CRUISE REPORT FRS *AFRICANA* VOYAGE 258

CRUISE:	**Geochemistry and Ecology of the Namibian Upwelling System (GENUS Project) and St Helena Bay Monitoring Line (SHBML)**
SAILING:	Cape Town, Tuesday 01 December 2009
CHANGE-OVERS:	Leg 1a: Sandy Point, Thursday 03 December 2009 Leg 1b: Walvis Bay, Monday 07 December 2009
RETURN:	Cape Town, Thursday 17 December 2009
AREA OF OPERATION:	Shelf/slope between Cape Town and just south of the Kunene River mouth

Cruise participants

	Leg 1a CT-SHB	**Leg 1b** SHB-WVB	**Leg 2** WVB-CT
Chief Scientist	Werner Ekau	Werner Ekau	Hans Verheye
Sampling Team	Fritz Buchholz Thorsten Werner Niko Lahajnar Andreas Neumann Markus Ankele Sarina Jung Volker Mohrholz Toralf Heene Anna Schukat Nadine Moroff Beau Tjizoo Simon Geist Anita Flohr Tim Rixen Mutchutchu Tsanwani	Fritz Buchholz Thorsten Werner Niko Lahajnar Andreas Neumann Markus Ankele Sarina Jung Volker Mohrholz Toralf Heene Anna Schukat Nadine Moroff Beau Tjizoo Simon Geist Anita Flohr Tim Rixen Mutchutchu Tsanwani Tammy Morris	Werner Ekau Fritz Buchholz Niko Lahajnar Andreas Neumann Markus Ankele Rolf Koppelmann Sarina Jung Volker Mohrholz Toralf Heene Annethea Müller Anna Schukat Nelda Katjivena Oliver Mungu Numwa Simon Geist Anita Flohr Tim Rixen Lena Teuber Holger Auel Thorsten Werner Tammy Morris
Electr. Techn.	Hermann Engel	Hermann Engel	Hermann Engel
Hydroacoustics	Kanakana Mushanganyisi	Kanakana Mushanganyisi	
Fishing Master		Clive Nash	
SHBML Team	Susan Jones Larry Hutchings Keshnee Pillay		

Cruise report compiled by
Hans M. Verheye and Werner Ekau

17 December 2009

INTRODUCTION AND BACKGROUND

Data collection during this voyage contributed to two ongoing programmes, namely (in chronological order) the South African monthly St Helena Bay Monitoring Line (SHBML) and the German Geochemistry and Ecology of the Namibian Upwelling System (GENUS) project.

A. SHBML – The St Helena Bay Monitoring Line was initiated as a BENEFIT-driven project on "Shipboard Monitoring in the Benguela Current upwelling ecosystem", which links with similar transects run in Namibia and Angola. Each transect samples across the shelf in areas that are important to the early life history of target fish resources: anchovy, sardine, horse mackerel and hake. South Africa also samples the SARP line off the Cape Peninsula for the transport of anchovy and sardine eggs and early larvae around Cape Point to the west coast nursery grounds.

The SHBML samples in the nursery grounds and in the last part of the transport zone. The objective is to obtain seasonal and interannual information on the hydrology and productivity of the area as it relates to young fish stages (up to the recruitment to the fishery). Data on harmful algal blooms, low-oxygen water, and intrusions of Agulhas Bank water along the west coast are also collected. A long time-series of information already exists for this important region and it is hoped that this time-series is maintained to detect long-term changes in the hydrology and the plankton, which are important for the detection of regime shifts between dominant pelagic fish species.

B. GENUS - The global coastal ocean comprises around 7% of the Earth surface, has a significant role in the sequestration of carbon by hosting 25% of global biological productivity (prominently in upwelling areas) and storing 90% of organic carbon runoff from land in sediments, and yields 90% of global fisheries. While the physical boundary conditions of shelf seas (and upwelling systems in particular) are adjusting to global warming, human society continues to exploit their natural resources (minerals, fossil fuels, fisheries) without sufficient understanding and prognostic capabilities to foresee how exactly the interplay of changing physical drivers and continued exploitation will affect essential ecosystem goods and services.

GENUS is a joint research effort that aims to clarify relationships between climate change, biogeochemical cycles of nutrient elements, radiatively active gases, and ecosystem structure in a large marine ecosystem, the upwelling system of the northern Benguela/SE Africa. This will be pursued by empirical studies into processes and rates of ocean circulation, biogeochemical cycling of nutrient elements between water column, biota and sediments, trophic interactions and energy flows, and a hierarchy of numerical models from regional climate, ocean circulation, ecosystems, and energy flows. Reasons for choosing the coastal upwelling system off Namibia are (a) the direct coupling between circulation, oxygen supply to the shelf, and processes in the ecosystem to the atmospheric forcing that varies on seasonal to inter-annual time scales, (b) short trophic chains that facilitate a rigorous book-keeping of energy flows, and (c) a significant knowledge base and availability of data and model components.

GENUS comprises four themes that will be investigated by empirical and theoretical approaches. These are: (1) retrospective analyses of physical boundary conditions and biogeochemical cycles; (2) identification of key processes/species and analysis of key rates of physical, biogeochemical and biological ecosystem components; (3) quantifying feedback of trophic structures on biogeochemical cycles; and (4) simulations of interactions between shelf ecosystem – open ocean – atmosphere.

Seven sub-projects of GENUS are grouped in three work packages "Circulation", "Material Cycles " and "Producers/Consumers", which perform experimental and theoretical work to adapt the model cascade to the specific conditions in the northern Benguela upwelling system. While data are being compiled from data banks and gathered from two GENUS expeditions in 2008 to provide a basis for model evaluation (first year, 2009), the modeling components (REMO and MOM4) will be adapted and tested, and first

runs with the ecosystem model ERGOM will be conducted and evaluated. The first and second year (2009-2010) will see improved parameterizations in MOM4, ERGOM, and ECOPATH/ECOSIM (a model of energy flow through higher trophic levels of food webs) from data gathered during the expedition in 2008, and two additional expeditions in 2009 (FRS *Africana*) and 2010 (RV *Discovery*). Year 2 (2010) will be devoted to simulation (REMO, MOM4, ERGOM and ECOPATH/ECOSIM) of the period 1960-2008, which encompasses a pronounced regime shift in the Benguela system. Efforts in Year 3 (2011) will focus on repeat simulations of the 1960-2008 period with the improved model system, including a carbon cycle module in ERGOM, and retrospective analyses of two climatic extremes of the last 1000 years (MWP and LIA), followed by joint evaluation of model results.

GENUS is a contribution to the international IMBER (integrated Marine Biogeochemistry and Ecosystem Research) of the International Geosphere and Biosphere Programme (IGBP). GENUS builds on previous engagement of several project partners in regional BENEFIT (Benguela Environment Fisheries Interaction and Training, 1997-2007) and BCLME (Benguela Current Large Marine Ecosystem, 2002-2007) initiatives that fostered fruitful and intense cooperation with research institutions in the region (MCM, South Africa; NatMIRC, Namibia; INIP, Angola). These partners are involved in several past and forthcoming GENUS expeditions with RV *Maria S Merian* (2008), FRS *Africana* (this cruise), RV *Discovery* (2010) and RV *Meteor*/RV *Maria S. Merian*. (2011). Parts of this programme are integrated into the Census of Marine Life and CMarZ (Census of Marine Zooplankton) initiatives. The project is linked with the "EurOceans" Network of Excellence of the European Commission under Eeu-Oceans System 7: „Upwelling Systems" (http://www.euroceans.eu/marine_systems/up/). GENUS contributes to the national Research Initiative "Environment and Sustainability", in particular to the program „System Earth: Research on Climate Change" of the German Federal Ministry of Education and Research (BMBF).

OVERALL CRUISE OBJECTIVES (in chronological order)

A. SHBML:

- To monitor the general oceanography and plankton in St Helena Bay;
- To collect phytoplankton, microzooplankton and mesozooplankton on a transect starting off Elands Bay in 20m of water and finishing in a depth of 1400m;
- To collect data on temperature, salinity, dissolved oxygen and fluorescence with Seabird CTD;
- To collect predatory fish stomach contents to determine the presence of pre-recruit forage fish.

B. GENUS:

The overall goal of the GENUS Project is, as stated earlier, to realize a joint research effort that aims to clarify relationships between climate change, biogeochemical cycles of nutrient elements, radiatively active gases, and ecosystem structure in the upwelling system of the northern Benguela/SE Atlantic off southern Africa. This is pursued by empirical studies of processes and rates of ocean circulation, biogeochemical cycling of nutrient elements between water column, biota and sediments, trophic interactions and energy flows, and a hierarchy of numerical models from regional climate, ocean circulation, ecosystems, and energy flows.

The cruise onboard the FRS *Africana* is the third in a series of cruises that take place in the Benguela upwelling region between 2008 and 2011 to collect data and samples for the different aforementioned GENUS programme themes. Considering the ability of the FRS *Africana* to perform pelagic and bottom trawling, one of the foci of this cruise was placed on the collection of juvenile and adult stages of key fish species in the area in order to analyse their trophic position and energetic characteristics. Biogeochemical

investigations provided an overview on the distribution of nutrients and a quantitative estimate of natural ranges in mass fluxes between the shelf system and the adjacent mesopelagic ocean. Routine plankton sampling filled gaps in our interpretation of the distribution of zooplankton communities and the processes that govern them.

Specific objectives for each of the Working Groups that took part in the cruise are given under each Working Group's activity report.

AREA OF INVESTIGATION

FRS *Africana* operated in the shelf and slope regions off the west coast off South Africa and Namibia, between Cape Town and just south of the Kunene River mouth. Sampling stations were positioned along four cross-shelf transects: St. Helena Bay transect (32.5°S), Rocky Point transect (19°S), Kunene River transect (17.3°S), and Walvis Bay transect (23°S). Scientists from Germany, South Africa and Namibia carried out hydrological measurements and net sampling for plankton using standard oceanographic research equipment, as well as some sediment sampling using a multicorer; midwater and bottom trawling was also conducted for the collection of pelagic, mesopelagic and demersal fish species in South African and Namibian waters south of Walvis Bay (Leg 1). An overview of the location of stations and the cruise track are given in Figures 1a and 1b; a list of stations summarizing station details and sampling activities is given in Appendix 1. Figure 2 shows the development of coastal upwelling conditions along the Namibian coast, proxied by sea surface temperature, for the period 1-13 December 2009.

SAMPLING GEAR AND EQUIPMENT

- CTD SBE 911+ with Rosette water sampler;
- LADCP (Lowered ADCP 300kHz Workhorse) mounted on the CTD frame;
- VMADCP (Vessel-mounted ADCP 75kHz Ocean Surveyor) mounted on ship's hull;
- Oceanographic mooring HRMB (recovered during the cruise);
- Thermo-salinograph SBE21;
- Ship's weather station (Aanderaa);
- FerryBox and *Systea* auto-analyser;
- Membrane Inlet Mass Spectrometre – MIMS;
- Underway Carbon Dioxide Analyser SUNDANS;
- WP-2 net (300 µm, with modified, large-volume cod-end) – vertical hauls;
- Drift net (200 µm, with large-volume cod-end);
- Multinet (Hydrobios) Type Midi (0.25 m^2 mouth area) with five 200 µm (vertical hauls) and 500 µm (oblique hauls) meshed nets;
- MOCNESS (Multiple Opening and Closing Net and Environmental Sensing System) with nine 333 µm meshed nets;

- Tucker Trawl (1000 µm) opening/closing net;
- CUFES (Continuous Underway Fish Egg Sampler);
- Multicorer;
- Midwater and demersal trawls.

CRUISE NARRATIVE

Date	***Time*** (UTC)	***Task; comments***
30.11.2009	11:00	Unloading equipment from the container
01.12.2009	11:00	Departure from Cape Town Assembling and testing of equipment
02.12.2009	05:30	Start St. Helena Bay Monitoring Line (SHBML transect)
03.12.2009	07:00	End SHBML transect (14 CTD casts, 9 LADCP casts). Upwelling and strong primary production at the coast
	09:00	Personnel exchange at Sandy Point (SHBML Team disembarking, Fishing Master embarking)
	11:00	Start fish trawls at 32°S, each haul starts with a CTD/LADCP cast
04.12.2009	03:00	Continuing fish trawls at 30.5°S
05.12.2009	05:00	Continuing fish trawls at 28.5°S
06.12.2009	05:00	Continuing fish trawls at 25.7°S
	14:00	Strong algal bloom off the Namibian coast, extremely high fluorescence in the surface waters accompanied with anoxic bottom conditions
	20:00	End of trawling operations, steaming to Walvis Bay
07.12.2009	06:00	Walvis Bay: exchange of some scientific personnel
	11:00	Recovery of HRMB mooring 23 nm off Walvis Bay. All devices have worked and have logged data
	12:00	Steaming to Walvis Ridge transect
08.12.2009	08:00	Test station
	13:45	Start station work at the Rocky Point transect
09.12.2009	08:00	End station work at the Rocky Point transect, 4 stations

		Steaming northward to the Kunene River transect
	17:30	Start station work at the Kunene River transect
10.12.2009	23:00	End station work at the Kunene River transect Steaming southward to the oceanic station at Rocky Point transect
11.12.2009	09:30	Start oceanic station at Rocky Point transect
	15:00	End oceanic station at Rocky Point transect Steaming southward to the Walvis Bay Transect
12.12.2009		On the way southward to the Walvis Bay Transect
	18:30	Start station work at the Walvis Bay transect
13.12.2009	08:30	Communication test with the releaser of the LTSE mooring. First trial was successful
	10:00	Continuing station work at the Walvis Bay transect
14.12.2009	05:00	End station work at the Walvis Bay transect Steaming southward to Cape Town
15.12.2009	03:00	Two additional CTD stations in 300 and 1000 m near Lüderitz en route to CapeTown
		End of station work Steaming southward to Cape Town
17.12.2009	08:00	Arrival in Cape Town harbour

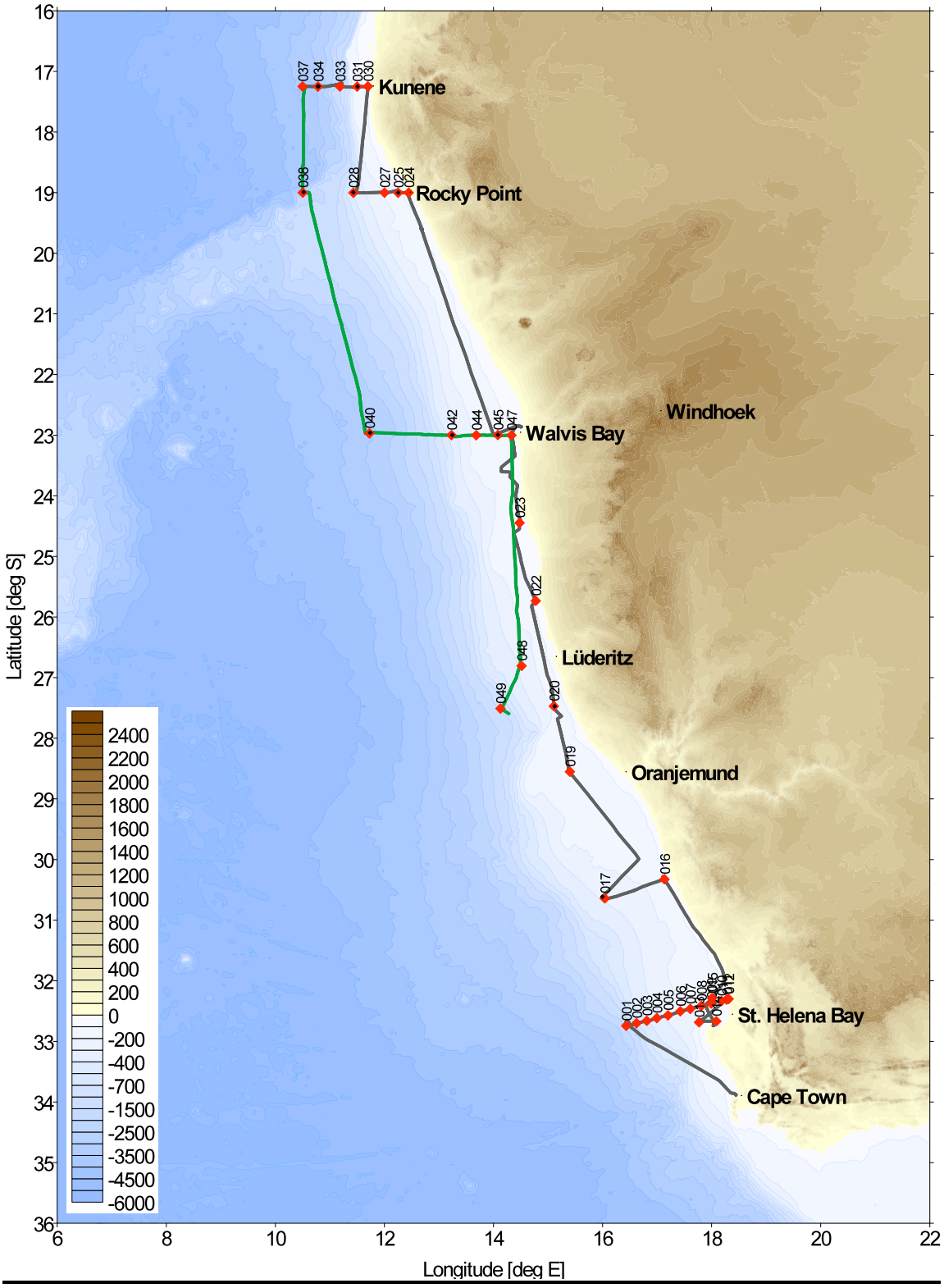


Figure 1a. Map showing the cruise track and station positions occupied during Legs 1 and 2 of the GENUS cruise onboard the FRS *Africana*, 1-17 Decmber 2009.

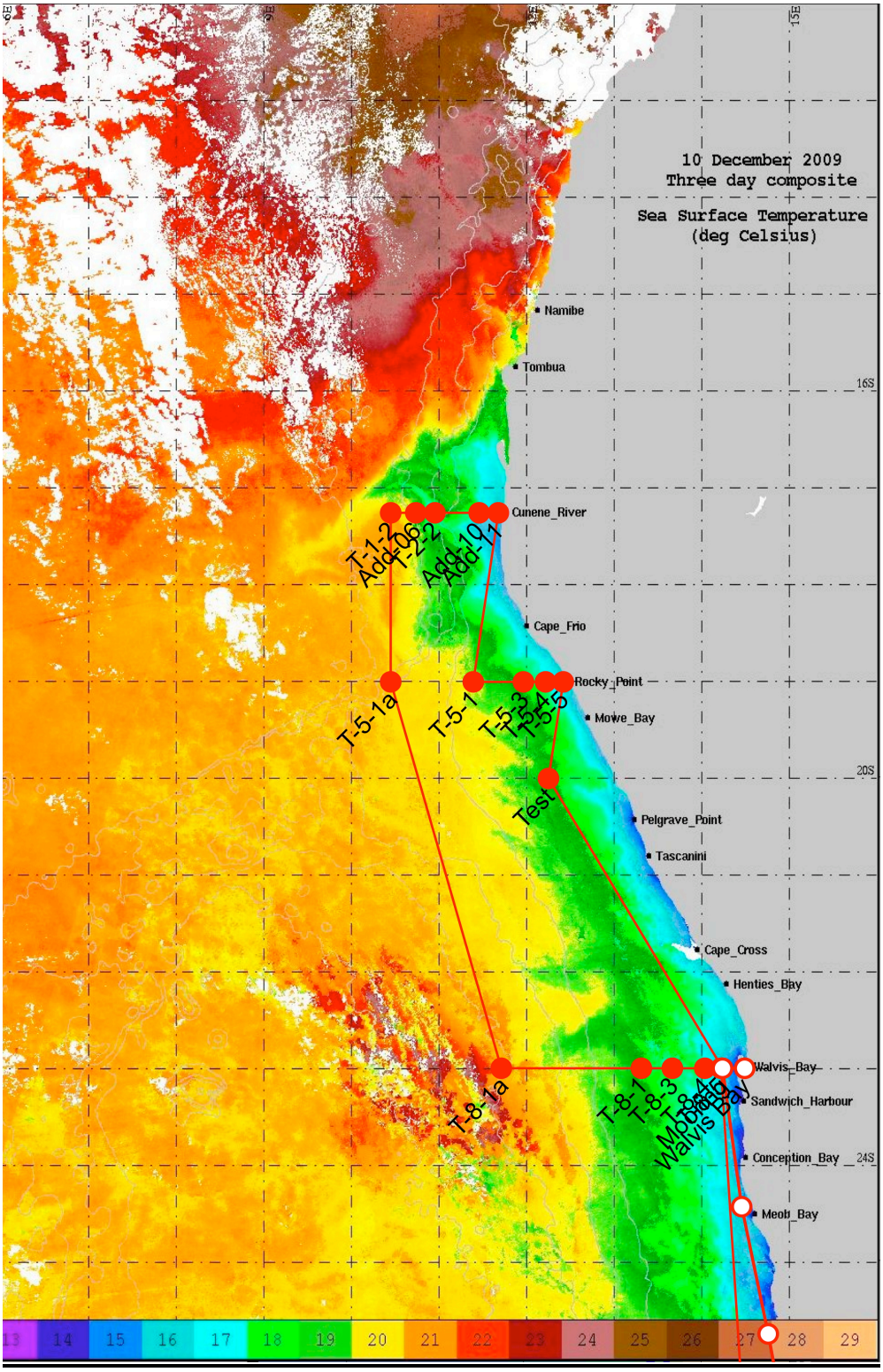
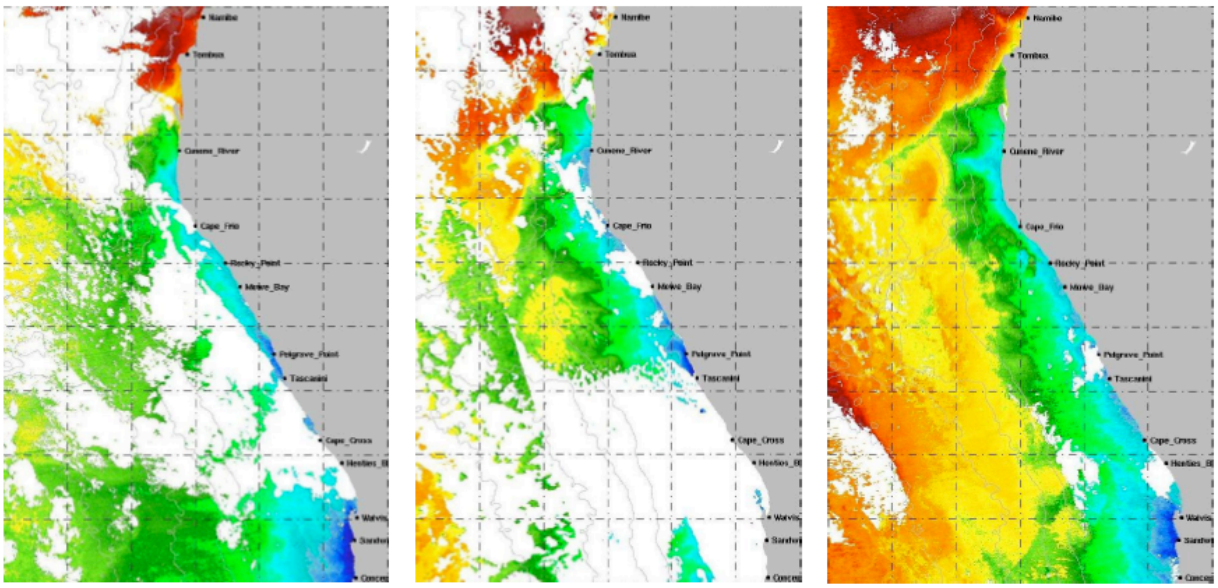


Figure 1b. Leg 2 cruise track superimposed on remotely sensed SST, showing the station positions relative to different water masses associated with coastal upwelling in the northern Benguela Current system off Namibia and with the Angola Current (satellite image courtesy of Christo Whittle, University of Cape Town (UCT)).



