



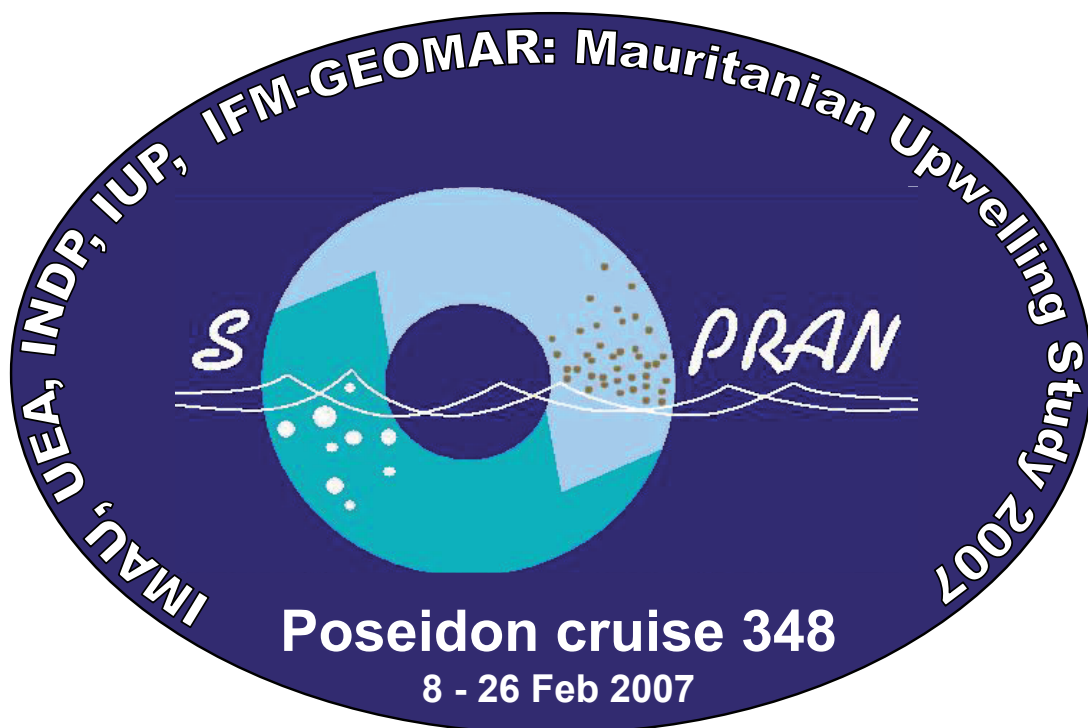
IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

**FS Poseidon
Fahrtbericht / Cruise Report P348**

SOPRAN: Mauritanian Upwelling Study 2007

Las Palmas - Las Palmas
08.02. - 26.02.2007



Berichte aus dem Leibniz-Institut
für Meereswissenschaften an der
Christian-Albrechts-Universität zu Kiel

Nr. 18
Juli 2008



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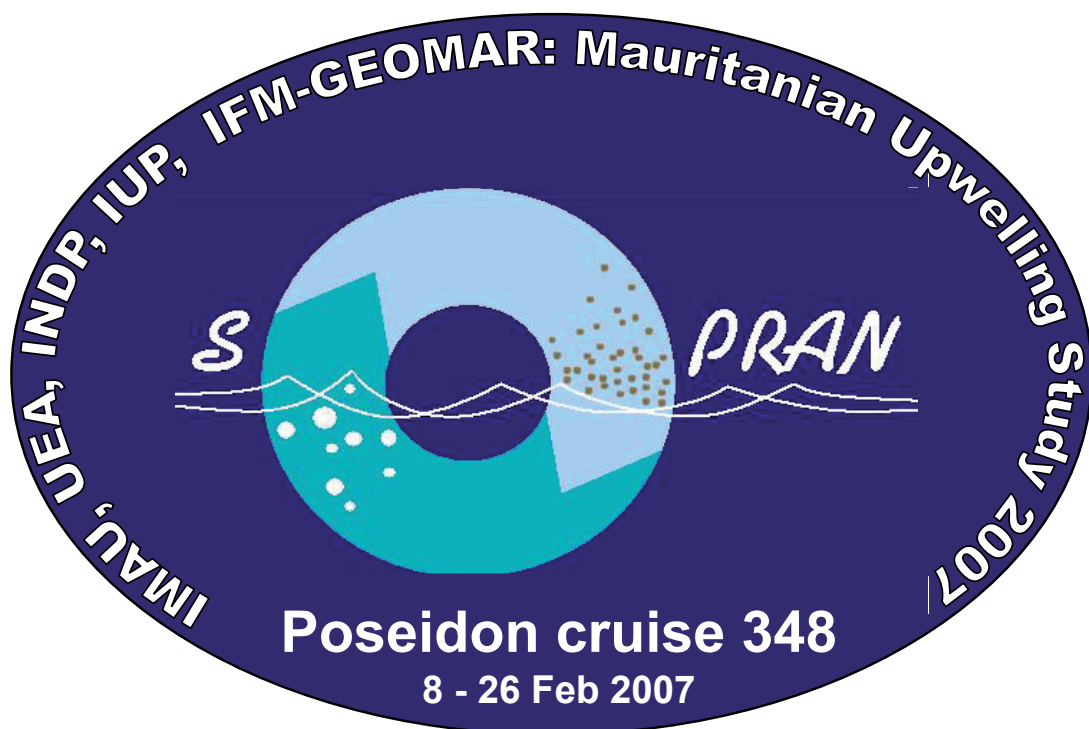
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Herausgeber / Editor:

Hermann W. Bange

IFM-GEOMAR Report

ISSN Nr.: 1614-6298

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**IFM-GEOMAR,
Leibniz-Institut für
Meereswissenschaften
an der Universität Kiel**

20 September 2007

Cruise Report

Compiled by: PD Dr Hermann W. Bange, IFM-GEOMAR, Kiel, Germany

R/V Poseidon Cruise No.: 348 (P348)

Dates of Cruise: 8 – 26 Feb 2007

Research Topics: Mar. Biogeochem., Phys. Oceanogr., Atmos. Chem.

Oceanic Region: Eastern Tropical North Atlantic Ocean, Upwelling off Mauritania

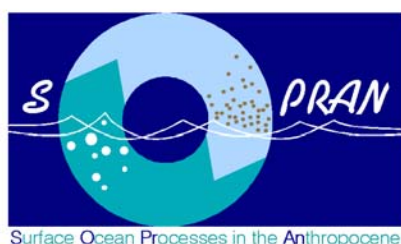
Port Calls: Las Palmas (Canary Islands), Mindelo (Cape Verde Islands)

Institute: IFM-GEOMAR, Kiel, Germany

Chief Scientist: PD Dr Hermann W. Bange, IFM-GEOMAR, Kiel, Germany

Number of Participants: 10 scientists

Project: SOPRAN (Surface Ocean PRocesses in the ANthropocene)



This cruise report consists of 36 pages including cover page:

1. Scientific team
2. Research programme
3. Narrative of cruise
4. Technical report
5. Scientific equipment and instruments
6. Acknowledgements
7. First results
8. Appendices

1. Scientific team

1.1 List of participants

Name	Function	Institute
01 Dr Hermann W. Bange	<i>Chief Scientist</i>	IFM-GEOMAR
02 Jens Georg Fischer	Student	IFM-GEOMAR
03 Alina Freing	Scientist	IFM-GEOMAR
04 Tim Kalvelage	Student	IFM-GEOMAR
05 Annette Kock	Student	IFM-GEOMAR
06 Uwe Koy	Technician	IFM-GEOMAR
07 Frank Malien	Technician	IFM-GEOMAR
08 Maria Martin	Student	IUP*
09 Ivanice Monteiro	Technician	INDP**
10 Dr Sylvia Walter	Scientist	IMAU***
11 Felix Kasten [§]	Journalist	Spiegel TV****
12 Jürgen Staiger [§]	Journalist	Spiegel TV****

* Institut für Umweltphysik, Universität Heidelberg

** Instituto Nacional de Desenvolvimento das Pecas, São Vicente, Cape Verde Islands

*** Institute for Marine and Atmospheric Research Utrecht, The Netherlands

**** Spiegel TV, Hamburg

[§] On board Poseidon from 13 to 14 Feb 2007

Chief Scientist

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1.2 National and international collaborators

- Alex Baker, University of East Anglia, Norwich, UK: Aerosols
- Peter Brandt, Marcus Dengler, IFM-GEOMAR: Microstructure
- Julie LaRoche, IFM-GEOMAR: *nifH* genes
- Katrin Bluhm, IFM-GEOMAR: Dissolved iodine compounds
- Arne Körtzinger, IFM-GEOMAR: pCO₂, NOAA surface drifter, PROVOR floats
- Tobias Steinhoff, IFM-GEOMAR: pCO₂
- Ilka Peeken, IFM-GEOMAR: Phytoplankton distribution
- Ulrich Platt, IUP, Univ. Heidelberg: Atmospheric halogen compounds
- Maren Voss, IOW: ¹⁵NO₃⁻
- Doug Wallace, IFM-GEOMAR: Nutrients, O₂, ¹⁵NO₃⁻

2. Research programme

The major objectives of cruise P348 – SOPRAN were to investigate

- (i) the cycling of trace gases between the ocean mixed layer and the atmospheric boundary layer,
- (ii) the aerosol input to the ocean and
- (iii) the turbulence structure and biological setting of the upper water column.

The target areas were

- (i) the eastern tropical North Atlantic (West-to-East transect along 18°N) and
- (ii) the coastal upwelling region off Mauritania.

The measured or sampled parameters were:

- Atmospheric halogen compounds (BrO, IO, OIO, I₂)
- Aerosol composition (soluble Fe, Al, Mn, Ti, Zn; major ions (Na⁺, Mg²⁺, K⁺, Ca²⁺, NH₄⁺, Cl⁻, NO₃⁻, SO₄²⁻, C₂O₄²⁻; total soluble nitrogen and soluble phosphate and silicate)
- Atmospheric and dissolved hydrogen, isotopic composition
- Underway atmospheric and dissolved carbon dioxide (CO₂) and methane (CH₄)
- Underway dissolved O₂, fluorescence, gas tension, Chl a
- Depths profiles of nitrous oxide (N₂O), hydroxylamine (NH₂OH) and CH₄
- Dissolved nutrients (nitrate, nitrite, phosphate, silicate) and O₂
- Dissolved ¹⁵NO₃⁻
- Dissolved I⁻ and IO₃⁻
- Depth profiles of Chl a, marker pigments for phytoplankton distribution
- Plankton samples for *Uthermöhl* microscopy
- DNA for *nifH* gene analysis
- Acoustic Doppler current profiler
- Turbulence profiles of upper water column
- Standard hydrographic (CTD, thermosalinograph) and meteorological parameters (wind speed, wind direction etc.)

Moreover, we deployed:

- 2 PROVOR floats
- 5 NOAA surface drifters

3. Narrative of cruise

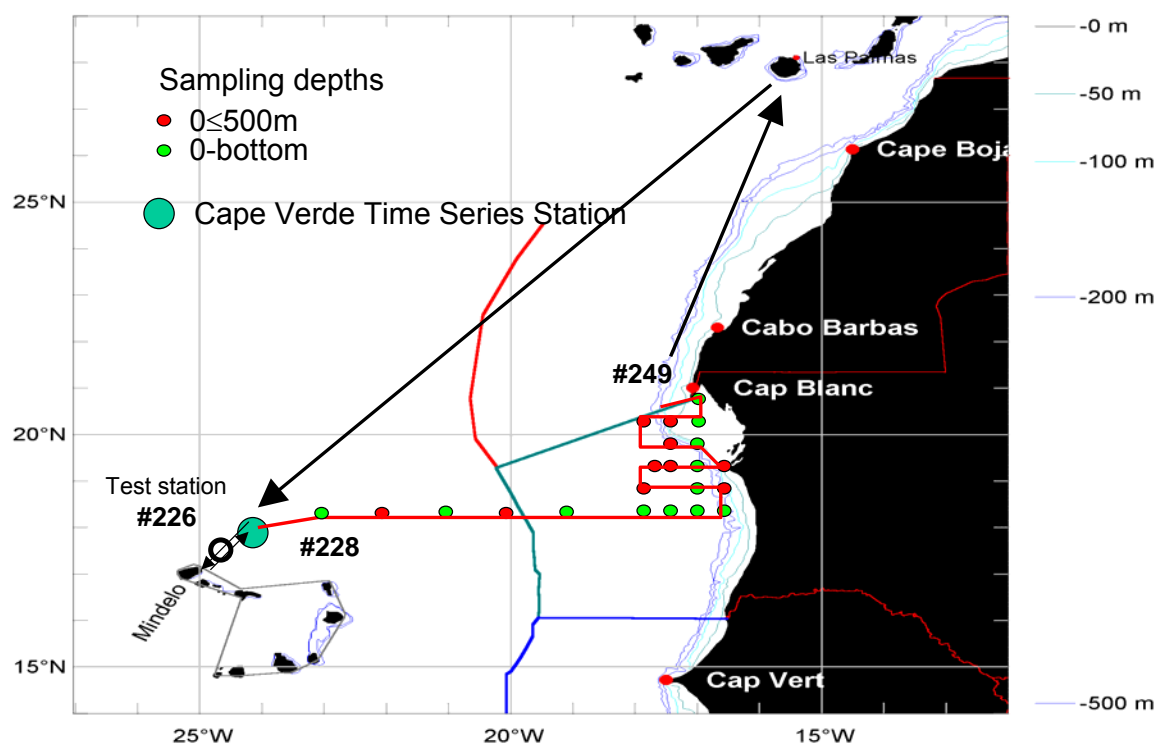
The announced observer from Mauritania did not show up. The reason for this is unknown. R/V Poseidon left Las Palmas (Canary Islands) on 8 Feb 2007. From 8 – 12 Feb we were sailing south towards Cape Verde Islands. A “test station” was planned for the 10 Feb; however, because of strong winds, the “test station” was delayed several times. Finally, we performed the “test station” on 12 Feb (17.26°N 24.76°W, stat #226). On the afternoon of the same day we arrived in Mindelo (Cape

Verde Islands) to pick up two journalists of a Spiegel TV film team. They joined us from 13 to 14 Feb. The Cape Verde Time Series Station (CVTSS, 17.6°N 24.3°W, stat #227) was sampled on 13 Feb. After two CTD casts we deployed the two PROVOR floats at CVTSS. The film team disembarked from Poseidon in Mindelo in morning of 14 Feb. Then we sailed to our first station along the 18°N transect. The sampling along 18°N started with stat #228 at 23°W. Stations along 18°N were sampled with a 1 degree resolution, which was changed to a 0.5 degree resolution when approaching the coast. The transect along 18°N was finished with stat #236 at 16.5°W close to the coast of Mauritania on 19 Feb. We continued with a grid consisting of 4 short transects (at 18.5°, 19°, 19.5°, 20° N each from 18°W to the coast or vice versa) perpendicular to the Mauritanian coast. The resolution of the station sampling was 0.5 degree. However, some stations had to be cancelled or shifted because of the strong winds. The station work ended with stat #249 (20.5°N 17.22°W) on 23 Feb. Then we steamed north towards Las Palmas. The cruise ended in Las Palmas (Canary Islands) on 26 Feb 2007.

