.12.2006	23:57	16° 20.30'	60° 30.30'	4953.2	CTD/rosette		cable problem, stop winch
970-1	05.12.2006	00:28	16° 20.30'	60° 30.30'	4953.2	CTD/rosette		continue
970-1	05.12.2006	02:05	16° 20.30'	60° 30.30'	4953.2	CTD/rosette	at depth	4900 m cable length
970-1	05.12.2006	07:45	16° 20.30'	60° 30.30'	4953.2	CTD/rosette	on deck	finish cast
970-2	05.12.2006	12:26	16° 20.40'	60° 37.14'	48.9	Mooring M4/V407-6	release command	start recover mooring
970-2	05.12.2006	17:00	16° 19.33'	60° 36.82'	2809.2	Mooring	on deck	finish recover
972-1	05.12.2006	17:58	16° 19.04'	60° 37.86'	2800	Transponder #01	release command	no response, lost
973-1	05.12.2006	20:09	16° 19.07'	60° 35.65'	43.4	Transponder #02	release command	no response, lost
974-1	05.12.2006	22:03	16° 20.25'	60° 35.50'	3192.1	CTD/rosette	at surface	start CTD cast
974-1	05.12.2006	23:08	16° 20.26'	60° 35.51'	3194.9	CTD/rosette	at depth	3118 m cable length
974-1	06.12.2006	01:22	16° 20.26'	60° 35.51'	3190.6	CTD/rosette	on deck	
975-1	06.12.2006	02:45	16° 21.30'	60° 29.26'	4990	PIES123	start reading	
975-1	06.12.2006	06:24	16° 21.31'	60° 29.08'	44.2	PIES123	finish reading	no signal data

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
976-1	06.12.2006	12:29	16° 21.37'	60° 36.52'	45	Transponder #03	release command	start recover transponder
976-1	06.12.2006	15:23	16° 21.26'	60° 36.17'	51	Transponder #03	on deck	finish recover
977-1	06.12.2006	17:34	16° 19.80'	60° 36.90'	2838	Mooring M4/V407-7	start launch	buoy first
977-1	06.12.2006	21:24	16° 19.83'	60° 36.85'	2718	Mooring M4/V407-7	anchor slipped	
977-1	06.12.2006	21:45	16° 19.69'	60° 36.10'	0	Mooring M4/V407-7		buoy subsurface
978-1	06.12.2006	23:03	16° 21.30'	60° 29.25'	4960	CTD/rosette/lADCP	at surface	start CTD cast
978-1	07.12.2006	00:37	16° 21.30'	60° 29.25'	4959.4	CTD/rosette/lADCP	at depth	4926 m cable length
978-1	07.12.2006	03:48	16° 21.30'	60° 29.25'	4958.7	CTD/rosette/lADCP	on deck	
979-1	07.12.2006	10:20	16° 17.14'	60° 39.50'	2064.9	Mooring M3/V406-7	start launch	buoy first
979-1	07.12.2006	15:34	16° 20.28'	60° 29.70'	4902.3	Mooring M3/V406-7	anchor slipped	
979-1	07.12.2006	16:16	16° 20.15'	60° 30.89'	4901.4	Mooring M3/V406-7		buoy subsurface
980-1	09.12.2006	01:05	20° 36.51'	56° 40.78'	5112.8	CTD/rosette	at surface	start CTD cast
980-1	09.12.2006	02:37	20° 36.51'	56° 40.78'	5056.9	CTD/rosette	at depth	4919 m cable length /, test acoustic releaser.
980-1	09.12.2006	05:50	20° 36.51'	56° 40.78'	5060	CTD/rosette	on deck	
981-1	09.12.2006	06:26	20° 36.50'	56° 41.36'	5060	PIES128	start reading	
981-1	09.12.2006	07:32	20° 36.54'	56° 41.36'	5060	PIES128	finish reading	no signal data
982-1	09.12.2006	13:15	20° 35.52'	56° 40.87'	5020	PIES128	release command	start recover mooring
982-1	09.12.2006	15:10	20° 35.44'	56° 40.93'	5020	PIES128	on deck	finish recover
983-1	11.12.2006	11:12	15° 27.25'	51° 31.34'	0	Mooring M1/V404-6	release command	start recover mooring
983-1	11.12.2006	16:19	15° 32.17'	51° 26.54'	0	Mooring M1/V404-6	mooring on deck	
984-1	11.12.2006	17:09	15° 32.41'	51° 25.47'	0	Transponder #04	release command	finish recover
984-1	11.12.2006	18:40	15° 28.47'	51° 31.34'	0	Transponder #04	on deck	