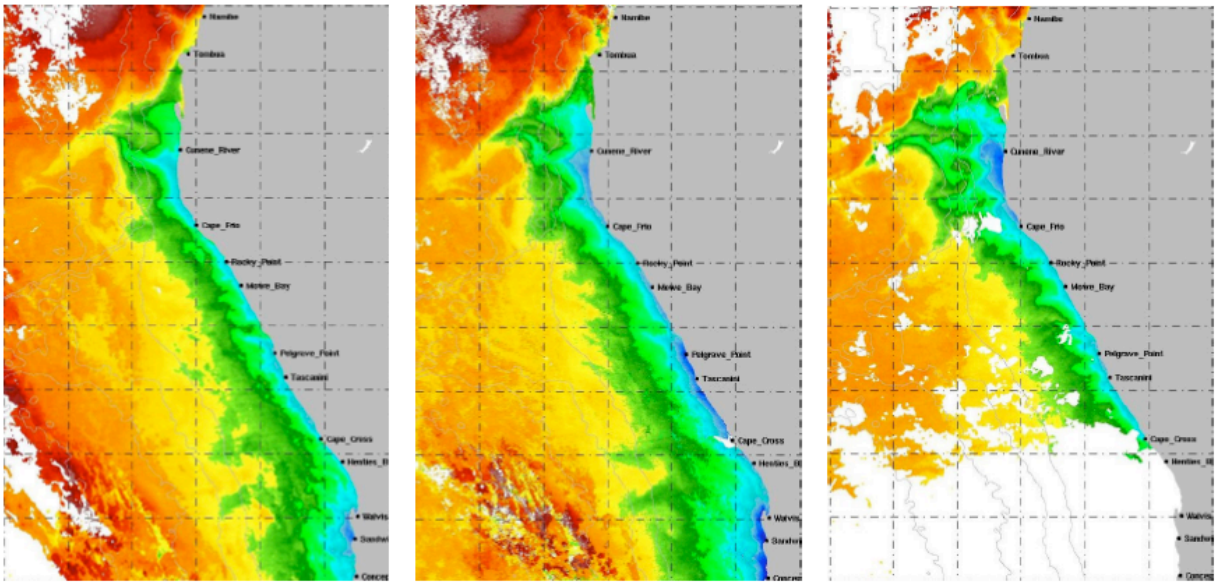


Figure 2. Development of sea surface temperature conditions in the area of investigation during the study period 1-13 December 2009 (satellite images prepared by Christo Whittle, UCT)

WORKING GROUP REPORTS

1. WORKING GROUP 'HYDROGRAPHY'

Personnel: Volker Mohrholz, Toralf Heene (Baltic Sea Research Institute, Warnemünde), Mutchutchu Tsanwani (Marine and Coastal Management, Cape Town) Tammy Morris (Bayworld Centre for Research and Education, Cape Town), Annethea Müller (University of Namibia, Windhoek)

1.1. Data processing and quality assurance

1.1.1. CTD

The CTD-system "SBE 911plus" (SEABIRD-ELECTRONICS, USA) was used to measure the following parameters:

- Pressure
- Temperature
- Conductivity
- Oxygen concentration
- Chlorophyll-a fluorescence (683nm)

The CTD has a pumped system. In addition, the CTD-probe was equipped with a Rosette water sampler with 11 Niskin bottles of 8 litres volume.

Data were monitored and stored to hard disk with Seasave Version 7. For each station a configuration file (*stationname.con*) was written that contains the complete parameter set, especially sensor coefficients used for the conversion of raw data (frequencies) to standard output format.

A CTD cast started below the sea surface with the pressure sensor usually at about 4 m depth to prevent contamination of the CTD pumping system with air bubbles. Data were collected down to 1500 m or 5 m above the bottom at shallower stations. Sampling rate of the CTD probe was 24 Hz. Data were displayed online to determine appropriate sampling depth and were stored on a PC hard drive.

The probe sheds a large amount of water in its wake. Hence, only downcast data logging was reliable. Upcast logging was used only for water sampling, where the closing depth was determined during the downcast. For closing the bottles the probe was stopped and the closing appeared after a span of about 30 s. When the device was back on deck oxygen samples were taken first, followed by water samples for analyses of salinity, nutrients and several biological parameters and manipulations.

The CTD sensors were checked during the cruise by comparison measurements. However, a correction of the temperature sensor (SN 4136, calibration 28.08.2008) was not applied since there were no instruments for temperature comparison measurements on board.

Salinity samples were taken approximately once a day. The samples were stored in brown glass bottles and will be analysed at IOW.

Conductivity (then salinity) of the samples was determined by means of a salinometer AUTOSAL Model 8400B (accuracy of 0.001). The salinometer was calibrated by means of standard seawater (Ocean Scientific International) Batch P148. A new calibration was carried out for about XX samples. Cell temperature was 24°C. New coefficients will be derived and provided at a later stage.

The sensitivity (slope) of the oxygen sensor SBE 43 (SN 1708, calibrated on 11.11.2009), was determined from water samples. Oxygen content of the samples was determined with a titration set (Winkler method, accuracy of 0.02 ml/l). The Weiss salinity correction for the oxygen saturation partial pressure is part of the data conversion run with SeaSoft. The influence of temperature on the oxygen saturation pressure was corrected by a sensor internal thermistor network.

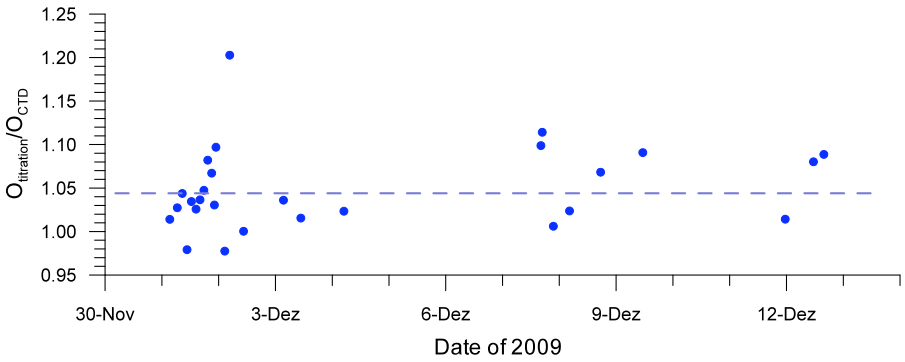


Figure 1: Comparison between CTD oxygen concentration and Winkler titration of water samples.

The deviation in the slope oxygen sensor compared to the titration values was determined as:

$$O_{titration} / O_{CTD} = 1.0432 \quad \pm \quad 0.0375$$

An online pre-correction of CTD pressure measurements (with Digiquartz-pressure sensor SN 77520, calibrated 15.09.2007) on air pressure was done using a default value of 1013 hPa. Pressure sensor values of air pressure (on deck registration) have been compared to air pressure values of the ships weather station.

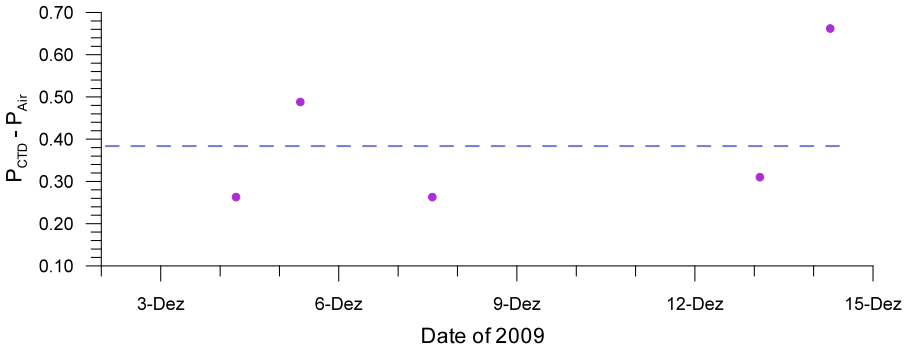


Figure 2: Deviation of CTD pressure values from 0 dBar at sea surface.

The deviation of the CTD pressure sensor at the surface to the measured air pressure was determined as follows:

$$P_{CTD} - P_{Air} = 0.397 dBar \quad \pm \quad 0.175 dBar$$

Calibration measurements for the fluorometer data have not yet been done, since no quantitative phytoplankton analysis on water samples collected from the sea surface could be performed onboard during the cruise.

The residual errors after validation are listed for each parameter in the following table:

Sensor	***Type***	***SN***	***Residual error after calibration***
pressure	Digiquartz	0586	± 0.175 dBar
temperature	SBE 3	4136	± 0.0002K, calibrated by manufacturer (28.08.2008)
conductivity	SBE 4	2615	To be determined
oxygen	SBE 43	1708	± 3.75% of measured value
Chl-a fluorescence	WET Labs	FLRTD-1002	Not calibrated

During CTD cast stn034 a number of communication errors occurred. The raw data of this profile are contaminated by several bad sensor data. A median filter of width of 15 data lines was applied to this profile to eliminate the outliers.

An electrical blackout on 04. Dec caused a reset of SeaSave software to a standard configuration. Thus, position data of profiles stn018 to stn038 contain only a constant position from the start of the profile. For all other casts the position was updated for each data line.

1.1.2. LADCP

During the cruise a LADCP-2 system was used to obtain full depth velocity profiles of currents at each CTD-station. Two ADCP WH-300 units were mounted in the frame of the CTD-probe. The LADCP-system was equipped with an external battery case for elimination of magnetic disturbances by battery packs. One LADCP was used in upward looking mode (serial number: 1129) and one in downward looking mode (serial number: 0586) in order to get as large a range as possible.

The Workhorse LADCP produces profiles of velocity and echo intensity. In addition, temperature inside the ADCP's case is recorded.

Post-processing of LADCP data was carried out with MATLAB LADCP-2 software Version 7 by Martin Visbeck. First, the velocity profiles were differentiated with respect to depth to eliminate the CTD-package's motion. Then, a depth record was obtained by integrating the vertical velocity in time. The shear profiles were averaged within depth bins. The average shear profile was then integrated vertically to obtain a baroclinic velocity profile. The barotropic correction was calculated with start and end positions from GPS, which were recorded when the CTD-probe passed the 40 dbar depth level. The software package was extended by a routine for calculating the acoustic backscatter cross-section and a data export in BluePrint formatted file. The correction of magnetic deviation was applied during the data post-processing.

Table 1: Configuration of LADCP

Command	***Parameter***	***Value***
ES35	salinity	35
EX11111	co-ordinates	use earth co-ordinates
SA001	synchronizing pulse	before each ping
SW75	synchronizing wait time	75 milliseconds
TE00:00:02.00	time per ensemble	2 s
TP00:00.00	time between pings	as soon as possible
LD111100000	data output	vel, corr, intensity, % good
LF0400	blank after transmit	4 m
LP00003	ping per ensemble	3
LJ1	receiver gain	1
LN015	number of depth cells	15
LS0800	bin length	8 m
LV250	correlation velocity	2.5 m/s

LW1	band width	narrow band
LZ25,60	amplitude, correlation thresholds	25, 60 counts
EZ1111111	sensor source	use all
EA00000	heading alignment	0 deg
EB00000	heading bias	0 deg
CF11101	flow control	

1.1.3. VMADCP

A 75 kHz Acoustic Doppler Current Profiler (VMADCP) Ocean Surveyor, manufactured by RDInstruments, is mounted in the ships hull downward looking. The data output of the ADCP was merged online with the corresponding navigation data derived from GPS output, and stored on the hard disc using the program VMDAS. Additionally, heading information was provided by a gyro-compass. The VMADCP was operated continuously during the entire cruise.

Table 2: Configuration of VMACP

Command	***Parameter***	***Value***
Data option dialog of VMDAS software Version7 was used	salinity, temperature	35, measured
	co-ordinates	use beam co-ordinates
	bottom track	on
	heading source	gyro
	navigation source	NMEA
	time per ensemble	2 s
	time between pings	2 s
	data output	vel, corr, intensity, % good
	blank after transmit	5 m
	number of depth cells	70
	bin length	8 m
	transducer depth	5 m
	band width	narrow band

	amplitude, correlation thresholds	0, 0 counts
	sensor source	use all
	heading alignment / heading bias	0 deg / 0 deg
	short-term average	180 s
	long-term average	600 s
	data screening	off

Post-processing of the VMADCP data was carried out using the Matlab® ADCP toolbox of IOW. The final profiles are 300 s averages of the single ping profiles. A list of collected VMADCP data is given in Table 5.

The overall performance of the VMADCP was not as good as expected. The bottom track signal was lost below 600 m water depth. Reliable current velocity data were obtained only in the upper 350 m.

1.1.4. Mooring

On 07.12.2009 at 11:00 the HRMB mooring was recovered 23 nm off Walvis Bay. It was deployed nearly a month ago, on 30.10.2009, during a regular monitoring cruise of RV *Welwitschia* (NatMIRC, Swakopmund, Namibia). The first release of the mooring was successful. All devices were recovered. One MicroCat SBE37 (SN1276) was slightly damaged at the connecting plug.

The main purpose of this mooring was to obtain hydrographic data from the lower water column with a high temporal resolution. These data are used for detecting internal waves and other short-term processes that control the vertical mixing and re-suspension of SPM.

The mooring consists of a bottom-mounted Workhorse ADCP 600kHz, six MicroCat thermosalinometers SBE37 and five RBR TR1060 temperature recorders (Figure 3).

1.1.5. Underway measurements

The FRS *Africana* is equipped with a ship weather station (Aanderaa) providing continuously the following meteorological data:

- Air pressure
- Air temperature
- Humidity
- Wind speed

- Wind direction
- Surface PAR (SPAR)

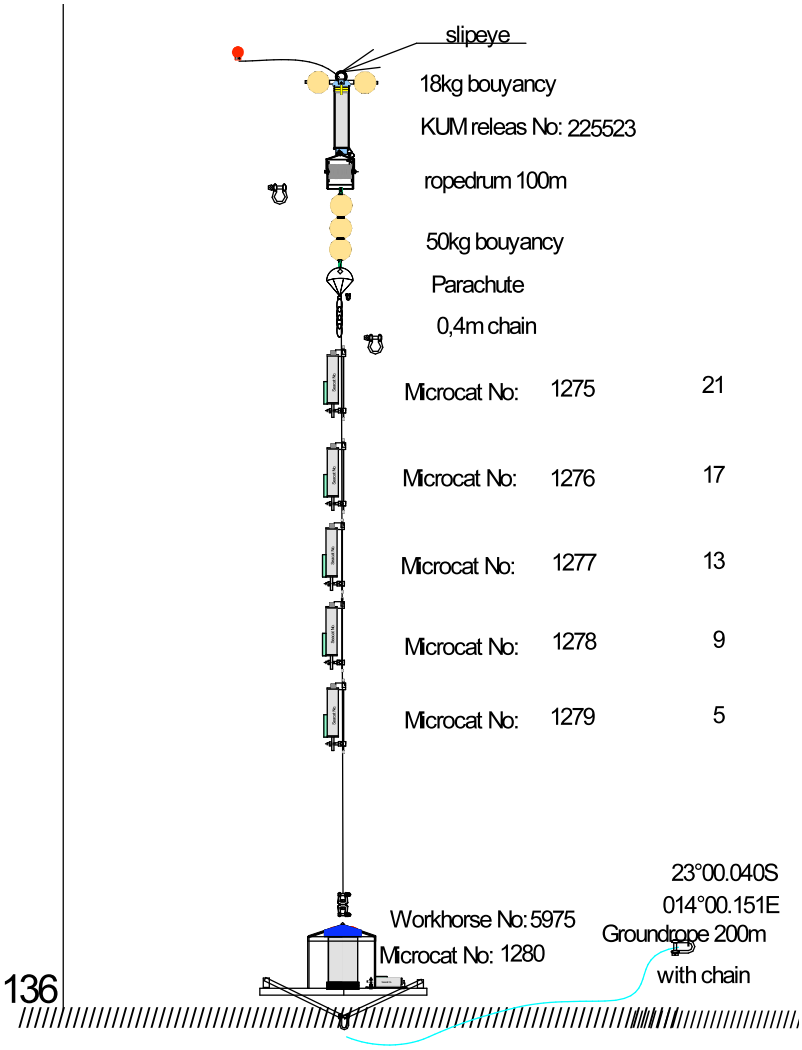


Figure 3: Sketch of the mooring recovered during the cruise

Until the morning of 7th Dec. the SPAR sensor was covered by a protecting cap. Therefore, no SPAR data are available for the first part of the cruise.

The thermosalinograph SBE21 (SN 2124777-3104) (TSG) is installed in the hydro lab. Seawater is pumped through a tube into the measurement chamber that is equipped with a Pt100 platin resistance thermometer and a 7-electrode conductivity sensor. The Pt100 temperature sensor has a nominal resolution of 0.002 K, the 7-electrode conductivity sensor resolves 0.005 mS/cm. Sensor stability should be better than 0.005 K and 0.01 mS/cm respectively. However, the last calibration by the manufacturer was carried out years ago, on 11 November 2003.

The validation of the TSG was carried out using the CTD surface measurements at 5 m depth. The TSG salinity data consist of a high number of outliers, most probably due to air bubbles in the tube system. Thus, the maximum salinity values of two-minute sections were used to construct a salinity time-series. The comparison with the CTD data was based on these 2-min maxima of salinity and 2-min averages of TSG temperature. A linear fit was applied to obtain a calibration function for the TSG values. The results are given in Table 3 and Figure 4. The calibration was applied to the temperature and salinity time-series of the TSG. The final temporal resolution of the validated CTD data is 2 min.

Table 3: Fit of TSG data to CTD measurements and residual errors of TSG data after calibration.

	Temperature	***Salinity***
Linear fit	T_{true} = 1.134 * T_{TSG} - 2.770K	S_{true} = 1.031 * S_{TSG} - 0.934
Number of data points	41	44
Coef of determination r^2	0.978	0.989
Residual error	0.237 K	0.029

The residual error of 0.24 K for the TSG temperature was relatively high and might be caused by surface temperature stratification at some CTD stations.

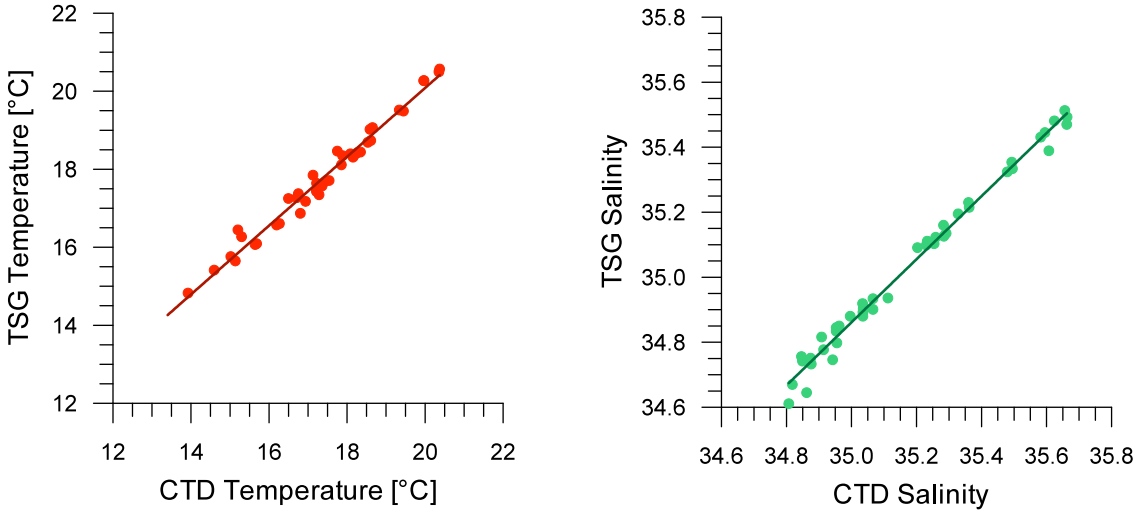


Figure 4: Comparison between TSG and CTD measurements.

Navigation data were provided from ship's GPS system and distributed via NMEA interface with serial communication.

The data of underway measurements on *Africana* are logged every 60 seconds with the NDS data collecting system and stored in daily files. The underway measurements were interrupted several times by "black outs" of the electrical power supply, that caused a number of gaps in the dataset.

1.1.6. Phytoplankton sampling

Samples for the investigation of the phytoplankton community were taken at selected stations. A mixed sample was created from the surface layer by pooling equal quantities of water from all bottles closed above the thermocline. In addition, a sample from the fluorescence maximum was collected. The samples were then split into two sub-samples of 200 ml each and fixed with Lugol's solution and formalin. A third sub-sample of 4 ml was also fixed with formalin but frozen and stored at -80°C.

The analysis of the phytoplankton samples will be carried out after the cruise in the laboratory at the IOW. A list of all phytoplankton samples is given in (Table 6).

1.2. Preliminary results

The results presented in the following section are preliminary, since they are usually based on non-validated data! The aim of this section is therefore to give a first impression of the collected dataset. An advanced data analysis will follow after all validated datasets have become available.