For further details see the weekly cruise reports (attached).

4. Technical report

4.1 Cruise track



4.2 List of stations

Stat #	CTD file no.	Estimated water depth, m	Day in Feb 2007	Time (GMT)	Lat N	Long W	Max. CTD depth, dbar
226 (Test)	127	2900	12	08:30	17°15'	24°46'	2926
227 (CVTSS)	128	3600	13	14:47	17°36'	24°18'	3647
227 (CVTSS)	129	3600	13	19:26	17°36'	24°18'	506
228	130	3500	15	03:00	18°00'	23°00'	3533
228	131	3500	15	06:43	18°00'	23°00'	404
229	132	3300	15	17:56	18°00'	22°00'	762
230	133	3000	16	06:00	18°00'	21°00'	3099
230	134	3000	16	08:55	18°00'	21°00'	504
231	135	3200	16	20:22	18°00'	20°00'	756
232	136	3100	17	08:20	18°00'	19°00'	3162
232	137	3100	17	11:09	18°00'	19°00'	504
233	138	2800	17	22:28	18°00'	18°00'	2814
233	139	2800	18	01:00	18°00'	18°00'	504
234	140	2500	18	08:30	18°00'	17°30'	2505
234	141	2500	18	10:25	18°00'	17°00'	252
235	142	1700	18	16:30	18°00'	17°00'	1722
235	143	1700	18	18:51	18°00'	17°00'	253
236	144	190	19	00:52	18°00'	16°30'	186
237	145	100	19	12:40	18°30'	16°30'	104
238	146	1600	19	18:55	18°30'	17°00'	1614
238	147	1600	19	21:00	18°30'	17°00'	203
239	148	2600	20	06:58	18°30'	18°00'	757
240	149	2400	20	16:30	19°00'	17°47'	755
241	150	2200	20	20:30	19°00'	17°30'	755
242	151	1200	21	03:09	19°00'	17°00'	1126
242	152	1200	21	05:15	19°00'	17°00'	201
243	153	60	21	10:00	19°00'	16°33'	58
244	154	100	21	18:00	19°30'	17°00'	102
245	155	1600	22	00:23	19°30'	17°30'	761
246	156	1900	22	11:51	20°00'	18°00'	753
247	157	70	22	18:20	20°00'	17°30'	68
248	158	20	22	22:00	20°00'	17°13'	23
249	159	30	23	08:06	20°29'	17°13'	31

CVTSS stands for Cape Verde Time Series Station

4.3 Water column sampling:

Stat #	Micro-structure	Nutr., O ₂	¹⁵ NO ₃ ⁻	N ₂ O	NH ₂ OH	CH ₄	Γ, IO ₃ ⁻	H ₂ isotopes	Chl a / pigments	Uthermöhl samples	<i>nifH</i> genes
226 (Test)	X	X		X		X					
227 (CVTSS)	X	X	X	X		X	X		X		
228	X	X		X		X			X		
229	X	X							X		
230	X	X	X	X		X	X		X		
231	X	X							X		
232	X	X		X		X			X		X
233	X	X		X		X			X		
234	X	X		X		X			X		
235	X	X		X		X		X	X	X	X
236	X	X		X		X		X	X	X	
237	X	X	X				X		X		
238	X	X	X	X				X	X	X	
239	X	X							X		
240	X	X		X	X				X		
241	X	X		X	X			X	X	X	
242	X	X		X	X		X	X	X	X	
243		X	X	X	X			X	X	X	
244	X	X	X*				X	X	X	X	
245		X	X*								
246	X	X	X*						X		
247	X	X					X	X	X		
248		X						X	X		
249		X	X					X	X		

CVTSS stands for Cape Verde Time Series Station

* sampling for IOW and IFM-GEOMAR, otherwise sampling for IFM-GEOMAR only

4.4 Underway water sampling:

ADCP measurements (ADCP was installed in the moon pool).

Continuous underway measurements of dissolved CO₂, CH₄, O₂, gas tension, fluorescence, salinity and water temperature from a water depth of about 4 m (water supply by a submersible pump placed in the ship's moon pool).

Thermosalinograph (Temperature, Salinity)

List of discrete Chl a samples (1L filtered) taken from the continuous seawater supply:

#	Date	UTC	Latitude	Longitude
1	10.02.07	16:33	22,0779	-20,9285
2	11.02.07	09:17	20,0072	-22,6008
3	11.02.07	18:18	18,8996	-23,4711
4	12.02.07	08:09	17,2699	-24,7552
5	12.02.07	13:56	16,9935	-24,9726
6	13.02.07	11:01	17,2532	-24,6670
7	13.02.07	14:44	17,6001	-24,3003
8	14.02.07	14:49	17,2006	-24,4917
9	14.02.07	19:35	17,5100	-23,9140
10	15.02.07	08:43	17,9991	-22,8592

11	15.02.07	12:14	17,9991	-22,5169
12	15.02.07	19:17	18,0150	-22,0044
13	16.02.07	10:07	17,9993	-20,9374
14	16.02.07	14:13	17,9999	-20,5548
15	16.02.07	19:54	17,9990	-20,0282
16	17.02.07	10:23	18,0046	-18,9984
17	17.02.07	15:07	18,0160	-18,7450
18	18.02.07	10:12	18,0112	-17,4995
19	18.02.07	14:49	17,9985	-17,1767
20	19.02.07	10:07	18,5033	-16,3005
21	19.02.07	14:39	?	?
22	19.02.07	18:28	18,4948	-16,9750
23	20.02.07	08:26	18,5041	-18,0000
24	20.02.07	12:59	18,8748	-18,0102
25	20.02.07	18:17	?	?
26	21.02.07	08:09	19,0006	-16,7097
27	21.02.07	13:58	19,2211	-16,7001
28	21.02.07	17:38	19,4981	-16,9774
29	22.02.07	13:09	20,0120	-18,0016
30	22.02.07	18:13	19,9982	-17,5003
31	23.02.07	09:09	20,5341	-17,2304
32	23.02.07	14:59	21,1725	-17,4997
33	23.02.07	18:08	21,5074	-17,6356

4.5. Atmospheric sampling:

Continuous measurements of atmospheric CO₂ and CH₄.

Daytime measurements of BrO, NO₂, IO, I₂, OIO; O₄ (O₂ dimers).

68 glass flasks were filled from 14 to 23 Feb for H₂ isotope analysis.

11 aerosol filter samples were collected on a daily basis from 14 to 24 Feb.

Standard meteorological parameters (wind speed, wind direction etc.)

4.6 Deployments:

2 PROVOR floats (#73060 and #73061) were deployed at the CVTSS (stat #227, 17.6°N 24.3°W)

5 NOAA surface drifters were deployed:

#62289, 19 Feb 07, 21:29(GMT), 18.50°N 17.00°W

#62286, 21 Feb 07, 05:43(GMT), 18.99°N 16.99°W

#62287, 21 Feb 07, 18:47(GMT), 19.51°N 17.00°W

#62285, 22 Feb 07, 22:24(GMT), 20.00°N 17.22°W

#62288, 23 Feb 07, 10:30(GMT), 20.66°N 17.29°W

4.7 Summary

All sampling devices and instruments worked well, except for the PROVOR float #73061 which did not start signal transmission after deployment and the NOAA surface drifters #62286 and #62288 which were caught by local fishermen after deployment. Due to technical problems with valve switching CH₄ measurements are not available along the 18°N transect.

5. Scientific equipment

The major scientific equipment consisted of:

- 12x 10L water sampler rosette with CTD
- Free-falling microstructure probe
- ADCP
- 2 PROVOR floats
- 5 NOAA surface drifters
- Submersible water pump
- Equilibrator/Gas chromatograph with FID
- Gas chromatograph with ECD
- Equilibrator/IR gas analyser
- O₂ optode
- Gas tension device
- Fluorescence probe
- Autoanalyzer
- O₂ titration device
- Seawater filtration racks
- Aerosol collector
- Air pump
- MAX-DOAS
- miniMAX-DOAS
- Hand-held plankton net

6. Acknowledgements

I am indebted to all participants of P348 and the many other colleagues for their excellent collaboration without P348 would not have been successful. Moreover, I especially acknowledge the excellent support by the officers and crew of R/V Poseidon. I thank the authorities of Mauritania and Cape Verde Islands for the permissions to work in their territorial waters. The cruise P348 was funded by the BMBF joint project SOPRAN with grant no. 03F0462A.

7. First results

7.1 Aerosols

Alex Baker (UEA, Norwich, UK; alex.baker@uea.ac.uk)

Eleven daily aerosol samples were collected by Hermann Bange, IFM-GEOMAR between 14th and 25th February 2007 aboard RV *Poseidon*. Sample positions are summarised in Table 1. To date the samples have been analysed for their concentrations of soluble Fe, Al, Mn, Ti and Zn (Figure 1). Analyses for aerosol major ions (Na^+ , Mg^{2+} , K^+ , Ca^{2+} , NH_4^+ , Cl^- , NO_3^- , SO_4^{2-} , $\text{C}_2\text{O}_4^{2-}$), total soluble nitrogen and soluble phosphate and silicate are yet to be completed.

Table 1: P348 aerosol sample start and end locations.

Sample	Start date	Start Position	End Date	End Position
TM01	14/02/2007	17.1N 24.8W	15/02/2007	18.0N 22.5W
TM02	15/02/2007	18.0N 22.5W	16/02/2007	18.0N 20.7W
TM03	16/02/2007	18.0N 20.7W	17/02/2007	18.0N 19.0W
TM04	17/02/2007	18.0N 19.0W	18/02/2007	18.0N 17.5W
TM05	18/02/2007	18.0N 17.5W	19/02/2007	18.5N 16.5W
TM06	19/02/2007	18.5N 16.5W	20/02/2007	18.8N 18.0W
TM07	20/02/2007	18.8N 18.0W	21/02/2007	19.1N 16.6W
TM08	21/02/2007	19.1N 16.6W	22/02/2007	20.0N 18.0W
TM09	22/02/2007	20.0N 18.0W	23/02/2007	20.9N 17.4W
TM10	23/02/2007	20.9N 17.4W	24/02/2007	23.2N 17.2W
TM11	24/02/2007	23.2N 17.2W	25/02/2007	25.6N 16.2W

7.1.1 Methods

All analytical methods employed are based on extraction of soluble aerosol components into aqueous solution, filtration and appropriate analysis. For major ions and total soluble nitrogen analysis the extraction solution is ultrapure water, while for the other species pH buffered solutions are employed (pH 4.7 for trace metals, pH 7 for phosphate and silicate). Analysis of extract solutions is by ion chromatography (major ions), high temperature catalytic oxidation (total soluble nitrogen), inductively coupled plasma – optical emission spectrometry (trace metals) or spectrophotometry (phosphate and silicate). Full details of analytical methods can be found in Baker et al., 2007.

7.1.2 Initial Results

Orange / brown Saharan dust was clearly visible on the aerosol filters for the first 8 samples collected during P348. The presence of this dust resulted in the high concentrations of soluble Fe, Al, Mn and Ti observed (Figure 7.1.1). Indeed, we have not recorded soluble Fe concentrations greater than 700 pmol m^{-3} during 14 previous cruises through the Saharan dust plume region. In part, this high concentration of Saharan dust is due to the proximity of the cruise track to the African coast, but during cruise P320/1 (which took place in the same region) soluble Fe concentrations did not exceed 400 pmol m^{-3} . Soluble Zn concentrations were more uniform during P348. This is the only trace metal measured here that does not have a significant source from Saharan dust, its principle source being high-temperature anthropogenic activity.

7.1.3 Reference

Baker, A. R., Weston, K., Kelly, S. D., Voss, M., Streu, P. and Cape, J. N., 2007. Dry and wet deposition of nutrients from the tropical Atlantic atmosphere: links to primary productivity and nitrogen fixation. *Deep-Sea Research Part I*, in press.

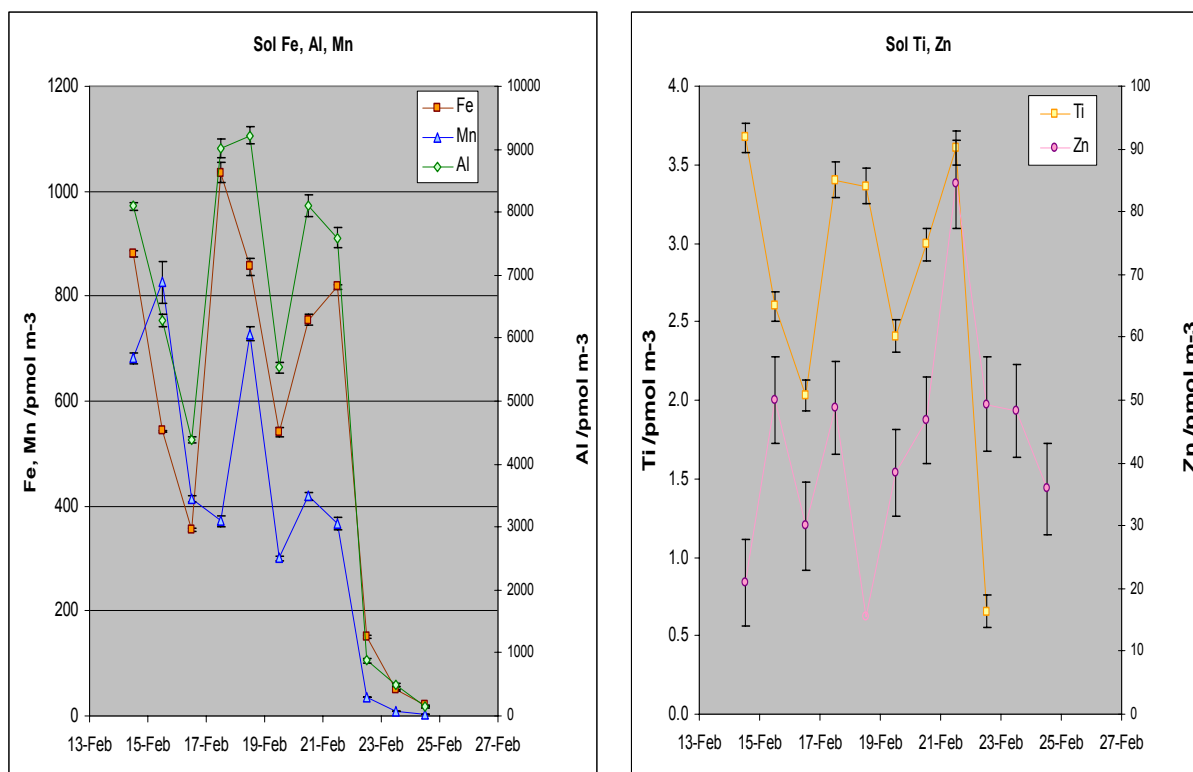


Figure 7.1.1: Concentrations of soluble Fe, Al, Mn, Ti and Zn during cruise P348.