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
985-1	11.12.2006	19:23	15° 26.86’	51° 31.44’	0	CTD/rosette	at surface	start CTD,, start reading PIES127
985-1	11.12.2006	20:51	15° 26.86’	51° 31.44’	0	CTD/rosette	at depth	4925 m cable length
985-1	11.12.2006	22:57	15° 26.85’	51° 31.44’	1	CTD/rosette	on deck	
986-1	11.12.2006	22:58	15° 26.86’	51° 31.44’	4900	PIES127	start reading	
986-1	12.12.2006	00:03	15° 26.86’	51° 31.44’	4900	PIES127	stop reading	no signal data
987-1	12.12.2006	02:11	15° 22.49’	51° 13.43’	3467.3	CTD/rosette	at surface	start CTD cast
987-1	12.12.2006	03:19	15° 22.49’	51° 13.43’	3469.9	CTD/rosette	at depth	3400 m cable length
987-1	12.12.2006	04:53	15° 22.49’	51° 13.43’	3465.9	CTD/rosette	on deck	
988-1	12.12.2006	10:03	15° 26.09’	51° 30.12’	4973.4	Transponder #05	release command	start recover transponder
988-1	12.12.2006	11:44	15° 26.14’	51° 30.16’	4974.9	Transponder	on deck	
989-1	12.12.2006	11:55	15° 26.28’	51° 29.91’	4969.1	Transponder #06	release command	
989-1	12.12.2006	13:28	15° 26.17’	51° 32.84’	4993.6	Transponder #06	on deck	
990-1	12.12.2006	14:10	15° 26.98’	51° 31.80’	4985.8	PIES127	released	start recover PIES127
990-1	12.12.2006	16:09	15° 26.98’	51° 31.59’	4988.4	PIES127	on deck	finish recover
991-1	12.12.2006	17:04	15° 26.99’	51° 37.21’	5045.7	Mooring M1/V404-7	start launch	buoy first
991-1	12.12.2006	20:05	15° 27.03’	51° 30.25’	4969.5	Mooring M1/V404-7	anchor slipped	
991-1	12.12.2006	20:59	15° 27.04’	51° 31.25’	4979	Mooring M1/V404-7	action	buoy subsurface
992-1	13.12.2006	02:15	15° 29.97’	52° 4.04’	4812.7	CTD/rosette	at surface	start CTD cast
992-1	13.12.2006	03:47	15° 29.97’	52° 4.04’	4812	CTD/rosette	at depth	4822 m cable length
992-1	13.12.2006	05:30	15° 29.97’	52° 4.04’	4806.4	CTD/rosette	on deck	
993-1	13.12.2006	08:34	15° 33.41’	52° 30.05’	5122.9	CTD/rosette	at surface	start CTD cast
993-1	13.12.2006	10:05	15° 33.40’	52° 30.00’	5134.2	CTD/rosette	at depth	4915 m cable length
993-1	13.12.2006	12:20	15° 33.40’	52° 30.00’	5116.8	CTD/rosette	on deck	