1.2.1. Meteorological conditions

During the first two days of the cruise strong southerly winds forced upwelling off the west coast of southern Africa. The following days were characterized by moderate winds from varying directions. From the 8th Dec. onward, upwelling-favourable winds started again, lasting for the duration of sampling on the Rocky Point and Kunene transects.

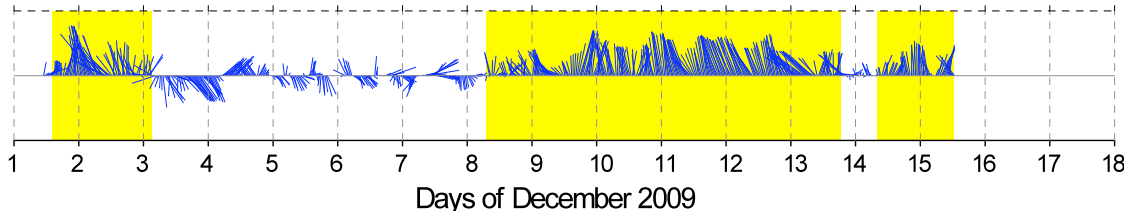


Figure 5: Stick plot of wind vector measured by the ship weather station of FRS *Africana*. The yellow shaded areas indicate periods of upwelling-favourable winds.

Maximum wind speed reached about 15 m/s on 2nd and 10th Dec. Mean wind speed during the cruise varied between 5 and 8 m/s.

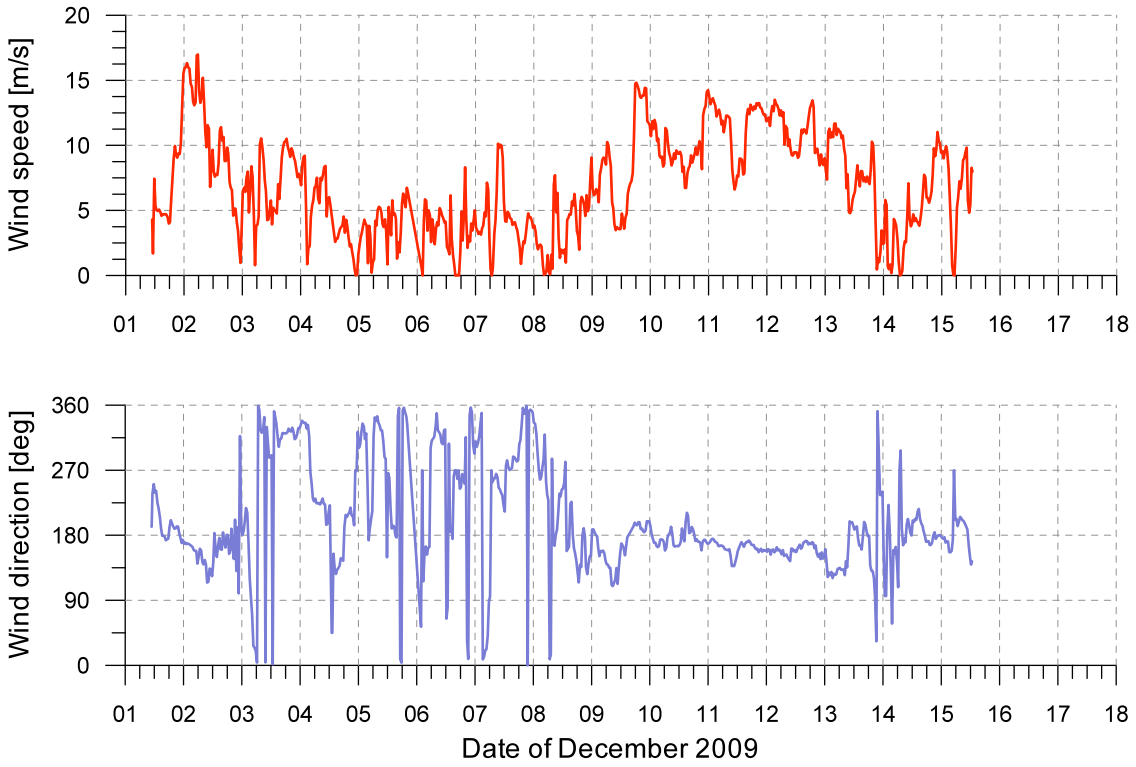


Figure 6: Wind speed and direction measured by the weather station onboard FRS *Africana*.

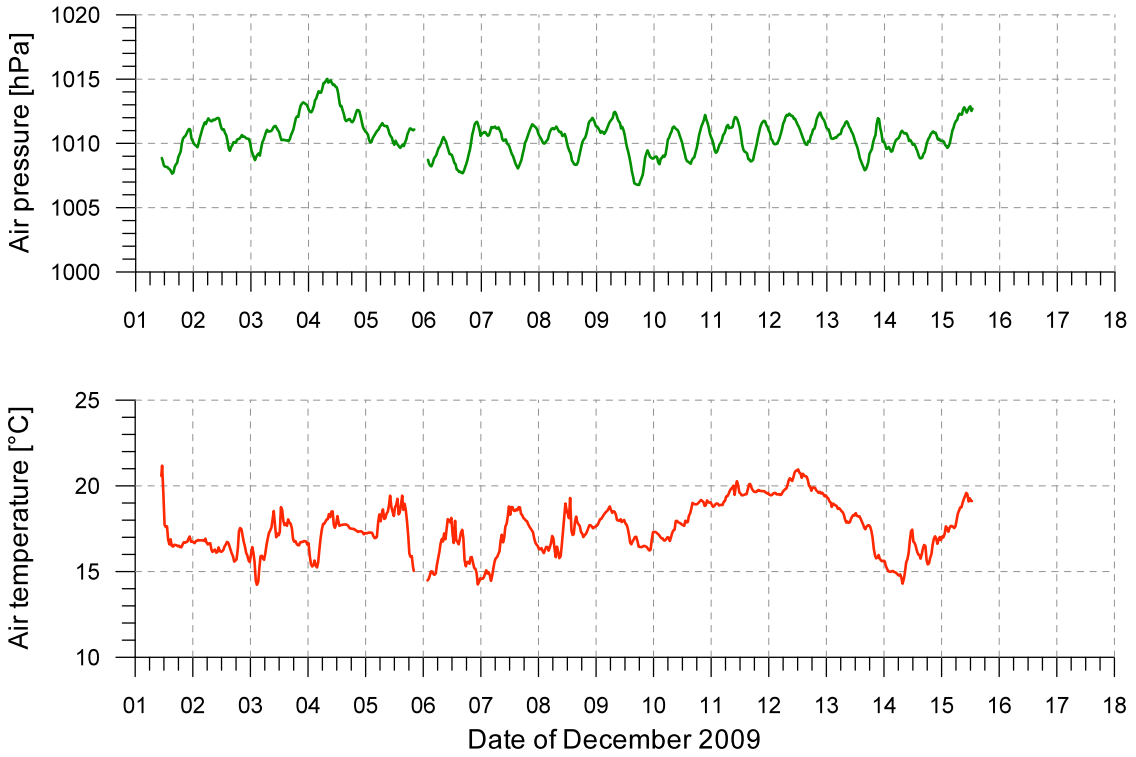


Figure 7: Air pressure and temperature measured by the ship weather station of RV Africana.

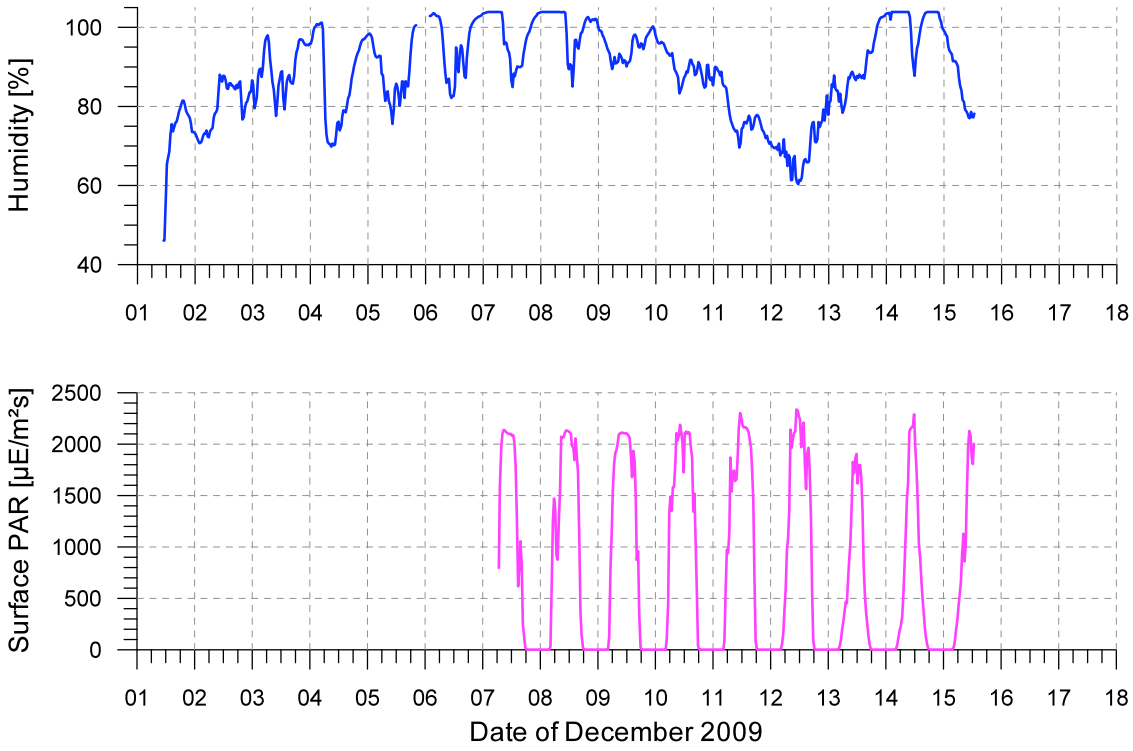


Figure 8: Humidity and global radiation measured by the ship weather station of RV Africana.

The air pressure showed a semi-diurnal cycle, as expected for this trade wind region. It showed only minor excursions around a mean value of 1010 hPa. The air temperature varied according to the diurnal cycle between 15 and 20°C.

The humidity was relatively high, between 80% and 100% near to the coast.

Unfortunately, surface PAR was only available during the second part of the cruise. Maximum values at noon were about 2200 µE/m^{2}s.

1.2.2. St. Helena Bay transect (32.5°S)

The St. Helena Bay transect was carried out in the framework of the standard monitoring programme of MCM, Cape Town. It consists of 12 CTD stations. Nine of them were additionally worked with the LADCP.

In general, the hydrography was determined by the occurrence of moderate coastal upwelling. The thermocline depth (15°C isotherm) decreased continuously from 120 m at the shelf edge toward the coast. The thermocline intersects the surface 10 nm offshore. The cold upwelled water at the coast originated from a depth of 100 to 200 m.

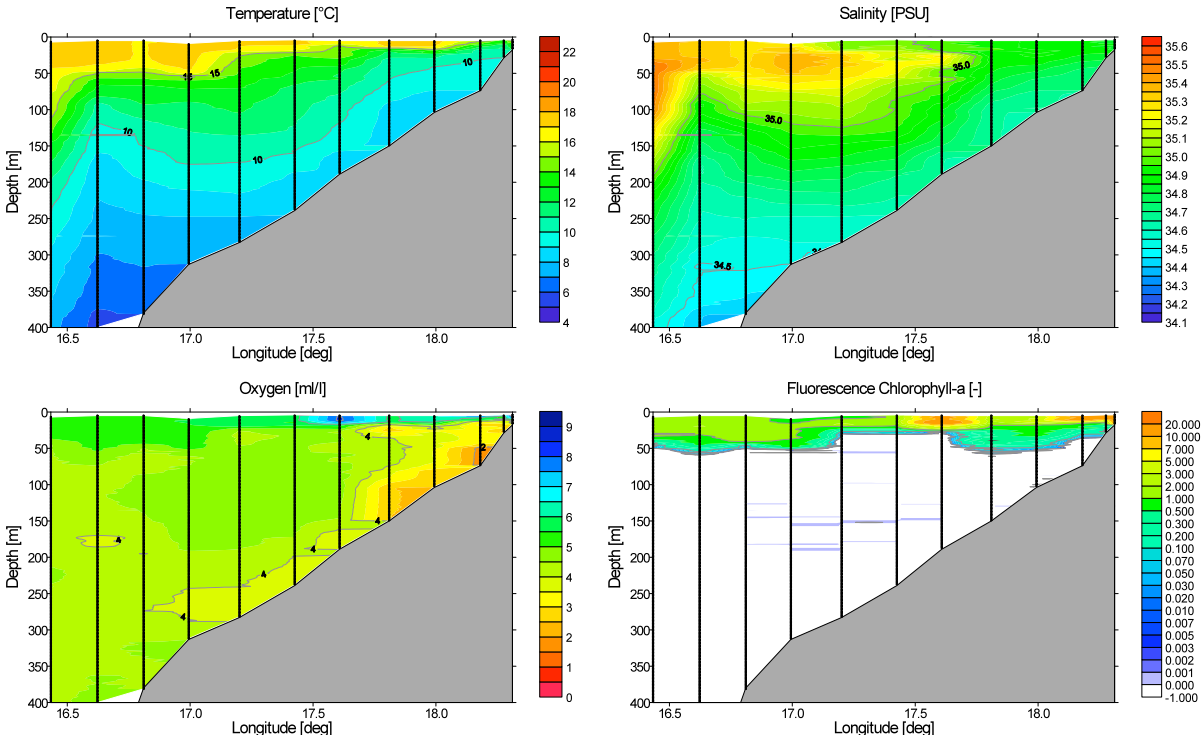


Figure 9: Distribution of temperature, salinity, oxygen and Chl-*a* fluorescence at the St. Helena Bay transect (02.12.2009 03:28 - 22:56 UTC).

The bottom layer on the shelf was covered by oxygen-depleted waters. The oxygen concentrations decreased from 4 ml/l at the shelf edge down to 1.7 ml/l inshore. In contrast, the surface layer showed high oxygen concentrations up to 8 ml/l within 30 nm from the coast, suggesting a high level of primary production. This was also supported by the distribution of Chlorophyll-*a* fluorescence that showed two intensive patches in the surface layer at the location of high oxygen concentration (Figure 9).

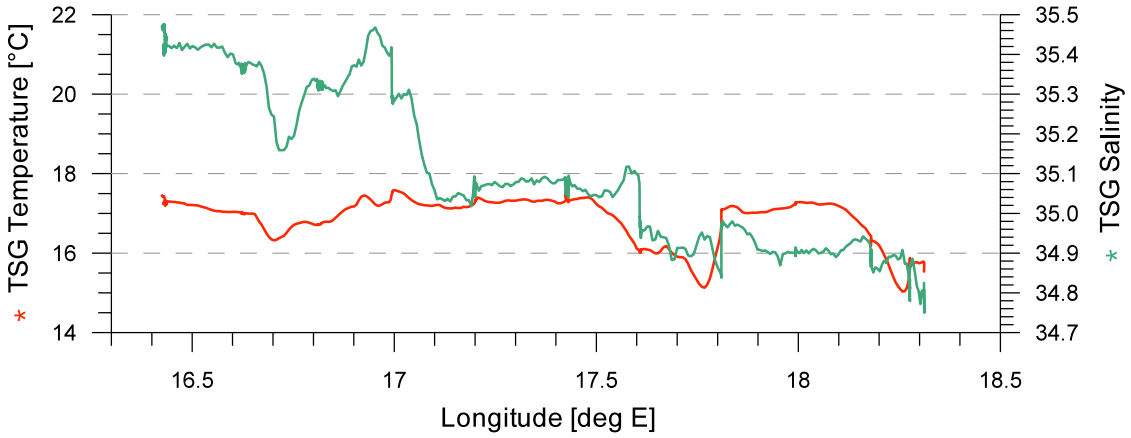


Figure 10: Surface temperature and salinity along the St. Helena Bay transect (TSG data).

The central water layer along the transect consisted exclusively of Eastern South Atlantic Central Water (ESACW), which was expected at this latitude (Figure 11). At depth of the Antarctic Intermediate Water (AAIW) a different, interleaving water mass is evident in the TS diagram as well as in the vertical profile at around 750 m depth. However, the LADCP current profile depicts no anomaly at this depth (not shown).

The offshore surface waters form a patch of more saline water. This patch is the uppermost layer of an eddy-like structure over the shelf edge. The current meter data as well as the sloping isotherms at the shelf edge point to a cyclonic eddy in the upper 400 m of the water column.

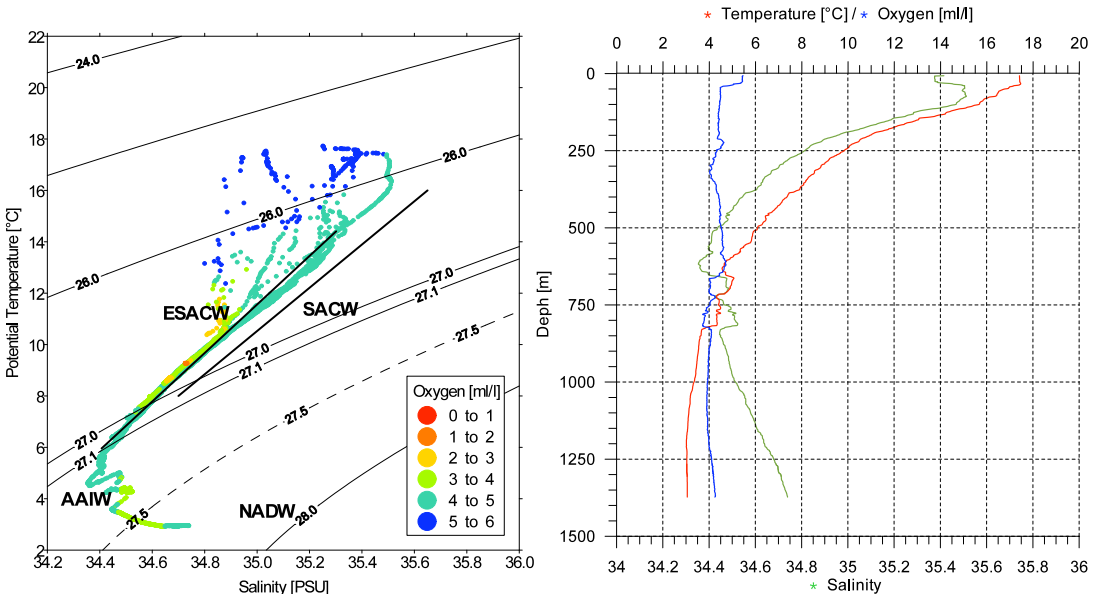


Figure 11: TS-diagram of the St. Helena Bay transect (left) and shelf-edge CTD profile of this transect (right).

The VMADCP and LADCP data provided consistent current patterns (compare Figure 12 and Figure 13).

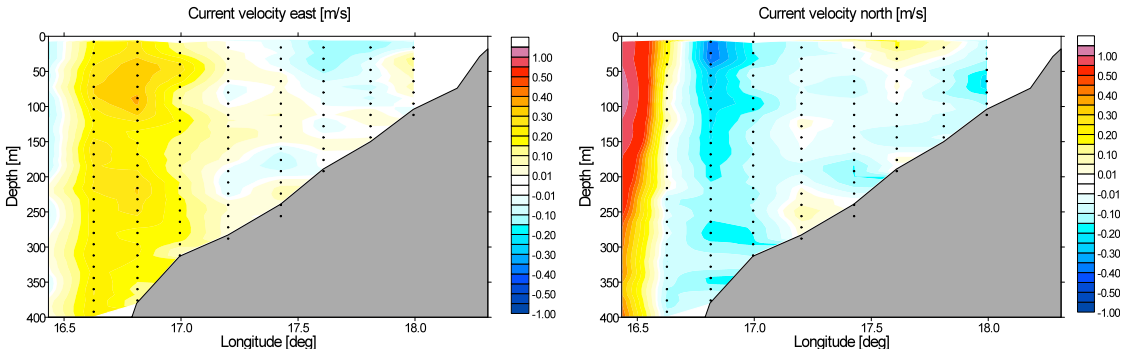


Figure 12: Distribution of current velocity along the St. Helena Bay transect (LADCP data, 02.12.2009 04:05 - 19:33 UTC)

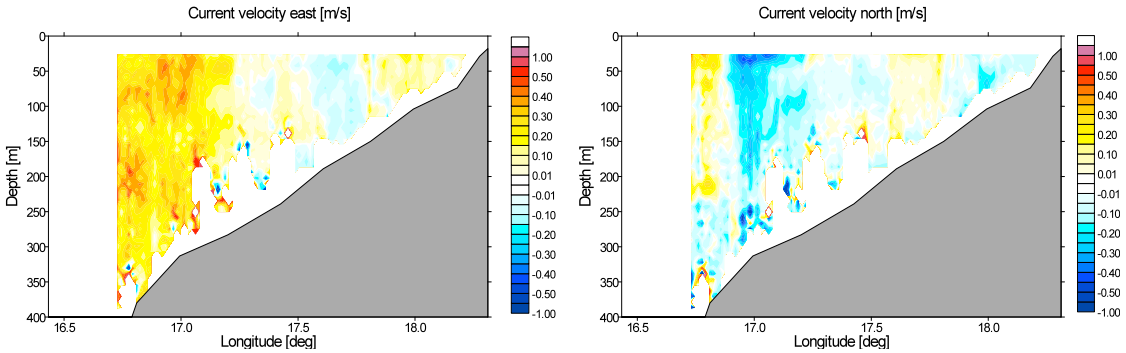


Figure 13: Distribution of current velocity along the St. Helena Bay transect (VMADCP data, 02.12.2009 04:05 - 19:33 UTC)

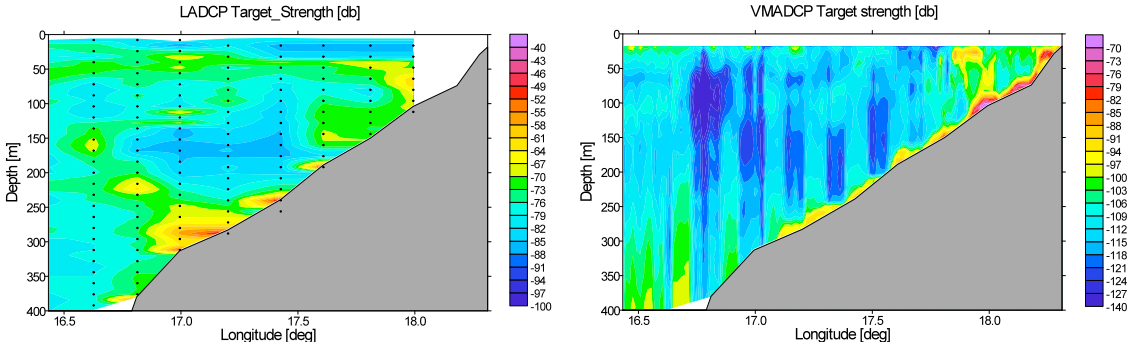


Figure 14: Distribution of target strength along the St. Helena Bay transect (LADCP data – left panel, VMADCP data – right panel, 02.12.2009 04:05 - 19:33 UTC)

1.1.3. Walvis Bay transect (23°S)

The Walvis Bay transect was worked on the way back to Cape Town from 12 to 14 Dec. This transect consisted of 5 CTD stations. Strong upwelling-favourable winds prevailed prior to and during sampling on this transect. Thus, the vertical distributions of temperature, salinity and oxygen show a typical coastal upwelling pattern. The thermocline depth decreased from 50 m at the oceanic edge to 15 m mid shelf, and intersected the surface at 15 to 20 nm off the coast (Figure 15).