7.2 Atmospheric halogen compounds

Maria Martin (IUP, Heidelberg Univ.; maria.martin@iup.uni-heidelberg.de)

7.2.1 Method

The short-lived atmospheric trace gases BrO, NO₂, O₄ (O₂ dimers), IO, I₂ and OIO have been measured with a Multi-AXis Differential Optical Absorption Spectroscopy (MAX-DOAS) instrument. The DOAS technique relies on structured absorption in the ultraviolet, visible, or near infrared spectral ranges of the species to be measured. The specific spectral absorption features (spectral finger prints) of the BrO, IO, OIO and I₂ are found in the near UV, blue and green wavelength ranges, they allow specific and highly sensitive detection of the above species at detection limits around one ppt for BrO, IO, OIO and about 10 ppt for I₂. Measurements in these wavelength ranges were performed by three parallel operating spectrometers, which are specifically optimized in their wavelength range, resolution and sensitivity for the respective absorbers by using the sun as light source. In addition, the column density of oxygen dimers (O₄) was determined, which allows to derive the aerosol optical density.

7.2.1 First results

BrO was showed a clear signal on 18 Feb (see Figure 7.2.1), whereas only a weak signal was visible on 22 Feb. IO mixing ratios were generally close to the detection limit, thus they are difficult to separate from the background signal. Because of difficulties with the data evaluation of IOI and I₂ no results are available yet.

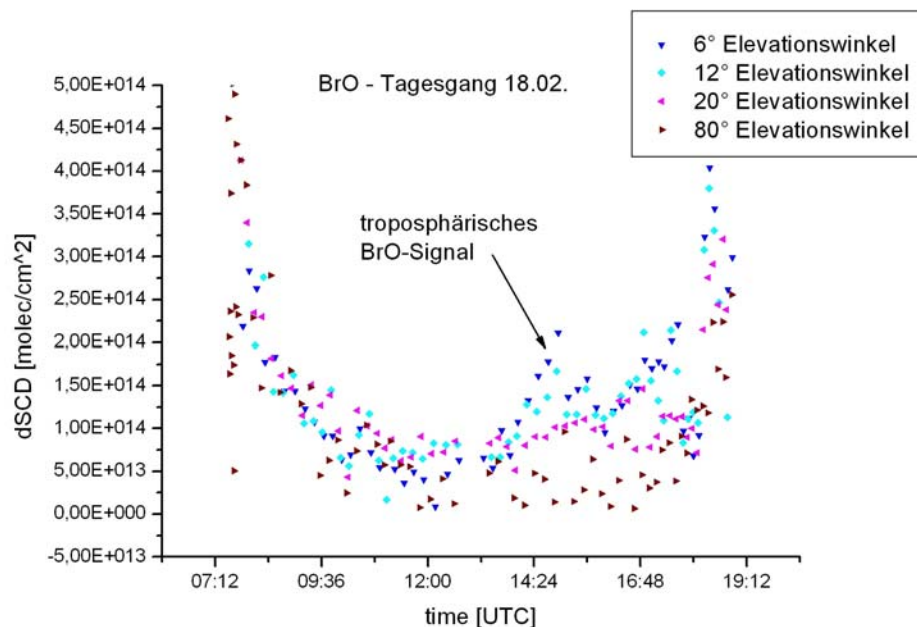


Figure 7.2.1: MAX-DOAS measurements on 18 Feb. The BrO signal is marked by the arrow.

7.3 H₂ isotopes

Sylvia Walter (IMAU, Utrecht Univ., The Netherlands; s.walter@phys.uu.nl)

Although hydrogen (H₂) is considered as one of the most important energy carriers in the future, relatively little is known about the global biogeochemical cycle of this trace gas. To better quantify sources and sinks of H₂ measurements of the D/H isotopic ratio are a helpful tool. Oceans are a source of atmospheric H₂, probably produced by phytoplankton and bacteria. However, the isotopic ratio of released H₂ is unknown and has so far only been estimated from thermodynamic equilibrium.

During this cruise samples were taken to investigate the D/H isotopic ratio of H₂ with main focus on differences between upwelling areas and the open ocean. On this purpose air samples were taken regularly. Additionally, at selected stations H₂ was extracted from surface water. These results will be compared with the results of pigment analysis.

Table 7.3.1: Station / position of sampling for D/H measurements, samples already measured (one transect) are marked in red.

Associated Station	Date	Time	Longitude	Latitude	Flask	Water samples		
Mindelo time series station	14.02.07	12.36	24	45.50	17	3.40	1	
228	15.02.07	7.21	22	59.40	18	0.20	2	
229	15.02.07	20.13	21	55.30	18	0.60	3	
230	16.02.07	9.29	20	59.90	18	0.10	4	
/	16.02.07	14.34	20	31.20	17	59.90	5	
231	16.02.07	21.14	19	59.70	18	0.20	6	
/	17.02.07	7.26	19	0.40	17	59.96	7	
232	17.02.07	11.15	18	59.98	18	0.35	8	
/	17.02.07	14.36	18	47.87	18	1.19	9	
233	18.02.07	1.35	17	59.90	18	0.10	10	
234	18.02.07	11.00	17	30.40	18	0.95	11	
235	18.02.07	19.22	17	0.02	18	0.12	12	1
/	18.02.07	20.50	16	51.90	17	59.87	13	
236	19.02.07	1.27	16	30.00	18	0.18	14	1
/	19.02.07	10.53	16	22.80	18	30.01	15	
237	19.02.07	13.27	16	30.50	18	30.70	16	
-	19.02.07	14.45	16	37.98	18	28.90	17	
-	19.02.07	15.41	16	42.08	18	29.09	18	
-	19.02.07	16.37	16	47.20	18	29.34	19	
-	19.02.07	18.08	16	56.60	18	29.54	20	
238	19.02.07	21.33	17	0.60	18	30.25	21	1
239	20.02.07	7.31	17	59.98	18	29.95	22	
-	20.02.07	8.29	18	0.01	18	30.30	23	
-	20.02.07	9.20	18	0.21	18	34.49	24	
-	20.02.07	10.34	18	0.20	18	38.80	25	
-	20.02.07	11.26	18	0.28	18	44.16	26	
-	20.02.07	12.33	18	0.77	18	50.14	27	
-	20.02.07	13.36	18	0.41	18	56.02	28	
-	20.02.07	14.32	17	59.18	19	0.40	29	
-	20.02.07	15.37	17	52.07	19	0.18	30	
240	20.02.07	16.25	17	47.18	19	0.07	31	
241	20.02.07	18.40	17	44.05	19	1.20	32	1
-	20.02.07	19.35	17	36.68	19	0.30	33	
242	21.02.07	6.31	16	58.80	18	59.98	34	1
-	21.02.07	7.32	16	48.36	19	0.05	35	
-	21.02.07	8.30	16	39.99	19	0.02	36	
-	21.02.07	9.33	16	32.90	18	59.93	37	
243	21.02.07	10.27	16	31.15	18	59.70	38	1
-	21.02.07	11.29	16	29.02	19	1.50	39	
-	21.02.07	12.25	16	34.77	19	4.70	40	
-	21.02.07	13.41	16	41.01	19	11.59	41	
-	21.02.07	14.38	16	44.47	19	17.84	42	
-	21.02.07	15.37	16	47.05	19	24.70	43	
-	21.02.07	16.29	16	49.73	19	29.97	44	
-	21.02.07	17.28	16	57.25	19	29.90	45	
244	21.02.07	18.51	17	0.38	19	30.42	46	1
-	21.02.07	19.32	17	4.24	19	29.99	47	
-	21.02.07	20.30	17	9.58	19	29.84	48	
-	22.02.07	7.03	18	0.07	19	32.54	49	
-	22.02.07	8.00	18	0.09	19	37.62	50	
-	22.02.07	8.57	18	0.22	19	42.90	51	
-	22.02.07	10.06	18	0.09	19	49.89	52	
-	22.02.07	11.02	18	0.03	19	55.60	53	
246	22.02.07	12.49	18	0.08	20	0.23	54	
-	22.02.07	14.03	17	56.88	20	0.90	55	
-	22.02.07	14.56	17	52.36	20	0.89	56	

-	22.02.07	16.13	17	44.38	20	0.37	57	
-	22.02.07	17.05	17	38.18	20	0.09	58	
-	22.02.07	18.09	17	30.46	19	59.86	59	
247	22.02.07	19.09	17	28.62	20	0.01	60	1
-	22.02.07	20.03	17	23.81	19	59.81	61	
-	22.02.07	21.00	17	18.79	19	59.90	62	
248	22.02.07	22.30	17	13.19	19	59.91	63	1
-	22.02.07	23.14	17	18.04	20	0.64	64	
-	23.02.07	0.03	17	21.74	20	2.86	65	
-	23.02.07	7.24	17	15.40	20	29.24	66	
249	23.02.07	7.55	17	13.00	20	29.95	67	1
-	23.02.07	9.50	17	16.25	20	35.12	68	

In total 68 atmospheric air samples and 10 air samples extracted from the surface water were taken. The latter ones have to be measured, and approximately 20% of the atmospheric air samples are measured now.

7.3.1 Method

Atmospheric air samples were taken regularly over the cruise track. Samples were taken on the peildeck in 1L glass flasks and stored in the dark until measurements. To investigate H₂ concentrations and isotope ratios of the surface water gases were extracted with a purge system and stored in 1L glass flasks. The analytical method applied for measuring concentrations and D/H isotopic ratios of atmospheric H₂ was a modification of the method described by Rhee et al. (2004). The method consists of four steps: (1) the air sample is cryogenically separated at -240°C, i.e. gases such as O₂ and N₂ are frozen whereas H₂ remains gaseous; (2) H₂ is pre-concentrated using a molecular sieve at -210°C; (3) H₂ is focused and chromatographically separated from remaining non-condensed gases; (4) the D/H ratio of molecular H₂ is determined by continuous flow GC/IRMS.

7.3.2 Results

Up to now one transect is analyzed, for details see Table 7.3.1 .

The H₂ concentration ranged from 468 to 513 ppb, with a mean of 486 ± 12 ppb. The $\delta^3\text{H}/^2\text{H}$ isotope ratios ranged from 112 to 129 ‰, mean 123 ± 4 ‰. These results are in good agreement with previous data (Rhee et al. 2006). We found the H₂ concentration slightly positively correlated to the SST, the wind speed and the salinity (see Figure 7.3.1 a-c), probably explained by physical solubility effects. Up to now no correlations between the isotope ratio and other parameters were found.

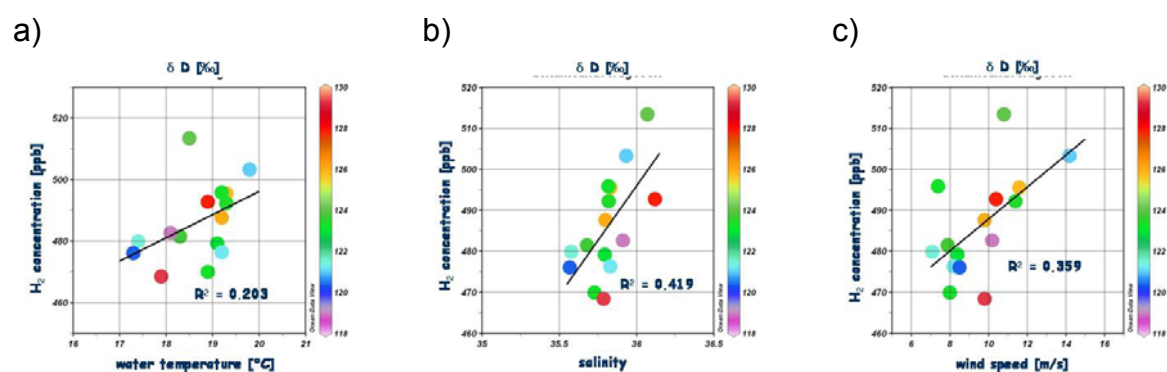


Figure 7.3.1: H₂ concentration plotted against a) water temperature; b) salinity; c) wind speed; the isotopic ratio is color coded

Figure 7.3.2 and 7.3.3 show the diurnal variability of the H₂ concentration and the H₂

isotope ratio. We see a small increase in concentrations and δD values after sun rise and in concentrations after sun down, however, these effects might be caused not only by diurnal variability but also by position effects. During this transect course was set eastwards after midday, towards the coast and the upwelling regions. This might explain the increase in concentrations, if H_2 is produced in upwelling areas. Further investigations to clarify these questions are planned for the future, including a comparison with pigment data. This might show if a connection between H_2 concentrations, H_2 isotope ratios and phytoplankton communities exist.

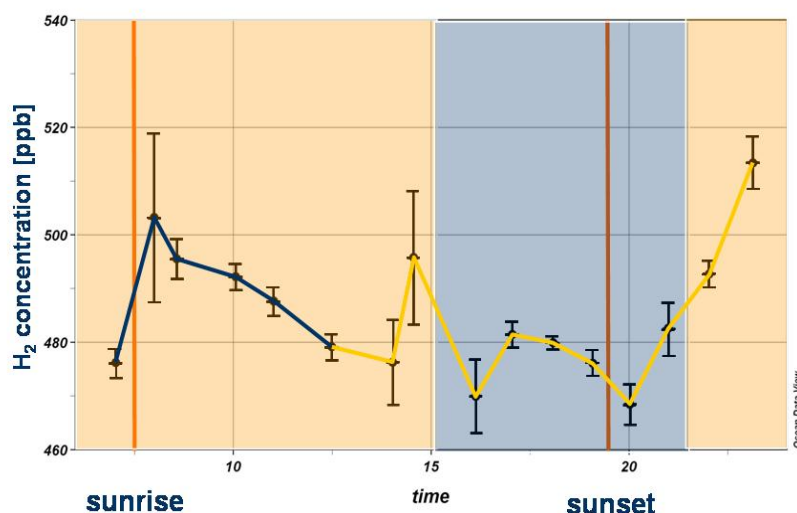


Figure 7.3.2: H_2 concentration of the transect plotted against time [h]; wind direction is coded by background color: orange – offshore, blue – onshore; course is coded by line color: yellow – eastwards (to the coast), blue – northwards

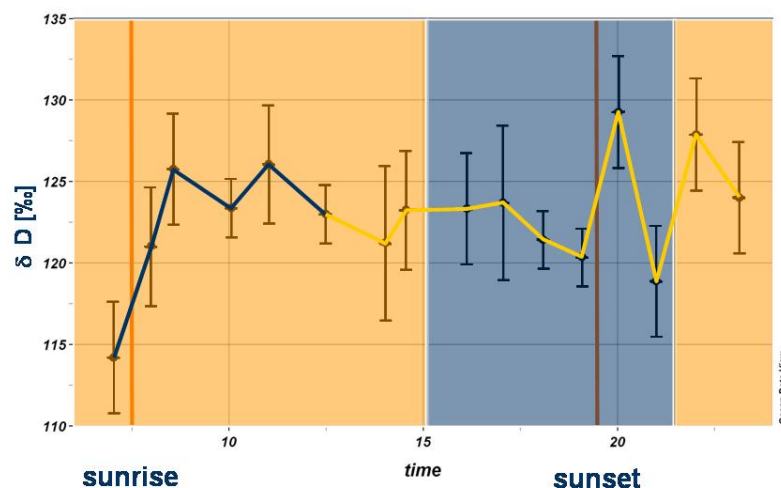


Figure 7.3.3: δD of the transect plotted against time [h]; wind direction is coded by background color: orange – offshore, blue – onshore; course is coded by line color: yellow – eastwards (to the coast), blue – northwards

7.3.3 Literature

Rhee et al.: Continuous-flow isotope analysis of the deuterium/hydrogen ratio in atmospheric hydrogen; Rapid Commun. Mass Spectrom.; 18: 299–306; 2004.

