METEOR-Berichte

Mixing and Circulation in the Tropical Atlantic

Cruise No. M98

July 01 – July 28, 2013

Fortaleza (Brazil) – Walvis Bay (Namibia)

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1 Summary

Cruise M98 to the southern tropical Atlantic is a joint effort of the BMBF project RACE and the BMBF project SACUS. Both projects have the overarching goal to gain better understanding for the role of the tropical Atlantic in relation to climate variability in the Atlantic region. According to the special issues within the subprojects, this cruise has two major regional focuses:
Within the framework of RACE, the aim of this cruise is to investigate the variability of the western boundary current system offshore of South America. A special focus is placed on the transport variability of the North Brazil Undercurrent (NBUC) and the Deep Western Boundary Current (DWBC) – as part of the meridional overturning circulation (AMOC) – on timescales from intraseasonal to decadal. The project SACUS is concerned with the influence of the equatorial Atlantic on the upwelling region off Southwest Africa. This cruise aims at investigating these teleconnections from the equatorial region towards the upwelling system and their attributed time scales via wave propagation and water mass advection. The substantial part of work for this cruise consists of the deployment of two mooring arrays at 11°S at the shelf and continental slope off the Brazilian coast and off the Angolan coast. Additionally, the boundary current systems are surveyed with two high-resolution, hydrographic sections (CTD/LADCP, shipboard ADCP) at 5°S and 11°S off Brazil and a hydrographic section (CTD, microstructure, shipboard ADCP) at 11°S off Angola. In addition, the flux of CO_2 and Dimethylsulphide (DMS) between the sea surface and the overlying atmosphere is monitored continuously during the cruise.

Zusammenfassung

Die Reise M98 in den südlichen tropischen Atlantik vereint Feldarbeiten des BMBF Projektes RACE sowie des BMBF Projektes SACUS. Beide Projekte haben das übergeordnete Ziel, ein besseres Verständnis für die Rolle des tropischen Atlantiks in Bezug auf Klimaschwankungen im atlantischen Raum zu erlangen. Der speziellen Zielsetzung der beiden Teilprojekte entsprechend besitzt diese Reise zwei regionale Schwerpunkte: Im Rahmen des RACE Projektes hat die Reise das Ziel, die Variabilität der westlichen Randstromzirkulation vor Südamerika zu untersuchen. Hierbei liegt ein spezieller Focus auf Transportschwankungen des Nordbrasilunterstroms (NBUC) und des tiefen westlichen Randstroms (DWBC) - als Teil der meridionalen Umwälzbewegung (AMOC) - auf intrasaisonalen bis dekadischen Zeitskalen. Das Projekt SACUS beschäftigt sich mit dem Einfluss des äquatorialen Atlantiks auf das Auftriebsgebiet vor der Küste Südwestafrikas. Ziel dieser Reise ist es, die Fernwirkung aus der äquatorialen Region sowohl durch Wellenausbreitung als auch durch Wassermassentransport und die dazugehörigen Zeitskalen zu vermessen. Ein Großteil der Arbeit auf dieser Reise stellt die Auslegung von 2 Verankerungsarrays bei 11°S einerseits vor der brasilianischen und andererseits vor der Küste Angolas dar. Zusätzlich werden die Randstromzirkulationssysteme durch zwei hochauflösende hydrographische Schnitte (CTD/LADCP, Schiffs-ADCP) entlang von 5°S und 11°S vor Brasilien und einen hydrographischen Schnitt (CTD, Mikrostruktur, Schiffs-ADCP) entlang von 11°S vor Angola vermessen. Außerdem wird der Fluss von CO_2 und Dimethylsulphide (DMS) zwischen Ozeanoberfläche und angrenzender Atmosphäre kontinuierlich während der Fahrt bestimmt.

2 Participants

1	Brandt, Peter, Prof. Dr.	Chief Scientist	GEOMAR
2	Arevalo Martinez, Damian	Underway N_2O, CO, CO_2	GEOMAR
3	Bonou, Frédéric Kpèdonou	CTD, UCTD	UFPE
4	de Araújo Magalhães, Phellipe	Brazilian observer	CHM
5	Dengler, Marcus, Dr.	Microstructure, vmADCP	GEOMAR
6	Didwischus, Sven-Helge	CTD, UCTD, moorings	GEOMAR
7	Hounsou-Gbo, Gbèkpo Aubains	CTD, UCTD	UFPE
8	Lüdke, Jan	CTD, UCTD	GEOMAR
9	Kisjeloff, Boris	CTD, optodes, MicroCATs	GEOMAR
10	Krahmann, Gerd, Dr.	LADCP, CTD processing, glider	GEOMAR
11	Macuéria, Marisa Francisca de Novato	CTD, UCTD	INIP
12	Marandino, Christa, Prof. Dr.	Atmospheric flux DMS, CO_2	GEOMAR
13	Müller, Mario	CTD, UCTD, moored ADCPs	GEOMAR
14	Niehus, Gerd	Moorings, CTD, releaser	GEOMAR
15	Ostrovski, Marek	CTD, vmADCP	IMR
16	Papenburg, Uwe	Moorings, current meters	GEOMAR
17	Pereira da Silva, Mario, Dr.	CTD, UCTD	UFRN
18	Raeke, Andreas	Meteorology	DWD
19	Rühs, Siren	Salinometer, CTD, UCTD	GEOMAR
20	Schweizer, Ellen	Winkler oxygen, DMS, CO_2	GEOMAR
21	Steinhoff, Tobias, Dr.	Underway CO_2, CO, N_2O	GEOMAR
22	Tchipalanga, Pedro Cláver Mota	Angolan observer, CTD, UCTD	INIP
23	Vasco, Enoque Canganjo	CTD, UCTD	INIP
24	Vogel, Bendix	Salinometer, CTD, UCTD	GEOMAR
25	Zavarsky, Alex	Atmospheric flux DMS, CO_2	GEOMAR

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DWD	Deutscher Wetterdienst, Seeschifffahrtsberatung, Bernhard-Nocht-Straße 76, 20359 Hamburg, Germany, http://www.dwd.de
IMR	The Institute of Marine Research IMR, Bergen, Norway
INIP	Instituto Nacional de Investigação Pesqueira Republica de Angola
UFPE	Lab. Oceanografia Física Estuarina e Costeira – LOFEC, Depart. Oceanografia da Universidade Federal de Pernambuco – UFPE, Av. Arquitetura, s/n, 50740-550 - Cidade Universitária Recife-PE Brasil, http://www.ufpe.br/docean/index.php
UFRN	Departamento de Geofísica / CCET, Universidade Federal do Rio Grande do Norte – UFRN, Lagoa Nova, Natal - RN, Brazil. CEP 59078-970, http://www.ccet.ufrn.br/

3 Research Program

The research program of M98 consisted of hydrographic and current observations to study the tropical circulation and water mass pathways along the western boundary off Brazil at about 5°S and 11°S and along the eastern boundary off Angola at 11°S. The main tasks during M98 were the deployment of two mooring arrays at about 11°S at the shelf and continental slope off the Brazilian coast and off the Angolan coast, station work with a CTD/Lowered ADCP/Underwater Vision Profiler (UVP) and a microstructure probe, including a short duration deployment of a glider/microstructure package. This program was complimented by continuous measurements of near-surface concentrations of CO_2, N_2O, DMS, and acetone, air-sea gas exchange measurements via turbulent gas fluctuation measurements in the atmosphere, sea surface temperature and salinity as well as measurements of upper ocean temperature and salinity using the underway CTD (UCTD) system, and currents using the two shipboard ADCPs.

4 Narrative of the Cruise

Several events aimed at enhancing the scientific cooperation between different research groups from Brazil and Germany were planned around R/V Meteor cruise M98. As early as 28 June, a joint meeting between Labomar, the Marine Research Institute of the Federal University of Ceará, Fortaleza (UFC), and GEOMAR took place to initiate collaboration between the institutes. During the meeting, a scientific symposium on the subject "Ocean research on biochemical-physical interactions in the tropical Atlantic," in May 2014 was agreed upon which could serve as a highlight towards the conclusion of the German-Brazilian Year (2013/2014). In addition, on 29 June, about 50 invited guests from science, politics and government attended a reception on R/V Meteor. There were many stimulating discussions on the role of science in society, but also related to specific research projects with our various Brazilian partners. Once again, R/V Meteor was open for visiting students, and many expressions of admiration were seen and heard throughout regarding the great opportunities that R/V Meteor has to offer various research groups on board.

The working groups on board this cruise again reflect the strong international focus of our research programs. In addition to colleagues from the Universities of Natal and Recife in Brazil, we welcomed three scientists from Angola on board. They come from the Fisheries Institute INIP of Angola and are partners in SACUS. This collaboration is further strengthened by the EU FP7 project PREFACE "Enhancing Prediction of Tropical Atlantic Climate and its Impacts", which will officially begin in November 2013. This project brings together scientists from 17 European and 10 African institutions. Overall we were very relieved that after many problems upon arrival, with a general strike in Portugal, delayed flights and no luggage, as well as the late berthing after the on-time arrival of R/V Meteor in Fortaleza, all personnel and most of our equipment was sufficiently on time to leave the harbor as scheduled on July 1, 2013 at 9:00.

On July 2 at 13:30, one day after departure from Fortaleza, we commenced the research program with measurements using the CTD/LADCP system along 5°S. Such measurements have been carried out several times during the period 1990 to 2004. With the new measurements, we wanted to demonstrate possible changes in the water mass characteristics of the North Brazil Current due to an increased influx from the Indian Ocean into the South Atlantic. After completion of measurements at 5°S with 13 surface-to-bottom CTD/LADCP stations on July 4, 2013 at 16:50, R/V Meteor headed southwest towards Recife where we stopped offshore briefly to obtain spare parts for the UCTD that had not been delivered in time to Fortaleza. After transit to the next working area, the CTD/LADCP station and mooring work along 11°S commenced on July 5, 2013. Along this section, 4 current meter moorings, one bottom pressure sensor and one PIES (inverted echo sounder with pressure sensor) were deployed. The mooring work went very smoothly without any problems: MicroCAT instruments were calibrated at the CTD prior to deployment. In between and following the mooring work, a total of 21 surface-to-bottom CTD/LADCP station were carried out. Water samples were taken only for calibration of salinity and oxygen sensors of the CTD system. The CTD section was finished on July 10, 2013, and the UCTD section commenced with hourly measurements along the 11-day transit from Brazil to Angola. During this transit, three APEX floats were deployed additionally.

One important aspect of this cruise crossing the South Atlantic at about 11°S were the measurements with the chemistry underway systems. These systems have been working non-stop, providing information on the air-sea concentration gradients of climate-relevant trace gases, namely CO_2, N_2O, DMS, and acetone. In addition, during the first two weeks of the cruise, the TRASE-EC team was working to assemble and test the eddy covariance (EC) DMS, acetone, and CO_2 air-sea gas exchange systems to be ready for this transit. The goal of this work is to directly and simultaneously measure the air-sea flux of the aforementioned gases in conjunction with their air-sea concentration gradients in order to derive the gas transfer coefficient (k). In general, the signals were rather weak during the Atlantic crossing, but were strongly enhanced in the eastern tropical South Atlantic, particularly close to the coastal upwelling regions.