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
994-1	13.12.2006	15:32	15° 36.81’	53° 0.04’	5367.2	CTD/rosette	at surface	start CTD cast
994-1	13.12.2006	17:11	15° 36.81’	53° 0.04’	5366.6	CTD/rosette	at depth	4927m cable length
994-1	13.12.2006	18:53	15° 36.81’	53° 0.04’	5379.8	CTD/rosette	on deck	
995-1	14.12.2006	04:07	15° 40.18’	53° 30.05’	5475.6	CTD/rosette	at surface	start CTD cast
995-1	14.12.2006	05:38	15° 40.18’	53° 30.05’	5476	CTD/rosette	at depth	4917m cable length
995-1	14.12.2006	07:32	15° 40.18’	53° 30.05’	5477	CTD/rosette	on deck	
996-1	14.12.2006	10:56	15° 43.61’	54° 0.01’	5474.1	CTD/rosette	at surface	start CTD cast
996-1	14.12.2006	12:32	15° 43.60’	54° 0.00’	5476.4	CTD/rosette	at depth	4919 m cable length
996-1	14.12.2006	14:20	15° 43.60’	54° 0.00’	5472.8	CTD/rosette	on deck	
997-1	14.12.2006	16:08	15° 43.08’	54° 13.63’	5480.9	PIES012	release command	start recover mooring
997-1	14.12.2006	20:08	15° 43.10’	54° 13.74’	0	PIES	sighted	
997-1	14.12.2006	20:21	15° 43.20’	54° 14.23’	0	PIES	recovered	finish recover
997-2	14.12.2006	20:41	15° 43.22’	54° 14.35’	0	CTD/rosette	at surface	start CTD cast
997-2	14.12.2006	22:11	15° 43.22’	54° 14.35’	5477.7	CTD/rosette	at depth	4916 m cable length
997-2	15.12.2006	01:14	15° 43.22’	54° 14.35’	5481.4	CTD/rosette	on deck	
998-1	15.12.2006	03:04	15° 47.00’	54° 30.05’	5519.3	CTD/rosette	at surface	start CTD cast
998-1	15.12.2006	04:39	15° 46.99’	54° 30.05’	5519.3	CTD/rosette	at depth	4924m cable length
998-1	15.12.2006	06:59	15° 47.00’	54° 30.05’	5516.5	CTD/rosette	on deck	
999-1	15.12.2006	10:27	15° 49.44’	55° 0.07’	5491.3	CTD/rosette	at surface	start CTD cast
999-1	15.12.2006	11:56	15° 49.44’	55° 0.06’	5498	CTD/rosette	at depth	4915 m cable length
999-1	15.12.2006	14:38	15° 49.43’	55° 0.07’	5491.7	CTD/rosette	on deck	
1000-1	15.12.2006	19:05	15° 51.93’	55° 30.08’	5115.3	CTD/rosette	at surface	start CTD cast
1000-1	15.12.2006	20:31	15° 51.94’	55° 30.08’	5118.6	CTD/rosette	at depth	4910 m cable length
1000-1	15.12.2006	23:12	15° 51.93’	55° 30.08’	5127.5	CTD/rosette	on deck	

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
1001-1	16.12.2006	02:58	15° 54.33’	56° 0.09’	5190.9	CTD/rosette	at surface	start CTD cast
1001-1	16.12.2006	04:29	15° 54.33’	56° 0.09’	5184.4	CTD/rosette	at depth	4925 m cable length
1001-1	16.12.2006	06:41	15° 54.33’	56° 0.09’	5191.9	CTD/rosette	on deck	
1002-1	16.12.2006	10:30	15° 56.79’	56° 30.02’	5201.2	CTD/rosette	at surface	start CTD cast
1002-1	16.12.2006	12:15	15° 56.79’	56° 30.02’	5197.9	CTD/rosette	at depth	
1002-1	16.12.2006	13:55	15° 56.79’	56° 30.02’	5191.7	CTD/rosette	on deck	start CTD cast
1003-1	16.12.2006	17:40	15° 59.21’	56° 57.07’	5001.1	PIES165	release command	start recover PIES165
1003-1	16.12.2006	19:53	15° 59.36’	56° 57.33’	5033.6	PIES165	on deck	finish recover
1003-2	16.12.2006	20:09	15° 59.21’	56° 57.06’	5005.3	CTD/rosette	at surface	start CTD cast
1003-2	16.12.2006	21:41	15° 59.21’	56° 57.06’	4994.1	CTD/rosette	at depth	4921m cable length
1003-2	17.12.2006	00:51	15° 59.21’	56° 57.06’	5002.2	CTD/rosette	on deck	
1004-1	17.12.2006	03:59	16° 2.09’	57° 30.07’	5351.5	CTD/rosette	at surface	start CTD cast
1004-1	17.12.2006	05:30	16° 2.09’	57° 30.07’	5353.3	CTD/rosette	at depth	4925 m cable length
1004-1	17.12.2006	07:41	16° 2.09’	57° 30.07’	5351.8	CTD/rosette	on deck	
1005-1	17.12.2006	11:39	16° 5.03’	58° 5.02’	5228.9	CTD/rosette	at surface	start CTD cast
1005-1	17.12.2006	13:13	16° 5.02’	58° 5.02’	5226.4	CTD/rosette	at depth	4928 m cable length
1005-1	17.12.2006	15:13	16° 5.03’	58° 5.02’	5228.2	CTD/rosette	on deck	
1006-1	17.12.2006	20:18	16° 10.02’	58° 43.12’	0	PIES005	release command	start recover PIES005
1006-1	17.12.2006	22:29	16° 10.60’	58° 43.08’	0	PIES005	on deck	finish recover
1007-1	18.12.2006	00:49	16° 9.99’	59° 5.04’	5364.3	CTD/rosette	at surface	start CTD cast
1007-1	18.12.2006	02:18	16° 9.99’	59° 5.04’	5399.7	CTD/rosette	at depth	4927 cable length
1007-1	18.12.2006	05:18	16° 9.99’	59° 5.04’	5362.4	CTD/rosette	on deck	