Rhee et al.: The overwhelming role of soils in the global atmospheric hydrogen cycle; Atmos. Chem. Phys., 6, 1611–1625, 2006

7.4 Hydrography and microstructure

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7.4.1 Technical aspects and performance of the instruments

7.4.1.1 CTD/O₂ system

During Poseidon cruise 348, conductivity-temperature-depth and oxygen (CTD/O₂) profiles were sampled using a Seabird (SBE) 9 plus CTD-system referred to as „Ifm-Geomar SBE3“ (Seabird serial number 09P25213-0615). Altogether 33 profiles were collected at 24 stations (Table 7.4.1). The CTD-rosette was equipped with a pressure sensor (ser. nr 82991) and two independent sets of temperature, conductivity and oxygen sensors. In addition, a fluorescence sensor (Chlorophyll a, ser. nr 14010) and an altimeter were attached to the rosette. Routinely, CTD casts were made from surface to bottom. On some stations, however, additional CTD casts were necessary because of the high demand of water samples. These casts were typically made from surface to a depth of about 250-500 m (marked by “shallow water CTD” in Table 7.4.1). The distribution of CTD cast positions is shown in Figure 7.4.1.

Station work began with a section along 18°N from Cape Verde to the Mauritanian coast. This was followed by stations close to the Mauritanian coast to the north of the 18°N section, where typical station spacing was between 30 and 60nm. Due to strong winds two planned CTD stations were omitted, while another two planned stations (150 and 158) were relocated. About 30 water samples were collected to calibrate conductivity sensors, predominately from the deeper water column. These samples were analyzed with a laboratory salinometer (Guildline Autosal) after the cruise in Kiel. Resulting calibration coefficients were used to correct downcast profiles of salinity.

7.4.1.2 Microstructure probe

During P348 a microstructure profiling system manufactured by Sea and Sun Technology (Trappenkamp, Germany) was used to collect microstructure shear and temperature profiles. The system consisted of a profiler (MSS 26), a winch and data interface. The profiler can operate 16 channels with a very high data transmission rate of 1024 Hz that is sufficient to resolve small vertical scales of turbulent fluctuations in the ocean. The profiler is equipped with two shear probes (airfoil, 4ms response time), a fast-responding temperature sensor (microthermistor FP07, 12 ms response time), an acceleration sensor and conductivity, temperature, depth sensors that sample at a lower frequency (24 Hz). Additionally the profiler is equipped with two tilt sensors (for details see Table 2). The nearly free-falling profiler is optimized to sink at a rate of about 0.6 m/s and is capable of measuring microstructure up to a depth of 2000m. Shear fluctuations recorded due to vibration of the profiler while sinking can be diagnosed from the acceleration sensor.

In total, 58 microstructure profiles were collected at 20 stations (see Table 7.4.1 and Figure 7.4.1). Cast at a single station were repeated three or four times to increase statistical significance. Routinely microstructure profiles were made from the surface

to about 150-250 m depth or to the bottom in shallow waters. Due to strong winds during CTD Station 155, no microstructure profiles were collected.

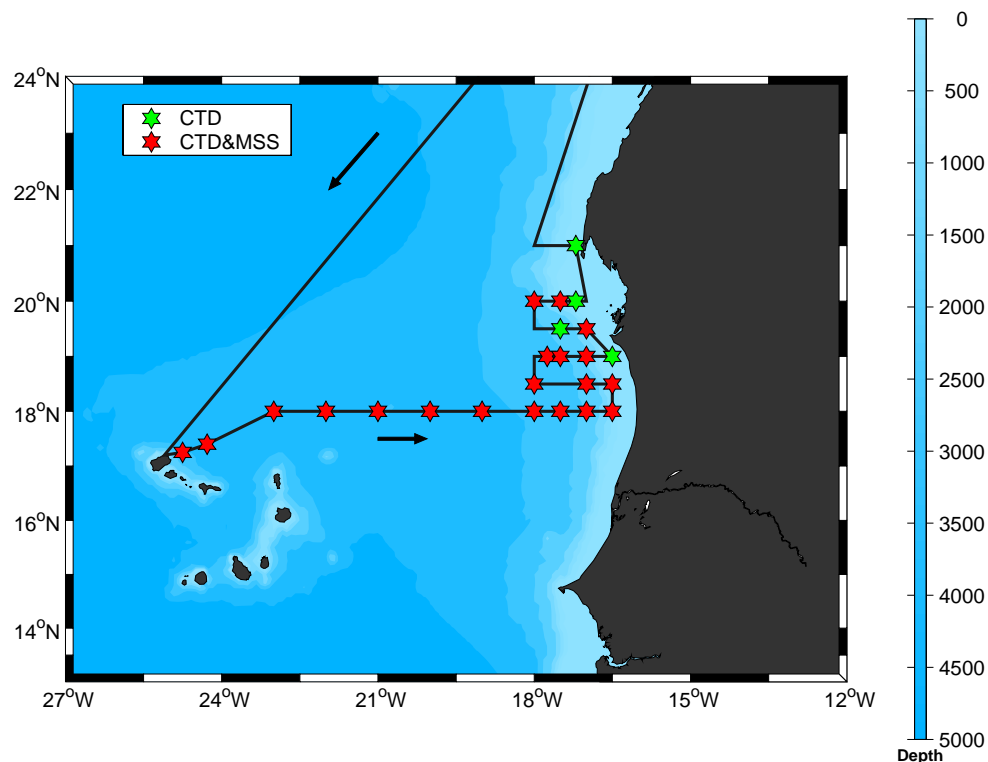


Figure 7.4.1: Working area, red stars represent microstructure & CTD stations, green stars only CTD.

Table 7.4.1: Station overview

No. Ship Station	Time (UTC)	Date	Latitude	Longitude	No. MSS	Max. Depth (m) (MSS)	No. CTD Cast	Max. Depth (m) (CTD)
226	10:37	12/02/2007	17°15.42' N	24°45.78' W	1	155	127	2900
226	10:48	12/02/2007	17°15.22' N	24°45.65' W	2	153	127	
227	18:23	12/02/2007	17°37.73' N	24°17.73' W	3	159	128	3603
227	18:31	12/02/2007	17°37.65' N	24°17.86' W	4	155	128	
227	18:40	12/02/2007	17°37.55' N	24°17.93' W	5	137	128	
227		shallow water CTD			##	##	129	500
228	05:57	15/02/2007	18°00.07' N	23°00.01' W	6	145	130	3489
228	06:06	15/02/2007	18°00.56' N	22°59.98' W	7	155	130	
228	06:16	15/02/2007	18°00.78' N	22°59.89' W	8	156	130	
228		shallow water CTD			##	##	131	500
229	18:43	15/02/2007	18°00.30' N	23°59.98' W	9	165	132	3290
229	18:52	15/02/2007	18°00.50' N	23°00.23' W	10	167	132	
229	19:02	15/02/2007	18°00.60' N	23°00.31' W	11	164	132	
230	08:01	16/02/2007	18°00.08' N	20°59.99' W	12	147	133	3065
230	08:10	16/02/2007	18°00.56' N	20°59.98' W	13	154	133	
230	08:20	16/02/2007	18°00.79' N	20°59.99' W	14	168	133	
231	21:04	16/02/2007	18°00.04' N	19°59.75' W	15	163	134	3196
231	21:12	16/02/2007	18°00.35' N	19°59.71' W	16	178	134	
231	21:22	16/02/2007	18°00.45' N	19°59.66' W	17	203	134	
231		shallow water CTD			##	##	135	750
232	10:19	17/02/2007	18°00.15' N	18°59.90' W	18	157	136	3133
232	10:28	17/02/2007	18°00.19' N	18°59.93' W	19	162	136	
232	10:37	17/02/2007	18°00.25' N	18°59.88' W	20	145	136	
232		shallow water CTD			##	##	137	500
233	00:14	18/02/2007	18°00.10' N	17°59.53' W	21	146	138	2789
233	00:23	18/02/2007	18°00.10' N	17°59.88' W	22	149	138	
233	00:32	18/02/2007	18°00.07' N	18°00.10' W	23	156	138	

233			shallow water CTD		##	##	139	500
234	09:28	18/02/2007	18°00.33' N	17°29.13' W	24	148	140	2497
234	09:37	18/02/2007	18°00.76' N	17°29.10' W	25	170	140	
234	09:46	18/02/2007	18°00.99' N	17°29.04' W	26	162	140	
234			shallow water CTD		##	##	141	250
235	18:07	18/02/2007	17°59.99' N	16°59.99' W	27	143	142	1717
235	18:15	18/02/2007	18°00.34' N	17°00.12' W	28	146	142	
235	18:24	18/02/2007	18°00.43' N	17°00.18' W	29	158	142	
235			shallow water CTD		##	##	143	250
236	01:23	19/02/2007	18°00.10' N	16°29.99' W	30	140	144	190
236	01:31	19/02/2007	18°00.52' N	16°30.05' W	31	165	144	
236	01:41	19/02/2007	18°00.73' N	16°30.12' W	32	146	144	
237	13:05	19/02/2007	18°29.98' N	16°30.29' W	33	54	145	104
237	13:09	19/02/2007	18°30.08' N	16°30.25' W	34	73	145	
237	13:13	19/02/2007	18°30.16' N	16°30.22' W	35	99	145	
238	20:15	19/02/2007	18°30.16' N	16°59.70' W	36	146	146	1608
238	20:25	19/02/2007	18°30.43' N	17°00.47' W	37	163	146	
238	20:33	19/02/2007	18°30.62' N	17°00.47' W	38	149	146	
238			shallow water CTD		##	##	147	500
239	08:14	20/02/2007	18°30.03' N	17°59.94' W	39	155	148	2000
239	08:24	20/02/2007	18°30.44' N	18°00.01' W	40	167	148	
240	17:38	20/02/2007	19°00.69' N	17°47.42' W	41	142	149	2000
240	17:47	20/02/2007	19°00.98' N	17°47.55' W	42	144	149	
240	17:55	20/02/2007	19°01.32' N	17°47.67' W	43	137	149	
241	21:32	20/02/2007	19°00.50' N	17°30.12' W	44	140	150	2216
241	21:41	20/02/2007	19°00.87' N	17°30.43' W	45	146	150	
241	21:50	20/02/2007	19°01.26' N	17°30.69' W	46	144	150	
242	04:25	21/02/2007	18°59.84' N	16°59.22' W	47	143	151	1111
242	04:35	21/02/2007	19°00.05' N	16°59.12' W	48	176	151	
242	04:45	21/02/2007	19°00.12' N	16°58.98' W	49	156	151	
242			shallow water CTD		##	##	152	500
243	09:35	21/02/2007	18°59.62' N	16°32.89' W	##	##	153	60
244	18:28	21/02/2007	19°30.13' N	16°59.93' W	50	70	154	102
244	18:33	21/02/2007	19°30.14' N	16°59.99' W	51	77	154	
244	18:38	21/02/2007	19°31.17' N	17°00.01' W	52	98	154	
245	00:24	22/02/2007	19°29.90' N	17°30.01' W		MSS cancelled	155	1619
246	12:46	22/02/2007	20°00.16' N	18°00.08' W	53	162	156	1853
246	12:56	22/02/2007	20°00.53' N	18°00.07' W	54	165	156	
246	13:05	22/02/2007	20°00.61' N	18°00.09' W	55	159	156	
247	18:38	22/02/2007	19°59.96' N	17°29.98' W	56	56	157	70
247	18:41	22/02/2007	20°00.11' N	17°30.01' W	57	60	157	
247	18:44	22/02/2007	20°00.22' N	17°30.02' W	58	57	157	
248	22:08	22/02/2007	19°59.98' N	17°13.01' W	##	##	158	90
249	07:55	22/02/2007	20°59.95' N	17°12.99' W	##	##	159	50

Table 7.4.2: Setup Microstructure Probe MSS 26

Sensor	Type	Respond time	Serial No.
Temperature	PT100	160 ms	
Conductivity	ADM	100 ms	
Pressure	Keller PA7-200	40 ms	
Acceleration	ACC	4 ms	8022
Tilt X	ADXL 203	~100ms	
Tilt Y	ADXL 203	~100ms	
Shear	Airfoil	4 ms	6055
Shear	Airfoil	4 ms	6075
Temperature	NTC; FP07	12 ms	40

7.4.1.3 Current observations by Vessel mounted ADCP

Continuous velocity measurements were carried out using a vessel-mounted 75 kHz RDI Ocean Surveyor acoustic Doppler current profiler (ADCP), in the following abbreviated as OS75. The OS75 is a narrow band phased array with a 30 degree beam angle. Data were logged on a PC, using RDI data acquisition software VmDas. Data collection was started at February 9th and stopped at February 22nd with the end of station work. The OS75 was lowered into the moon pool located in mid-ship in a depth of around 6 m. The same instrument configuration as during the previous cruise P347 was used - a 8 m blank, 8 m bin range, and 8 m pulse length and a sampling interval 'as fast as possible' which resulted in an effective time interval between consecutive pings of approximately 2.4 sec. High quality heading data is crucial for obtaining accurate measurements of ocean currents using vessel mounted ADCPs. On RV Poseidon different sources for heading data are available. Most suitable for our purpose was heading information from an Ashtec ADU2 system, which derives heading information using a four antenna GPS-system. To obtain accurate absolute velocity measurements from the OS75, a calibration for the misalignment angle between the ADCP axis and the axis of the ships compass is essential. Water track calibration following the method described by Joyce [1989] led to a misalignment angle of 3.722° with a standard deviation $\sigma = 0.477^\circ$ and to an amplitude factor of 1.0078 ($\sigma = 0.001$) calculated for 10 min. ensembles. Overall, the quality of the OS75 velocities and the navigation data acquired during P348 was excellent. The maximum profiling range of the OS75 was about 750 m.