The salinity distribution shows a less saline surface layer of upwelled central water of 20 m thickness. The original depth layer of the upwelled water was approximately 150 to 200 m. The salinity maximum was found closely below the thermocline. The upwelling dynamics lifts oxygen-depleted water onto the shelf. The decomposition of organic matter in the mud belt leads to anoxic conditions at the shelf. Free hydrogen sulfide was present in the bottom water at the coastal station.

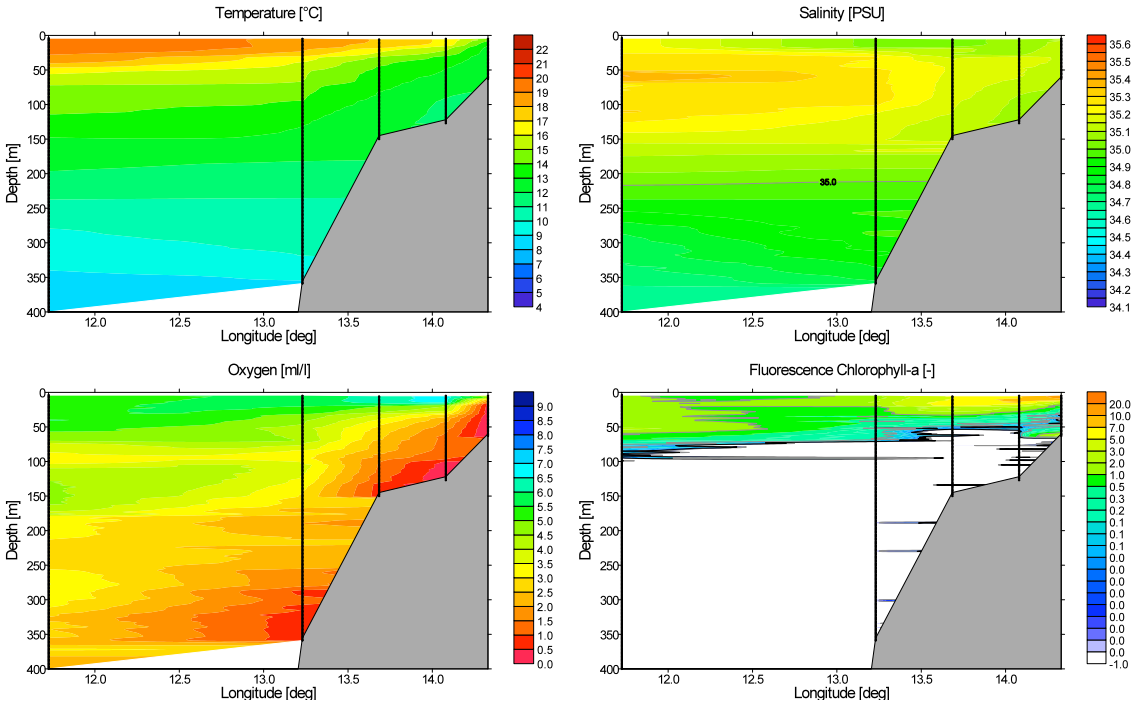


Figure 15: Distribution of temperature, salinity, oxygen and Chl-a fluorescence along the Walvis Bay transect (12.12.2009 21:48 - 14.12.2009 01:53 UTC).

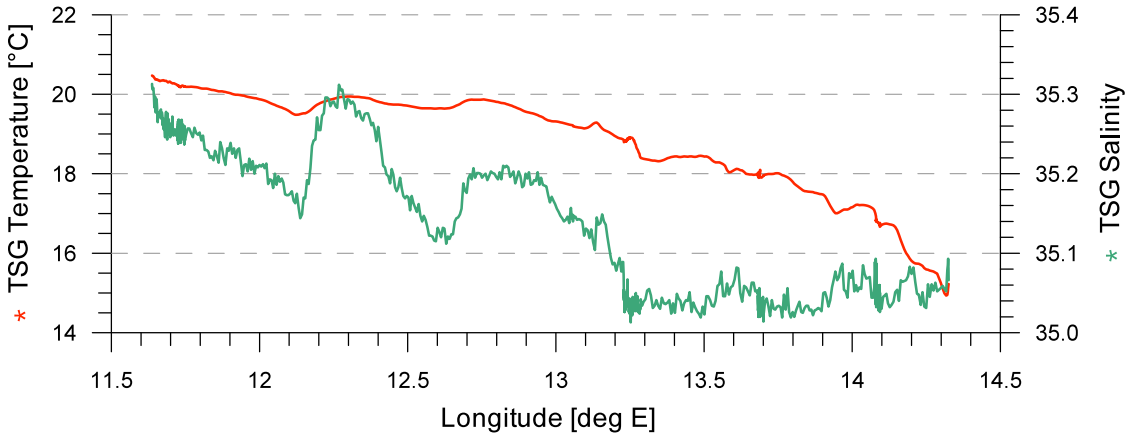


Figure 16: Surface temperature and salinity along the Walvis Bay transect (TSG data).

The intense upwelling causes a high primary production in a thin surface layer on the inner shelf, depicted by the enhanced oxygen concentrations and the high Chl-*a* fluorescence.

Between the thermocline and 400 m depth, ESACW with different oxygen concentrations was present. The changing oxygen levels point to an interleaving of ESACW of varying age. Below 400 m down to 600 m an increasing fraction of SACW was found. The SACW fraction increases towards the shore. The core of AAIW was located at 760 m.

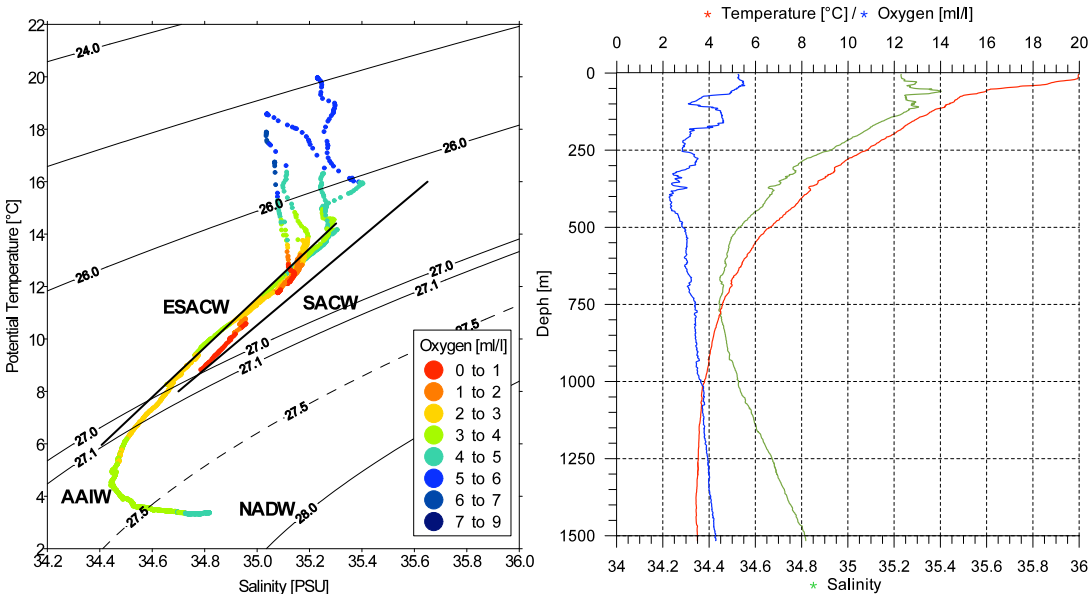


Figure 17: TS-diagram of Walvis Bay transect (left) and shelf-edge CTD profile of this transect (right).

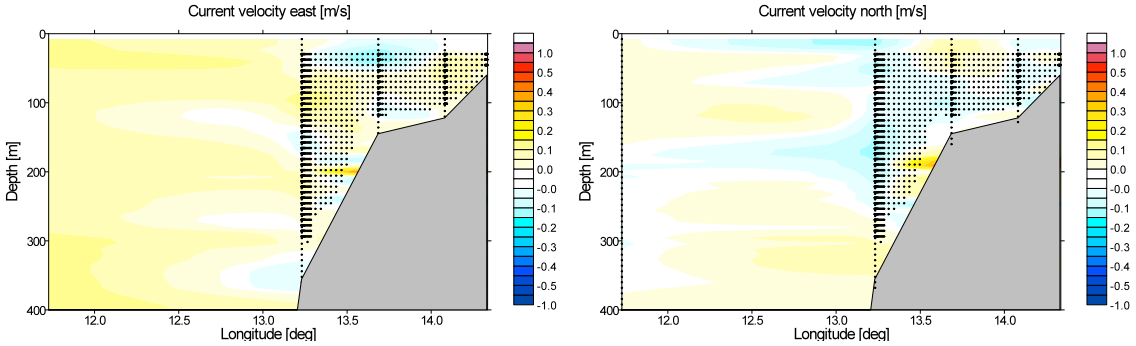


Figure 18: Distribution of current velocity along the Walvis Bay transect (12.12.2009 21:48 - 14.12.2009 01:53 UTC, composite of VMADCP and LADCP data)

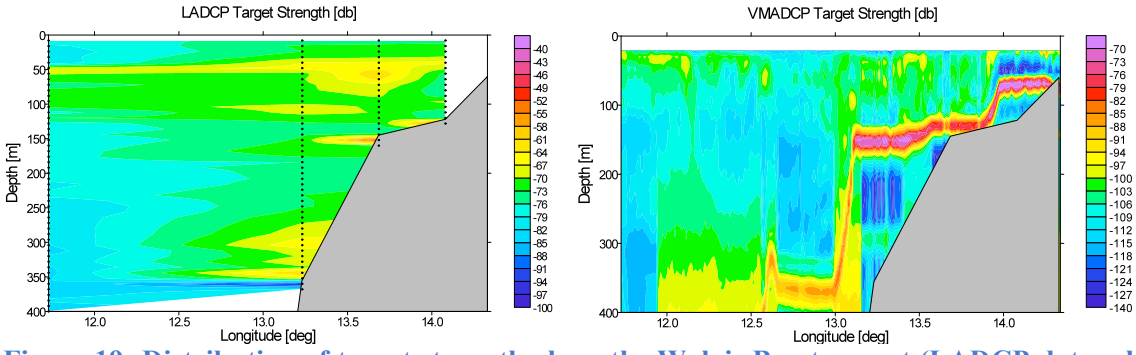


Figure 19: Distribution of target strength along the Walvis Bay transect (LADCP data – left panel, VMADCP data – right panel, 12.12.2009 21:48 - 14.12.2009 01:53 UTC)

1.1.4. Rocky Point transect (19°S)

The Rocky Point transect was worked in two steps. The 4 inshore stations were done on the way to the Kunene transect at 08/09 December. The fifth oceanic station was sampled on the way back to Walvis Bay on 11 December.

Due to the upwelling-favourable winds from 08 Dec onwards, an active upwelling cell was observed at the coast. At the inshore station cold oxygen-depleted water was lifted up to the surface. The primary production near the coast was limited to a shallow surface layer of about 25 m depth (Figure 20). Further offshore the productive layer covered the upper 50 m down to the thermocline.

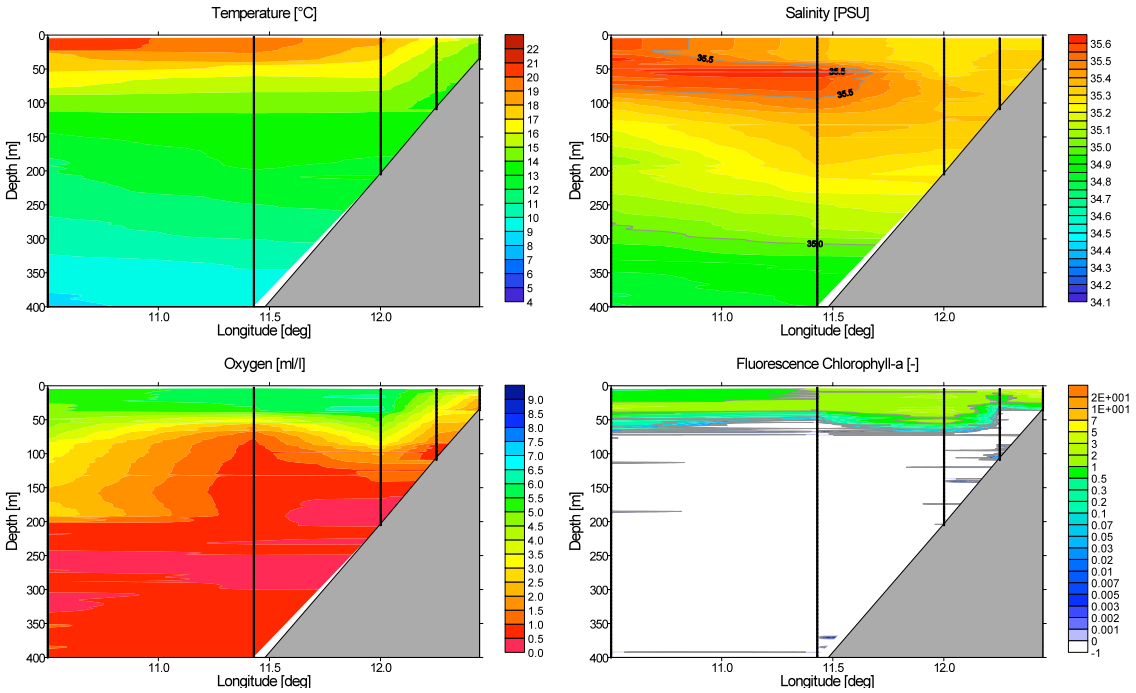


Figure 20: Distribution of temperature, salinity, oxygen and Chl-*a* fluorescence at the Rocky Point transect (08.12.2009 13:53 - 09.12.2009 03:13 UTC, 11.12.2009 09:30).

The surface layer on the shelf was covered by low-salinity water, most probably upwelled and central water transported offshore from a depth of about 150 m. Below the thermocline the oxygen concentration decreased rapidly, except at the westernmost station. The core of the oxygen minimum layer was found at a depth range of 200 to 300 m. In middle of the transect, where the core of the oxygen minimum layer hits the bottom, station 30253 depicts anoxic bottom waters.

The central water layer at this transect is covered by South Atlantic Central Water (SACW), except at the westernmost station where the upper 200 m consists mainly of ESACW. The vertical transition between both central water masses is clearly seen in the TS-diagram as well as in the vertical profile of this station (Figure 22). The core of AAIW was found at 820m depth.

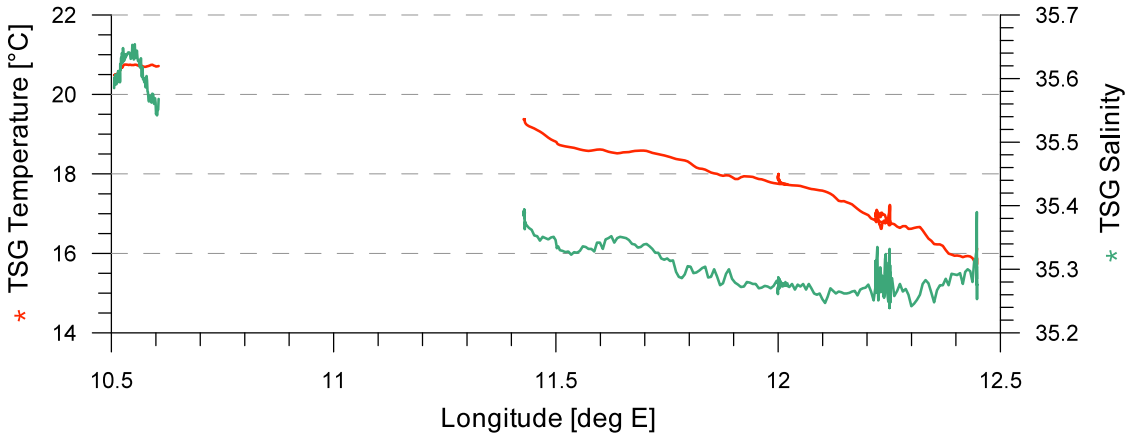


Figure 21: Surface temperature and salinity along the Rocky Point transect (TSG data).

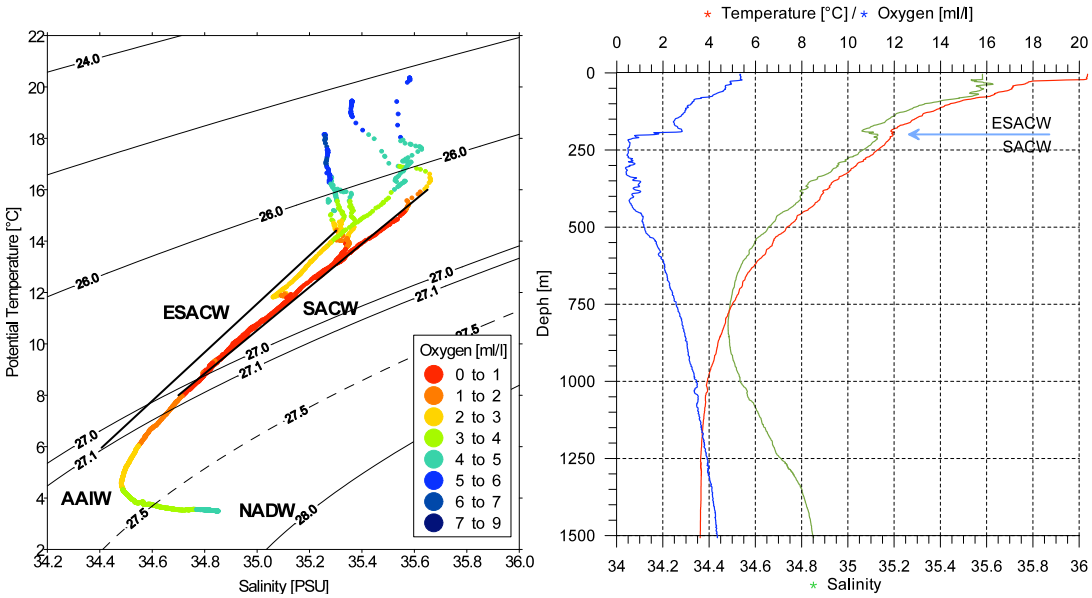


Figure 22: TS-diagram of Rocky Point transect (left) and shelf-edge CTD profile of this transect (right).

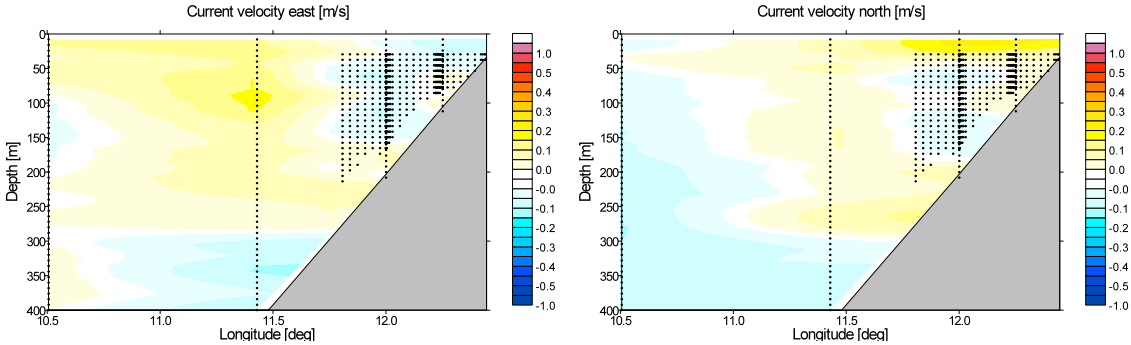


Figure 23: Distribution of current velocity at the Rocky Point transect (08.12.2009 16:21 - 11.12.2009 10:02 UTC, composite of VMADCP and LADCP data)

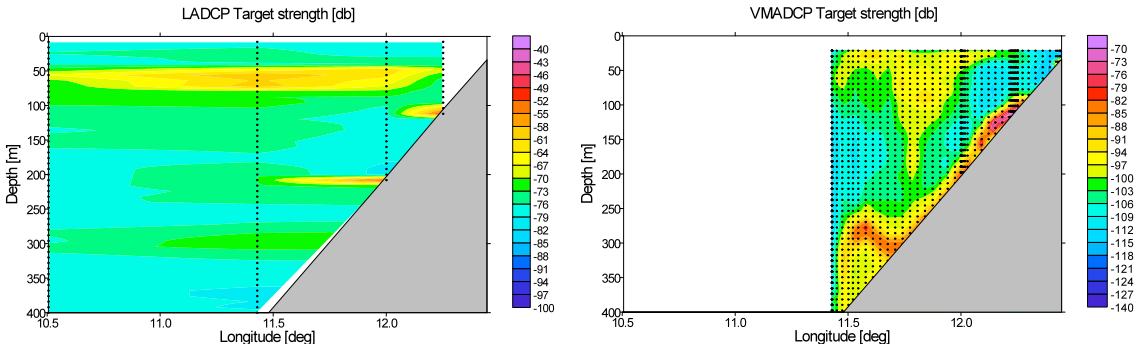


Figure 24: Distribution of target strength at the Rocky Point transect (LADCP data – left panel, VMADCP data – right panel , 08.12.2009 16:21 - 11.12.2009 10:02 UTC)

1.2.5. Kunene transect (17.25°S)

The Kunene transect was sampled during strong upwelling-favourable winds on 09/10 December 2009. The active upwelling at the coast is clearly seen in the distribution of temperature and oxygen along the transect (Figure 25). The entire surface layer was covered by high-salinity water. Salinity at the coast was slightly lower due to upwelled water from deeper layers.