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
1008-1	18.12.2006	08:25	16° 13.98’	59° 35.03’	5194.4	CTD/rosette	at surface	start CTD cast
1008-1	18.12.2006	10:02	16° 13.98’	59° 35.03’	5212.3	CTD/rosette	at depth	4926 m cable length
1008-1	18.12.2006	11:56	16° 13.98’	59° 35.03’	5207	CTD/rosette	on deck	
1009-1	18.12.2006	12:54	16° 14.68’	59° 41.72’	4906.4	towed CTD	at surface	1st try testing towed CTD, small jib boom
1009-1	18.12.2006	13:17	16° 14.60’	59° 42.23’	4871	towed CTD	at depth	stop test; at small jib boom not successful
1009-1	18.12.2006	13:29	16° 14.58’	59° 42.22’	4871.7	towed CTD	on deck	
1009-2	18.12.2006	13:49	16° 14.58’	59° 42.27’	4877.1	towed CTD	at surface	2nd try testing towed CTD, big jibboom
1009-2	18.12.2006	16:18	16° 16.29’	59° 38.21’	5015	towed CTD	at depth	stop test, successful
1009-2	18.12.2006	16:48	16° 16.29’	59° 38.23’	5016.8	CTD/rosette	on deck	
1010-1	18.12.2006	19:54	16° 18.03’	60° 5.05’	4986.7	CTD/rosette	at surface	start CTD cast
1010-1	18.12.2006	20:58	16° 18.03’	60° 5.05’	4982.9	CTD/rosette	at depth	3457 m cable length
1010-1	18.12.2006	23:04	16° 18.03’	60° 5.05’	4984.5	CTD/rosette	on deck	
1011-1	19.12.2006	00:42	16° 17.41’	60° 20.07’	4801.2	CTD/rosette	at surface	start CTD cast
1011-1	19.12.2006	02:11	16° 17.41’	60° 20.07’	4802	CTD/rosette	at depth	
1011-1	19.12.2006	04:47	16° 17.41’	60° 20.07’	4795.6	CTD/rosette	on deck	
1012-1	19.12.2006	06:08	16° 19.01’	60° 28.53’	4833.2	CTD/rosette	at surface	start CTD cast
1012-1	19.12.2006	07:31	16° 19.01’	60° 28.52’	4831	CTD/rosette	at depth	4733m cable length
1012-1	19.12.2006	11:26	16° 19.01’	60° 28.53’	1	CTD/rosette	on deck	
1013-1	19.12.2006	11:27	16° 19.01’	60° 28.53’	4900	PIES123	release command	start recover PIES123
1013-1	19.12.2006	13:23	16° 21.21’	60° 29.44’	4900	PIES	at surface	finish recover
1013-1	19.12.2006	13:55	16° 20.41’	60° 29.39’	4900	PIES123	recovered	

1.6 Station List MSM04/1 (continued)

Station	Date	Time	Latitude	Lonngitude	Depth	Gear	Action	Comment
MSM04/1		UTC	N	W	[m]			
1014-1	19.12.2006	14:43	16° 19.52’	60° 35.03’	3313.1	CTD/rosette/lADCP	at surface	start CTD cast
1014-1	19.12.2006	15:46	16° 19.52’	60° 35.03’	3314.2	CTD/rosette/lADCP	at depth	ca. 3220 m cable length
1014-1	19.12.2006	17:20	16° 19.52’	60° 35.03’	3302.9	CTD/rosette/lADCP	on deck	
1016-1	19.12.2006	20:45	16° 20.25’	60° 44.34’	999.5	CTD/rosette/lADCP	at surface	start CTD cast
1016-1	19.12.2006	21:08	16° 20.25’	60° 44.34’	1000.7	CTD/rosette/lADCP	at depth	965 m cable length
1016-1	19.12.2006	22:20	16° 20.25’	60° 44.39’	997.9	CTD/rosette/lADCP	on deck	finish cast & underway data recording

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