7.4.2 Preliminary results

7.4.2.1 CTD/O₂ measurements

Figure 7.4.2 shows a contour plot of temperature along the 18°N section. The dashed black and white line represents mixed layer depth (determined by an increase of density of 0.125 kg/m³ compare to surface values). Highest surface temperature (SST) values (>23°C) are observed far offshore in the western part of the section. In this region, deepest mixed layer depth (MLD) associated with weak stratification within the upper 50 m are found. Along 18°N we observed a monotonic decrease of SST to the east with coldest temperature of around 16-17°C close to the coast. This temperature decrease is accompanied by a successive decrease of MLD, a pattern typical for upwelling regions. Decrease of mixed layer depth and the raise of colder (older / less fresh) water is also mirrored in oxygen concentrations. In Figure 7.4.2 black contour lines represent the oxygen level in [ml/l]. Between surface and mixed layer depth highest concentrations of oxygen with values > 5 ml/l with negligible gradients were observed. In the depth range between 150-250m at CTD stations 128, 132 and 140, local maxima in oxygen values are observed. This depth range is dominated by central water masses (North Atlantic Central Water, NACW, and South Atlantic Central Water, SACW). The Cape Verde Frontal Zone (CVFZ) constitutes the boundary between these two water masses, separating the less saline, slightly cooler SACW from the NACW which is richer in oxygen. The temperature and oxygen distributions along 18°N illustrate some meandering of the CVFZ associated with the passage of eddies, although the eddy scales (see section on current observations) are not well resolved by the CTD spacing.

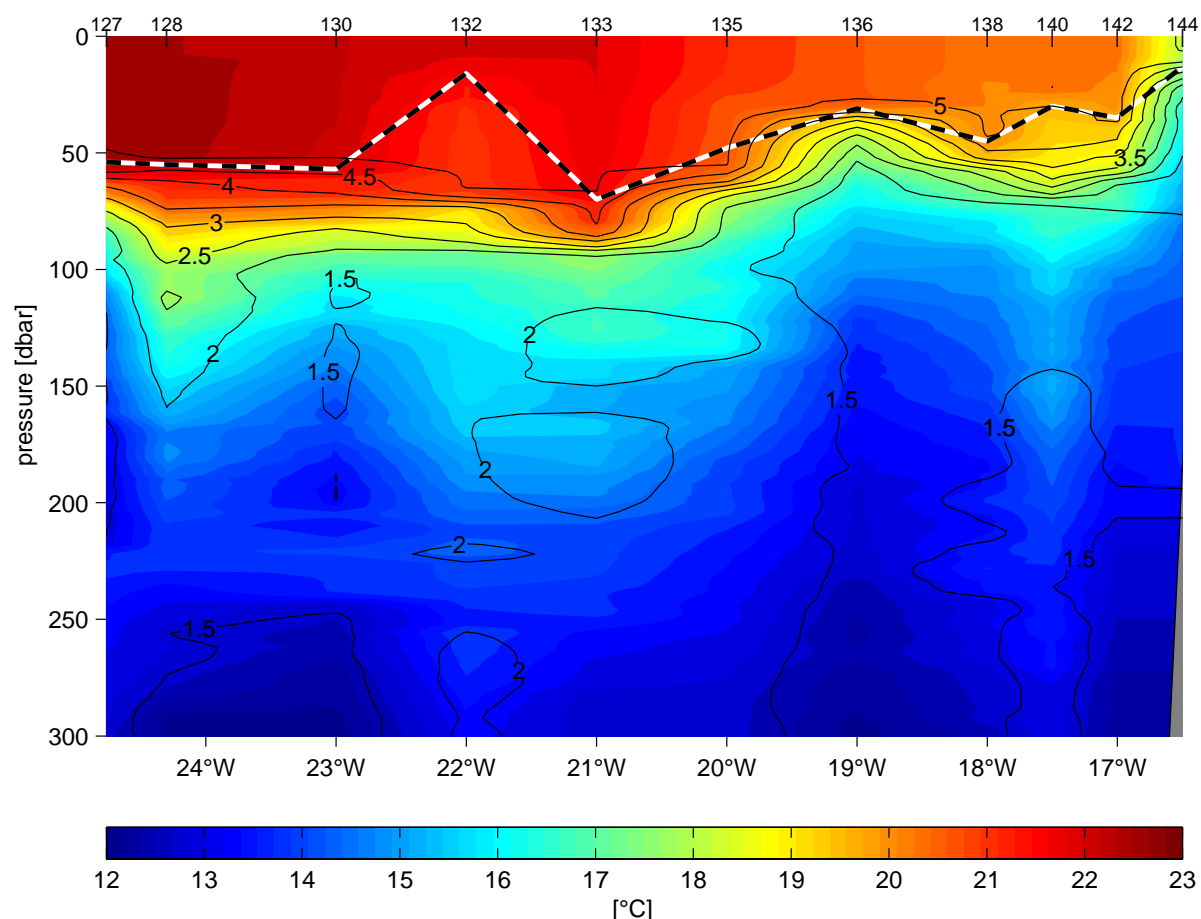


Figure 7.4.2: Contour plot of the CTD temperature (color) and oxygen [ml/l] (black contour interval). Dashed black and white line represents the mixed layer depth. Station numbers are marked on top (see station map and Table 7.4.1 for the position).

7.4.2.2. Microstructure measurements

Mixing processes in the ocean are closely connected with turbulence. The dissipation rate of turbulent kinetic energy (TKE) is a measure of the strength of turbulence and thus of diapycnal mixing. The dissipation rate of TKE (ϵ) was evaluated from the microstructure measurements along the 18° N section (from 23°W to 16.3°W) within the upper 100 m. In this region, wind stress and convection due to night time cooling of surface waters drives turbulence in the mixed layer. Figure 7.4.3 shows the dissipation rate of turbulent kinetic energy (color contours) for the 18°N section. As expected, particularly higher values of turbulence are associated with night time convection in this area. Highest values of ϵ are found in the mixed layer. Below the mixed layer, however, several maxima of turbulent dissipation are noticeable. These maxima are related to elevated large scale vertical shear of horizontal velocity, which is denoted by the black contour lines in Figure 3. Here, shear variance [$S^2 = (du/dz)^2 + (dv/dz)^2$] was calculated from the ADCP data collected while on station. Because of the setup of the OS75 shear values only available for depth > 20 and due to the bin length of 8 m only shear variance with scales > 16 m are resolved. Nonetheless there is a connection between large scale shear and same scale dissipation apparent along the 18°N section, as is expected from mixing processes that are related to breaking of internal waves.

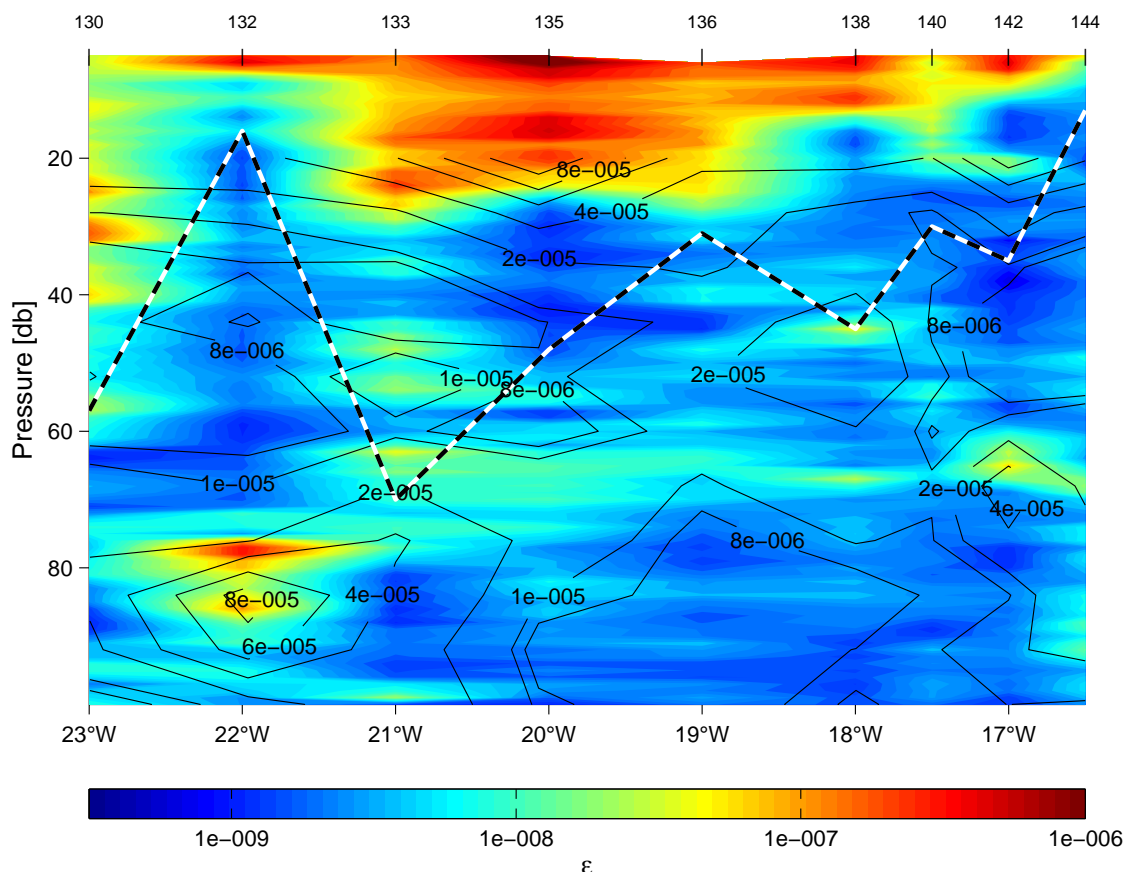


Figure 7.4.3: Contour plot of the log10 dissipation rate of turbulent kinetic energy (color) and velocity shear (S^2 [$1/S^2$], black contour interval). Dashed black and white line represents the mixed layer depth. Station numbers are marked on the top (see station map and Table 7.4.1 for the position).

7.4.2.3 ADCP measurements

The ocean surveyor data were mapped on a regular grid, using a Gaussian weighted interpolation scheme. As a preliminary observation the zonal section along 18°N is shown here. The 18°N section runs from 25°W to 16.3°W, the upper panel of Figure 7.4.4 shows the meridional velocity distribution between these boundaries and on the lower panel the cumulative northward transport across 18°N. Along this section 11 CTD-stations were collected (marked by tick on top of Figure 7.4.1). Velocities observed by the OS75 show a banded structure of the flow field within the upper 600 m, having horizontal scales of about 100 km. These structures, that have associated velocity fluctuation of up to 25 cm/s within the upper 150 m, can be explained as eddies and/or Rossby waves. Between 24°W and 21°W, southward velocities dominate, yielding in a transport of approximately 14 Sv to the south. Further to the east and the west mainly northward velocities prevail, compensating most of the mentioned southward transport. In total the velocity field results in a southward transport of around 3.8 Sv across this section above the $\sigma_\theta = 27.2$ kg/m³ isopycnal.

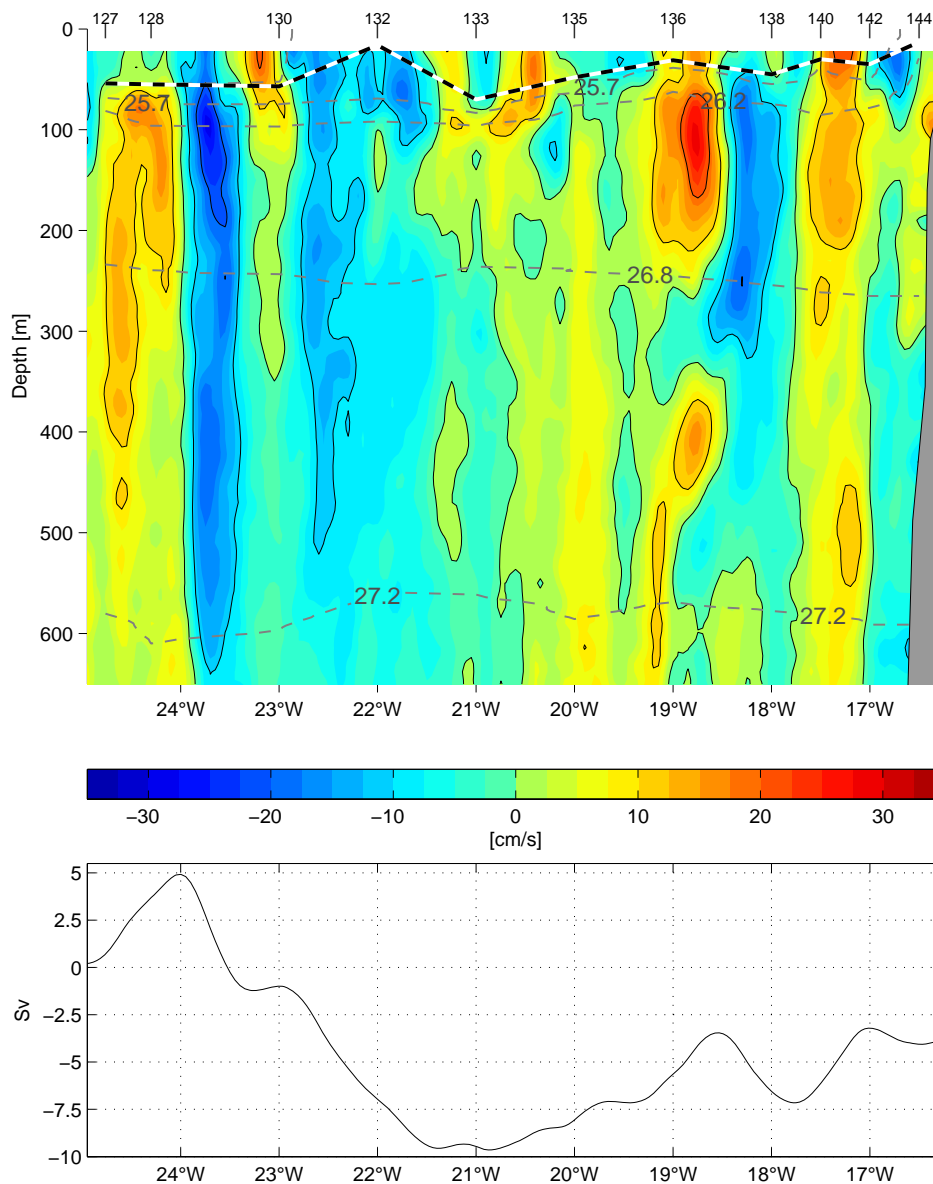


Figure 7.4.4: Upper panel: meridional velocity [cm/s] along 18°N from Ocean Surveyor 75 with a contour interval of 10 cm/s. Marked are isopycnals $\sigma_\theta = 25$, $\sigma_\theta = 25.7$, $\sigma_\theta = 26.8$ and $\sigma_\theta = 27.2$ [kg/m³] (gray dashed lines) as well as the mixed layer depth (black and white dashed line) and the locations and numbers of the related CTD-Cast at the top of the panel. Lower panel: cumulative transport above isopycnal $\sigma_\theta = 27.2$ kg/m³.

Joyce, T. M. (1989), On in situ “calibration” of shipboard ADCPs, *Journal Atmos. Oceanic Technol.*, 6, 169-172

7.5 Nutrients, O₂

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Depth profiles of nitrate (Figure 7.5.1) and phosphate (data not shown) along 18°N show a considerable enrichment in the water column with a pronounced maximum between 200 and 1000 m. Maximum nutrient concentrations were measured on the continental slope.