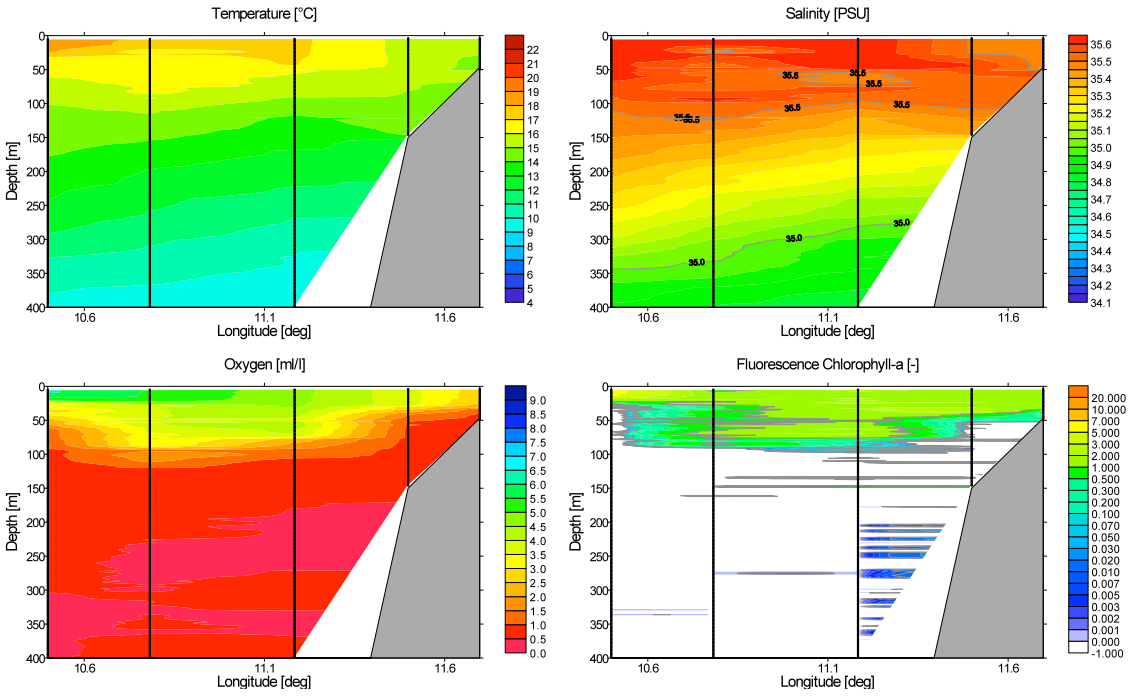


Figure 25: Distribution of temperature, salinity, oxygen and Chl-*a* fluorescence along the Kunene transect (09.12.2009 17:30 - 10.12.2009 16:12 UTC).

The oxygen minimum zone covers the entire central water layer from the thermocline at 50 to 100 m down to 600 m depth. The oxygen concentrations in the central water were below 1 ml/l.

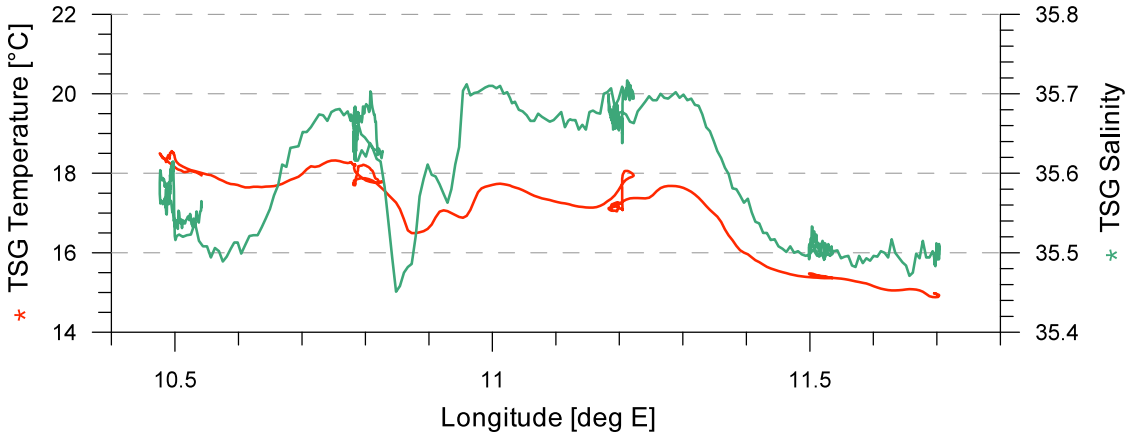


Figure 26: Surface temperature and salinity along the Kunene transect (TSG data).

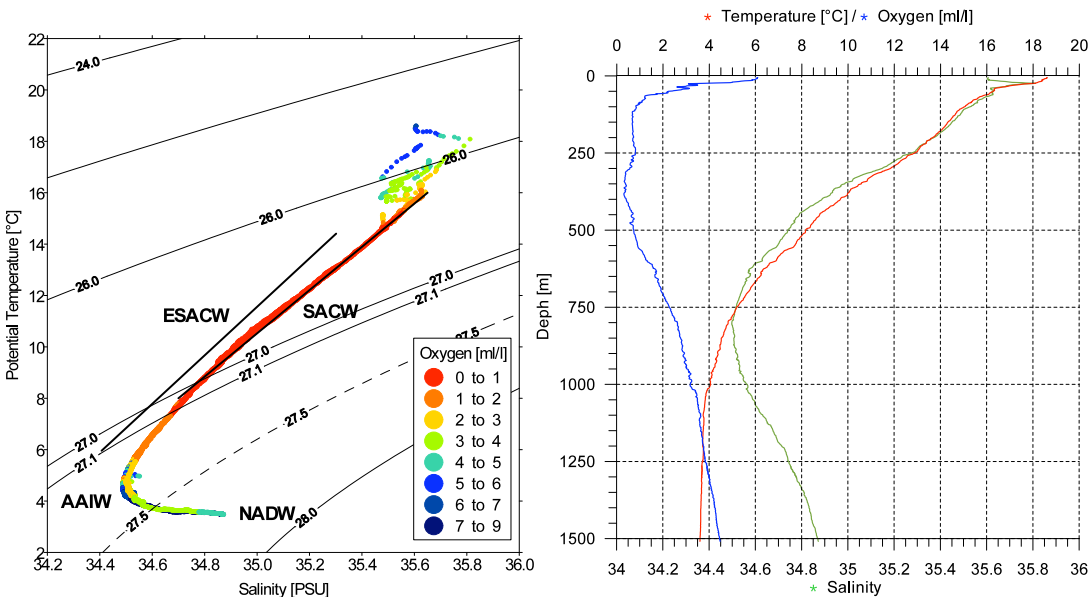


Figure 27: TS-diagram of the Kunene transect (left) and shelf-edge CTD profile of this transect (right).

At this transect the central water layer was covered exclusively by SACW with low oxygen concentration. Between 50 m and 600 m depth the oxygen concentration was well below 1ml/l. The core of AAIW was found at 800 m depth, 20 m higher than at the Rocky Point transect.

The current patterns showed the typical upwelling regime at the coast, with offshore Ekman transport in the upper 40 m and an onshore compensation flow below the thermocline. At the oceanic edge of the transect a northwestward current was observed in the upper 250 m.

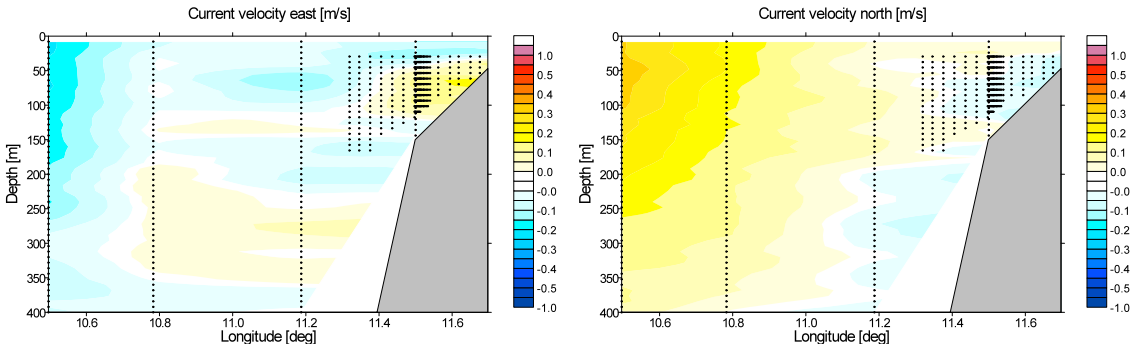


Figure 28: Distribution of current velocity at the Kunene transect (09.12.2009 20:15 - 10.12.2009 16:43 UTC, composit of VMADCP and LADCP data)

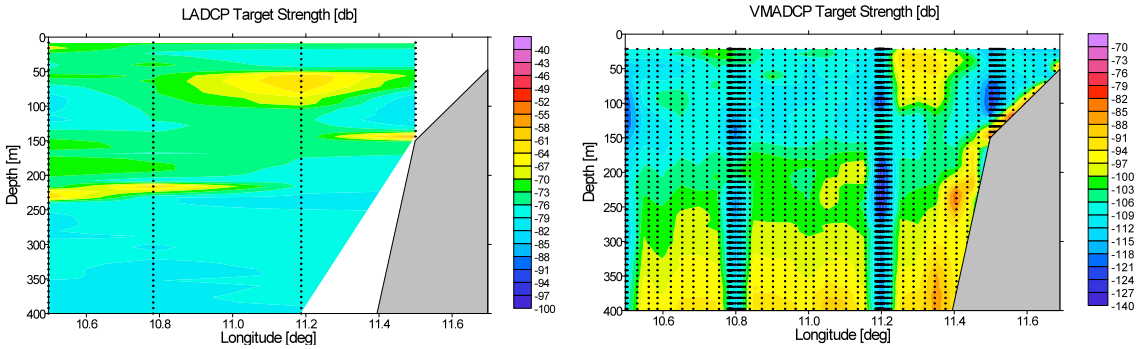


Figure 29: Distribution of target strength at the Kunene transect (LADCP data – left panel, VMADCP data – right panel , 09.12.2009 20:15 - 10.12.2009 16:43 UTC)

1.2.6. Lüderitz area

In the area off Lüderitz two additional stations were worked on the way back to Cape Town. The aim was to improve the data coverage between the Walvis Bay and the St. Helena Bay transects.

The less saline surface water indicated upwelling at the coast. However, at the position of station stn049 the upwelled water at the surface was aged. The Chl-*a* fluorescence in the upper 40 m was low. At the depth of the thermocline an intensive subsurface Chl-*a* fluorescence maximum was observed.

The upper central water layer was covered by pure ESACW down to 300 m. Between 300 and 500 m depth few layers of interleaving ESACW and SACW were observed and caused a high vertical variability in temperature, salinity and oxygen concentration. The core of AAIW was found at 670 m depth, which was much shallower than expected for this region.

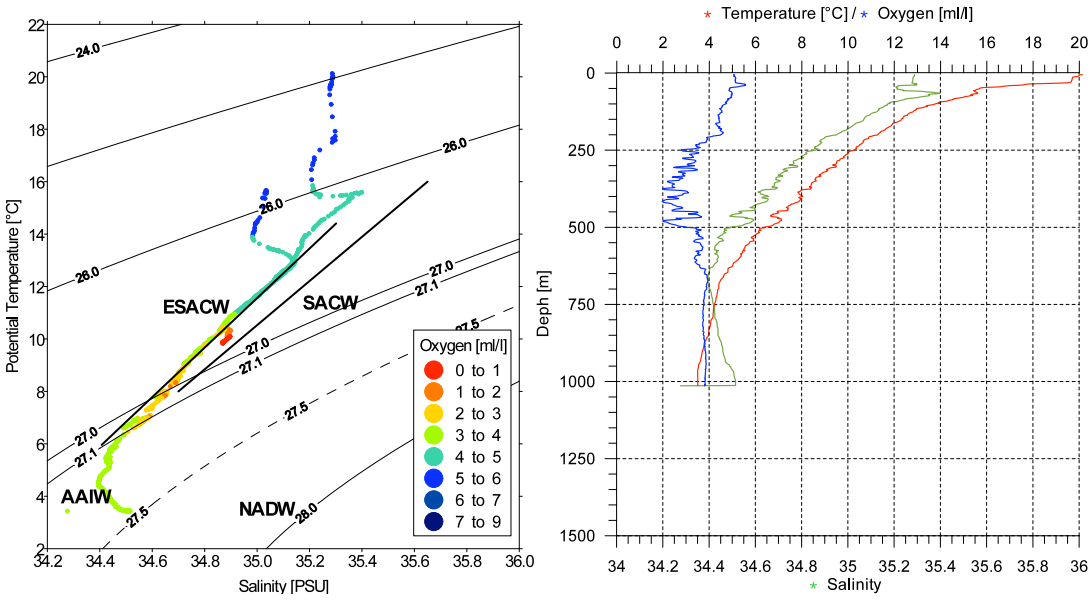


Figure 30: TS-diagram of the Lüderitz area stations (left) and shelf edge CTD profile of this transect (right).

1.2.7. Large scale distributions

The data from the CTD and the thermosalinograph were used to derive horizontal distributions of physical parameters. The pictures shown here should, again, be interpreted with caution, since the data were collected over an extended period of 16 days.

At 20 m depth the temperature distribution shows upwelling along the entire coast, except for a small area off Oranjemund. In the northern Benguela the upwelled water is strongly oxygen depleted.

The central water distribution at 100 m depth is depicted by the salinity distribution. High salinities in the north are associated with SACW, the lower-salinity water in the south is ESACW. The transition zone between both water masses stretches from the Rocky Point transect southward to Lüderitz.

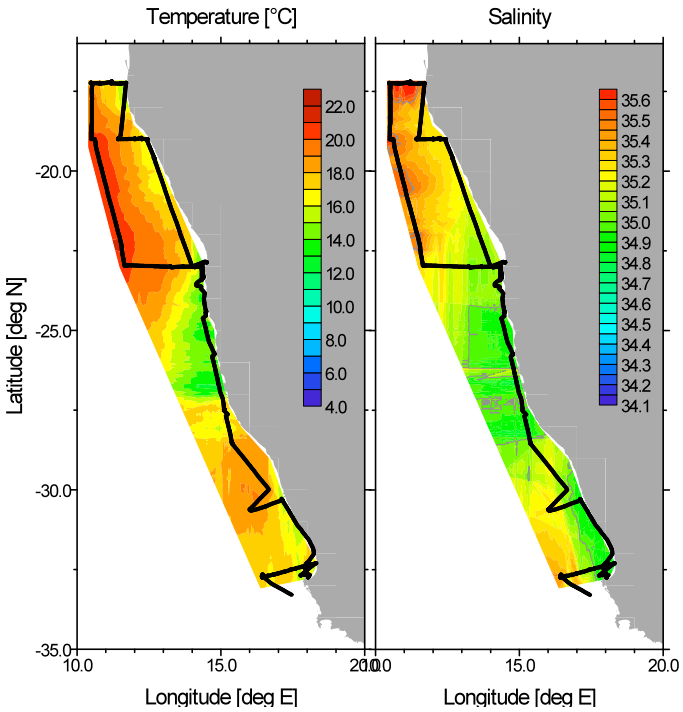


Figure 31: Horizontal distribution of sea surface temperature and salinity during the cruise (TSG data, the cruise track is indicated by the black line).

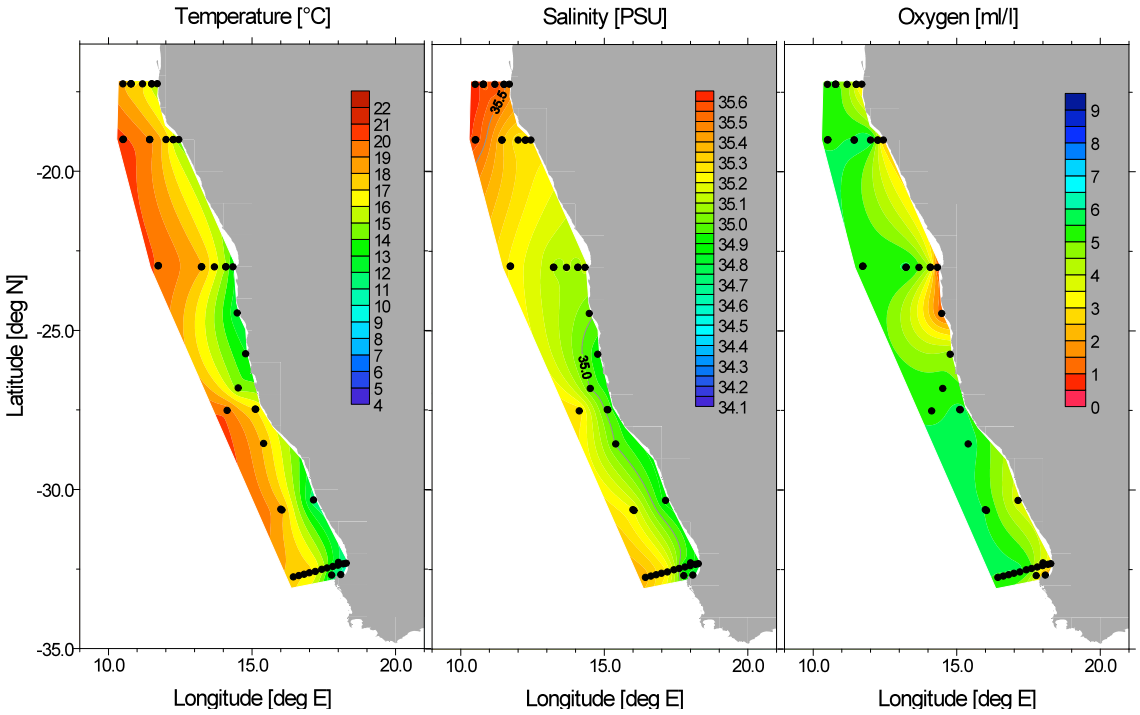


Figure 32: Horizontal distribution of temperature, salinity and oxygen at 20 m depth (based on CTD data)

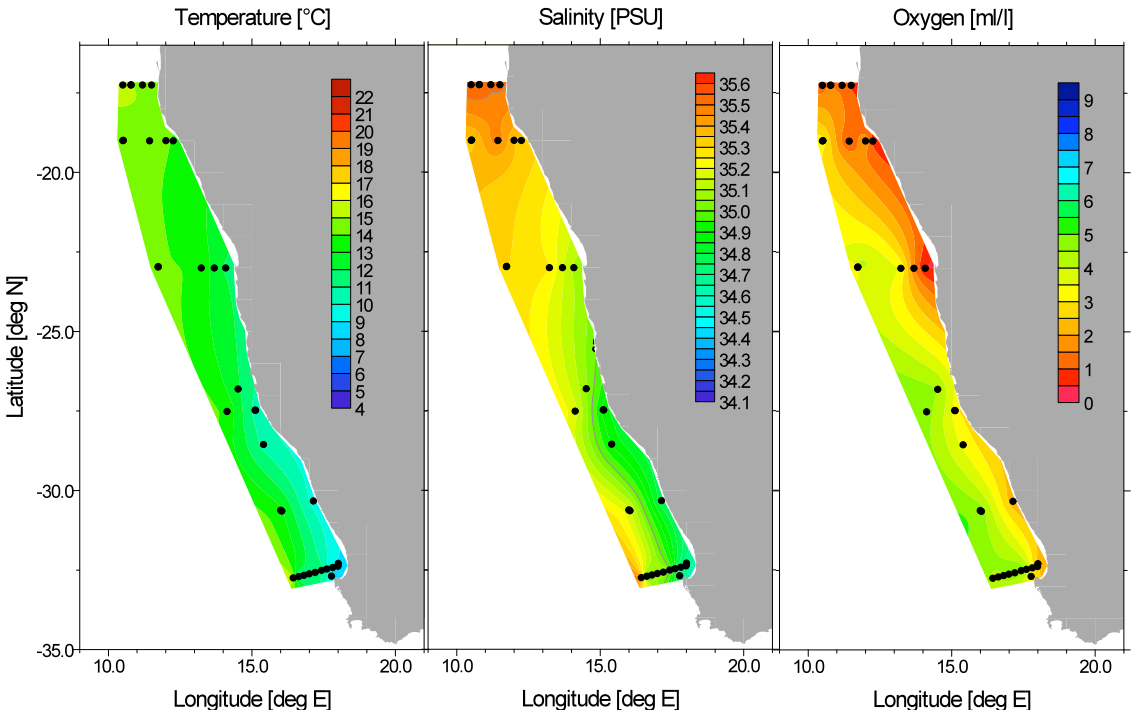


Figure 33: Distribution of temperature, salinity and oxygen at 100 m depth (based on CTD data)

1.2.8. Mooring 23 nm off Walvis Bay

The HRMB mooring revealed time-series of temperature, salinity and currents from the bottom layer covering the depth range of 114 to 135 m. During the first part of the deployment the temperatures varied between 11.5 and 11.6°C. From 15 Nov. onward a weak temperature increase was observed (Figure 34).

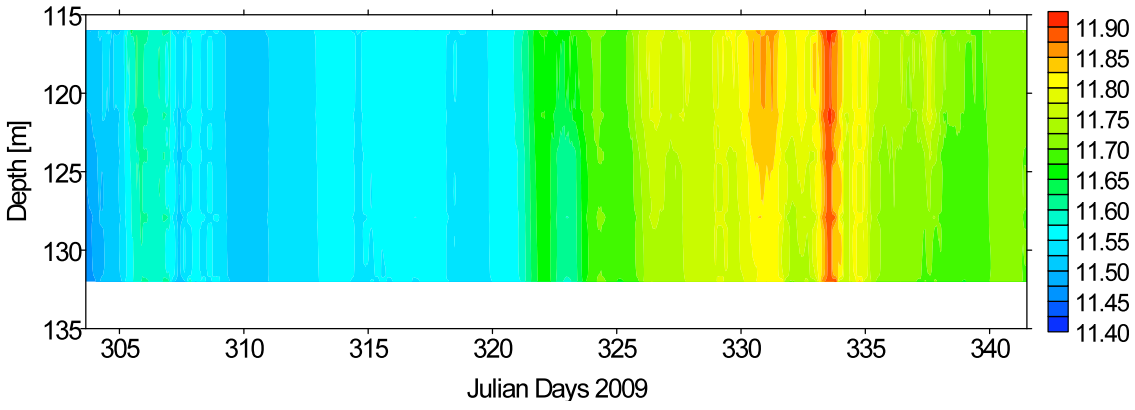


Figure 34: Temperature time-series from the moored instruments 23 nm off Walvis Bay.