After arriving in Angolan waters on July 21, 2013, the station work started with a CTD station at the continental slope aimed at calibrating salinity and oxygen sensors for the upcoming mooring deployments. R/V Meteor then sailed along the section on the shelf from 11°S, 12°45’E to 10°30’S, 13°30’E at 7kn to measure the bathymetry using the echo sounder EM122, as well as currents using both shipboard ADCPs. The detailed topography survey allowed us to determine the final mooring positions along this section. In the shallow waters on the shelf, starting at about 40m water depth, microstructure and CTD measurements were taken during the night to reach the first mooring position at the shelf break (200m water depth).

On July 22, 2013, the first of the two bottom shields with a 150 kHz ADCP was deployed without problems. At the same position, following the mooring deployment, the glider ifm02 with a microstructure probe attached was deployed using the zodiac of R/V Meteor. The glider was programmed to profile along a 4 nm-section following the 200 m isobath, measuring the turbulent mixing at the shelf break for about two days. Weak winds and waves allowed for a very smooth deployment. After deploying a bottom pressure sensor at about 300m water depth, the deployment of the second bottom shield with a 75 kHz Longranger ADCP started after lunch of the same day at a water depth of 500 m. The procedure to deploy the bottom shield was again to lower the shield with the ship’s wire close to the bottom and then release it with a standard mooring release. The depth of this release as well as the release in the bottom shield can be ranged by acoustic signals transferred via a hydrophone from a board unit. Unfortunately, the shield release opened and due to its buoyancy - the shield plus instrumentation rose to the surface. We recovered the shield and prepared it for another deployment. The following night was used to continue the CTD and microstructure section from the night before. We noted that the microstructure board unit did not receive data from the probe, indicating a potential problem with the cable – a problem we had also experienced during previous cruises. An inspection of the microstructure cable showed indeed a long cut in the cable mantle for unknown reasons. The cable had to be substantially shortened to continue with microstructure measurements during the next day. On July 23, the second bottom shield was deployed without problems. It was released a few meters above the bottom and was easily tracked after dropping to the sea floor. On the same day the last two moorings, one at the shelf at 450 m depth with temperature, salinity and oxygen sensors and another one at about 1230 m depth with another 75 kHz Longranger ADCP, were deployed. The CTD section was completed with a station spacing of about 3.5 nm. During the night about 11 h of microstructure measurements on the shelf were carried out at ship speed of about 1.5 kn. These measurements were aimed at understanding the strong sea surface cooling observed near the coast under very low wind conditions that likely is triggered by the breaking of tidally induced internal waves generated at the continental slope and propagating onshore. After recovery of glider ifm02, the scientific program at the 11°S section was completed and the ship headed toward Walvis Bay with a continuation of underway measurements. The last station of M98 was the glider deployment off Walvis Bay on July 27, 2013. The glider is aimed at surveying the upwelling filaments, the research subject of cruise M99 with chief scientist Detlef Quadfasel on board. The glider will be recovered at the end of M99.

The ship arrived at the port of Walvis Bay, Namibia on July 28 at 8:00. The cruise track of M98 is depicted in Fig. 4.1.

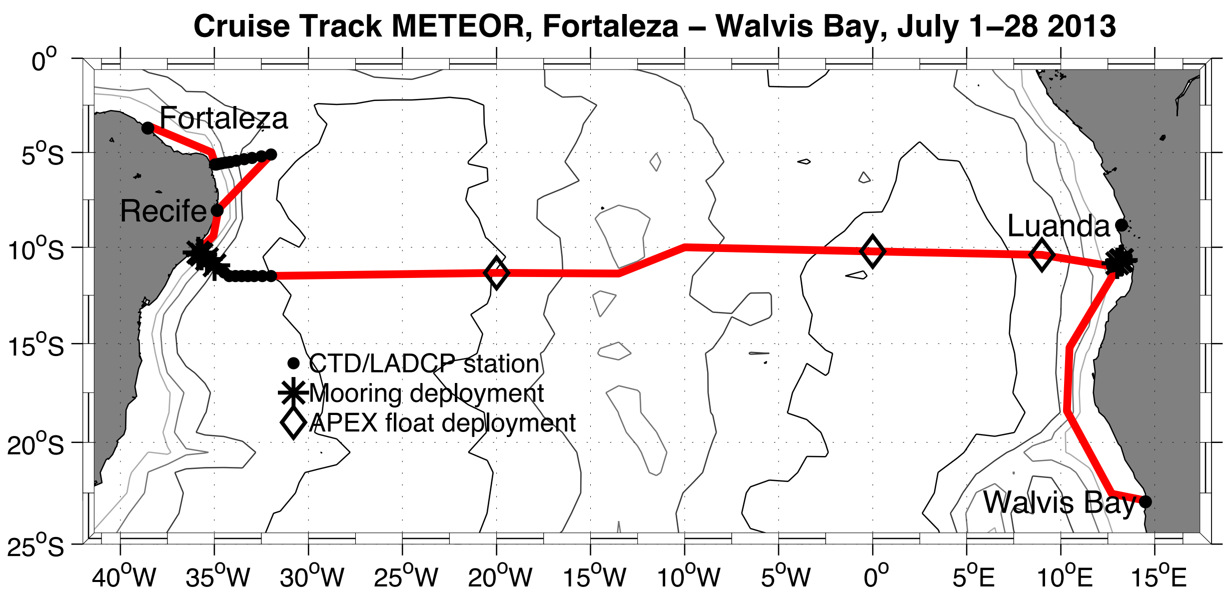

Fig. 4.1 Ship track of R/V METEOR cruise M98 (red line) with locations of CTD/LADCP stations (dots), mooring deployments (stars), and APEX float deployments (diamonds) marked.

5 Preliminary Results

5.1 CTD, Oxygen Measurements and Underwater Vision Profiler

(Gerd Krahmann, Ellen Schweizer, Helena Hauss)

During M98 a total of 55 CTD profiles were collected down to full ocean depth (see CTD station list). During the whole cruise the GEOMAR SBE#3 with a Seabird SBE 9 CTD rosette system was used. The CTD system was equipped with one Digiquartz pressure sensor (s/n 615) and double sensor packages (temperature 1 = s/n 4835, temperature 2 = s/n 2120, conductivity 1 =

s/n 3374, conductivity 2 = s/n 3300, oxygen 1 (sbe 43) = s/n 1287, oxygen 2 (sbe 43) = s/n 1718). Data acquisition was done using Seabird Seasave software version 7.21k. Initially GEOMAR's deckunit system CTD-DU 04 was used during profile 1. At about 85 m depth the system malfunctioned with the deckunit's fuses blowing repeatedly. The CTD-rosette was brought back on deck for error analysis. With varying configurations we were not able to set up a properly working system by connecting GEOMAR's deckunit 04 or the spare system deckunit 05 with the CTD. R/V Meteor is equipped with a similar system. The ship's deckunit never displayed any problems with the CTD and it was decided to use this one for the remainder of the cruise. No further problems occurred with this deck unit.

The CTD was mounted on the GO4 rosette frame with a 24-bottle rosette sampling system with 10 l bottles. In varying configurations, a maximum of 21 bottles were attached to the rosette.

Except for the primary oxygen sensor, all sensors worked without problems during the whole cruise. The primary oxygen sensor had a sudden change in measured values at about the deepest part of profile 29. Since the secondary sensor was working well, the problematic sensor was not exchanged. For the final data we decided to use the secondary set of sensors for the whole cruise. The GEOMAR Guildline Autosal salinometer #7 was used for CTD conductivity cell calibration (operated by B. Vogel and S. Rühs). Calibration during operation was done in two ways: IAPSO Standard Seawater (P150, K15=0.99978) was measured at the beginning of the salinometer use. In addition, a so-called "substandard" (essentially a large volume of water with constant but unknown salinity), obtained from deep bottles from the CTD casts was used to track the stability of the system. For the first half of the cruise the salinometer worked quite well. During the second half of the cruise we found the system to be noisier. Likely causes are the only shallow stations of the second half of the cruise and some problems with the temperature control of the gravimeter room where the Autosal measurements took place.

The conductivity calibration of the downcast data was performed using a linear fit with respect to conductivity, temperature, pressure, and days since the first CTD (C_corrected = C_observed -0.00149 - 1.128e-007 * P -7.6938e-005 * T + 0.0009244 * C). Using 67% of the 259 samples for calibration a RMS of 0.00027 S/m corresponding to a salinity of 0.0026 PSU was found for the downcast. We chose the downcast as final dataset as: 1) Sensor hysteresis starts from a well-defined point, and 2) the incoming flow is not perturbed by turbulence generated by the CTD-rosette.

For the oxygen calibration, 286 water samples were taken from the CTD rosette. These samples were titrated using standard Winkler technique (operated by E. Schweizer). The oxygen calibration of the downcast data was then done using a linear fit with respect to oxygen concentration, temperature, and pressure (O_corrected = O_observed 0.32202 + 0.0029847 * P + 0.089071 * T + 0.071781 * O). Using 67% of the 286 samples, an RMS uncertainty of 1.4852 μmol/kg was determined.

As an example, oxygen concentration measured along the 5°S section off Brazil is shown in Fig. 5.1a.

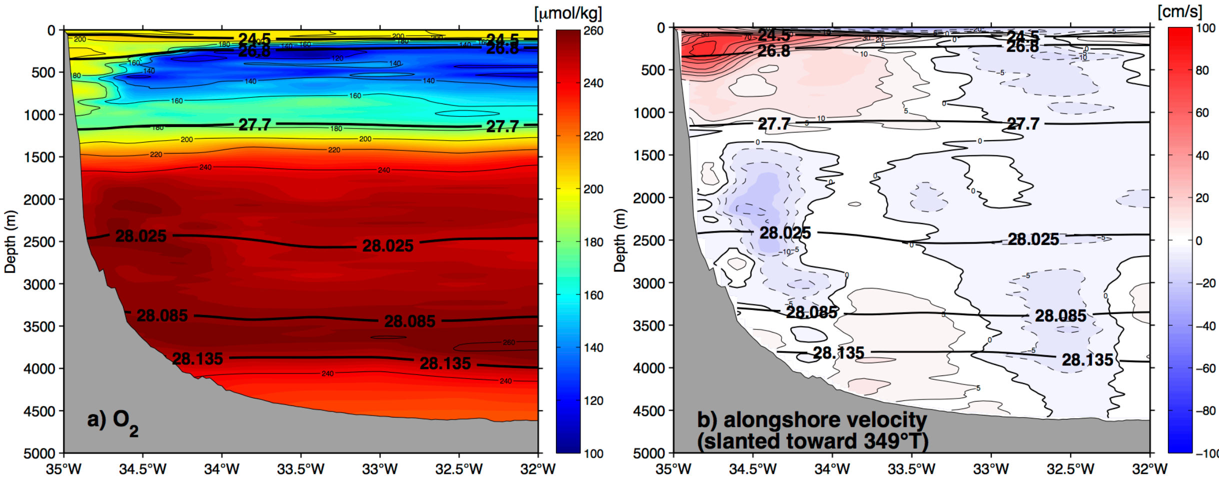

Fig. 5.1 Dissolved oxygen concentration (a) and alongshore velocity (b) at ~5°S off Brazil measured during M98 with neutral density surfaces (thick solid lines) superimposed. Positive velocity (reddish colors) in (b) is toward 349° relative to true north (~North by west).