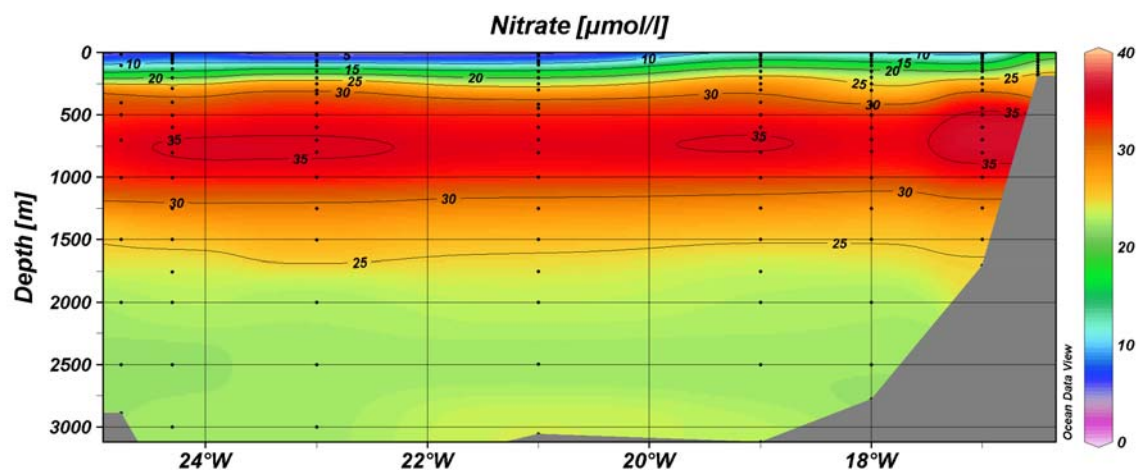


Figure 7.5.1: Nitrate along 18°N.

Oxygen depth profiles on the other hand show a minimum zone between 100 and 800 m, which is clearly related to the upwelling (Figure 7.5.2). Between 16° and 20° W minimum oxygen values were 50 $\mu\text{mol L}^{-1}$. A less intense minimum was observed between 20 and 22° W.

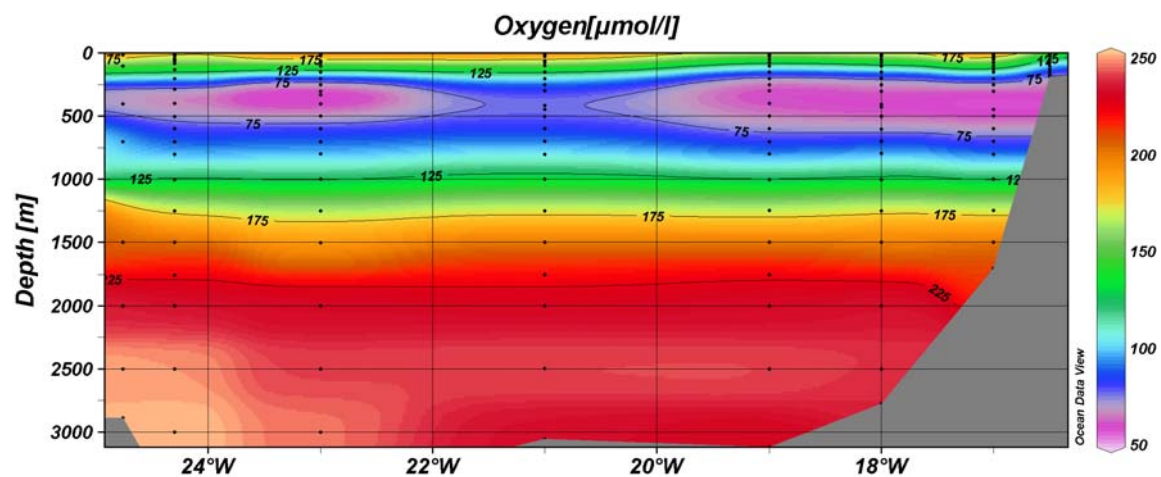


Figure 7.5.2: Oxygen along 18°N.

7.6 N₂O/NH₂OH/CH₄

Alina Freing, Annette Kock, Hermann Bange (IFM-GEOMAR; afreing@ifm-geomar.de, akock@ifm-geomar.de, hbange@ifm-geomar.de)

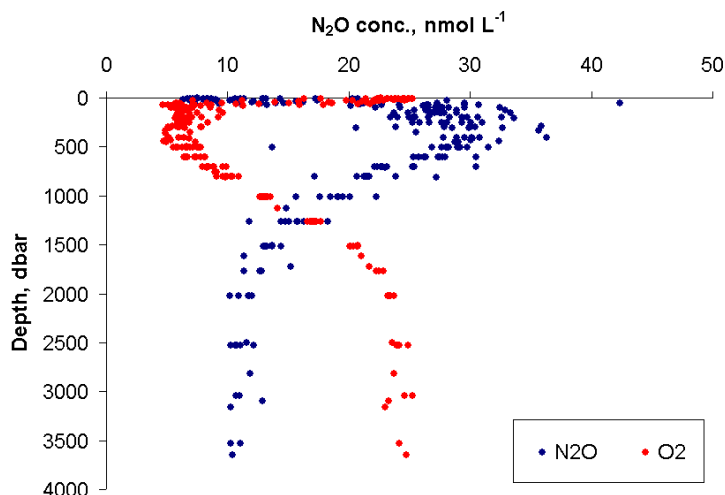
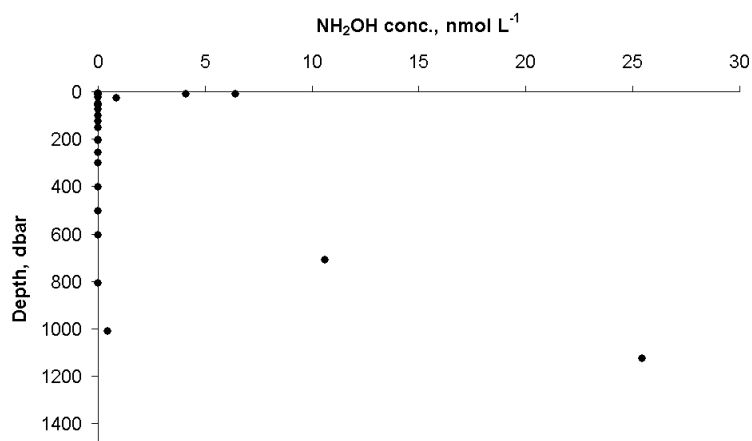
7.6.1 N₂O/NH₂OH

Water samples for N₂O analysis were collected in triplicate from various depths. Bubble free samples were taken immediately following oxygen sampling in 24 mL glass vials, sealed directly with butyl rubber stoppers and crimped with aluminium caps. To prevent microbial activity, samples were poisoned with mercury chloride solution. Then 10 mL of sample was replaced with a helium headspace for each vial, and the samples were allowed to equilibrate for at least two hours at room temperature (temperature was recorded continuously). A 9 mL subsample from the headspace was used to flush a 2 mL sample loop after passing through a moisture trap (filled with Sicapent[®], Merck Germany). Gaschromatographic separation was performed at 190 °C on a packed molecular sieve column (6ft x 1/8"SS, 5A, mesh 80/100, Alltech GmbH, Germany). The N₂O was detected with an electron capture detector. A mixture of argon with 5 % by volume methane was used as carrier gas. For the two-point calibration procedure we used standard gas mixtures with 314.2 ± 0.1 ppb and 356.0 ± 0.2 ppb N₂O in synthetic air (Deuste Steininger GmbH, Mühlhausen Germany). The standard mixtures have been calibrated against the NOAA (National Oceanic and Atmospheric Administration, Boulder, Co.) standard scale in the laboratories of the Max Planck Institute for Biogeochemistry, Jena, Germany. The mean relative analytical error for the N₂O concentrations was estimated to be ± 5 %.

Water samples (24 mL) for NH₂OH analysis were collected in triplicate from various depths at selected stations. NH₂OH samples were acidified (with acetic acid) and oxidized to N₂O (with an aqueous Fe(III)NH₄(SO₄)₂ solution). Then the samples were treated in the same way as described above. The initial NH₂OH concentration was calculated as the difference of the background N₂O concentration and the N₂O resulting from the conversion of NH₂OH. The recovery factor was determined by addition of four different NH₂OH standard solutions to triplicate water samples from deep waters. Typical mean relative errors are about ± 20 % for concentrations up to 20 nmol L⁻¹. Lower NH₂OH concentrations are associated with larger errors. Concentrations <2 nmol L⁻¹ have relative errors of >100% and are statistically insignificant.

The water column distributions of nitrous oxide (N₂O) and hydroxylamine (NH₂OH) are shown in Figures 7.6.1 and 7.6.2. Enhanced N₂O concentrations of up to 36 nmol L⁻¹ were found in the oxygen minimum zone during the transect along 18°N. The maximum N₂O concentration of 42 nmol L⁻¹ was observed in 50m close to the ocean bottom of station #243 (19°N 16.55°W). In general, N₂O concentrations were well correlated with oxygen (O₂) concentrations.

NH₂OH was detectable only in a few samples. The NH₂OH concentrations were highly variable and ranged from not detectable to about 25 nmol L⁻¹. There was no general trend in the water column distribution.

Figure 7.6.1: N₂O and O₂ profiles.Figure 7.6.2: NH₂OH profiles.

7.6.2 CH₄

CH₄ in the surface layer was determined with a gas chromatograph system equipped with a flame ionisation detector and connected to a shower type equilibrator developed by R.F. Weiss (Scripps Institution of Oceanography, La Jolla, CA). Concentrations and resulting saturation values were corrected for difference between the water temperature at the sea chest and the continuously recorded water temperature in the equilibrator. A series of measurements of seawater and ambient air followed by two standards (1.779 ± 0.002 and 2.543 ± 0.002 ppm CH₄ in synthetic air) were repeated every 22 min. The gravimetrically prepared gas standards (made by DEUSTE Steininger GmbH, Mühlhausen, Germany) were calibrated against the actual NOAA standard scale in the laboratories of the Max Planck Institute for Biogeochemistry in Jena, Germany. The mean relative errors of the CH₄ concentrations and saturations, were estimated to $\pm 5\%$. Saturation values are expressed in % (i.e., 100% = equilibrium). Continuous time series of seawater temperature (SST) and salinity were obtained from the ship's records. SST and salinity were measured by the ship's thermosalinograph and calibrated against CTD values.

Discrete sampling and analysis followed the procedure described for N₂O. Discrete

CH₄ samples were poisoned on board with aqueous HgCl₂ solution and stored for later analysis in our laboratory in Kiel.

The atmospheric methane (CH₄) dry mole fractions were highly variable and ranged from 1.8 to 2.5 ppm (Figure 7.6.3). They are in reasonable agreement with the monthly mean CH₄ dry mole fraction of 1.836 ± 0.017 ppm measured in February 2007 at Izaña [E. Dlugokencky, personal communication]. During P348 enhanced CH₄ mole fractions were found between 19°N and 21°N. This could result from air masses, which became enriched with CH₄ while crossing the Banc d'Arguin area as indicated by air mass backward trajectories (Figure 7.6.3). Dissolved CH₄ concentrations were variable and ranged from 2.1 to 4.9 nmol L⁻¹. CH₄ saturations ranged up to 179 % (Figure 4). The majority of low CH₄ concentrations were found in the western part of the transect at 18.5°N and north of 20°N, whereas significantly enhanced CH₄ concentrations were mainly found close to the coast between 19° and 19.5° N (Figure 7.6.4).

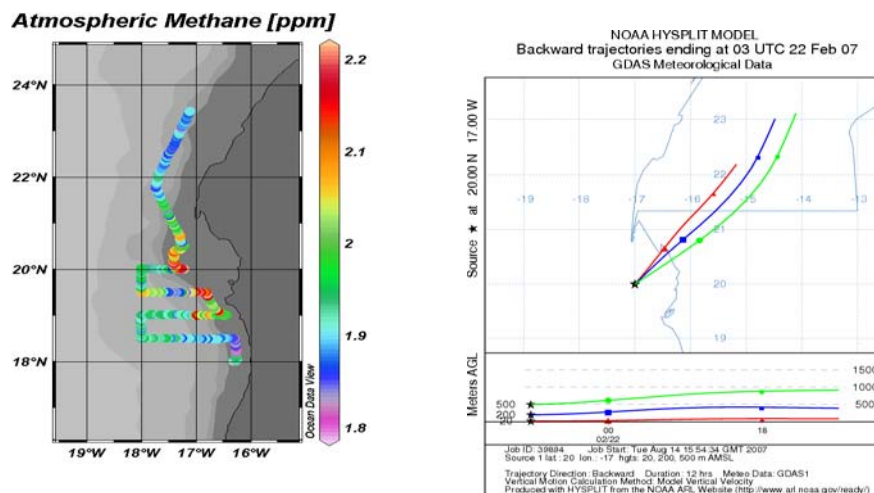


Figure 7.6.3: Atmospheric CH₄ during P348 (left panel) and 12h backward trajectories in 20m (red line), 200m (blue line) and 500m (green line) heights above sea level (right panel).

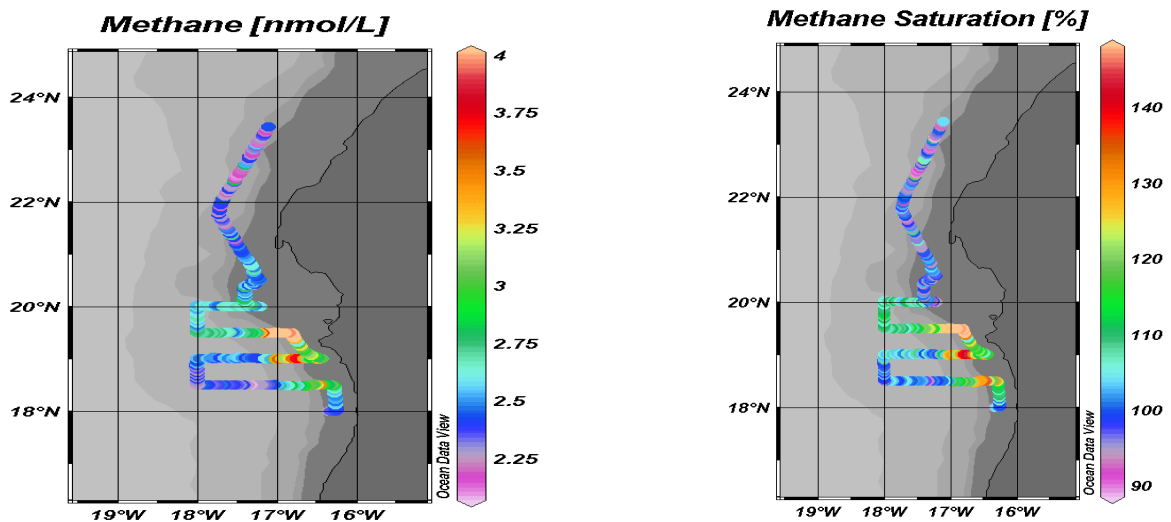


Figure 7.6.4: CH₄ concentration (left panel) and CH₄ saturation (right panel).