The stratification in the 20 m above the bottom is very weak during the entire measuring period. Between 03 and 18 Nov. the bottom layer was completely mixed (Figure 35).

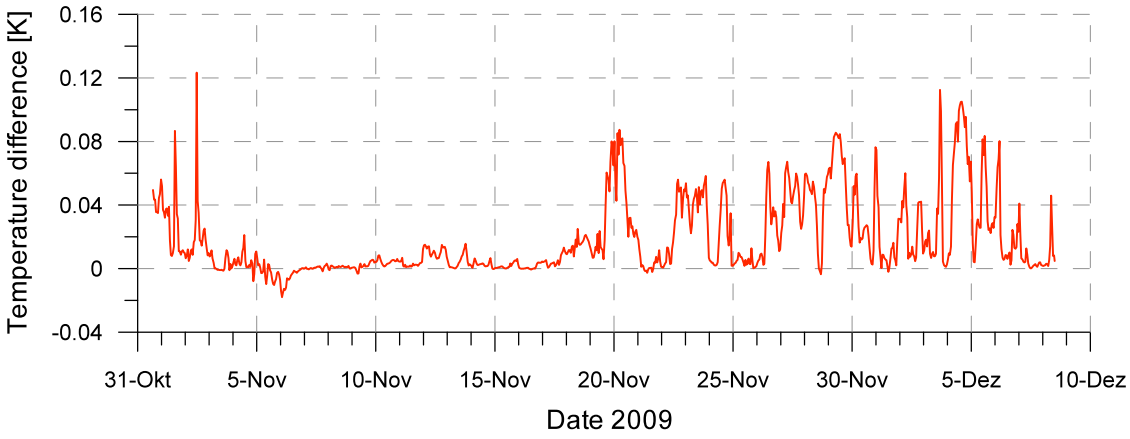


Figure 35: Time-series of temperature difference between 116 m and 132 m at the HRMB mooring.

The current signal is dominated by the M2 tidal current with speeds up to 6 cm/s. The north component showed a superimposed poleward background current until 08 Nov. (Figure 36).

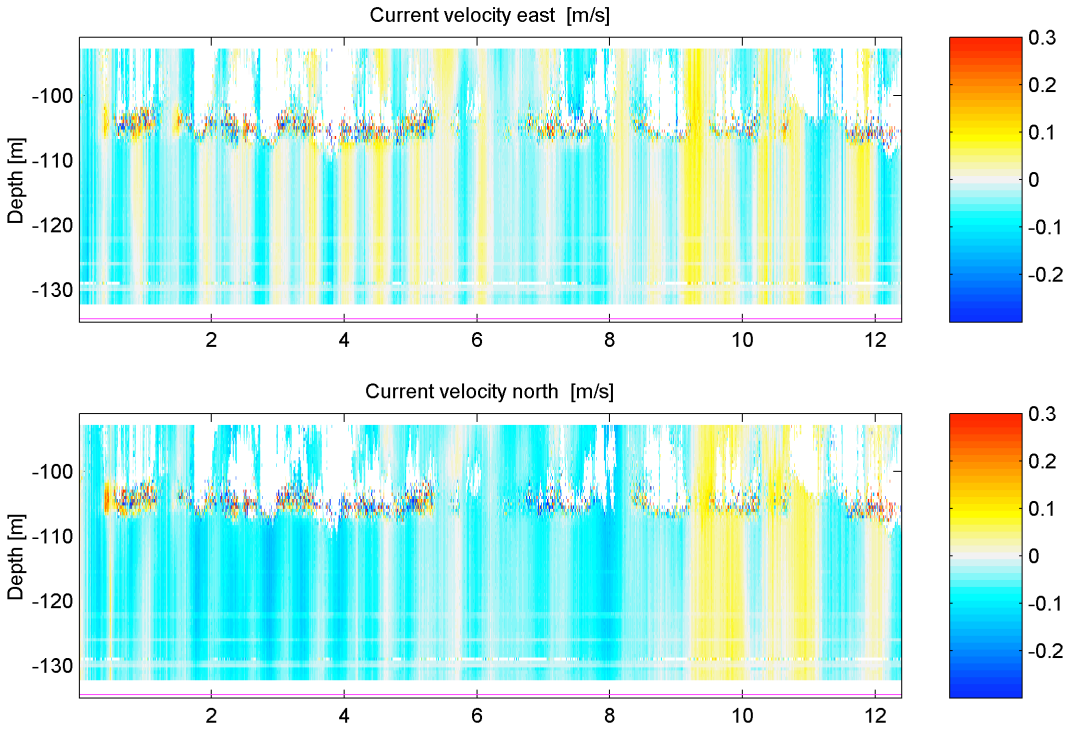


Figure 36: Time-series of current measurements at the mooring position (01 Nov – 12 Nov 2009)

Short-term fluctuations in current velocity are mainly caused by internal waves. Wave periods are ranging approximately between 20 min and 1.5 hours. An example of such waves is given in Figure 37. The figure shows a one-day section of the current time-series. The vertical current

velocities, associated with internal waves, were about 1 cm/s. The strong signal in the vertical current velocity and in the acoustic backscatter (Figure 38) at 04:00 and 17:00 UTC was caused by diel vertical migration of zooplankton.

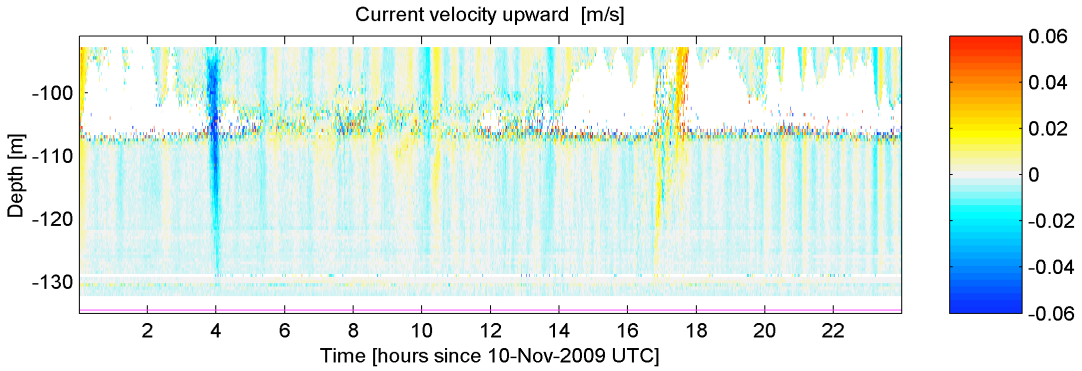


Figure 37: One-day section of vertical current velocity at the mooring position (10 Nov 2009).

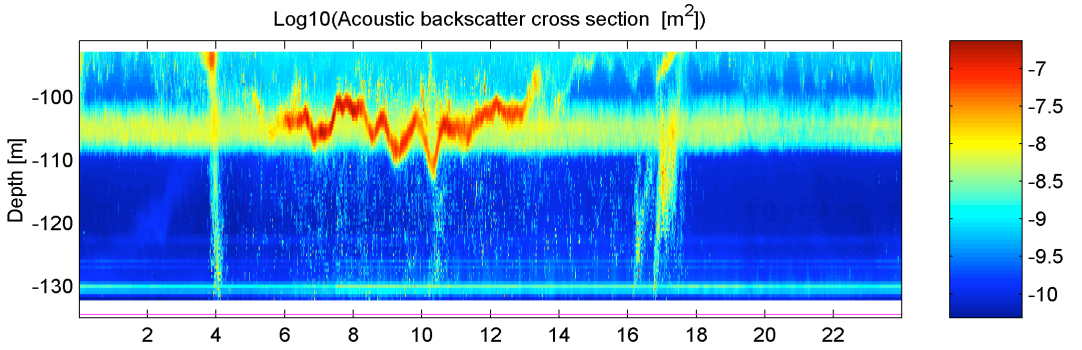


Figure 38: One-day cross-section of acoustic backscatter at the mooring position (10 Nov 2009).

1.3. Stations and deployments

Table 4: List of CTD/LADCP stations

No.	*Station No.* *Stat. Name*		*Date*	*Time [UTC]*	*Latitude*	*Longitude*	*CTD cast*	*LADCP cast*
1	30230 09-12-12	Begin	02.12.2009	03:00:56	32° 44.29'S	016° 26.17'E	Stn001	Ax001
		End	02.12.2009	04:56:25	32° 42.17'S	016° 25.73'E		
2	30231 09-12-11	Begin	02.12.2009	06:25:43	32° 42.11'S	016° 37.27'E	Stn002	Ax002
		End	02.12.2009	07:26:15	32° 41.45'S	016° 38.00'E		

3	30232	Begin	02.12.2009	08:31:14	32° 39.53'S	016° 48.59'E	Stn003	Ax003
	09-12-10	End	02.12.2009	09:25:33	32° 39.98'S	016° 49.36'E		
4	30233	Begin	02.12.2009	10:33:56	32° 36.88'S	016° 59.56'E	Stn004	Ax004
	09-12-09	End	02.12.2009	11:14:48	32° 37.00'S	016° 59.81'E		
5	30234	Begin	02.12.2009	12:26:02	32° 34.22'S	017° 11.96'E	Stn005	Ax005
	09-12-08	End	02.12.2009	13:04:05	32° 34.18'S	017° 12.23'E		
6	30235	Begin	02.12.2009	14:25:00	32° 30.18'S	017° 25.44'E	Stn006	Ax006
	09-12-07	End	02.12.2009	15:00:38	32° 30.07'S	017° 25.82'E		
7	30236	Begin	02.12.2009	16:01:27	32° 27.85'S	017° 36.41'E	Stn007	Ax007
	09-12-06	End	02.12.2009	16:39:00	32° 27.66'S	017° 36.66'E		
8	30237	Begin	02.12.2009	17:44:16	32° 24.91'S	017° 48.57'E	Stn008	Ax008
	09-12-05	End	02.12.2009	18:16:01	32° 24.94'S	017° 48.68'E		
9	30238	Begin	02.12.2009	19:23:10	32° 22.42'S	017° 59.55'E	Stn009	Ax009
	09-12-04	End	02.12.2009	19:59:08	32° 22.39'S	018° 00.32'E		
10	30239	Begin	02.12.2009	21:00:45	32° 19.82'S	018° 10.80'E	Stn010	-
	09-12-03	End	02.12.2009	21:27:18	32° 20.01'S	018° 10.76'E		
11	30240	Begin	02.12.2009	22:09:55	32° 18.59'S	018° 16.54'E	Stn011	-
	09-12-02	End	02.12.2009	22:24:41	32° 18.72'S	018° 16.56'E		
12	30241	Begin	02.12.2009	22:51:20	32° 18.03'S	018° 18.67'E	Stn012	-
	09-12-01	End	02.12.2009	23:05:55	32° 18.00'S	018° 18.64'E		
13	30242	Begin	03.12.2009	02:33:53	32° 40.97'S	017° 46.12'E	Stn013	-
	09-12-22	End	03.12.2009	03:00:18	32° 40.99'S	017° 46.08'E		
14	30243	Begin	03.12.2009	04:38:37	32° 40.00'S	018° 05.11'E	Stn014	-
	09-12-21	End	03.12.2009	04:53:35	32° 40.11'S	018° 05.07'E		
15	30244	Begin	03.12.2009	10:29:14	32° 17.14'S	018° 00.41'E	Stn015	Ax010
	Fi-1	End	03.12.2009	12:30:00	32° 19.57'S	017° 58.19'E		
16	30245	Begin	04.12.2009	01:58:07	30° 19.05'S	017° 07.90'E	Stn016	

16	Fi-2	Begin	04.12.2009	01:58:07	30° 19.05'S	017° 07.90'E	Stn016	Ax011
		End	04.12.2009	04:08:36	30° 19.33'S	017° 07.94'E		
17	30246	Begin	04.12.2009	10:40:12	30° 38.50'S	016° 02.37'E	Stn017	Ax012
	Fi-3	End	04.12.2009	13:26:36	30° 36.54'S	016° 00.14'E	Stn018	Ax013
18	30247	Begin	05.12.2009	03:45:23	28° 29.74'S	015° 22.54'E	Stn019	Ax014
	Fi-4	End	05.12.2009	06:06:12	28° 32.97'S	015° 23.63'E	Stn019k	
19	30248	Begin	05.12.2009	13:24:01	27° 28.26'S	015° 06.41'E	Stn020	Ax015
	Fi-5	End	05.12.2009	15:42:12	27° 30.87'S	015° 07.23'E	Stn021	Ax016
20	30249	Begin	06.12.2009	03:16:15	25° 44.54'S	014° 46.20'E	Stn022	Ax017
	Fi-6	End	06.12.2009	05:23:31	25° 44.06'S	014° 46.00'E	Stn022k	
21	30250	Begin	06.12.2009	13:33:18	24° 25.49'S	014° 28.39'E	Stn023	-
	Fi-7	End	06.12.2009	14:15:51	24° 26.72'S	014° 28.76'E		
22	30251	Begin	08.12.2009	13:50:23	19° 00.06'S	012° 26.73'E	Stn024	-
	T-5-5	End	08.12.2009	15:03:01	19° 00.33'S	012° 26.68'E		
23	30252	Begin	08.12.2009	16:09:34	19° 00.05'S	012° 15.09'E	Stn025	Ax018
	T-5-4	End	08.12.2009	19:56:36	18° 57.59'S	012° 14.49'E	Stn026	
24	30253	Begin	08.12.2009	21:26:03	19° 00.09'S	011° 59.90'E	Stn027	Ax019
	T-5-3	End	08.12.2009	23:54:28	18° 59.27'S	012° 01.26'E		
25	30254	Begin	09.12.2009	03:08:23	19° 00.13'S	011° 25.88'E	Stn028	Ax020
	T-5-1	End	09.12.2009	07:55:20	18° 57.92'S	011° 29.19'E	Stn029	
26	30255	Begin	09.12.2009	17:26:45	17° 14.85'S	011° 41.82'E	Stn030	-
	Add-11	End	09.12.2009	18:36:58	17° 14.69'S	011° 42.12'E		
27	30256	Begin	09.12.2009	20:01:35	17° 15.03'S	011° 29.93'E	Stn031	Ax021
	Add-10	End	09.12.2009	22:15:01	17° 15.96'S	011° 32.07'E	Stn032	
28	30257	Begin	10.12.2009	00:22:13	17° 14.97'S	011° 10.98'E	Stn033	Ax022
	T-2-2	End	10.12.2009	06:59:52	17° 12.56'S	011° 11.94'E		
29	30258	Begin	10.12.2009	09:28:31	17° 15.06'S	010° 46.93'E	Stn034	

29	Add-06	Begin	10.12.2009	09:28:31	17° 15.06'S	010° 46.93'E	Stn035	Ax023
		End	10.12.2009	13:27:40	17° 14.97'S	010° 46.94'E	Stn036	
30	30259	Begin	10.12.2009	16:08:45	17° 14.93'S	010° 29.98'E	Stn037	Ax024
	T-1-2	End	10.12.2009	21:33:35	17° 14.95'S	010° 32.52'E		
31	30260	Begin	11.12.2009	09:29:08	18° 59.99'S	010° 30.02'E	Stn038	Ax025
	T-5-1a	End	11.12.2009	15:08:47	19° 00.13'S	010° 37.18'E	Stn039	
32	30261	Begin	12.12.2009	19:35:12	22 57.93S	011 38.95E	Stn040	Ax026
	T-8-1a	End	13.12.2009	00:54:25	22 57.31S	011 44.82E	Stn041	
33	30262	Begin	13.12.2009	09:43:10	22 59.99S	013 13.68E	Stn042	Ax027
	T-8-1	End	13.12.2009	13:35:40	23 01.43S	013 17.22E	Stn043	
34	30263	Begin	13.12.2009	15:46:26	23 00.08S	013 40.97E	Stn044	Ax028
	T-8-3	End	13.12.2009	18:41:20	23 00.46S	23 00.46S		
35	30264	Begin	13.12.2009	20:46:10	23 00.00S	014 04.60E	Stn045	Ax029
	T-8-4	End	14.12.2009	00:11:05	23 00.70S	014 05.58E	Stn046	
36	30265	Begin	14.12.2009	01:33:19	22 59.88S	014 19.33E	Stn047	-
	T-8-5	End	14.12.2009	03:57:01	22 59.67S	014 19.19E	Stn047k	
37	30266	Begin	15.12.2009	03:16:31	26 47.37S	014 30.03E	Stn048	-
	H-4	End	15.12.2009	05:32:49	26 47.54S	014 30.00E	Stn048k	
38	30267	Begin	15.12.2009	10:46:32	27 30.62S	014 07.68E	Stn049	Ax030
	Add-ctd	End	15.12.2009	11:35:57	27 30.55S	014 07.77E		

Table 5: Vessel mounted ADCP deployments

Deployment	***Start date***	***Start time [UTC]***	***End date***	***End time [UTC]***	***Comment***
Afr258_001	01.12.2009	11:09:48	01.12.2009	12:02:51	
Afr258_002	01.12.2009	12:05:41	01.12.2009	17:14:24	
Afr258_003	01.12.2009	17:16:11	02.12.2009	09:26:38	St Helena Bay transect
Afr258_004	02.12.2009	09:27:10	03.12.2009	06:20:34	St Helena Bay transect

Afr258_005	03.12.2009	06:21:40	03.12.2009	17:13:42	
Afr258_006	03.12.2009	17:14:25	04.12.2009	12:31:12	
Afr258_007	04.12.2009	13:12:52	04.12.2009	14:48:41	
Afr258_008	04.12.2009	15:08:17	05.12.2009	20:11:19	
Afr258_010	05.12.2009	20:27:29	06.12.2009	01:50:17	Bad heading data
Afr258_011	06.12.2009	01:51:25	07.12.2009	07:17:05	End at Walvis Bay
Afr258_012	07.12.2009	08:10:01	09.12.2009	17:31:57	Rocky Point transect
Afr258_013	09.12.2009	17:32:12	12.12.2009	22:11:42	Kunene transect
Afr258_014	12.12.2009	22:12:03	15.12.2009	10:35:18	Walvis Bay transect
Afr258_015	15.12.2009	10:35:46			Bin size set to 16m

Table 6: List of phytoplankton samples

No.	*Station*	*Date*	*Time [UTC]*	*BID Mix sample*	*BID Fmax sample*	*Comments*	*CTD cast*
1	30232	02.12.2009	08:31:14	33-35	-	Cryo sample frozen at -20°C	Stn003
2	30234	02.12.2009	12:26:02	57-59	57		Stn005
3	30235	02.12.2009	14:25:00	68-70	68		Stn006
4	30236	02.12.2009	16:01:27	77-81	80		Stn007
5	30237	02.12.2009	17:44:16	89-93	92		Stn008
6	30245	04.12.2009	04:08:36	187-190	187		Stn016
7	30246	04.12.2009	13:26:36	210-214	211		Stn018
8	30251	08.12.2009	13:50:23	278-289	286		Stn024
9	30252	08.12.2009	16:09:34	303-311	309		Stn026
10	30253	08.12.2009	21:26:03	319-323	320		Stn027
11	30254	09.12.2009	03:08:23	344-348	343		Stn029
12	30255	09.12.2009	17:26:45	354-360	358		Stn030
13	30256	09.12.2009	20:01:35	375-384	372		Stn031

14	30257	10.12.2009	00:22:13	395-396	396		Stn033
15	30258	10.12.2009	09:28:31	412-420	420, 416	2 Fmax samples (25m, 75m)	Stn035
16	30259	10.12.2009	16:08:45	443-445	444		Stn037
17	30260	11.12.2009	09:29:08	462-465	463		Stn039
18	30261	12.12.2009	19:35:12	485-490	485		Stn041
19	30262	13.12.2009	09:43:10	509-515	511		Stn043
20	30263	13.12.2009	15:46:26	523-528	525		Stn044
21	30264	13.12.2009	20:46:10	544-549	549		Stn046
22	30265	14.12.2009	01:33:19	559-564	563		Stn047
23	30266	15.12.2009	03:16:31	572-576	576		Stn048
24	30267	15.12.2009	10:46:32	584-588	586		Stn049

2. WORKING GROUP 'NUTRIENT FLUXES - GEOCHEMICAL AND ISOTOPIC TRACERS'

Personnel: Niko Lahajnar, Andreas Neumann and Markus Ankele (Institute for Biogeochemistry and Marine Chemistry, University of Hamburg, Germany and GKSS Research Institute, Geesthacht, Germany)

Major contributions of the working group *Nutrient fluxes - Geochemical and Isotopic Tracers* to the GENUS project and specifically during the *Africana* Voyage 258 were to measure, analyse and interpret the biogeochemical cycling of nutrient elements between the atmosphere, water column, biota and sediments. These results are prerequisites to understand the trophic interactions and energy flows within the biotic system and to validate and improve existing models, which are part of other sub-projects within the GENUS framework. In particular, we focussed our work on three subjects:

- Automatic detection of physical variables, nutrients and gas components in the surface water throughout the entire cruise (Ferrybox and *Systea* auto-analyser)
- Sampling and filtration of particulate matter (*seston)* and dissolved components (nutrients and other organic and inorganic substances for stable isotope analysis)
- Surface sediment sampling (Multicorer and MIMS)

2.1. Ferrybox and *Systea* auto-analyser

The Ferrybox including the autoanalyser *Systea Micromac 1000* was connected to a continuous flow (10-15 Litres per minute) of surface seawater, and measured every minute (every 30

minutes for nutrients) the following variables: conductivity, temperature, salinity, oxygen (content and saturation), fluorescence, turbidity, pH, NO_2, NO_3, PO_4 and SiO_2. Precision of nutrient measurements was checked against fresh calibration standards on a daily basis. In addition, samples for re-calibration in our home laboratories were taken every day. Thus, it is cautioned that some of the results shown below should be treated as preliminary and have to be validated after the cruise.