During 52 CTD casts, an Underwater Vision Profiler 5 (UVP 5) - kindly provided by Prof. Lars Stemmann, Laboratoire d'Océanographie de Villefranche (LOV), France - was mounted on the CTD rosette. The instrument consists of one downward-facing HD camera in a 6000dbar pressure-resistant case and two red LED lights, which illuminate a 0.93L-volume. During the downcast, the UVP takes 3-11 pictures per second of the illuminated volume. For each picture, the number and size of particles are counted and stored for later data analysis. Furthermore, images of particles with a size > 500 µm are saved as a separate "Vignettes" - small crop-outs of the original picture – which allow for subsequent computer-assisted identification of these particles and their grouping into different particle, phyto- and zooplankton classes. Since the UVP was integrated in the CTD rosette and interfaced with the CTD sensors, fine-scale vertical distribution of particles and major planktonic groups can be related to environmental data.

5.2. Current Observations: Technical Aspects

5.2.1 Vessel-Mounted ADCP

(Marcus Dengler)

R/V Meteor's two vessel-mounted acoustic Doppler current profilers were used continuously to record upper-ocean velocities during the cruise. Throughout most of the cruise, the OS75 was configured to sample data in narrow-band mode using a bin size of 8m, a pulse length of 8m and a blanking distance of 4m. In this configuration, 100 depth bins were recorded. To better resolve non-linear internal waves on the continental slope and shelf off Angola at 11°S, the sampling configuration was altered for the data collected between 04:45 UTC to 16:20 UTC on July 24. During this period, the OS75 was pinging in broad-band mode using a bin length of 4m, a pulse length and blank of 4m while 60 bins were recorded. The OS38 was configured to use 32m bins in narrowband mode. Furthermore, a pulse length of 32m and a blanking distance of 16m were used and 55 bins were recorded. The configuration of the OS38 was not altered during the cruise. While the range of the OS75 was typically about 700m, the range of the OS38 varied between 1200 m and 1600m depending on sea state and ship speed. The ping rates were 2.4 seconds for the OS75 and a little more than 3 seconds for the OS38. Both Ocean Surveyors worked well throughout the cruise. Due to a power failure on R/V Meteor on July 5th, a 1.5 hour data gap resulted in the proximity of the continental slope at 11°S. Although the power failure lasted only a few seconds, the data acquisition software did not automatically restart.

The post-processing of the OS75 worked well and a mean misalignment angle of 1.16° resulted from calibration. Scatter of the calibration angle was significantly reduced when accounting for a time shift of the heading data relative to the raw OS data. Here, an optimum calibration was found when shifting the heading data from the SeaPath device by 7.5 seconds backward relative to the recorded ping. The standard deviation of the misalignment calibration then yielded 0.66. Post-processing of the OS38 data has not been completed to date. Although a relatively small average misalignment angle of 0.38° was determined for the transducers and a much larger delay of the heading data delay (15 seconds) seems to optimize the miss-alignment angle calibration, there seems to be a dependence of the misalignment on the average roll angle of the vessel. This dependence is currently being investigated.

The post-processed OS data from the 75kHz instrument was used to constrain the processing of the lowered-ADCP data (see next section). A merged velocity section of the circulation present along the western boundary at 11°S with the North Brazil Undercurrent in the upper 1000 m and the Deep Western Boundary Current below is shown in Fig. 5.1b. Measurements at the eastern boundary at 11°S focus on the upper ocean circulation as measured with the OS75 (Fig. 5.2). At depths between 50m and 250m, the Angola Undercurrent, a poleward flowing current carries waters from the equatorial region and from the Angola Dome southward. The mooring array deployed along this section will allow us to determine the variability of the Angola Undercurrent after the array will be retrieved in 2014.

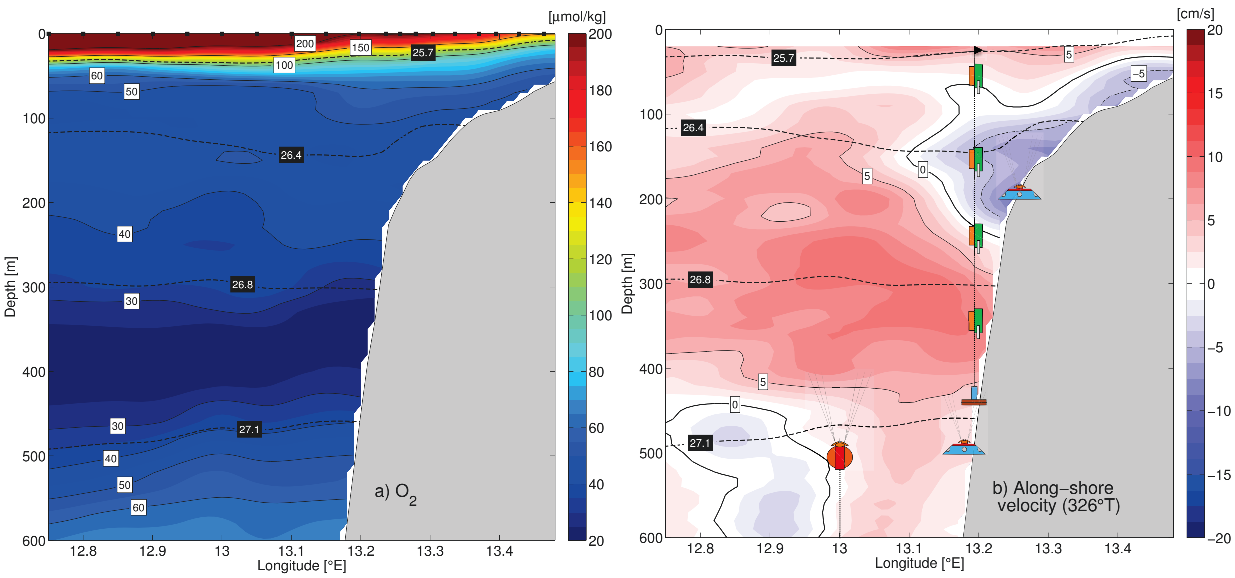

Fig. 5.2 Dissolved oxygen concentration (a) and alongshore velocity (b) at ~11°S off Angola measured during M98 with potential density surfaces (thick dashed lines) superimposed. Positive velocity (reddish colors) in (b) is toward 326° relative to true north (~Northwest by north). Schematic of moored instrumentation is superimposed in (b). The mooring array is equipped with three ADCPs, two ADCPs within bottom shields on the shelf at 200 m and 500 m depth and one ADCP at 500 m depth at 13°E. The hydrographic mooring located at the shelf at a water depth of about 450 m is equipped with 4 MicroCATs and 4 oxygen loggers measuring at 350, 250, 150 and 50 m depth.

5.2.2 Lowered ADCP Sampling

(Gerd Krahmann)

During the entire cruise the CTD system used was equipped with a lowered ADCP setup based on two Teldyne RDI ADCPs. Initially a setup similar to that of MSM 22 was in operation with a downlooking 150 kHz system and an uplooking 300 kHz system. Similar to that cruise, the two systems were mounted within the CTD-Rosette with especially manufactures frames protecting the instruments and zero obstruction of the acoustic beams. A battery pack was mounted below the uplooking slave instrument (SN #11436), both ADCPs were connected to it as it is the connection point for the data interface cable. During profiles 1 to 9, the 150 kHz system #14910 was used. During profile 9, it developed a bad beam and was replaced by system #14911. This instrument also developed a bad beam during profile 33. After that we installed the 300 kHz system #6468 as the down-looking master system. The two 300 kHz systems worked fine until the end of the cruise.

Several times problems occurred with the data download system, a GEOMAR developed cable arrangement. After profile 29, downloading was not possible with the system. A lengthy analysis of all involved components showed that a cable inside the deckunit had a faulty contact. This cable was replaced with the respective operational part from another deckunit, which had another problem on M96. After profile 41, the data download failed a second time. Again we found a cable fault, this time in the long cable connecting the deckunit with the battery pack. This cable was reconfigured and was operational again from profile 50 onward.

Data processing took place during the cruise using the GEOMAR LADCP processing software V10.17, which includes both shear and inversion methods to derive an absolute velocity profile. As additional data were necessary for the processing, the corresponding pre-processed CTD files for the cast P T S, time and navigation data were used.

Overall the RDI instruments performed well and resulted in good deep ocean velocity profiles when processed in conjunction with the observations of the shipboard ADCP. As an example, the alongshore velocity component measured along the 5°S section off Brazil is shown in Fig. 5.1b.

5.3 Mooring Operations

(Sven-Helge Didwischus, Peter Brandt)

During the cruise, 11 moorings were deployed (Table 5.1). Along the 11°S section at the Brazilian coast, an array of 4 current meter moorings was deployed that represent a repetition of similar moored observations during the period 2000-2004 (Dengler et al., 2004; Schott et al. 2005). Off the coast of Angola along the 11°S section, a mooring array was deployed, consisting of one mooring measuring temperature, salinity and oxygen, two bottom shields equipped with ADCPs, and one ADCP mooring. On both sides of the basin, bottom pressure sensors were deployed at 300m depth. At the Brazilian coast at 500m, a Pressure Inverted Echo Sounder (PIES) was deployed which has an additional pressure sensor included in one of the bottom shields as the corresponding counterpart.

R/V Meteor M98 Mooring Deployments				
Mooring	**New ID**	**Latitude**	**Longitude**	**Deployment Date**
K1	KPO_1095	10°16.0'S	35°51.7'W	6-Jul-13
K2	KPO_1096	10°22.8'S	35°40.8'W	7-Jul-13
K3	KPO_1097	10°36.5'S	35°23.6'W	7-Jul-13
K4	KPO_1098	10°56.4'S	34°59.6'W	8-Jul-13
	KPO_1104	10°39.718'S	13°15.428'E	22-Jul-13
	KPO_1105	10°42.104'S	13°11.852'E	23-Jul-13
	KPO_1106	10°42.574'S	13°11.131'E	23-Jul-13
	KPO_1107	10°50.0'S	13°00.0'E	23-Jul-13
	KPO_1108	10°13.677'S	35°52.5'W	6-Jul-13
	KPO_1109	10°14.149'S	35°51.905'W	6-Jul-13
	KPO_1110	10°40.443'S	13°14.433'E	22-Jul-13

Table 5.1 Mooring deployments.