Methane saturation profiles (Figure 7.6.5) reveal several trends: Open ocean surface waters were only slightly supersaturated and saturation declined to less than 50 % below 1000 m. Towards the continental slope the water column was supersaturated. Values up to 250 % were measured in the bottom waters between 17 and 17.5° W, indicating a strong sediment source. Maximum surface water saturations reached 170 % between 16.5° W and 17.5° W and indicated the upwelling-influenced area. The impact of upwelling on surface water concentrations extended about 200 km offshore. West of 18.5° N, surface and subsurface saturations declined. A pronounced subsurface maximum at 100 m depth was observed between 20 and 22° W. Two subsurface maxima were observed near the slope with enhanced saturations at about 100 m and 400 m.

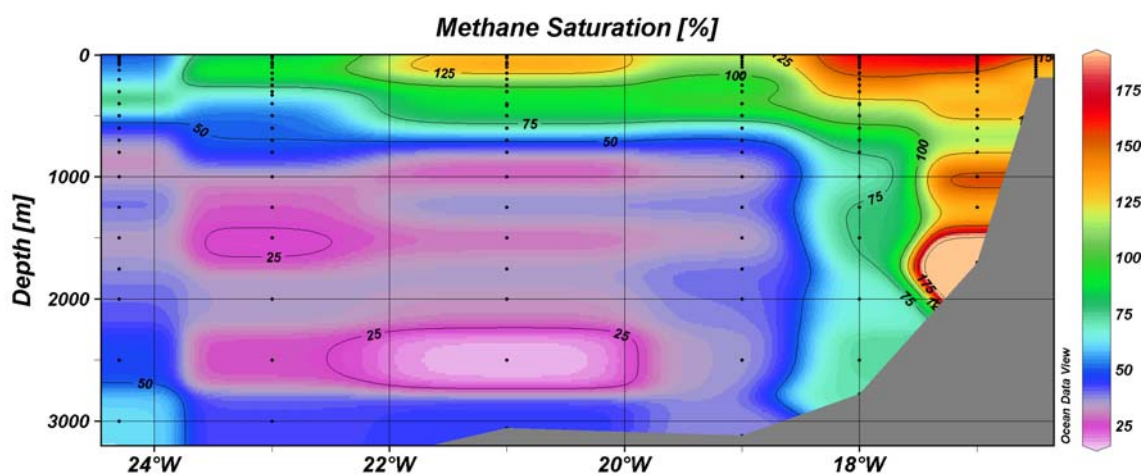


Figure 7.6.5: CH₄ saturations along 18°N.

7.7 pCO₂

Tobias Steinhoff (IFM-GEOMAR; tsteinhoff@ifm-geomar.de)

On Poseidon cruise P348 we ran several underway instruments to measure the following parameters: dissolved oxygen, chlorophyll, gas tension of all dissolved gases and partial pressure of CO₂ (*p*CO₂). The instruments were fed with a seawater flow from a submersible pump that was installed in the ships moonpool (~ 5m depth). The *p*CO₂ system was directly connected to the water line while the other sensors were put in a bath (Coleman® cooling container) that were flushed with the seawater.

7.7.1 Underway measurements

7.7.1.1 pCO₂

The automated underway system with a non-dispersive infrared gas detector for CO₂ was continuously operated along the cruise track. A continuous flow of seawater was drawn at approximately 5 m depth from the ship's moon pool which was equipped with a CTD. Every minute a *p*CO₂ data point together with temperature and salinity from the CTD were logged along with the position data from an independent GPS system. The *p*CO₂ data were calibrated against standard gases and after a thorough QC procedure we got more than 10,000 data points. The accuracy of the *p*CO₂ data is estimated to ±2µatm.

7.7.1.2 Oxygen

Dissolved Oxygen was determined via an optode (Aanderaa Instruments AS, Bergen, Norway). This technique is based on dynamic luminescence quenching. The raw data were corrected for salinity but not calibrated against discrete oxygen samples that were also taken during this cruise.

7.7.1.3 Gas tension

The PSI-GTD-Pro (Pro-Oceanus Systems Inc., Halifax, Canada) measures the total dissolved gas pressure of all gases. A small sample volume of air is equilibrated to all dissolved gases in the water through a special membrane. The GTD was also installed in the water bath.

7.7.1.4 Chlorophyll

The Chlorophyll sensor (fluorescence) was installed in the water line that was fed by seawater. The sensor wasn't calibrated, so we could only detect trends in the chlorophyll concentration.

7.7.2 First results

Figure 7.7.1 shows underway data of P348. As expected the upwelling takes place only directly at the coast. The lowered sea surface temperature in Figure 7.7.1a shows clearly these upwelling events: As one can see temperatures around 22°C in the open ocean the temperature goes down to 17°C in the upwelling region. Also the oxygen and $p\text{CO}_2$ data (Figure 7.7.1b and 7.7.1d) draw the same picture. Typical $p\text{CO}_2$ -values around the atmosphere concentration and oxygen saturation around 100% in the open ocean and high $p\text{CO}_2$ values (up to 700) and low oxygen saturation in the upwelled water.

The gas tension data are shown in Figure 7.7.1c. The gas tension is mainly driven by oxygen and nitrogen and therefore you can see the good correlation with the oxygen saturation data.

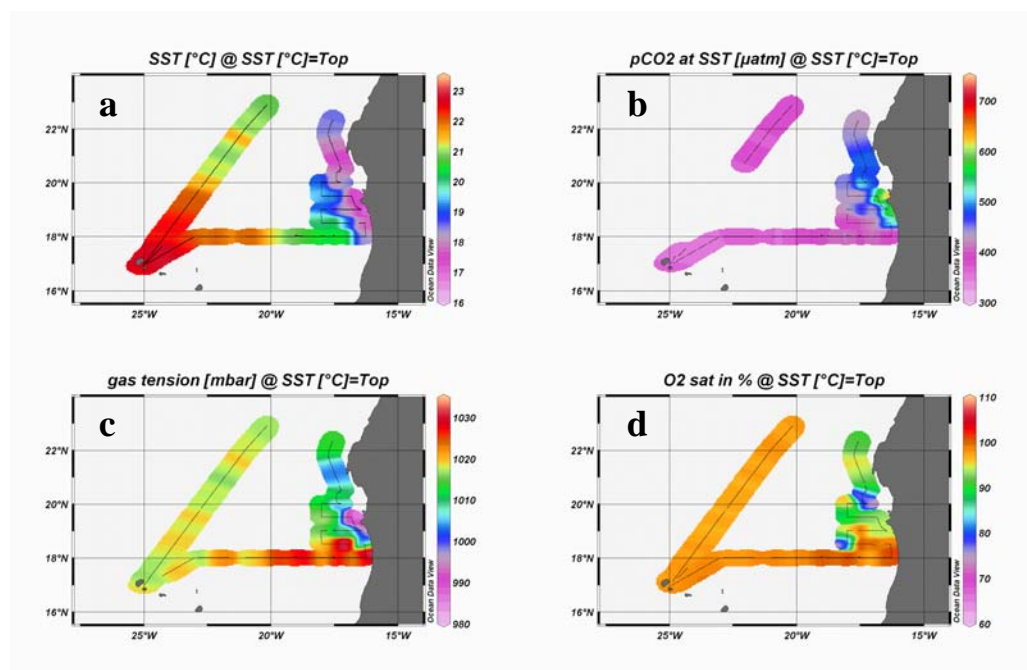


Figure 7.7.1: Underway data of Poseidon cruise P348.

7.8 Chl a / phytoplankton distribution

Ilka Peeken (IFM-GEOMAR; ipeeken@ifm-geomar.de)

7.8.1 Empirical approach

Routine phytoplankton pigments measurements of CTD water were performed as part of an empirical approach to determining the biological drivers of ocean-atmospheric exchange and to characterize biology during a strong upwelling scenario off the coast of Mauritania in spring.

7.8.2 Sampling scheme

Depending on the water depth at 22 stations between 5 - 9 depths were sampled from CTD casts for marker pigments in the upper 125m. The volume of water filtered was dependent on the amount of biomass in the water and was between 1 – 4 L and filtered onto GF/F filters (Whatman), rinsed with filtered seawater, placed in Cryovials and immediately frozen at -80°C.

In total 135 samples have been analysed with High Performance Liquid Chromatography (HPLC) for various marker pigments after a modified method of *Hoffmann et al.* [2006].

7.8.3 Preliminary results

The phytoplankton biomass indicator, chlorophyll a (Figure 7.8.1a) showed elevated concentrations in the upwelling region close to the Mauritanian coast with maximum values of 6500 ng L⁻¹ in the surface ocean (10m). The Mindelo time series study (most south-westerly point Figure 7.8.1) has with roughly 100 ng chl_a L⁻¹ a very low biomass. The upwelling is characterised by a high proportion of diatoms, reflected in the accompanying results of chlorophyll a to the marker pigment fucoxanthin, which mainly occurs in diatoms (Figure 7.8.1). In opposite to this the indicator for cyanobacteria (zeaxanthin, Figure 7.8.1c), dominates the oligotrophic regions away from the coast. 19-hexanoyl-oxy-fucoxanthin, the marker for prymnesiophytes is limited mainly to the south of the investigation area and seemed not directly be affected by the upwelling.

Compared to previous studies in this region (P320/1, March/April 2005 & M68/3, July 2006), where a rapid change between oligotrophic and eutroph phytoplankton communities from one station to the other was observed, in the current data set the eutroph upwelling region seemed be much clearer separated from the phytoplankton communities of the oligotrophic region of the tropical Atlantic.

Hoffmann, L., I. Peeken, K. Lochte, P. Assmy, and M. Veldhuis, Different reactions of Southern Ocean phytoplankton size classes to iron fertilization., *Limnology and Oceanography*, 51 (3), 1217-1229, 2006.

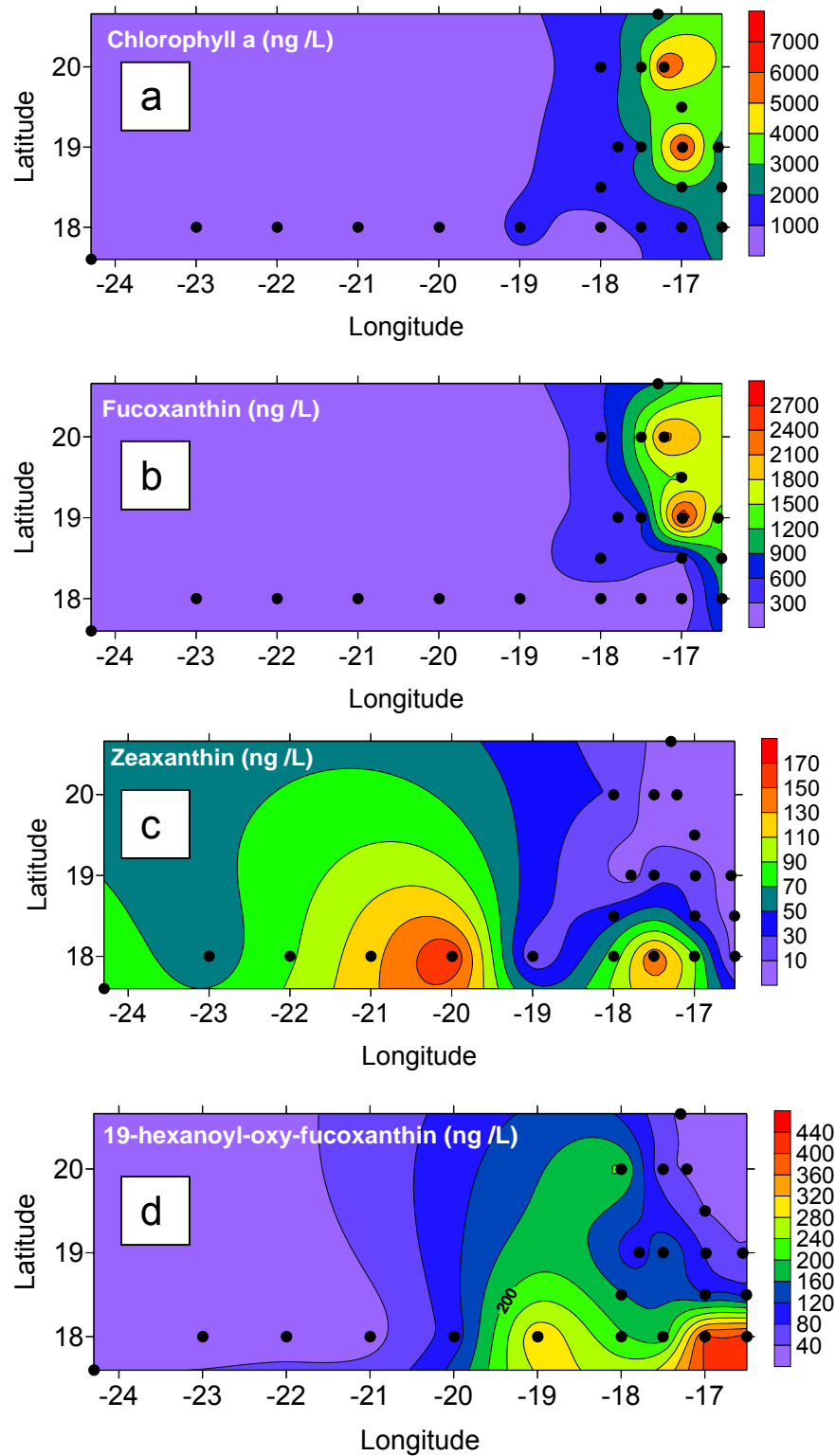


Figure 7.8.1 a-d: Contour plots of the station grid during the Poseidon 348 cruise in February 2007 for various marker pigments in 10m water depth.

7.9 $^{15}\text{NO}_3$

Nicola Wannicke (IOW, nicola.wannicke@io-warnemuende.de)

Samples for isotopic analysis in nitrate ($\delta^{15}\text{N-NO}_3$) were taken at three stations (244: 19°30.00'N, 17°0.0'W; 245: 19°30.0'N, 17°30.0'W and 246: 20°0.0'N, 18°0.0'W) during an upwelling situation along the Mauritanian coast in 2007. Samples were acidified to a pH below 3, stored, and transported to the Institute of Baltic Sea Research, Warnemünde (IOW) for further treatment. It is expected that the nitrate isotope values indicate which role primary production or nitrogen fixation play for the formation of the isotopic signatures in the region.

Nitrate will be analyzed by reduction to ammonia, which trapping on an acidified GF/F-filter (Sigman et al., 1997). First results from station 245 (Table 7.9.1 and Figure 7.9.1) suggest relatively low values around 4‰ at depth below 750m. Since the mean ocean values are between 4,5-6‰ our data may indicate high fractionation within the upwelling area.

Altogether, there are still 25 $\delta^{15}\text{N-NO}_3$ values left to be determined from the station 245, 246 and 244.