Nonetheless, the results show very clear trends where, for example, upwelling in terms of changing water temperature and conductivity occurred along the coastline from approx. 27° to 23°S as well as in the Kunene area at approx. 17°S. They also demonstrate how the water chemistry was affected by these water mass flows. However, it turned out that there was no direct 1:1 correlation between the extent and intensity of upwelling on the one hand and the geochemical state of the respective water mass at the surface on the other hand. In the Kunene area physical and chemical properties were somehow connected, i.e. low water temperature went along with enhanced nutrient concentrations, oxygen depletion and very elevated CO_2 levels (results from Carbon Biogeochemistry Working Group - T. Rixen). This relationship was less pronounced or even quite ambiguous in the coastal area between 27° and 23°S where the chemical composition of the coastal water was patchy and characterised by small-scale variations (see Figure 1). The varying chemical inventory in the upwelling cells were to some extent based on the fact that the upwelled water masses were of different origin and therefore also of different age or stage.

The Ferrybox measurements revealed a short-term and small-scale variability and patchiness of the Benguela upwelling system and emphasised the necessity to conduct field expeditions under various oceanographic conditions in order to be able to understand and at least to some extent to quantify nutrient fluxes and their impact on the food chain in the Benguela area.

2.2. Water Sampling

Water samples were taken from almost every CTD cast from various depths (Table 1). The particulate matter fraction was filtered on GF/F filters. Further analytical investigations of this particulate fraction will be carried out for the bulk geochemical content, isotopic composition (^{13}C and ^{15}N) and biogeochemical proxies such as, for example, amino acid spectra. The filtrate will be analysed for the isotopic composition of nutrients (^{15}N and ^{18}O) of NO_3, NO_2 and DON. These results are a prerequisite for understanding nutrient cycling and biotic interactions.

Moreover, one major aim is to establish empirical fractionation factors of dissolved inorganic nitrogen and diagenetic alteration by paired analyses of $\delta^{15}N$ in dissolved components compared to chlorophyll, bulk particulate mater, and surface sediments. Analogous analyses at higher trophic levels will be done by other sub-projects. In addition to the filtration campaign, incubation experiments with labelled nitrogen gas ($^{15}N_2$) were carried out at selected stations in order to detect and describe potential nitrogen fixation in the Benguela upwelling system (see Montoya et al. 1996, Environmental Microbiology 62, 986-993 and Wasmund et al. 2001, Marine Ecology Progress Series, 214, 1-14 for further details on the analytical method).

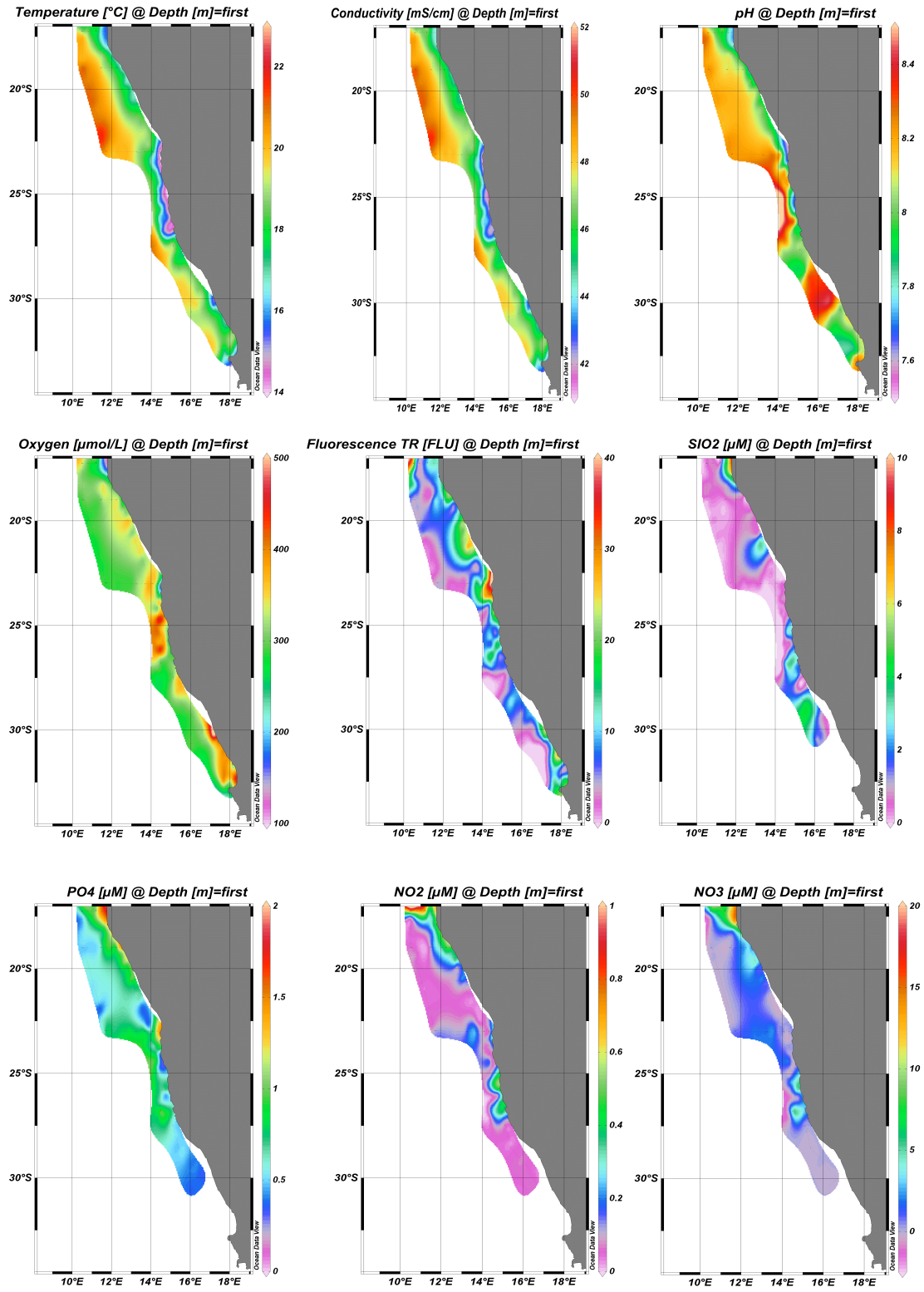


Figure 1: Physical and chemical properties of the Benguela upwelling area in December 2009 obtained from continuous measurements (>17 000 data points) of a Ferrybox and *Systea* autoanalyser installed on FRS *Africana*.

Table 1: Water samples taken from CTD casts. N-Fix = nitrogen fixation experiments carried out with labelled $^{15}N_2$ gas in an incubation box installed on deck. PM = particulate matter filtered on GF/F filters.

Station No.	Position [Lat/Lon]	Bottle Depth [m]	Nutrients	$^{15}NO_2$	$^{15}NO_3$	N-Fix	PM [Liter]	Remarks
30231	32°42.14'S	Surface	x		x			
	16°37.32'E	11.1	x		x			
		24.9	x		x			F-Max
		30.5	x		x			
		49.7	x		x			
		100.8	x		x			
		201.2	x		x			
		504.4	x		x			
		546.5	x		x			
30233	32°36.92'S	Surface	x		x			
	16°59.64'E	10.6	x		x			
		19.5	x		x			F-Max
		29.7	x		x			
		50.3	x		x			
		101.7	x		x			
		200.8	x		x			
		310.8	x		x			
30235	32°30.21'S	Surface	x		x			
	17°25.49'E	11.8	x		x			
		23.2	x		x			F-Max
		30.3	x		x			
		49.6	x		x			
		100.5	x		x			
		237.0	x		x			
30237	32°24.92'S	Surface	x		x			
	17°48.58'E	10.8	x		x			F-Max

		19.8	x		x		
		29.6	x		x		
		50.1	x		x		
		99.4	x	x	x		
		148.0	x	x	x		
30239	32°19.92'S	Surface	x		x		F-Max
	18°10.82'E	20.0	x		x		
		28.8	x		x		
		50.8	x		x		
		72.6	x	x	x		
30244	32°17.15'S	Surface	x		x	2.0	
	18°00.43'E	10	x		x	3.5	F-Max
		40	x		x	6.5	
		80	x	x	x	6.5	
		111	x	x	x	6.0	
30246	30°36.81'S	Surface	x		x	8.0	
	15°59.82'E	30.1	x		x	6.0	
		80.8	x	x	x	7.5	
		121.1	x	x	x	7.5	
		162.4	x	x	x	7.5	
		213.0	x		x	7.0	
30248	27°28.20'S	Surface	x		x	8.0	
	15°06.54'E	9.5	x		x	6.5	
		19.8	x		x	6.5	
		27.5	x		x	7.0	F-Max
		39.6	x		x	7.0	
		50.3	x		x	6.0	
		79.9	x		x	7.0	
		101.1	x	x	x	7.0	

		125.6	x	x	x	7.0	
		151.6	x	x	x	7.0	
30249	25°44.03'S	Surface	x		x	7.0	
	14°46.42'E	9.0	x		x	6.0	
		19.6	x		x	5.0	F-Max
		29.8	x		x	7.0	
		40.7	x		x	7.0	
		49.6	x		x	7.0	
		57.9	x		x	7.0	
30250	24°26.82'S	Surface	x		x	5.0	F-Max
	14°28.62'E	10.3	x		x	6.0	
		20.3	x		x	6.0	
		30.3	x		x	7.0	
		42.2	x		x	7.0	O_2-depleted
30251	19°00.04'S	Surface	x		x	7.0	F-Max
	12°26.77'E	8.8	x		x	7.0	
		20.0	x		x	7.0	
		30.9	x		x	5.0	
		35.0	x		x	5.0	
30252	19°00.04'S	Surface	x		x	5.0	F-Max
	12°15.08'E	10.0	x		x	6.0	
		19.9	x		x	7.0	
		30.1	x		x	7.0	
		39.6	x		x	7.0	
		50.5	x		x	7.0	
		59.5	x		x	7.0	
		69.8	x		x	7.0	
		80.0	x	x	x	7.0	
		90.4	x	x	x	7.0	

		107.8	x	x	x	7.0	O_2-depleted
30253	19°00.04'S	Surface				x	
	12.00.05'E						
30254	19°00.13'S	Surface	x		x	6.0	F-Max
	11°25.88'E	10.6	x		x	7.0	
		20.6	x		x	7.0	
		35.6	x		x	7.0	
		60.7	x		x	7.0	
		75.6	x		x	7.0	
		100.0	x		x	7.0	
		150.0	x		x	7.0	
		200.0	x		x	7.0	
		281.0	x		x	7.0	
		422.0	x		x	7.0	
30255	17°14.82'S	Surface	x		x	5.0	no F-Max
	11°47.83'E	19.8	x		x	7.0	
		34.7	x		x	7.0	
		41.0	x		x	7.0	
		47.0	x		x	7.0	
30256	17°15.05'S	Surface	x		x	7.0	
	11°30.03'E	9.5	x		x	7.0	
		15.2	x		x	7.0	
		20.0	x		x	7.0	
		29.8	x		x	7.0	
		41.2	x		x	7.0	F-Max
		60.2	x		x	7.0	
		79.8	x	x	x	7.0	
		100.0	x	x	x	7.0	
		120.4	x	x	x	7.0	

		144.7	x	x	x		7.0	
30258	17°15.02'S	Surface	x		x	x	7.0	
	10°46.95'E	10.2	x		x		7.0	
		24.6	x		x		6.0	F-Max
		50.8	x		x		7.0	
		75.5	x		x		7.0	F-Max
		100.0	x		x		7.0	
		251.0	x		x		7.0	
		300.0	x		x		9.0	↑
		400.0	x		x		19.0	SACW
		800.0	x		x		21.0	AAIW
		1500	x		x		20.0	NADW
30260	18°59.66'S	Surface	x		x		6.0	
	10°30.48'E	29.9	x		x		7.0	F-Max
		99.8	x		x		7.0	
		159.9	x		x		7.0	EASCW
		200.0	x		x		7.0	EASCW/SACW
		220.0	x		x		7.0	SACW
		397.6	x		x		7.0	SACW
30261	22°58.26'S	Surface	x		x		8.0	
	11°43.51'E	25,7	x		x		7.0	
		50,9	x		x		7.0	F-Max
		99,6	x		x		7.0	
		201	x		x		7.0	
		299,7	x		x		7.0	
		394,4	x		x		7.0	
30262	22°59.86'S	Surface	x		x		8.0	
	13°14.55'E	10.7	x		x		6.0	
		19.8	x		x		6.0	F-Max

		50.2	x		x		7.0	
		80.7	x		x		7.0	
		91.0	x		x		7.0	
		220.0	x		x		14.0	
		357.0	x		x		14.0	
30263	23°00.08'S	Surface	x		x	x	5.0	
	13°40.97'E	15.6	x		x		6.0	F-Max
		149.8	x	x	x		7.0	
30264	23°00.00'S	Surface	x		x		3.0	
	14°04.80°E	10.8	x		x		4.0	F-Max
		19.8	x		x		7.0	
		30.5	x		x		7.0	
		41.8	x		x		7.0	
		61.0	x		x		7.0	
		79.5	x	x	x		7.0	
		101.3	x	x	x		7.0	O_2-depleted
		111.0	x	x	x		7.0	anoxic
		123.7	x	x	x		7.0	anoxic
30265	23°00.05'S	Surface	x		x		4.0	F-Max
	14°19.78'E	20.2	x		x		5.0	O_2-depleted
		40.9	x		x		7.0	anoxic
		62.8	x		x		2 x 3.0	H_2S!
30266	26°48.22'S	Surface	x		x		6.0	F-Max
	14°30.67'E	30.3	x		x		7.0	ESACW
		202.2	x		x		7.0	
		298.2	x		x		7.0	ESACW/SACW
30267	27°30.58'S	Surface	x		x		10.0	ESACW
	14°07.87'E	42.5	x		x		7.0	
		70.6	x		x		7.0	

	151.5	x	x	7.0	
	400.0	x	x	15.5	SACW
	1011	x	x	14.0	AAIW

2.3. Surface Sediment Sampling (Multicorer)

Surface sediment samples were collected using a multicorer. Due to the technical limitation of *Africana* (i.e. wire length and accurate payout load display) only shallow water (< 420 m) stations were successfully sampled during the cruise.

Surface sediments somehow represent an end-member of particulate and dissolved matter cycling and because of partly anoxic conditions they have a great impact on the water chemistry in the Benguela upwelling area. The Multicorer was used along the shelf off Namibia to sample the interface between the water column and the sediment. This interface is of special interest for the GENUS project due to the intense exchange of different compounds between water column and sediment. For example, the sediment receives particulate organic matter from the epipelagic zone, which is then degraded and subsequently released into the bottom water, thus making the sediment a potential source of nitrate. If this mineralisation is very intense due to high loads of particulate organic matter, then the sediment becomes anoxic, and the available nitrate is consumed by denitrification. This turns the sediment into a sink for nitrate. The processes illustrated in this example, as well as others that occur in the sediment, are modulated by the processes in the water column above. Upwelling finally closes the cycle between the sediment and the epipelagic zone, when the bottom water reaches the surface and provides for multiple feedbacks. In another example, intensive primary production in the epipelagic zone stimulates processes in the sediment, which reduce the concentration of reactive nitrogen in the bottom water. This low concentration of reactive nitrogen reaches the epipelagic zone via upwelling and thus reduces primary production. Moreover, a low concentration of reactive nitrogen favours primary producers capable of nitrogen fixation, which alters the species composition of the phytoplankton, and thus significantly affects the whole ecosystem.

The Multicorer was deployed during leg 2 at all shallow stations with water depths up to 420 m (Table 2). Unfortunately, the Multicorer failed repeatedly to obtain sediment cores owing to suspected obstacles like strong currents and very soft sediments. The circumstantial demands on the Multicorer and the ship's gear have not been met fully, which made deployment of the Multicorer impossible at deeper stations.

Whenever cores were obtained, they were used immediately after retrieval to measure oxygen concentration profiles at the water-sediment interface with an oxygen optode. Afterwards the concentration profiles of nitrogen and carbon dioxide were measured in the same core with a membrane probe coupled to a quadrupole mass spectrometer (membrane inlet mass spectrometry - MIMS) to calculate the rates of remineralisation in the sediment and compound fluxes across the water-sediment interface.

Additional cores have been used to sample the pore water and the particulate matter. The first will be used for measurements of dissolved hydrogen sulfide and nutrients, while the latter will be used for analyses of the content of organic and inorganic carbon, the C:N ratio and the nitrogen stable isotope ratio. The supernatant just above the sediment within the core liners was also sampled by the pCO_2 Working Group to obtain samples of bottom water, which is not accessible with a CTD.

Table 2: Surface Sediment Sampling

Station	Water Depth [m]	Cores obtained ?
30250	40	yes
30251	33	no
30252	105	no
30253	200	yes
30254	420	yes
30255	50	yes
30256	145	yes
30262	360	no
30263	146	yes
30264	125	no
30265	50	yes
30266	300	no

Besides sampling of the sediment, a pilot experiment has been conducted with surface water samples to examine the feasibility of the membrane inlet mass spectrometer for measuring nitrogen fixation rates. This will help to expand the range of possible applications of membrane inlet mass spectrometry in marine science. The raw data has not been processed at the time this report was written.

3. WORKING GROUP 'CARBON BIOGEOCHEMISTRY'

Personnel: Tim Rixen, Anita Flohr (Leibniz Centre for Tropical Marine Ecology – ZMT, Bremen)

Within the GENUS framework, the subproject TP4-Biogeochemistry aims at studying the functioning of the biological pump. It is referred to as the uptake of carbon through the photosynthesis of organic matter, the precipitation of calcium carbonate and its subsequent transport from the surface ocean into the sediments. The biological pump strongly influences CO_2 fluxes across the air-water interface and the distribution of dissolved oxygen in the water column. Furthermore it plays an important role for the long-term sequestration of atmospheric CO_2 by linking the three major carbon reservoirs: atmosphere, ocean and lithosphere.

The main aims during the Africana cruise were:

- to quantify CO_2 fluxes across the air-water interface;
- to collect samples for the determination of CH_4 and N_2O as well as nutrients (PO_4, NO_3, NO_2, Si), alkalinity (TA) and total dissolved inorganic carbon (DIC) concentrations; and
- to measure the stable carbon isotope ratios of the DIC ($\delta^{13}C$ – DIC).

Methods – The mole fraction of CO_2 (xCO_2) was continuously measured in the ocean and the atmosphere by using an „*underway carbon dioxide analyser*" SUNDANS. Seawater temperature, salinity, wind speed and the atmospheric pressure continuously recorded by the FRS *Africana* were evaluated and used to convert xCO_2 into the fugacity of CO_2 (fCO_2), which is required to calculate the CO_2 flux across the seawater-air interface. The temporal resolution of the obtained dataset was one minute, which accounted for 1 440 datasets per day.

Samples for the determination of CH_4, N_2O, nutrients, TA, DIC and $\delta^{13}C$ – DIC were taken from the Niskin bottles attached to the CTD-rosette and will be analysed at NatMIRC in Swakopmund, Namibia and at ZMT in Bremen, Germany.

Preliminary results and discussion – Based on the xCO_2 measurements, the transect from Cape Town to the Kunene River can be divided into three sections: the South African coast representing the first section (section I) was characterized by fluxes of CO_2 from the atmosphere into the ocean as indicated by xCO_2 which were lower in the water than in the atmosphere (Figure 1). The second section (II) covering approximately the area between the South Africa-Namibia border and Walvis Bay revealed extremely strong variations of the xCO_2. Within this section the seawater temperatures were lower than both in the south (section I) and in the north (section III). Since wind speeds were relatively low it is assumed that signals of an upwelling event were recorded that occurred in this region prior to the vessels's passage. En route toward the Kunene River, which represents the third section, we sailed directly into an active upwelling cell as shown by the decreasing SWT, the increasing winds speeds and the rising xCO_2 levels.

The extreme variations of xCO_2 within sections II and III are likely to be caused by the passage through alternating filaments of newly and aged upwelled water. Contrary to the CO_2-rich newly upwelled water, phytoplankton blooms reduced the CO_2 concentration in the aged upwelled water.

In order to estimate the CO_2 fluxes across the sea water interface the ΔfCO_2 (fCO_{2ocean}-$fCO_{2atmos.}$) were calculated, averaged for each of the three sections and multiplied by the area of the continental margin characterized by a water depth of < 500m. The resulting CO_2 fluxes showed a weak CO_2 uptake in section I, a weak degassing of CO_2 within section II, and a strong degassing of CO_2 in the active upwelling area of section III. Extrapolated, the cruise data would account to an annual mean CO_2 emission from the Namibian shelf of ~ 11.2 Tg C yr^{-1} whereas the South African shelf would take up ~ 2.5 Tg C yr^{-1}. The extreme spatial and temporal variability within the Benguela upwelling system strongly indicates that the preliminary estimates presented here have to be treated with extreme caution and emphasize the need to increase the sampling density in order to obtain reliable annual mean CO_2 flux estimates.

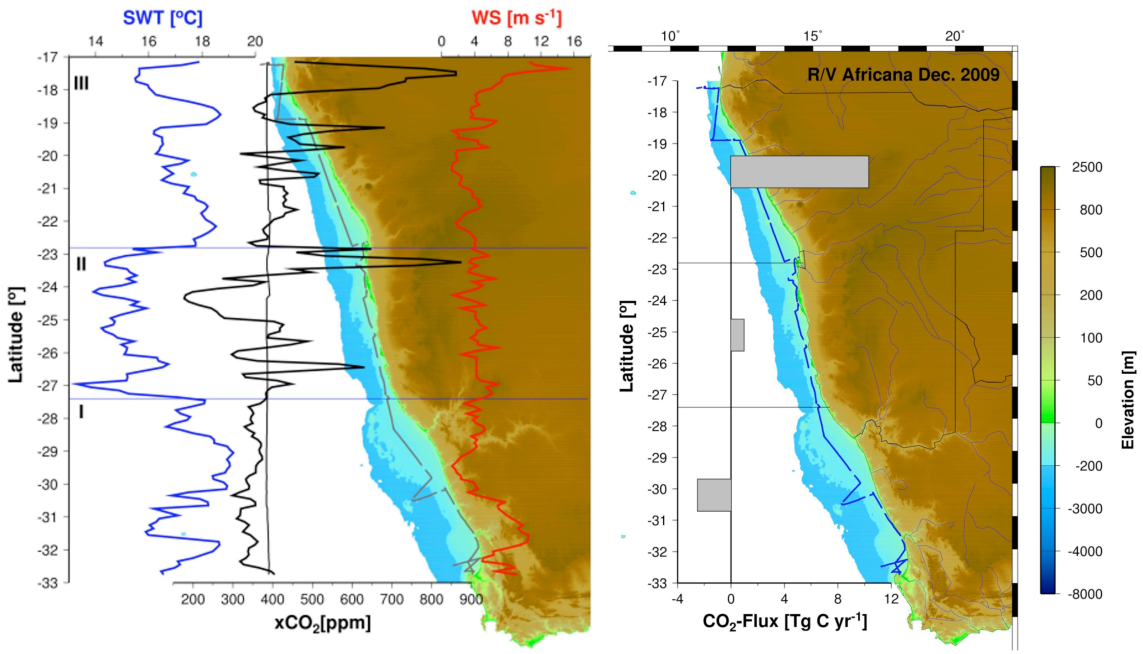


Fig. 1: Seawater temperatures (SWT), xCO_2, and winds speed measured along the transect from Cape Town to the Kunene River at the Angola-Namibia border as well as the CO_2 fluxes averaged for three sections of the transect. For calculating the CO_2 fluxes only the area of the continental margin was considered where the water depth is < 500 (marked in blue). The dark blue line shows the cruise track along which xCO_2, SWT and wind speed were measured.