5.4 Glider Operations

(Gerd Krahmann)

During the cruise, one autonomous glider system manufactured by Teledyne Webb Research was deployed. The system (ifm02/deepy) was equipped with a set of built-in sensors. They encompassed a CTD, an Aanderaa optode to measure dissolved oxygen, and a Wetlabs combined CHL-a fluorescence and turbidity sensor. In addition to this regular set of sensors, ifm02/deepy carried an external microstructure sonde manufactured by Rockland Scientifc. On 22 July, the glider system ifm02/deepy was deployed at 10°40'S, 13°15'E. The system was commanded to measure between two waypoints within 2 nm of the deployment location. The glider was recovered on 24 July. Initial inspection of the recovered data indicated that all systems, including the microstructure probe, had worked well. The same glider was again deployed on 27 July at 22°35'S, 12°36.7'E. The glider was commanded to measure along a track towards 26°15'S, 11°15'E. On 17 August this glider was successfully recovered during cruise M99 (chief scientist Detlef Quadfasel). All deployment and recovery operations were done using the inflatable boat of R/V Meteor.

5.5 Autonomous and Shipboard Microstructure Measurements

(Marcus Dengler)

A microstructure measurement program was carried out off Angola aimed at quantifying diapycnal fluxes of solutes, in particular the fluxes of the greenhouse gases N_2O and CO_2, along the Angolan continental margin and identifying the dominant physical processes responsible for elevated mixing along the continental slope and mixing processes associated with filaments in the Namibian Upwelling region. The dataset is necessary to achieve the research objectives of the BMBF Joint Projects SACUS and SOPRAN. The measurement program consisted of autonomous microstructure sampling by a glider equipped with a MicroRider microstructure instrument (Rockland Scientific), and of shipboard microstructure sampling using a profiling system manufactured by Sea & Sun Technology.

Glider-MicroRider package

The MicroRider (S/N 038) was attached to the top of glider ifm02/deepy. The glider-MicroRider package allows sampling of autonomous microstructure profiles for periods of up to 4 weeks per deployment without requiring additional ship time except for glider deployment and recovery. During M98, the package was deployed twice, but only recovered once. The final recovery of the package took place during the follow-up cruise M99. The MicroRider was equipped with two microstructure shear sensor and two fast-responding temperature sensors (FP07). No sensor failure was found after the first recovery and the same set of sensors detailed in Table 5.2 was used during both deployments.

Mission / Glider / MR	**Date and time (UTC)**	**Channel and shear sensors, sensitivity and orientation**	**Channel and Temp. sensors**
Dive 1 / ifm02 MR sn 38	22nd Jul. 08:47 – 24th Jul. 13:51	S1: M930, S_0=0.0768, w' (vert.) S2: M932, S_0=0.0607, v' (horiz.)	T1: T 724 T2: T 722
Dive 2 / ifm02 MR sn 38	27th Jul. 14:21 – 16th Aug. 07:50†	S1: M930, S_0=0.0768, w' (vert.) S2: M932, S_0=0.0607, v' (horiz.)	T1: T 724 T2: T 722

† - Recovered by R/V Meteor cruise M99

Table 5.2 Deployment schedule and configuration of Glider/MicroRider packages.

Microstructure Profiling

The ship-based microstructure measurements were performed using a MSS90-D profiler (S/N 32), a winch and a data interface. The loosely-tethered profiler was optimized to sink at a rate of 0.55 ms^{-1}. In total, 215 profiles were collected on 11 stations along the continental slope and the shelf region off Angola at 11°S. The profiler were equipped with three shear sensors, a fast-response temperature sensor, and an acceleration sensor, two tilt sensors and conductivity, temperature, depth sensors sampling with a lower response time. In addition, a fast responding oxygen sensor was attached to the profiler.

All sensors worked well throughout the measurement program. Presumably due to bites into the tether cable by a sea lion, data transmission failed on July 22nd at 22:41 after profile 93. About 250m of microstructure cable had to be cut due to the damaged underwater cable. Profiling resumed on July 24 at 03:30. During the whole cruise, shear sensor sn 123 was attached to shear channel S1, shear senor sn 029 was attached to S2, and shear sensor sn 052 was attached to S3.

Along the Angolan shelf, surface flow convergence zones of 50-100m were prominent, indicative of nonlinear internal wave packages propagating onshore. With the collected data set, we intend to investigate the role of mixing by the nonlinear internal waves trains. A first impression of the mixing with such internal waves is given in Fig. 5.3.

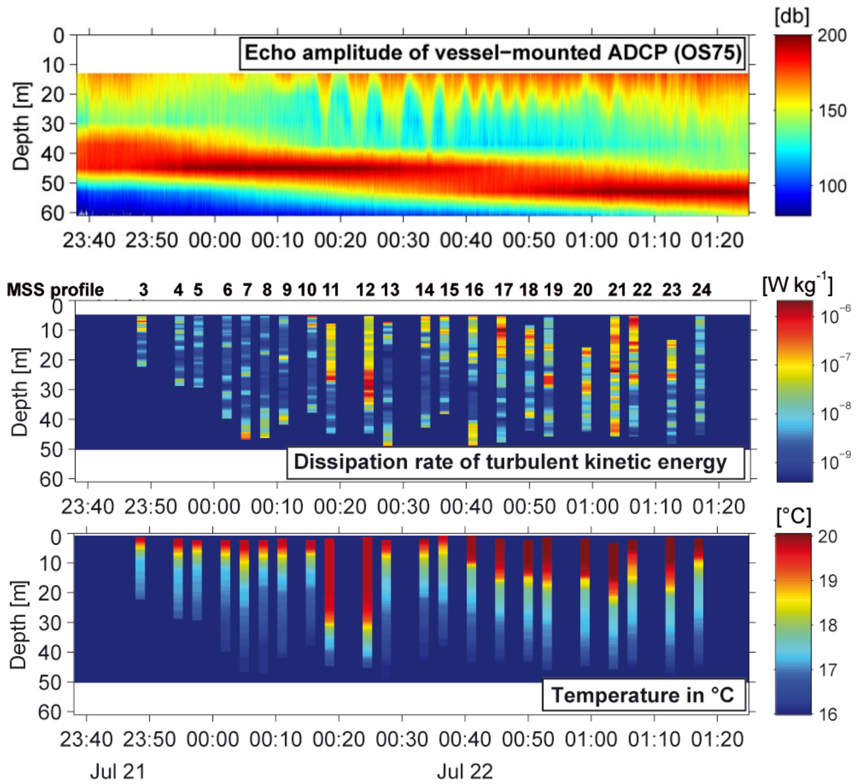

Fig. 5.3 Backscatter amplitude of shipboard ADCP (upper panel), dissipation rates of turbulent kinetic energy from shipboard microstructure profiling (middle panel), and temperature from microstructure profiles (lower panel). The plots show a nonlinear wave train and temperature variability on the shelf off Angola. Intense turbulence is associated with the nonlinear waves.

5.6 Chemical Measurements

5.6.1 Eddy Correlation Measurements of DMS, Acetone, and CO_2

(Alex Zavarsky, Tobias Steinhoff, Christa. A. Marandino)

Motivation

In order to investigate the ocean's role in the atmospheric budget of climate active trace gases, we deployed a new eddy covariance (EC) direct flux measurement system onboard M98. The EC technique can be used to perform biogeochemical cycling measurements without typical pitfalls associated with bulk flux calcuations, as well as to constrain the main forcings on air-sea gas exchange. Using the direct flux (F), $F = \rho <w'c'>$, from EC measurements, we can attempt to improve the gas transfer parameterization (k) used in bulk formulas, $F = (HC_w - C_a)$, where ρ is density, w' are the fast fluctuations in vertical wind speed, c' are the fast fluctuations in atmospheric gas concentrations (angle brackets denote time averages), C_w and C_a are water and air concentrations, respectively, and H is the Henry's law solubility constant. Our goal was to measure dimethylsulfide (DMS) and CO_2 flux, but we hope to expand the measurement technique to a wide range of OVOCs (oxygenated volatile organic compounds) and other important trace gases. Measurements began at 31°W, when steaming eastward along 11°S, and were continued until the end of the cruise track at Walvis Bay.

Instrumentation

Atmospheric and seawater levels of DMS and acetone were measured using an atmospheric pressure chemical ionization mass spectrometer (AP-CIMS) (Saltzman et al., 2009). Air was sampled through a ½" 15 m tube from a mast welded to the bow (approximately 10 m above the sea surface) at a flow rate of 75 l min^{-1}. Seawater was analyzed using an air stream continuously equilibrated with seawater pumped from the moon pool. CO_2 was measured using a Licor 7200 infrared analyzer. Air was sampled through a ½" 15 m tube from the bow mast at a flow rate of 16 l min^{-1}. Both air streams were dried with Nafions®. To obtain turbulent wind speed measurements and sensible heat flux, a sonic anemometer was placed at the bow mast. A GPS and inertial navigation system (INS) was used for motion correction (Fig. 5.4).

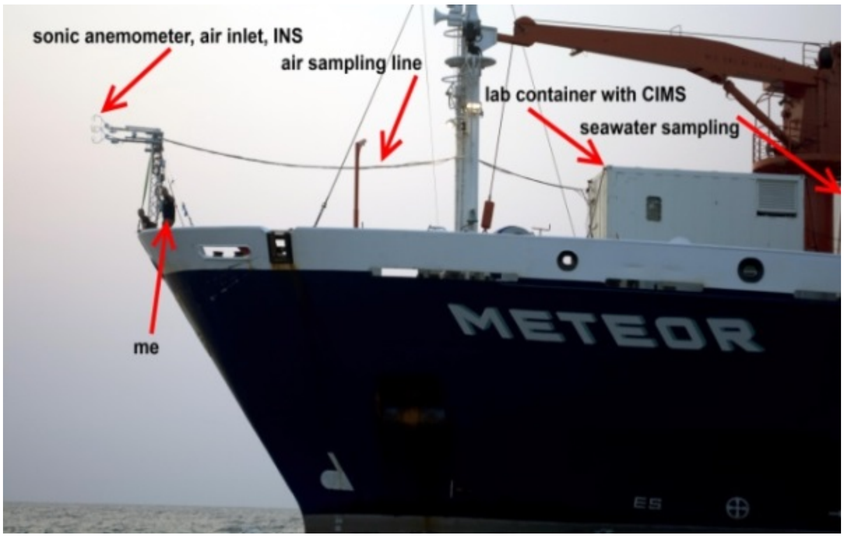

Fig. 5.4 EC instrumentation setup.