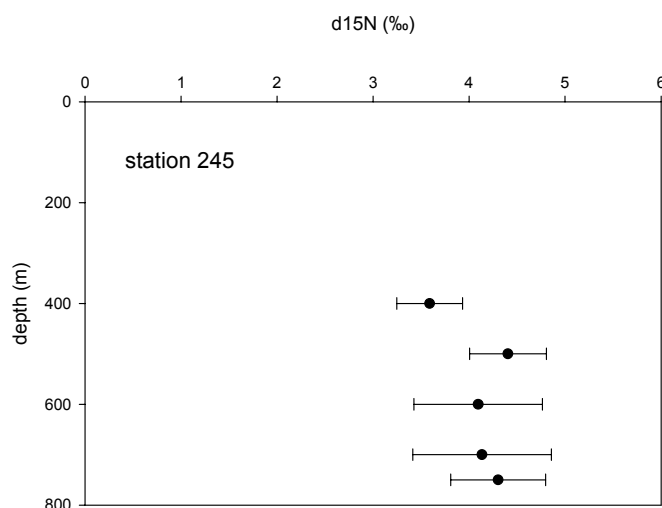


Figure 7.9.1:
 $\delta^{15}\text{N-NO}_3$ values for station 245 (19°30.0'N, 17°30.0'W), vs. depth February 2007. Note: high standard deviation requires reanalysis of samples.

Table 7.9.1: $\delta^{15}\text{N-NO}_3$ measured for three stations during the cruise POS 348

Sample no	date	station	depth	temp.	$\delta^{15}\text{N}$ (‰)	σ
107221	21.02.2007	244	100	14,75		
107222	21.02.2007		75	15,83		
107223	21.02.2007		50	16,86		
107224	21.02.2007		25	17,08		
107226	21.02.2007		10	17,39		
107227	21.02.2007		5	17,46		
107228	21.02.2007	245	750	7,9	4,30	0,494
107229	21.02.2007		700	8,16	4,14	0,722
107230	21.02.2007		600	9,21	4,10	0,670
107231	21.02.2007		500	10,34	4,41	0,400
107232	21.02.2007		400	11,39	3,59	0,343
107233	21.02.2007		300	12,63		
107234	21.02.2007		250	12,89		
107235	21.02.2007		200	13,54		
107236	21.02.2007		150	14,32		

107237	21.02.2007		100	16,62
107238	21.02.2007		16	19,14
107239	21.02.2007		10	19,13
107240	21.02.2007	246	750	7,61
107241	21.02.2007		700	7,95
107242	21.02.2007		600	9,03
107243	21.02.2007		500	10,3
107244	21.02.2007		400	11,58
107245	21.02.2007		308	12,16
107246	21.02.2007		250	12,83
107247	21.02.2007		200	13,96
107248	21.02.2007		150	14,53
107249	21.02.2007		100	15,32
107250	21.02.2007		16	18,95
107251	21.02.2007		10	18,96

7.9.1 Reference

Sigman, D.M., Altabet, M.A., Michener, R., McCorkle, D.C., Fry, B., Holmes, R.M., 1997. Natural abundance-level measurement of the nitrogen isotopic composition of oceanic nitrate: an adaptation of the ammonia diffusion method. *Marine Chemistry* 57 (3–4), 227–242.

7.10 Iodine

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7.10.1 Iodine depth profiles

Iodine occurs in seawater as iodate and iodide. While iodate is regarded as the stable form of iodine, there are significant amounts of iodide in surface waters. Thus in open oceans the concentration of iodate increases with depth to an approximately constant level while that of iodide decreases with depth to around the detection limit (0.1-0.2nM) below the euphotic zone.

6 vertical profiles were carried out for the distribution of iodate and iodide in the Mauretanian upwelling region. 2 were taken in the oligotrophic regions (St.227 and 230) and 4 in the eutrophic, upwelling regions (St. 237, 242, 244, 247). 8-10 depth were sampled from the CTD niskin bottles (10, 20, 40, 80, 150, 200, 1000, 1500, 2000m and deepest depth of the cast).

Samples were filtered over 0.2µm cellulose acetate filters and the filtrate was stored frozen until analysing. All parameters taken were measured and analysed at home. Iodide was measured via cathodic stripping square wave voltammetry, whereas iodate was measured spectrophotometrically.

7.10.2 Results

The concentration of total free iodine (iodate + iodide) is about 550nM in surface waters and 450nM in bottom waters. On the shelf and in the upwelling regions iodine concentrations were slightly lower (Figure 7.10.1).

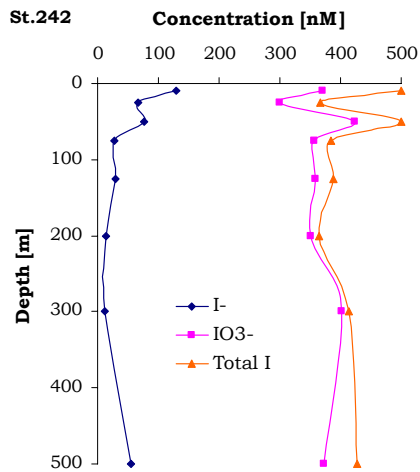
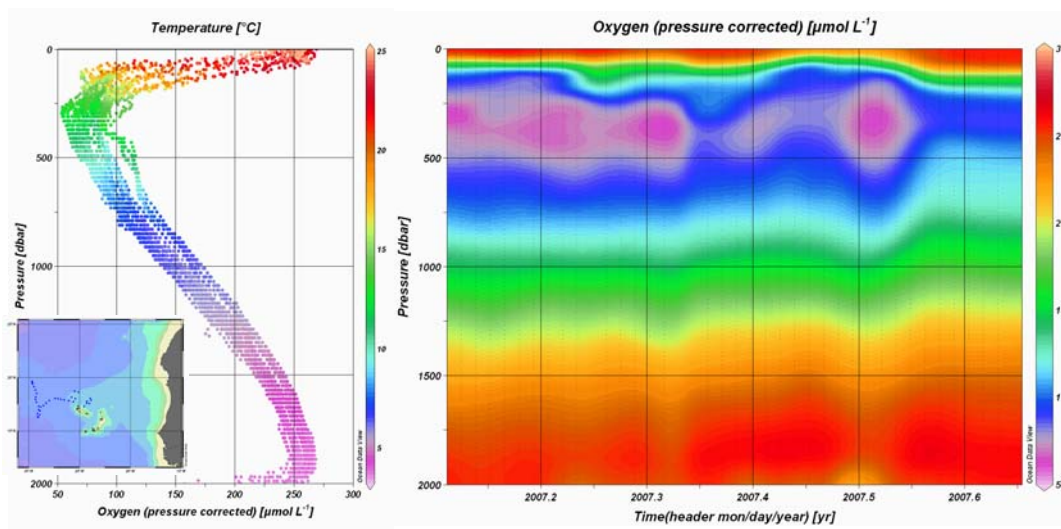


Figure 7.10.1. Shown is a vertical profile of iodine species at a shelf station. (St.242)

7.11 Floats

Arne Körtzinger (IFM-GEOMAR; akoertzinger@ifm-geomar.de)

Profiles of temperature and O₂ recorded by the PROVOR float #73060 are shown below.



8. Appendices: Weekly cruise reports



R/V Poseidon cruise P348: SOPRAN - Mauritanian upwelling study 2007

Hermann W. Bange & P348 scientific party
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Short cruise report 8 – 15 February 2007

Since one week we are sailing on R/V Poseidon on her 348th cruise in the tropical Northeast Atlantic Ocean. Our cruise is part of the activities of the new BMBF-funded joint project SOPRAN (Surface Ocean PRocesses in the ANthropocene), which is investigating the interactions between the ocean and the atmosphere. The contrasting regimes of the oceanic region between the Cape Verde Islands and Mauritania are ideally suited for this: On the one hand, this region is site of enhanced dust deposition because of its proximity to the Sahara desert. Saharan dust transports nutrients such as iron to oceanic sites and therefore the atmospheric deposition of nutrients via Saharan dust influences biological processes in the remote oligotrophic NE Atlantic Ocean. On the other hand, the coastal upwelling areas off Mauritania are characterized by extremely high nutrient concentrations, which lead to enhanced biological productivity making the Mauritanian upwelling to one of the most productive areas of the global ocean. The coastal upwelling areas off Mauritania are also significant sources for a variety of biologically produced climate-relevant trace gases such as carbon dioxide (CO₂), nitrous oxide (N₂O) and halogenated compounds (e.g. Bromoform).

Together with the measurements of the SOPRAN pilot studies P320/1 (in March/April 2005) and M68/3 (in July/August 2006), the results of P348 will allow us to quantify the trace gas emissions to the atmosphere as well as the trace metal deposition to the ocean. Various SOPRAN subprojects located at IFM-GEOMAR and the Institute for Environmental Physics of Heidelberg University are cooperating during the cruise in order to determine the distributions of trace gases (CO₂, N₂O, CH₄, and BrO) in the ocean and in the atmosphere as well as to investigate the mixing processes of the upper water column. In order to characterize the distribution of phytoplankton, seawater is filtered to extract characteristic phytoplankton pigments. The filter samples will be analyzed in our home laboratory at IFM-GEOMAR for chlorophyll and other marker pigments. Additionally, aerosol samples are collected in cooperation with the School of Environmental Sciences (University of East Anglia, Norwich, UK) and samples for the determination of the hydrogen isotope signature are taken in cooperation with the Institute for Marine and Atmospheric Research (Utrecht University, NL).

The set up of our instruments was finished before leaving Las Palmas on 8 February. Typical technical start-up problems could be solved quickly and efficiently. We acknowledge the excellent support by the ship's crew and the help of the ship's agent, without which the quick instrument set-up would not have been possible.

The first week of the cruise was highlighted by the one-day visit of a camera team of Spiegel TV. After four days of sailing south, we picked up two journalists from Spiegel TV in Mindelo (Cape Verde Islands) on 13th February. Both journalists enjoyed their stay on board while filming our activities. They also interviewed some of the P348 crew. Some scenes had to be repeated because of an unforeseen shadow or bad timing. A five minute report about P348 is scheduled for the 11th March on the German TV station RTL.



After dropping of the camera team from Spiegel TV in Mindelo in the morning of the 14th February, we are now heading towards the Mauritanian coastal upwelling area. Up to now no especially exciting results can be reported, because we are still at the beginning of our scientific activities. Additionally to our routine station work (CTD/rosette, microstructure), we successfully deployed two prototypes of "provor floats" at the Cape Verde Time Series Station. Moreover, the nutrient samples from the previous cruise P347 have already been analyzed.

The weather is fine with a lot of sunshine since we left Las Palmas. We have moderate winds from NE with wind forces up to 7 Bft. We are now used to the waves and the roll and pitch of the Poseidon. Dolphins did escort us, however, whales have not yet been sighted. The atmosphere on board is excellent and we are looking forward to the rest of the cruise.



R/V Poseidon P348: SOPRAN – Mauritanian Upwelling Study 2007

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2nd short cruise report 16 – 23 February 2007

In the second week of Poseidon cruise P348 we performed our work along the West-to-East transect along 18°N from the Cape Verde Islands to the Mauritanian coast. Deep stations (0 - bottom) alternated with shallow stations (0 - 750 m). The seasurface temperatures along the transect decreased about 21°C to about 18°C off the Mauritanian coast. Minimum seasurface temperatures of only 16°C were recorded during the later part of our cruise. These cold temperatures are indicators for coastal upwelling, which we wish to investigate. Enhanced nutrient concentrations (e.g. for nitrate) were associated with the decrease in water temperatures. The high nutrient concentrations are caused by upward transport via the upwelling of subsurface water from depths down to 200 m. Because of the high nutrient concentrations at the surface, the foodweb is fuelled and thus the coastal areas off Mauritania are rich in fishes and very attractive for fishing. We saw many small Mauritanian fishing boats, with up to 6 men in it, but we also saw large commercial fishing trawlers. Moreover, we were escorted by dolphins and many sea birds.

The productive region off Mauritania is also a source of atmospheric trace gases. Therefore we set up two fully automated, continuously working analytical systems for the measurements of carbon dioxide (CO₂) and methane (CH₄). This allows us to survey the distribution of dissolved and atmospheric CO₂ and CH₄ in the area with a very high temporal and spatial resolution. We are especially interested to investigate the concentration differences between the upwelling and the open ocean. As expected, we observed a significant increase in dissolved CO₂ and CH₄ as soon as we entered the cold upwelled waters. This result emphasizes the importance of coastal upwelling areas as a source of atmospheric trace gases.



View of Poseidon's wetlab with analytical systems for N₂O, CH₄ and CO₂ (left) and a filtration device for chlorophyll sampling (right).

The atmospheric dust (aerosol) input is sampled with an aerosol collector, which was installed on the uppermost deck of Poseidon. The collector continuously sucks air through a filter. The dust-loaded filter is changed every 24h. The dust on the filter will be analyzed for its chemical composition after the cruise. However, we can already say that the air during our cruise

was full of Saharan dust, which was visible as brownish dust deposited on the filters. Moreover, the Poseidon is covered everywhere with the same brownish dust. The other measurements, air sampling as well as the filtrations are running well.



Aerosol filter loaded with Sahara dust sampled 14 -15 Feb 07 near the Cape Verde Islands.

After finishing the long W/E transect along 18°N we are now working on a station grid with 4 shorter W/E transects perpendicular to the Mauritanian coast with the aim to investigate the upwelling area up to 20.5°N. Stations with CTD/rosette casts for water sampling are performed every 5-6 hours. The weather is still fine. However, because of strong winds up to 8 Bft we already had to cancel two stations, since the CTD/rosette cast were not possible to perform. The support from the ship's crew is still excellent. We could not celebrate carnival („Rosenmontag“) because of the tight station time table, however, we are looking forward to the “after work” party when station work is finished on Friday.



The team of P348 (from left to right), back row: Frank Malien, Ivanice Oliveira Monteiro, Jens Fischer, Tim Kalvelage, Uwe Koy; front row: Maria Martin, Annette Kock, Hermann Bange, Sylvia Walter, Alina Freing.

IFM-GEOMAR Reports

- | No. | Title |
|-----|---|
| 1 | RV Sonne Fahrtbericht / Cruise Report SO 176 & 179 MERAMEX I & II (Merapi Amphibious Experiment) 18.05.-01.06.04 & 16.09.-07.10.04. Ed. by Heidrun Kopp & Ernst R. Flueh, 2004, 206 pp.
In English |
| 2 | RV Sonne Fahrtbericht / Cruise Report SO 181 TIPTEQ (from The Incoming Plate to mega Thrust EarthQuakes) 06.12.2004.-26.02.2005. Ed. by Ernst R. Flueh & Ingo Grevemeyer, 2005, 533 pp.
In English |
| 3 | RV Poseidon Fahrtbericht / Cruise Report POS 316 Carbonate Mounds and Aphotic Corals in the NE-Atlantic 03.08.-17.08.2004. Ed. by Olaf Pfannkuche & Christine Utecht, 2005, 64 pp.
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