4. WORKING GROUP 'MESOZOOPLANKTON SAMPLING (GENUS SUBPROJECT 6)'

Personnel: Holger Auel, Anna Schukat, Lena Teuber (all Univ. of Bremen, Marine Zoology), Tammy Morris (BCRE, Cape Town)

Mesozooplankton, especially copepods, were sampled routinely at every station (18 in total) by vertical Multinet hauls (Hydro-Bios Kiel, mouth opening 0.25 m^2, mesh size 200 µm). At stations on the shelf and upper continental rise, the whole water column was sampled in five discrete depth intervals. Further offshore the maximum sampling depth was 680 m, limited by the maximum available wire length. Sampling depths were chosen based on the local hydrographic conditions established by CTD casts at every station prior to Multinet deployment. Special attention was given to the chlorophyll *a* maximum, which occurred substantially below the surface at some stations, and to the intermediate oxygen minimum layer. Both features have been shown to strongly affect mesozooplankton distribution during previous cruises.

All Multinet samples were split in two halves immediately after the catch by means of a Folsom plankton splitter. One half was preserved in a 4% formaldehyde-seawater solution for microscope analysis of abundance, species composition and biodiversity at the home laboratory. The other half was deepfrozen at -80°C for measurements of mesozooplankton biomass and biochemical analyses. These data will be used for trophic biomarker studies, in particular on the

role of diatoms vs. dinoflagellates as dominant primary producers at the base of the food web. In addition, the same dataset may be used to identify suitable feeding areas for pelagic fish.

In order to extrapolate the point measurements by Multinet to a larger spatial scale and to provide a higher spatial resolution, surface zooplankton samples were collected continuously en route by a CUFES system (Continuous Underway Fish Egg Sampler). Each discrete sample (69 in total) included the mesozooplankton filtered from 20 to 40 m^3 of surface water taken from approx. 4 m depth over a distance of ten to twenty nautical miles. CUFES samples were treated in the same way as the Multinet samples and split in two halves for separate preservation in formalin and frozen.

For a comparative study on the feeding ecology and trophic niches of dominant calanoid copepod and decapod species, over 300 samples were collected and deepfrozen for biochemical analyses. Each sample contained up to 60 individuals. For this purpose, individuals were also sorted from oblique Multinet and MOCNESS tows conducted at the same stations.

5. Working Group 'Mesozooplankton and Micronekton investigations (GENUS subprojects 5 & 7)'

Personnel: Rolf Koppelmann (Institute for Hydrobiology and Fisheries Science - IHFS, Hamburg), Friedrich Buchholz (Alfred Wegener Institute for Polar and Marine Research - AWI, Bremerhaven), Sarina Jung (IHFS), Thorsten Werner (AWI)

Zooplankton organisms are important producers and consumers of organic material in marine ecosystems. They transfer carbon to higher trophic levels via the food chain and contribute to the transport of carbon into greater depths. Zooplankton also play an important role in the remineralization of organic matter. GENUS subproject 5 (Meso- and macrozooplankton dynamics in the southwest African upwelling region: shelf sea - open ocean interactions) investigates different groups of zooplankton and micronekton and transfer rates between these groups. The advective transport of living and dead organic material from the upwelling region to the open ocean and to mesopelagic depths will be assessed. GENUS subproject 7 (Trophic role of euphausiids in the upwelling areas off SW Africa) investigates the abundance, distribution, and physiological rates of Euphausiacea in upwelling regions. Euphausiacea are an important group of Crustacea in the system since they can contribute substantially to the zooplankton biomass and are indicators of different water masses.

The following topics were/will be investigated in detail using material sampled during the cruise:

- Qualification and quantification of major zooplankton groups;
- Determination and quantification of vertically migrating taxa;
- Assessment of the abundance and predation pressure of gelatinous taxa;
- Biodiversity of Euphausiacea related to advective processes;
- Respiration rates of different species of Euphausiacea;

- Moulting and growth rates of Euphausiacea.

Samples were collected using a $1m^2$-MOCNESS (Multiple Opening and Closing Net and Environmental Sensing System), a Tucker Trawl, and a WP-2 net. The MOCNESS and the Tucker Trawl are closing net systems with 333 µm and 1000 µm mesh size, respectively, which are towed obliquely at a speed of 2 knots. The Tucker Trawl is designed for the collection of live organisms over a specific depth range, usually determined from prior observations using the multiple net systems. The WP-2 net is a ring net with a mesh size of 300 µm, which was towed vertically.

The MOCNESS is equipped with 9 nets, which can be opened and closed sequentially. The sampling intervals on this cruise were 25 m in the top 50 m, 50 m down to 100 m, and 100-200 m at greater depths. Samples were collected down to a maximum depth of 700 m at the offshore stations and close to the bottom at the inshore stations (Table 1). The volume filtered by each net is calculated from a flowmeter mounted in the net system's mouth. The device carries CTD-probes for the simultaneous collection of environmental data. Upon recovery of the MOCNESS, the nets were rinsed with seawater and Euphausiacea (krill), gelatinous species and fish larvae were sorted from some of the catches for subsequent biochemical analyses. The remaining catch was preserved immediately in a 4% formaldehyde-seawater solution buffered with sodium-tetraborate for future taxonomic analysis. The Tucker Trawl was deployed to a maximum depth of 260 m at 9 stations to obtain live Euphausiacea for onboard respiration experiments and for the determination of moult and reproductive stages in live specimens.

Respiration measurements of four euphausiid species (*Euphausia hanseni*, *Euphausia lucens*, *Nematoscelis megalops* and *Nyctiphanes capensis*) were used to estimate standard metabolic rates (SMR). Experiments with low oxygen saturation were conducted onboard to assess adaptations of these species to environmental conditions in the oxygen minimum zone (OMZ). Samples for subsequent biochemical analyses were collected from MultiNet, MOCNESS and Tucker Trawl catches and stored at -80°C. These will be analysed for enzymatic activities and the amount of metabolites produced under different conditions (ambient and both normoxic and hypoxic conditions in captivity). Stable isotope analysis will be done for all euphausiid species and some other zooplankton, e.g. jellyfish and salps. The results will help to determine the position of these taxa within the food web of the northern Benguela ecosystem.

At MOCNESS stations, the WP-2 net was towed vertically from the same maximum depth as the MOCNESS to the surface. The cod-end of this net was modified to accommodate the collection of fragile gelatinous organisms that will be used for biochemical analyses.

Overall, a good dataset was obtained with these three gears on three transects (17°15' S, 19° S, 23° S) in the northern Namibian upwelling region that is suitable for the intended biological investigations to be conducted. While detailed analyses and data interpretation still need to be done later in the home-laboratory, preliminary results indicate a distinct vertically stratified distribution of different groups of zooplankton. Onshore-offshore gradients are also evident with large amounts of Cnidaria at the inshore stations, significant amounts of salps at the intermediate stations, and a very diverse community at the offshore stations typical for oceanic samples.

Krill abundance appeared to be the lowest encountered in the four years of sampling conducted in the region thus far. Moult and reproductive activity was low in the Rocky Point transect (T5)

and showed increasing rates on the Kunene River transect (T2), possibly reflecting different states of the upwelling cycle. These observations will be related to the hydrography, i.e. upwelling events, once the data have been analysed by the oceanographers on board.

Table 1: Sampling intervals of MOCNESS hauls. Tucker trawls were also deployed at stations shown in bold.

Haul	Station	Date	Time	Sounding (m)	Sample intervals
01	**Test**	08.12.2009	Day	75-80	horizontal at 50 m
02	**T5-4**	08.12.2009	Night	108	0-90-50-25-0
03	**T5-1**	09.12.2009	Day	378	0-330-200-100-50-25-0
04	Add 10	09.12.2009	Night	130	0-100-50-25-0
05	**T2-2**	10.12.2009	Sunrise	855	0-750-600-400
06	T2-1	10.12.2009	Night	3256	0-650-500-400-300-200-100-50-25-0
07	**T5-1a**	11.12.2009	Day	2008	0-700-600-400-300-200-100-50-25-0
08	T8-1a	12.12.2009	Night	3142	0-650-500-400-300-200-100-50-25-22
09	T8-1	13.12.2009	Day	361	0-300-200-100-50-25-0
10	**T8-3**	13.13.2009	Sunset	145	0-100-50-25-0
11	T8-4	13.12.2009	Night	122	0-100-50-25-0

6. WORKING GROUP 'ICHTHYOPLANKTON AND FISH STUDIES'

Personnel: Werner Ekau, Simon Geist (both ZMT, Bremen), Nadine Moroff, Beau Tjizoo, Oliver Mungu Numwa, Nelda Katjivena (National Marine Information and Research Centre - NatMIRC, Swakopmund)

One of the central aims of the work within GENUS is to understand the trophic interrelationships between the different components of the northern Benguela upwelling system and their response to climatic and anthropogenic changes. In order to identify the key processes and species and analyse key rates of biological ecosystem components, a number of seagoing campaigns have been organised to collect the required data and samples. While the first sampling campaign of the early life-history stages of fish was carried out in 2008 aboard the German RV *Maria S. Merian*, this cruise on the FRS *Africana* was used to complement the sampling of fish with juvenile and adult stages; compared with the other ships used in the project, the *Africana* is a fully equipped

fisheries research vessel capable of performing both pelagic and demersal trawling. The pelagic trawl used here had an opening of 14 m height by 20 m width.

Target species for larvae, juveniles and adults were sardine, anchovy, round herring, hake, gobies and horse mackerel. Of interest were also flatfish and mesopelagics as well as the jellyfish.

On the way from Cape Town to Walvis Bay (Leg 1) a total of seven pelagic and demersal trawls were performed. Details are given in the table below.

Station number		Lat	Long	Dist. (m)	Date	Time (UTC)	Tow (min)
30244	Fi 01	-32,30	17,99		03.12.2009	11:35:35	
	demersal	-32,32	17,96	3.974	03.12.2009	12:07:31	32
30245	Fi 02	-30,29	17,11		04.12.2009	2:26:47	
	pelagic	-30,32	17,13	3.510	04.12.2009	2:56:32	30
30246	Fi 03	-30,63	16,02		04.12.2009	12:14:40	
	demersal	-30,63	16,00	1.749	04.12.2009	12:29:25	15
30247	Fi 04	-28,50	15,37		05.12.2009	3:51:14	
	pelagic	-28,54	15,40	5.322	05.12.2009	4:38:29	47
30248	Fi 05	-27,48	15,11		05.12.2009	14:56:39	
	demersal	-27,51	15,11	3.314	05.12.2009	15:27:38	31
30249	Fi 06	-25,75	14,76		06.12.2009	3:24:06	
	pelagic	-25,75	14,77	379	06.12.2009	4:11:30	47
30250	Fi 07	-24,43	14,47		06.12.2009	13:38:24	
	pelagic	-24,44	14,47	1.117	06.12.2009	13:48:19	10

Fishing stations were selected based on acoustic observations. The first haul resulted in a good (for biological investigations) number of hakes, gobies and some flatfishes. The myctophids from the second catch will give some representative results for mesopelagics. A major catch of horse mackerel and hake could be boarded with the third haul providing a high number of medium-sized hakes! Round herring as one of the small pelagic target species was caught in the 4th haul together with the only two sardines caught during this leg. Adult horse mackerel were caught in the 5th haul together with medium-sized hake.

North of Lüderitz up to Walvis Bay massive targets in the upper water column up to the surface were observed on the echograms. They were identified as being mainly jellyfish, which was confirmed by direct observations of *Chrysaora hysoscella* and *Aequorea* sp. from the ship. Clouds of *Aequorea* sp. were drifting at the surface. Hence the two catches done in this area

(hauls 6 & 7) resulted in huge amounts of jellyfish. An interesting feature in haul 7 was the comparatively and unexpectedly high amount of small gobies (4-5 cm).

Ichthyoplankton samples were collected on 3 transects by means of a Multinet (MN_{obl}). The Multinet was equipped with five nets of 500 µm mesh size and a mouth area of 0.25 m^2. It was towed obliquely in five depth strata. A total of 23 hauls was made. The Multinet is equipped with two flowmeters, one inside and another one outside the net, to measure the nets' trajectory through the water and calculate the volume of water filtered by each net. All samples were roughly analysed on board for their content of fish larvae. Samples were preserved in buffered formalin (4% in seawater) for subsequent community studies, in alcohol for genetic studies, or frozen for age determination and stomach content, fatty acid composition and stable isotope studies.

In total, 787 fish larvae were caught during leg 2. A single Tucker Trawl haul at XXX yielded about 400 larvae of *Trachurus trachurus capensis*. Gobies were the second most abundant species, found mainly in the inshore haul of the Walvis Bay transect. Both horse mackerel and goby larvae were caught alive in some cases, the horse mackerel larvae seemingly being the most robust ones.

Whereas several mesopelagic species were abundant at the deeper, outermost stations, clupeoid larvae were very scarce throughout the survey with only a few found on the Kunene transect, while no hake larvae were caught at all.

Regarding fish eggs, only one patch of unidentified eggs was encountered at Kunene and another dense patch of sardine and anchovy eggs appeared on the shelf off Walvis Bay at the penultimate station inshore. Fish eggs were kept alive until the end of the cruise. Hatching occurred after one or two days and the yolk sac stage lasted until the end of the cruise. Larvae were sorted out immediately after the catch and frozen at -80°C for subsequent trophic analysis in Germany.

ACKNOWLEDGEMENTS

We wish to thank the Master of the FRS *Africana*, Capt. Freddie Ligthelm, and his Officers, Engineers, Catering Staff, and Deck Crew for their professional assistance, excellent services and unbridled friendliness whilst onboard, which made this scientific voyage both successful and enjoyable. We are indebted to the Branch: Marine and Coastal Management (MCM) of the South African Department of Environmental Affairs (DEA) for the use of their flagship FRS *Africana* as a suitable and comfortable sampling platform for our research. Generous funding from the German Federal Ministry of Education and Research (BMBF) to undertake this research as part of the GENUS (Geochemistry and Ecology of the Namibian Upwelling System) Project is gratefully acknowledged. Permission from the Namibian Ministry of Fisheries and Marine Resources (MFMR) to conduct this collaborative research in Namibian waters is much appreciated.

												Gear													
										10		30	30	30	45	0	30	120	45	120		45	
CT - WB												60	45	30			30							45
WB - CT																								
stat	Africana station	CTD casts	Lat	Long	Start of station UTC	Water depth	Dis-tance (nm)	Time at station	End of station UTC	CTD	MNv	MNo	TT	Phyto	Bo/WP2	MOC	Multi corer	Mooring	Fish trawl					
Cape Town			**33°54'**	**18°26'**	**1.12.2009 09:00**																			
12/09/12	30230	001	32°44,8'	16°26,0'	2.12.2009 03:01	1400	122,29	115	2.12.2009 04:56	1					1									
12/09/11	30231	002	32°42,2'	16°37,2'	2.12.2009 06:25	<500	9,47	61	2.12.2009 07:26	1					1									
12/09/10	30232	003	32°39,5'	16°48,5'	2.12.2009 08:31	<500	9,73	54	2.12.2009 09:25	1					1									
12/09/09	30233	004	32°36,9'	16°59,5'	2.12.2009 10:33	<500	9,74	41	2.12.2009 11:14	1					1									
12/09/08	30234	005	32°34,3'	17°11,9'	2.12.2009 12:26	<500	10,31	38	2.12.2009 13:04	1					1									
12/09/07	30235	006	32°30,3'	17°25,3'	2.12.2009 14:25	<500	12,46	35	2.12.2009 15:00	1					1									
12/09/06	30236	007	32°27,7'	17°36,5'	2.12.2009 16:01	<500	9,75	38	2.12.2009 16:39	1					1									
12/09/05	30237	008	32°24,9'	17°48,5'	2.12.2009 17:44	<500	10,56	32	2.12.2009 18:16	1					1									
12/09/04	30238	009	32°22,4'	17°59,5'	2.12.2009 19:23	<500	9,50	36	2.12.2009 19:59	1					1									
12/09/03	30239	010	32°19,8'	18°10,7'	2.12.2009 21:00	<500	9,77	27	2.12.2009 21:27	1					1									
12/09/02	30240	011	32°18,5'	18°16,5'	2.12.2009 22:09	<500	5,17	15	2.12.2009 22:24	1					1									
12/09/01	30241	012	32°18,0'	18°18,7'	2.12.2009 22:51	<500	1,69	14	2.12.2009 23:05	1					1									
12/09/21	30242	013	32°40,0'	18°05,3'	3.12.2009 02:33	<500	24,58	27	3.12.2009 03:00	1					1									
12/09/22	30243	014	32°41,0'	17°46,0'	3.12.2009 04:38	<500	16,02	15	3.12.2009 04:53	1					1									
Fi-1	30244	015	32°18'	17°59'	3.12.2009 10:29	<500	98,63	121	3.12.2009 12:30	1		1							1					
Fi-2	30245	016	30°17,9'	17°06,5'	4.12.2009 01:58	<500	129,20	130	4.12.2009 04:08	1		1							1					
Fi-3	30246	017, 018	30°38'	16°01'	4.12.2009 10:40	<500	59,84	166	4.12.2009 13:26	2	1	1							1					
Fi-4	30247	019	28°30'	15°22'	5.12.2009 03:45	<500	132,42	141	5.12.2009 06:06	1	1	1							1					
Fi-5	30248	020, 021	27°29'	15°07'	5.12.2009 13:24	<500	62,42	138	5.12.2009 15:42	2		1							1					
Fi-6	30249	022	25°45'	14°46'	6.12.2009 03:16	<500	105,68	127	6.12.2009 05:23	1	1	1							1					
Fi-7	30250	023	24°26'	14°28'	6.12.2009 13:33	<500	80,66	43	6.12.2009 14:16	1		1							1					
			23°00'	14°15'	6.12.2009 22:56		86,82		6.12.2009 22:56															
Walvis Bay			**23°00'**	**14°30'**	**7.12.2009 06:31**		**13,81**	**180**	**7.12.2009 09:31**															
Mooring			23°00'	14°15'	8.12.2009 08:57		13,81	132	8.12.2009 11:09									1						
Test			20°00'	12°17'	8.12.2009 08:00		210,84	63	8.12.2009 09:03	1			1			1	1							
T-5-5	30251	024	19°00'	12°27'	8.12.2009 13:50	37	260,32	73	8.12.2009 15:03	1	1	1					1							
T-5-4	30252	025, 026	19°00'	12°15'	8.12.2009 16:10	111	11,35	227	8.12.2009 19:57	2	1	1	1		1	1								
T-5-3	30253	027	19°00'	12°00'	8.12.2009 21:26	211	14,18	148	8.12.2009 23:54	1	1	1					1							
T-5-1	30254	028, 029	19°00'	11°26'	9.12.2009 03:08	400	32,15	287	9.12.2009 07:55	2	1	1	1		1	1								
Add-11	30255	030	17°15'	11°43'	9.12.2009 17:26	50	106,24	70	9.12.2009 18:36	1	1	1												
Add-10	30256	031, 032	17°15'	11°30'	9.12.2009 20:01	150	12,42	134	9.12.2009 22:15	2	1	1			1	1								
T-2-2	30257	033	17°15'	11°00'	10.12.2009 00:22	850	28,65	397	10.12.2009 06:59	2	1	1	1		1	1								
Add-06	30258	034, 035, 036	17°15'	10°47'	10.12.2009 09:28	2900	12,42	239	10.12.2009 13:27	3	1	1	1											
T-1-2	30259	037	17°15'	10°30'	10.12.2009 16:08	3000	16,24	325	10.12.2009 21:33	1	1	1	1		1	1								
T-5-1a	30260	038, 039	19°00'	10°30'	11.12.2009 09:29	3000	105,00	339	11.12.2009 15:08	2	1	1	1		1	1								

									10	Gear									
CT - WB										30	30	30			30				45
WB - CT										60	45	30	45	0	30	120	45	120	
stat	Africana station	CTD casts	Lat	Long	Start of station UTC	Water depth	Dis-tance (nm)	Time at station	End of station UTC	CTD	MNv	MNo	TT	Phyto	Bo/WP2	MOC	Multi corer	Mooring	Fish trawl
T-8-1a	30261	040, 041	23°00'	11°45'	12.12.2009 19:35	3000	250,01	319	13.12.2009 00:54	1	1	1			1	1			
T-8-1	30262	042, 043	23°00'	13°20'	13.12.2009 09:43	356	87,45	233	13.12.2009 13:36	2	1	1			1	1			
T-8-3	30263	044	23°00'	13°41'	13.12.2009 15:46	154	19,33	175	13.12.2009 18:41	1	1	1	1		1	1	1		
T-8-4	30264	045, 046	23°00'	14°03'	13.12.2009 20:46	122	20,25	205	14.12.2009 00:11	1	1	1			1	1	2		
T-8-5	30265	047	23°00'	14°29'	14.12.2009 01:33	65	23,93	144	14.12.2009 03:57	1	1	1			1		3		
H-4	30266	048	26°47'	14°30'	15.12.2009 03:16	298	227,00	136	15.12.2009 05:32	1		1					2		
Add-CTD	30267	049	27°40'	14°30'	15.12.2009 10:46	980	53,00	50	15.12.2009 11:36	1									
Cape Town			**33°54'**	**18°26'**	17.12.2009 06:08		425,42		17.12.2009 06:08										
								ETA	17.12.2009 12:00	49	18	23	8	0	11	11	11	1	7
						Total	769	943											