Wind data correction and sensible heat flux

Before correlating wind and gas fluctuations, the ship's motion must be removed from the measured wind speed. GPS and INS data were used to compute the pitch, roll, and yaw of the ship. Additionally, we applied multilinear regression of all measured motion signals to further correct the wind speed. Sensible heat fluxes are measured using the vertical wind and sonic temperature (T') measured at the mast to correct the gas fluxes for high frequency signal attenuation in the tubing, $F = \rho c_p \langle w'T' \rangle$, where c_p is the heat capacity of air.

Bulk DMS and acetone concentrations

Fig. 5.5 shows elevated atmospheric mixing ratios and water concentrations just east of 12°E as coastal waters of Angola and high productivity areas were reached. Both saturation states indicate a flux from ocean to atmosphere. Nonetheless, the ocean's role as a source or sink for acetone is heavily disputed (Marandino et al., 2005; Sinha et al., 2007). This dataset supports the ocean as a source of acetone. However, the AP-CIMS sensitivity was not good enough to detect EC fluxes.

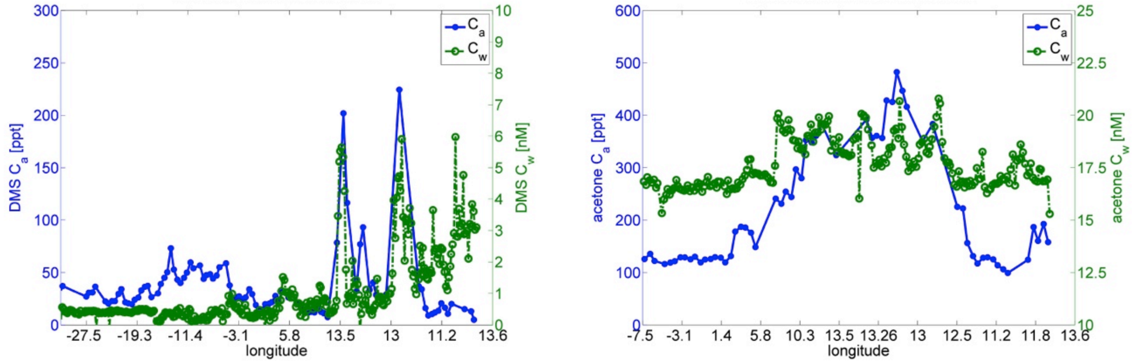

Fig. 5.5 Atmospheric mixing ratios (C_a, blue) and seawater concentrations (C_w, green) of DMS (left) and acetone (right) measured during M98.

CO_2 flux measurements

Coastal upwelling associated with reduced SST was observed close to the Angolan coast. Upwelling transports and mixes deeper water with higher CO_2 levels to the surface and causes supersaturation of CO_2 with respect to the atmosphere, thus triggering fluxes from the oceanic mixed layer to the atmosphere. Here we were able to detect CO_2 fluctuations in regions of favorable air-sea gradients, but concurrent measured wind speeds were not sufficiently high to perform the EC flux analysis. As an alternative, in this region, the diapycnal flux of CO_2 into the mixed layer will be calculated using microstructure measurements and concurrent gas profiles. In combination with air-sea fluxes calculated from the underway measurements, we aim to estimate a budget of this gas in the mixed layer.

5.6.2 Underway Measurements of CO_2, CO, and N_2O

(Damian L. Arévalo-Martínez and Tobias Steinhoff)

Oceanic and atmospheric measurements of N_2O, CO, and CO_2 were carried out by means of a continuous system based on the off-axis integrated cavity output spectroscopy technique (RMT-200 N_2O/CO Analyzer, Los Gatos Research Inc.) coupled to a CO_2 system based on non-dispersive infrared detection (General Oceanics Inc.). Water was drawn on board by using a submersible pump installed in the ship's moonpool at 6 m depth and was subsequently pumped at a rate of about 3 l min^{-1} through the equilibrator. Sample air from the headspace of the equilibrator was continuously pumped through the instruments and then back to the equilibration chamber forming a closed loop. The air stream was dried before being injected into the analyzers in order to diminish interferences due to the water vapor content of the sample. In order to correct for potential warming of the seawater between intake and equilibrator, the water temperature at the equilibrator was constantly monitored by means of a high accuracy digital thermometer and at the intake by a Seabird SBE38 high precision thermometer. Ambient air measurements were accomplished by drawing air into the system from a suction point located at the ships mast at about 30 m high. Control measurements and calibration procedures were performed every ~6 and 24 h respectively, by means of 3 standard gas mixtures. Fig. 5.7 shows the over- or undersaturation of N_2O and CO_2 with respect to the atmosphere. During most of the cruise, both gases were near equilibrium, while strong supersaturation was observed when entering the coastal upwelling region along the African coast.

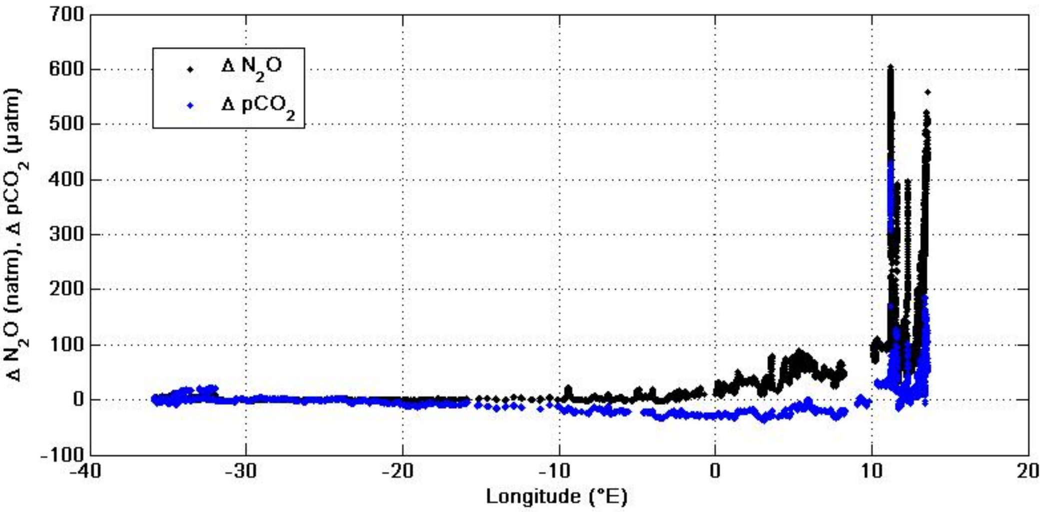

Fig. 5.7 Partial pressure difference between atmosphere and surface ocean of N_2O and CO_2. Positive values mean the seawater is oversaturated with respect to the atmosphere. In these regions the ocean acts as a source for these gases.

Underway measurements of surface water O_2, gas tension and salinity were carried out in a flow-through-flow box. The box was connected to the same water supply and the water flow was adjusted to 20 l min^{-1}. The following instruments were implemented: Aanderaa Oxygen Optode, Pro Oceanus Gas tension device, and Aanderaa Conductivity Sensor. The gas tension device physically measures the total pressure of all dissolved gases, i.e, pN_2, pO_2, pH_2O, and *p*Ar as well as minor trace gases below the instrument's accuracy. As water vapour pH_2O is a function of temperature and salinity, Argon pAr is constant, and Oxygen pO_2 is measured by the oxygen optode, it effectively gives the pN_2, which is a prime indicator of physical processes of gas exchange, such as bubble processes, and unaffected by biology. It thus helps to separate biological and physical contributions to air-sea gas exchange of O_2. This is complemented by the biology-dominated pCO_2 measurements in water and air. In combination with information about the mixed layer from the CTD, the continuous underway measurements thus yield insight into major physical and biological processes at play in the surface ocean. Occasionally, discrete oxygen and salinity samples were taken from the bypass to compare these underway measurements.

Discrete comparison samples for N_2O and CO_2 were carried out in 8 h intervals by sampling from the same water stream that fed the underway setup. N_2O and DIC/TA samples were collected and stored to be measured at the Chemical Oceanography Department of GEOMAR in Kiel. In addition, sampling for nutrients (NO_3^-, NO_2^-, PO_4^{-3} and SiO_4), CDOM (chromomorphic dissolved organic matter) and chlorophyll was carried out during the same periods and samples were frozen to be transported and processed in Kiel. Such measurements are needed in order to better understand the biogeochemical processes affecting dissolved gases in the surface ocean.

Depth profiles

A total of 10 N_2O and DIC/TA depth profiles were obtained by using a CTD-rosette (Table 5.3). Sampling was coordinated with other working groups such that every profile can be associated to microstructure measurements of the surface layer (up to ~200m depth). For N_2O, bubble-free samples were collected in triplicates from 10 l Niskin bottles and subsequently preserved by adding 50 µl of a saturated solution of mercuric chloride. DIC/TA samples were collected in 500 ml, borosilicate glass bottles (Schott Duran®) with ground glass stoppers and were preserved by adding 100 µl of a saturated solution of mercuric chloride. All samples were prepared for transport in order to be measured at the Chemical Oceanography Department of GEOMAR in Kiel.

#	Date	Position	Depths (m)
1	2013-07-21	10° 30.001'S 13° 30.004'S	2, 5, 10, 15, 20, 25, 30, 37, 42
2	2013-07-22	10° 31.444'S 13° 27.857'S	2, 5, 10, 15, 20, 24, 30, 36, 39, 45, 54
3	2013-07-22	10° 32.865'S 13° 25.702'S	2, 5, 10, 15, 20, 24, 30, 33, 38, 46, 50, 60, 73
4	2013-07-22	10° 34.183'S 13° 23.725'S	2, 5, 10, 15, 20, 30, 50, 70, 85
5	2013-07-22	10° 39.722'S 13° 15.422'S	2, 5, 10, 15, 20, 30, 50, 100, 150, 194
6	2013-07-22	10° 35.193'S 13° 22.214'S	2, 5, 12, 20, 25, 50, 75, 98
7	2013-07-22	10° 36.561'S 13° 20.162'S	2, 5, 15, 30, 40, 50, 75, 104
8	2013-07-22	10° 37.851'S 13° 18.231'S	5, 10, 15, 20, 30, 40, 65, 119
9	2013-07-22	10° 38.838'S 13° 16.754'S	5, 10, 15, 30, 40, 60, 90, 143
10	2013-07-23	10° 40.569'S 13° 14.191'S	5, 15, 25, 50, 130, 150, 200, 294

Table 5.3 List of stations where depth profiles of N_2O and DIC/TA were obtained.

5.7 Underway-CTD Measurements

(Sven-Helge Didwischus and Gerd Krahmann)

During the transit across the South Atlantic, 259 Underway CTD (UCTD) profiles were taken from 10 July to 21 July, providing a section from 32°45’W to 12°30’E down to about 360 m. In general profiles were taken hourly while steaming at about 10kn. Two probes (S/N 68, CTD-S/N 2078955 and S/N 138, CTD-S/N 2126794) were used alternately, changed for data download and recharging every 6 hours. On 16 July one probe (S/N 138) started to show noisy conductivity data, so only the other probe (S/N 68) was used afterwards.

During the cruise both UCTD winches had to be repaired due to jammed bearings. In one case the bearings of the spool had to be replaced. The same winch later also suffered a broken retaining pin and a frozen clutch, leading to the melting of conduits on the circuit board.

For calibration purposes the uppermost data of the UCTD systems was compared to thermosalinograph data that previously had been calibrated against the CTD. This comparison showed significant differences in salinity between the two UCTD and against the thermosalinograph. The reason for the comparatively high (about 0.2 PSU) and slowly changing differences is unclear, and further and very careful analysis is required. The temperature measurements agreed well between the two UCTD and the thermosalinograph systems.

5.8 Thermosalinograph Measurements

(Bendix Vogel)

During the cruise, sea surface temperature (SST) and sea surface salinity (SSS) were continuously measured by a Thermosalinograph. SSS and SST measurements worked well throughout the cruise. Both SST datasets (T1 and T2) as well as the SSS data were calibrated using data from 55 CTD stations and had an estimated standard error of 0.074°C (T1), 0.070°C (T2), and 0.031 (SSS) after calibration, respectively.

The accuracy of both temperature sensors changed slightly during the cruise. Whether this was due to a time drift or due to a temperature dependency cannot be decided because SST continuously decreased along the cruise track. However, temperature sensor T1 showed a mean offset of about −0.32°C compared to the CTD data, whereas the mean offset of T2 was only −0.02°C. The offset between T1 and T2 of about 0.3°C was mostly constant although during the last days of the cruise it increased to about 0.4°C.

In contrast to SST, for SSS a time drift of about 0.003/day could be clearly identified.

During cruise M99, D. Quadfasel reported a possible problem with the salinity values of the thermosalinograph system. This was apparently caused by a low flow rate in the system of some 10-15 l min-1 compared to the manufacturer's recommendation of 60 l min-1. This results in a 130 s delay between the conductivity measurements and the respective temperatures. We found no clear indication of this problem and thus leave this uncorrected for the moment.

6 Weather Report

(Andreas Raeke)

The research area encompasses the region off the northeastern coast of Brazil, the southern tropical Atlantic, and the region along the coasts of Angola and Namibia. At the beginning of the cruise, R/V Meteor was located between the monsoonal trough and a high over the southeastern Atlantic in a southeasterly airstream. On the night of 2 July, the southerly winds measured 6 to 7 Bft, and showery gusts of 9 Bft were reported. Later the wind shifted southeast and decreased to 4 Bft. The air temperature was hovering around 26 °C.

Until 7 July a low was located at the northeastern tip of Brazil producing precipitation at times. The sea reached at first 1.5 m and increased from 5 July up to 2 to 2.5 m with an east to southeast wind of 5 to 6 Bft.

In the more southern working area within a low-pressure gradient, the southeasterly wind abated to 4 to 5 Bft. On 9 July the southeast trade winds increased to 5 to 6 Bft due to an eastward migrating subtropical high located at 30°S and 40°W. R/V Meteor encountered constant headwinds while on transit to Angola. The chief scientist and the master agreed on the route as any alternative course would not have brought any time savings. The high moved at the same speed as R/V Meteor. The sea reached a height of around 2.5 m with a 2m swell from southeast. While headed eastward, the temperature dropped to 21°C. From 18 July on 0 meridian towards the east, no showers were experienced and the wind decreased to 4 to 5 Bft. The sea reached a height of 1.5 to 2m. Low stratus below the tradewind inversion around 1000m generated a depressive mood. As R/V Meteor approached the coast of Angola, the wind dropped further to 3 Bft. From 21 July in the working area close to the Angolan coast, the swell dropped further to 1m.

In the following days until the 24 July a shallow low was located over Angola. This resulted in mostly southerly winds with Bft 3 to Bft 4, at times from the north with 2 Bft.

In the vicinity of the coast, a land sea breeze set in. During the afternoon 24 July, the wind increased to 4 Bft. On 24 July, the pressure over southern central Africa deepened and a high-pressure ridge extended from South Africa to Angola. During the transit to Namibia, the pressure gradient increased with the result of the swell growing to 2m from the south and the sea increasing to 2.5m. R/V Meteor headed into a southerly wind of 4 to 5 Bft. On 25 July, the wind abated to 2 to 3 Bft and on 27 July the wind increased again to 4 to 5 Bft. During the transit from Angola to Namibia, with the cold Benguela current offshore, the temperature dropped from 21°C to 14°C before R/V Meteor reached the port of Walvis Bay in Namibia on 28 July.

7 Lists M98

7.1 Station List

Station No. M98 Ship/Science		**Latitude**	**Longitude**	**Time**	**Work**
1362	CTD_1	5°39.0'S	34°57.6'W	2.7. 13:30-13:50	**CTD/LADCP** station (250m), stopped at 80m
1363	CTD_2	5°39.0'S	34°57.6'W	2.7. 16:20-16:40	**CTD/LADCP** station (280m)
1364	CTD_3	5°38.3'S	34°56.0'W	2.7. 17:10-17:40	**CTD/LADCP** station (740m)
1365	CTD_4	5°38.0'S	34°54.0'W	2.7. 18:20-19:40	**CTD/LADCP** station (1680m)
1366	CTD_5	5°36.6'S	34°46.0'W	2.7. 21:00-23:00	**CTD/LADCP** station (2830m)
1367	CTD_6	5°34.8'S	34°36.0'W	3.7. 00:10-3:00	**CTD/LADCP** station (3400m)
1368	CTD_7	5°32.7'S	34°24.0'W	3.7. 4:20-7:10	**CTD/LADCP** station (3760m)
1369	CTD_8	5°30.2'S	34°10.0'W	3.7. 08:50-11:20	**CTD/LADCP** station (4110m)
1370	CTD_9	5°26.6'S	33°50.0'W	3.7. 13:20-16:30	**CTD/LADCP** station (4350 m)
1371	CTD_10	5°21.7'S	33°25.0'W	3.7. 19:00-22:20	**CTD/LADCP** station (4500 m)
1372	CTD_11	5°17.7'S	33°00.0'W	4.7. 01:00-04:20	**CTD/LADCP** station (4580 m)
1373	CTD_12	5°12.3'S	32°30.0'W	4.7. 07:30-10:10	**CTD/LADCP** station (4620 m)
1374	CTD_13	5°07.0'S	32°00.0'W	4.7. 13:20-16:50	**CTD/LADCP** station (4640 m)
1375	EM710 KPO1095	10°12.5'S 10°13.7'S	35°52.0'W 35°52.5'W	6.7. 5:30-7:30	**Topography sections along 300m, 500m and 900m depth** (at 7kn)
1376	KPO1109 PIES_1	10°14.15'S	35°51.9'W	6.7. 8:50-9:00	**Deployment of PIES** (500m)
		10°14.2'S	35°54.2'W	6.7. 9:30	**Start ADCP section** (70m)
1377	CTD_14	10°14.6'S	35°53.6'W	6.7. 9:50-10:10	**CTD/LADCP** station (220 m)
1378	CTD_15	10°15.3'S	35°52.6'W	6.7. 10:40-11:10	**CTD/LADCP** station (520 m)
1379	CTD_16	10°16.0'S	35°51.7'W	6.7. 12:10-12:50	**CTD/LADCP** station (900 m)

1380	KPO1095	10°16.0'S	35°51.7'W	6.7. 12:50-15:10	**Drifttest, Mooring deployment** (900 m)
1381	KPO1108 BPR_1	10°13.7'S	35°52.5'W	6.7. 15:40-16:10	**Deployment of Bottom Pressure Sensor** (300m)
1382	CTD_17	10°19.5'S	35°46.1'W	6.7. 17:20-19:00	**CTD/LADCP** station (1760 m)
1383/ 1384	CTD_18	10°22.8'S	35°40.8'W	6.7. 19:50-21:20	**CTD/LADCP** station (2320 m), releaser test
1385	CTD_19	10°27.4'S	35°34.9'W	6.7. 22:30-0:30	**CTD/LADCP** station (2880 m)
1386	CTD_20	10°32.0'S	35°29.3'W	7.7. 1:30-3:50	**CTD/LADCP** station (3210 m)
1387	CTD_21	10°36.5'S	35°23.6'W	7.7. 5:20-7:40	**CTD/LADCP** station (3520 m)
1388	KPO1097	10°36.5'S	35°23.6'W	7.7. 7:40-11:50	**Drifttest, Mooring deployment** (3520 m)
1389	KPO1096	10°22.8'S	35°40.8'W	7.7. 14:20-17:10	**Drifttest, Mooring deployment** (2320 m)
1390	CTD_22	10°41.4'S	35°17.6'W	7.7. 20:30-23:20	**CTD/LADCP** station (3680 m)
1391	CTD_23	10°46.4'S	35°11.6'W	8.7. 00:20-2:50	**CTD/LADCP** station (3880 m)
1392	CTD_24	10°51.4'S	35°05.6'W	8.7. 3:50-6:20	**CTD/LADCP** station (3970 m)
1393	CTD_25	10°56.4'S	34°59.6'W	8.7. 7:10-10:10	**CTD/LADCP** station (4110 m)
1394	KPO1098	10°56.4'S	34°59.6'W	8.7. 10:10-15:40	**Drifttest, Mooring deployment** (ca. 4110 m)
1395	CTD_26	11°07.6'S	34°43.9'W	8.7. 17:50-20:30	**CTD/LADCP** station (4250 m)
1396	CTD_27	11°18.8'S	34°28.2'W	8.7. 22:40-1:30	**CTD/LADCP** station (4630 m)
1397	CTD_28	11°30.0'S	34°13.0'W	9.7. 3:40-6:40	**CTD/LADCP** station (4580 m)
1398	CTD_29	11°30.0'S	33°53.0'W	9.7. 8:50-11:50	**CTD/LADCP** station (4620 m)
1399	CTD_30	11°30.0'S	33°33.0'W	9.7. 13:50-17:30	**CTD/LADCP** station (4960 m)
1400	UCTD				**UCTD** test with dummy
1401	CTD_31	11°30.0'S	33°13.0'W	9.7. 19:40-22:30	**CTD/LADCP** station (4280 m)
1402	CTD_32	11°30.0'S	32°53.0'W	10.7. 0:50-3:20	**CTD/LADCP** station (3540 m)
1403 - 1404	UCTD1 - 2			10.7. 4:15	**Underway-CTD** (every 1h)
1405	CTD_33	11°30.0'S	32°27.0'W	10.7. 6:40-9:50	**CTD/LADCP** station (4780 m)
1406 - 1407	UCTD3 - 4				**Underway-CTD** (every 1h)
1408	CTD_34	11°30.0'S	32°00.0'W	10.7. 13:00-	**CTD/LADCP** station (ca. 4400 m)

				15:50	
1409 - 1477	UCTD5 - 74				**Underway-CTD** (every 1h)
1478	APEX_1	11°20.0'S	20°00.0'W	13.7. 8:08	**APEX float deployment**
1479 - 1597	UCTD75 - 193				**Underway-CTD** (every 1h)
1598	APEX_2	10°13.1'S	0°00.2'W	18.7. 15:43	**APEX float deployment**
1599 - 1646	UCTD194 - 251				**Underway-CTD** (every 1h)
1647	APEX_3	10°24.1'S	9°00.0'E	20.7. 17:00	**APEX float deployment**
1648 - 1666	UCTD194 - 212				**Underway-CTD** (every 1h)
1667	CTD_35	11°00'S	12°45'E	21.7. 12:40-14:00	**CTD/LADCP** station (ca. 1200 m)
1668	MSS_1	11°00'S	12°45'E	21.7. 14:20-15:00	**Microstructure** (at 1.5 kn)
1669	EM122	11°00.0'S 10°30.0'S	12°45.0'E 13°30.0'E	21.7. 15:20-23:10	**Section with EM122 and shipboard ADCP** (at 7kn)
1670	CTD_36	10°30'S	13°30'E	21.7. 23:10-23:20	**CTD/LADCP** station (ca. 40 m)
1671	MSS_2	10°30'S	13°30'E	21.7. 23:50-1:20	**Microstructure** (at 1.5 kn)
1672	CTD_37	10°31.4'S	13°27.9'E	22.7. 1:30-1:40	**CTD/LADCP** station (50m)
1673	MSS_3	10°31.7'S	13°27.5'E	22.7. 2:00-3:20	**Microstructure** (at 1.5 kn)
1674	CTD_38	10°32.9'S	13°25.7'E	22.7. 3:30-3:40	**CTD/LADCP** station (75m)
1675	MSS_4	10°33'S	13°25.5'E	22.7. 3:50-5:10	**Microstructure** (at 1.5 kn)
1676	CTD_39	10°34.2'S	13°23.7'E	22.7. 5:20-5:40	**CTD/LADCP** station (90m)
1677	MSS_5	10°34.4'S	13°23.7'E	22.7. 5:40-6:00	**Microstructure** (at 1.5 kn)
1678	CTD_40	10°39.72'S	13°15.43'E	22.7. 7:00-7:40	**CTD/LADCP** station (200m)
1679	KPO1104	10°39.72'S	13°15.43'E	22.7. 8:30-9:30	**Bottom shield deployment** (200m)
1680	ifm02	10°39.72'S	13°15.43'E	22.7. 9:30-10:30	**Glider deployment**
1681	KPO1110	10°40.44'S	13°14.43'E	22.7. 11:00-11:30	**Deployment of Bottom Pressure Sensor** (300m)
1682	KPO1106	10°42.57'S	13°11.13'E	22.7. 12:30-14:40	**Bottom shield deployment** (500m), released and recovered
1683	MSS_6	10°34.4'S	13°23.4'E	22.7. 16:20-17:20	**Microstructure** (at 1.5 kn)
1684	CTD_41	10°35.2'S	13°22.2'E	22.7. 17:20-17:40	**CTD/LADCP** station (100m)
1685	MSS_7	10°35.2'S	13°22.2'E	22.7. 17:40-19:20	**Microstructure** (at 1.5 kn)

1686	CTD_42	10°36.6'S	13°20.2'E	22.7. 19:20-19:40	**CTD/LADCP** station (110m)
1687	MSS_8	10°36.6'S	13°20.1'E	22.7. 19:40-21:10	**Microstructure** (at 1.5 kn)
1688	CTD_43	10°37.9'S	13°18.2'E	22.7. 21:20-21:40	**CTD/LADCP** station (120m)
1689	MSS_9	10°37.9'S	13°18.2'E	22.7. 21:40-22:50	**Microstructure** (at 1.5 kn)
1690	CTD_44	10°38.8'S	13°16.8'E	22.7. 23:00-23:20	**CTD/LADCP** station (140m)
1691	CTD_45	10°40.6'S	13°14.2'E	23.7. 1:00-1:20	**CTD/LADCP** station (290m)
1692	CTD_46	10°42.1'S	13°11.8'E	23.7. 1:50-2:20	**CTD/LADCP** station (440m)
1693	CTD_47	10°44'S	13°09'E	23.7. 2:50-3:20	**CTD/LADCP** station (700m)
1694	CTD_48	10°46'S	13°06'E	23.7. 4:00-4:40	**CTD/LADCP** station (950m)
1695	CTD_49	10°48'S	13°03'E	23.7. 5:10-6:00	**CTD/LADCP** station (1160m)
1696	KPO1106	10°42.57'S	13°11.13'E	23.7. 7:40-9:00	**Bottom shield deployment** (500m)
1697	KPO1105	10°42.1'S	13°11.85'E	23.7. 10:00-11:00	**Drifttest, mooring deployment** (450 m)
1698	CTD_50	10°50'S	13°00'E	23.7. 12:40-13:10	**CTD/LADCP** station (1230m)
1699	KPO1107	10°50'S	13°00'E	23.7. 13:40-14:50	**Drifttest, mooring deployment** (1230 m)
1700	CTD_51	10°52'S	12°57'E	23.7. 15:20-16:10	**CTD/LADCP** station (1270m)
1701	CTD_52	10°54'S	12°54'E	23.7. 16:40-17:30	**CTD/LADCP** station (1340m)
1702	CTD_53	10°56'S	12°51'E	23.7. 18:00-19:00	**CTD/LADCP** station (1370m)
1703	CTD_54	10°58'S	12°48'E	23.7. 19:30-20:30	**CTD/LADCP** station (1410m)
1704	CTD_55	11°00'S	12°45'E	23.7. 21:10-22:10	**CTD/LADCP** station (1430m)
1705	ADCP	11°00.0'S 10°30.0'S	12°45.0'E 13°30.0'E	23.7. 22:30-3:40	**Section with shipboard ADCP**
1706/ 1707	MSS_10	10°27.9'S 10°37.3'S	13°33.0'E 13°19.0'E	24.7. 3:50-14:50	**Microstructure** (at 1.5 kn)
1708	ifm02	10°39.7'S	13°16.3'E	24.7. 15:40-15:50	**Glider recovery**
1709	Ifm02	22°34.85'S	12°36.92'E	27.7. 15:10-16:00	**Glider deployment**

7.2 Mooring Deployments

Mooring Deployment NBUC 11°S Array mooring K1 — **Notes** — **KPO_1095**

Vessel:	Meteor	M98				
Deployed:	6-Jul	2013				
Vessel:						
Recovered:						
Latitude:	10	16.000	S			
Longitude:	35	51.700	W			
Water depth:	900			Mag Var:	-22.7	

ID	Depth	Instr. type	s/n	Start-up	Remarks
		Watchdog	2263	x	
KPO_1095_01	150	Mini-TD /p	69		
KPO_1095_02	154	Microcat /p	6862	x	
KPO_1095_03	347	Microcat	1282	x	
KPO_1095_04	499	ADCP LR up /p	12530	x	Fl45: Flotec 3
KPO_1095_05	502	Microcat	921	x	
KPO_1095_06	643	Microcat	933	x	
KPO_1095_07	647	NORTEK /p	8409	x	
KPO_1095_08	874	Microcat	1288	x	
	875	Release AR661	839	Code:	
	875	Release AR861	95	Code:	

Mooring Deployment NBUC 11°S Array mooring K2 — **Notes** — **KPO_1096**

Vessel:	Meteor	M98				
Deployed:	7-Jul	2013				
Vessel:						
Recovered:						
Latitude:	10	22.800	S			
Longitude:	35	40.800	W			
Water depth:	2320			Mag Var:	-22.7	

ID	Depth	Instr. type	s/n	Startup	
		Watchdog	15173		
KPO_1096_01	139	Mini-TD /p	57		
KPO_1096_02	143	Microcat /p	2484	x	
KPO_1096_03	345	Microcat	935	x	
KPO_1096_04	506	ADCP LR /p	2330	x	Fl45: Animate 4
KPO_1096_05	650	Microcat	929	x	
KPO_1096_06	653	Argonaut	304	x	
KPO_1096_07	890	RCM-11 LR	293	x	
KPO_1096_08	1197	Microcat	934	x	
KPO_1096_09	1401	RCM-8 LR /p	00094	x	
KPO_1096_10	1497	Microcat	780	x	
KPO_1096_11	1904	Microcat	1281	x	
KPO_1096_12	1905	Argonaut	144	x	
KPO_1096_13	2292	Microcat	1319	x	
	2294	Release AR661	635	Code:	
	2294	Release AR861	271	Code:	

Mooring Deployment NBUC 11°S Array mooring K3 — **Notes** — **KPO_1097**

Vessel:	Meteor	M98
Deployed:	7-Jul	2013

Vessel:					
Recovered:					
Latitude:	10	36.500	S		
Longitude:	35	23.600	W		
Water depth:	3520		Mag Var:	-22.7	
ID	**Depth**	**Instr. type**	**s/n**	**Startup**	
		SMM 2000	7373	x	
KPO_1097_01	347	ADCP up	623	x	FI45: RO#3
KPO_1097_02	347	Mini-TD	23		
KPO_1097_03	351	Microcat /p	10609	x	
KPO_1097_04	476	RCM-8 LR	09346	x	
KPO_1097_05	652	RCM-11 LR	441	x	
KPO_1097_06	653	Microcat	3196	x	
KPO_1097_07	898	Argonaut	187	x	
KPO_1097_08	1396	NORTEK /p	8387	x	
KPO_1097_09	1895	RCM-8 LR/AR	9732	x	
KPO_1097_10	1897	Microcat	939	x	
KPO_1097_11	2404	RCM-8 /p LR	08411	x	
KPO_1097_12	2798	Microcat	278	x	
KPO_1097_13	3004	Argonaut	294	x	
KPO_1097_14	3400	Microcat	910	x	
	3403	Release AR661	659	Code:	
	3403	Release AR861	1648	Code:	

Mooring Deployment NBUC 11°S mooring offshore K4				**Notes**	**KPO_1098**
Vessel:	Meteor	M98			
Deployed:	8-Jul	2013			
Vessel:					
Recovered:					
Latitude:	10	56.400	S		
Longitude:	34	59.600	W		
Water depth:	4110		Mag Var:	-22.8	
ID	**Depth**	**Instr. type**	**s/n**	**Startup**	
		SMM 2000	11460		
KPO_1098_01	343	ADCP up	589	x	FI45: #3
KPO_1098_02	345	Mini-TD	47		
KPO_1098_03	345	Microcat	1286	x	
KPO_1098_04	470	RCM-11 LR	477	x	
KPO_1098_05	645	RCM-8 LR	8365	x	
KPO_1098_06	647	Microcat /p	10610	x	
KPO_1098_07	903	RCM-8 LR	10554	x	
KPO_1098_08	1907	RCM-8 AR/p	10776	x	
KPO_1098_09	1908	Microcat	0055	x	
	3803	Release AR661	220		Code:
	3803	Release AR861	975		Code:

Mooring Deployment SACUS Angola Array mooring (Shield)				**Notes**	**KPO_1104**
Vessel:	Meteor	M98			
Deployed:	22-Jul	2013			
Vessel:					
Recovered:					
Latitude:	10	39.718	S		
Longitude:	13	15.428	E		
Water depth:	200		Mag Var:	-5.4	

ID	Depth	Instr. type	s/n	Startup
		Argos	5461	
KPO_1104_01	200	ADCP LR 150kHz	14912	x
	200	Release	1641	Code:
	200	Shield	J08129-001	

Mooring Deployment SACUS Angola Array mooring				Notes	KPO_1105
Vessel:	Meteor	M98			
Deployed:	23-Jul	2013			
Vessel:					
Recovered:					
Latitude:	10	42.104	S		
Longitude:	13	11.852	E		
Water depth:	450		Mag Var:	-5.4	

ID	Depth	Instr. Type	s/n	Startup
		Argos	5639	
KPO_1105_01	50	Microcat /p	10631	x
KPO_1105_02	50	O2 Logger	1139	x
KPO_1105_03	153	Microcat /p	10611	x
KPO_1105_04	153	O2 Logger	145	x
KPO_1105_05	247	Microcat	1284	x
KPO_1105_06	247	O2 Logger	1067	x
KPO_1105_07	352	Microcat /p	10630	x
KPO_1105_08	352	O2 Logger	531	x
	375	Release AR661	121	Code:

Mooring Deployment SACUS Angola Array mooring (Shield)				Notes	KPO_1106
Vessel:	Meteor	M98			
Deployed:	23-Jul	2013			
Vessel:					
Recovered:					
Latitude:	10	42.574	S		
Longitude:	13	11.131	E		
Water depth:	498		Mag Var:	-5.5	

ID	Depth	Instr. type	s/n	Startup
		Argos	5507	
KPO_1106_01	498	ADCP LR 75kHz	19397	x
KPO_1106_02	498	SBE26plus	1356	x
	498	Release	1591	Code:
	498	Shield	J08183-001	Code:

Mooring Deployment SACUS Angola Array mooring				Notes	KPO_1107
Vessel:	Meteor	M98			
Deployed:	23-Jul	2013			
Vessel:					
Recovered:					
Latitude:	10	50.000	S		
Longitude:	13	0.000	W		
Water depth:	1230		Mag Var:	-5.6	

ID	Depth	Instr. type	s/n	Startup

KPO_1107_01	505	SMM2000 ADCP LR up	9243 19398	**x**	Fl45: Flotec 1
	1125	Release AR661	189	Code:	

Mooring Deployment bottom pressure sensor Brasil — **Notes** — **KPO_1108**

Vessel:	Meteor	M98		
Deployed:	6-Jul	2013	18:57	
Vessel:				
Recovered:				
Latitude:	10	13.677	S	
Longitude:	35	52.500	W	
Water depth:	310		Mag Var:	-22.7

ID	Depth	Instr. Type	s/n	Startup
KPO_1108_01	310	Animate 8A SBE26plus	1357	**x**
		Releaser Benthos 865A	678	Code:

Mooring Deployment PIES Brasil — **Notes** — **KPO_1109**

Vessel:	Meteor	M98		
Deployed:	6-Jul	2013	11:54	
Vessel:				
Recovered:				
Latitude:	10	14.149	S	
Longitude:	35	51.905	W	
Water depth:	501		Mag Var:	-22.7

ID	Depth	Instr. type	s/n	Startup
KPO_1109_01	501	PIES	123	**x**
				Code:

Mooring Deployment bottom pressure sensor Angola — **Notes** — **KPO_1110**

Vessel:	Meteor	M98		
Deployed:	22-Jul	2013		
Vessel:				
Recovered:				
Latitude:	10	40.443	S	
Longitude:	13	14.433	E	
Water depth:	303		Mag Var:	-5.4

ID	Depth	Instr. type	s/n	Startup
KPO_1110_01	303	Animate 8B SBE26plus	1355	**x**
	303	Releaser Benthos 865A	652	Code:

7.3 CTD Station List

Stat.	Date	Time	Latitude	Longitude	Depth	Max P [dbar]	Btls.	Samples
1	2013/07/02	15:34	5°38.57'S	34°57.65'W	280	85	0	
2	2013/07/02	19:16	5°38.57'S	34°57.65'W	280	259	0	
3	2013/07/02	20:11	5°38.36'S	34°56.02'W	774	702	6	1,2
4	2013/07/02	21:21	5°38.01'S	34°53.99'W	2093	1658	7	1,2
5	2013/07/02	23:58	5°36.59'S	34°45.94'W	3185	2742	6	1,2
6	2013/07/03	03:08	5°34.74'S	34°36.02'W	3366	3425	6	1,2
7	2013/07/03	07:22	5°32.81'S	34°24.07'W	3771	3804	7	1,2
8	2013/07/03	11:41	5°30.25'S	34°09.97'W	4108	4168	7	1,2
9	2013/07/03	16:23	5°26.63'S	33°50.01'W	4348	4371	8	1,2
10	2013/07/03	21:58	5°21.70'S	33°25.02'W	4503	4539	8	1,2
11	2013/07/04	03:55	5°17.69'S	33°00.03'W	4583	4614	8	1,2
12	2013/07/04	10:25	5°12.30'S	32°30.01'W	4626	4658	8	1,2
13	2013/07/04	16:21	5°06.99'S	32°00.01'W	4634	4663	8	1,2
14	2013/07/06	12:49	10°14.60'S	35°53.64'W	214	208	7	1,2
15	2013/07/06	13:42	10°15.31'S	35°52.63'W	498	505	8	1,2
16	2013/07/06	15:05	10°15.96'S	35°51.70'W	566	876	5	1,2
17	2013/07/06	20:17	10°19.47'S	35°46.10'W	1362	1721	8	1,2
18	2013/07/06	22:48	10°22.77'S	35°40.80'W	2290	2321	8	1,2
19	2013/07/07	01:26	10°27.36'S	35°34.89'W	2856	2899	7	1,2
20	2013/07/07	04:27	10°31.96'S	35°29.32'W	3197	3240	7	1,2
21	2013/07/07	08:14	10°36.49'S	35°23.61'W	3512	3552	8	1,2
22	2013/07/07	23:35	10°41.36'S	35°17.57'W	3683	3723	8	1,2
23	2013/07/08	03:18	10°46.42'S	35°11.66'W	3871	3920	7	1,2
24	2013/07/08	06:45	10°51.40'S	35°05.59'W	3966	4010	8	1,2
25	2013/07/08	10:11	10°56.39'S	34°59.61'W	4140	4155	8	1,2
26	2013/07/08	20:47	11°07.59'S	34°43.93'W	4248	4305	8	1,2
27	2013/07/09	01:38	11°18.77'S	34°28.23'W	4633	4703	8	1,2
28	2013/07/09	06:36	11°29.98'S	34°12.98'W	4574	4639	8	1,2
29	2013/07/09	11:49	11°29.96'S	33°52.99'W	4618	4685	8	1,2

30	2013/07/09	16:52	11°29.99'S	33°33.01'W	4969	5042	7	1,2
31	2013/07/09	22:42	11°29.97'S	33°13.01'W	4427	4338	8	1,2
32	2013/07/10	03:48	11°29.99'S	32°53.01'W	3869	3534	6	1,2
33	2013/07/10	09:33	11°29.98'S	32°27.02'W	4772	4844	8	1,2
34	2013/07/10	15:55	11°29.99'S	32°00.03'W	5031	5109	5	1,2
35	2013/07/21	12:42	11°00.04'S	12°45.00'E	1435	1430	8	1,2
36	2013/07/21	23:11	10°30.00'S	13°30.00'E	41	43	9	1,2,3
37	2013/07/22	01:29	10°31.44'S	13°27.85'E	53	55	11	1,2,3
38	2013/07/22	03:25	10°32.86'S	13°25.70'E	76	75	12	1,2,3
39	2013/07/22	05:19	10°34.18'S	13°23.72'E	87	87	9	1,2,3
40	2013/07/22	06:59	10°39.72'S	13°15.42'E	192	193	10	1,2,3
41	2013/07/22	17:20	10°35.19'S	13°22.21'E	98	98	8	1,2,3
42	2013/07/22	19:18	10°36.56'S	13°20.16'E	109	109	8	1,2,3
43	2013/07/22	21:20	10°37.85'S	13°18.23'E	118	115	8	1,2,3
44	2013/07/22	23:03	10°38.84'S	13°16.75'E	142	139	8	1,2,3
45	2013/07/23	00:59	10°40.56'S	13°14.19'E	297	287	8	1,2,3
46	2013/07/23	01:53	10°42.10'S	13°11.85'E	440	443	7	1,2
47	2013/07/23	02:51	10°44.04'S	13°08.99'E	640	699	14	1,2
48	2013/07/23	03:55	10°45.99'S	13°06.01'E	932	939	9	1,2
49	2013/07/23	05:07	10°47.99'S	13°03.01'E	1008	1155	12	1,2
50	2013/07/23	12:23	10°49.98'S	13°00.01'E	1219	1224	12	1,2
51	2013/07/23	15:17	10°51.97'S	12°57.00'E	1259	1261	8	1,2
52	2013/07/23	16:36	10°53.98'S	12°54.01'E	1327	1331	12	1,2
53	2013/07/23	18:04	10°56.00'S	12°51.01'E	1367	1371	8	1,2
54	2013/07/23	19:28	10°57.98'S	12°48.00'E	1386	1386	7	1,2
55	2013/07/23	21:09	10°59.97'S	12°45.01'E	1474	1429	7	

1 O_2
2 Salinity
3 N_2O

8 Data and Sample Storage and Availability

The Kiel Data Management Team (KDMT) provides an information and data archival system where metadata of the onboard DSHIP-System is collected and publicly available. This Ocean

Science Information System (OSIS-Kiel) is accessible for all project participants and can be used to share and edit field information and to provide scientific data as they become available. The central system OSIS is providing information on granted ship time with information on the scientific programm and the general details down to the availability of data files from already concluded cruises. This transparancy on the research activities shall be regarded as an invitation to external scientists to start communication on collaboration on behalf of the newly available data.

The KDMT, as data curators, will ensure fulfillment of the proposed publication of the data in a World Data Center (e.g. PANGAEA) which will then provide long-term archival and access to the data. The data publication process will be based on the available files in OSIS and is therfore transparent to all reviewers and scientists. This cooperation with a world data center will make the data globally searchable, and links to the data owners will provide points of contact to project-external scientists.

Availability of metadata in OSIS-Kiel (portal.geomar.de/osis): 2 weeks after the cruise
Availability of data in OSIS-Kiel (portal.geomar.de/osis): 6 months after the cruise
Availability of data in a WDC/PANGAEA (www.pangaea.de): 3 years after the cruise

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10 References

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