

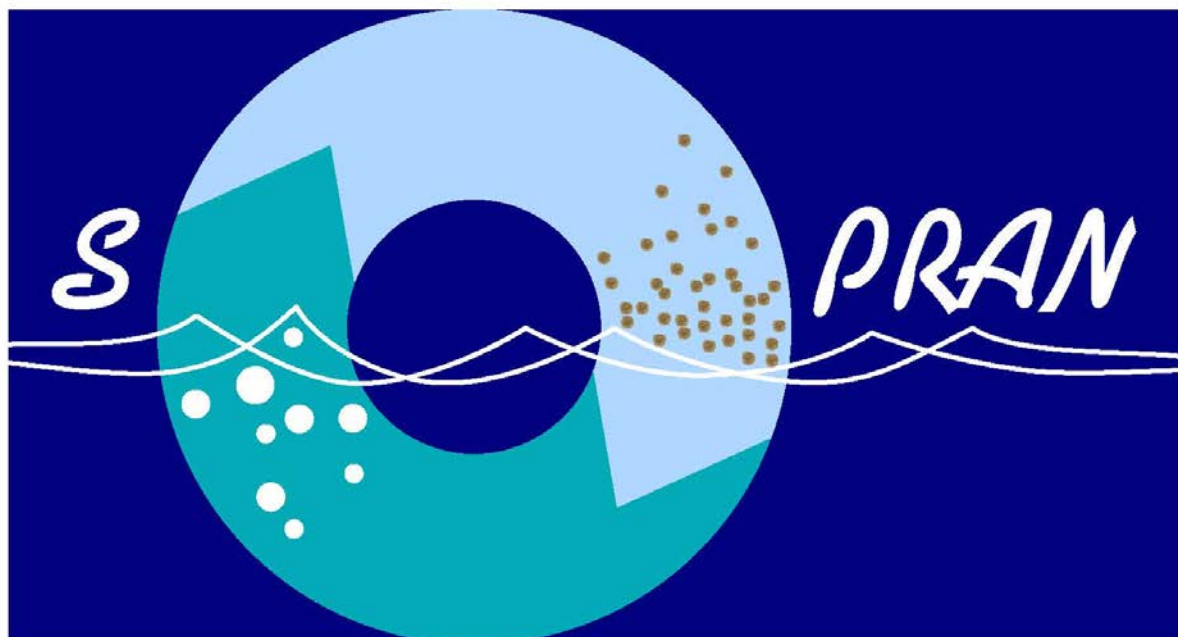
SHORT CRUISE REPORT

R/V L'Atalante Cruise IFM-GEOMAR, leg 3

from Dakar, Senegal to Mindelo, Cape Verde
February 3 to 20, 2008

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Surface Ocean Processes in the Anthropocene

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Research Program

This cruise leg on the R/V *L'Atalante* was carried out in the programmatic frame of the international "Surface Ocean Lower Atmosphere Study" (SOLAS, www.uea.ac.uk/env/solas/) and presents the 3rd major cruise of German SOLAS. Funding was provided through the SOPRAN project ("Surface Ocean Processes in the Anthropocene", sopran.pangaea.de/) of the German Research Ministry.

The cruise combined a wide spectrum of biological, chemical and physical oceanography as well as atmospheric chemistry under a regional focus on Cape Verdean waters and the coastal upwelling off Mauritania. This region is characterized by important SOLAS-relevant phenomena and processes – most importantly atmospheric dust deposition and coastal upwelling – which have major influence on substances (e.g., iron, nutrients, CO₂, volatile oxygenated and halogenated organics) and processes (e.g, nitrogen fixation, ocean-atmosphere gas exchange). Upwelling regions in major dust deposition areas can be viewed as biogeochemical reactors which are fuelled simultaneously by vertical supply of macro and micro nutrients from the mesopelagial below and the atmosphere above. At the same time, these regions provide means of ventilation of radiatively and chemically active trace gases (e.g., CO₂, nitrous oxide) which are produced sub-surface. The resulting flux densities are larger than in the oligotrophic background waters.

Short Cruise Report

The scientific party for leg 3 embarked in the port of Dakar/Senegal in the morning of Feb. 3. Due to problems with the availability of the port's mobile crane the container loading had not been finished and took place on Feb. 3. Immediately after that the scientific party starting unpacking the containers and installing the equipment in the various laboratories. R/V *L'Atalante* left the pier on Feb. 4 around 17:30 local time (i.e. later than originally planned) after most of the equipment had been set up in a seaworthy manner. After departure R/V *L'Atalante* steamed towards the first station at 17°50'N/16°34'W.

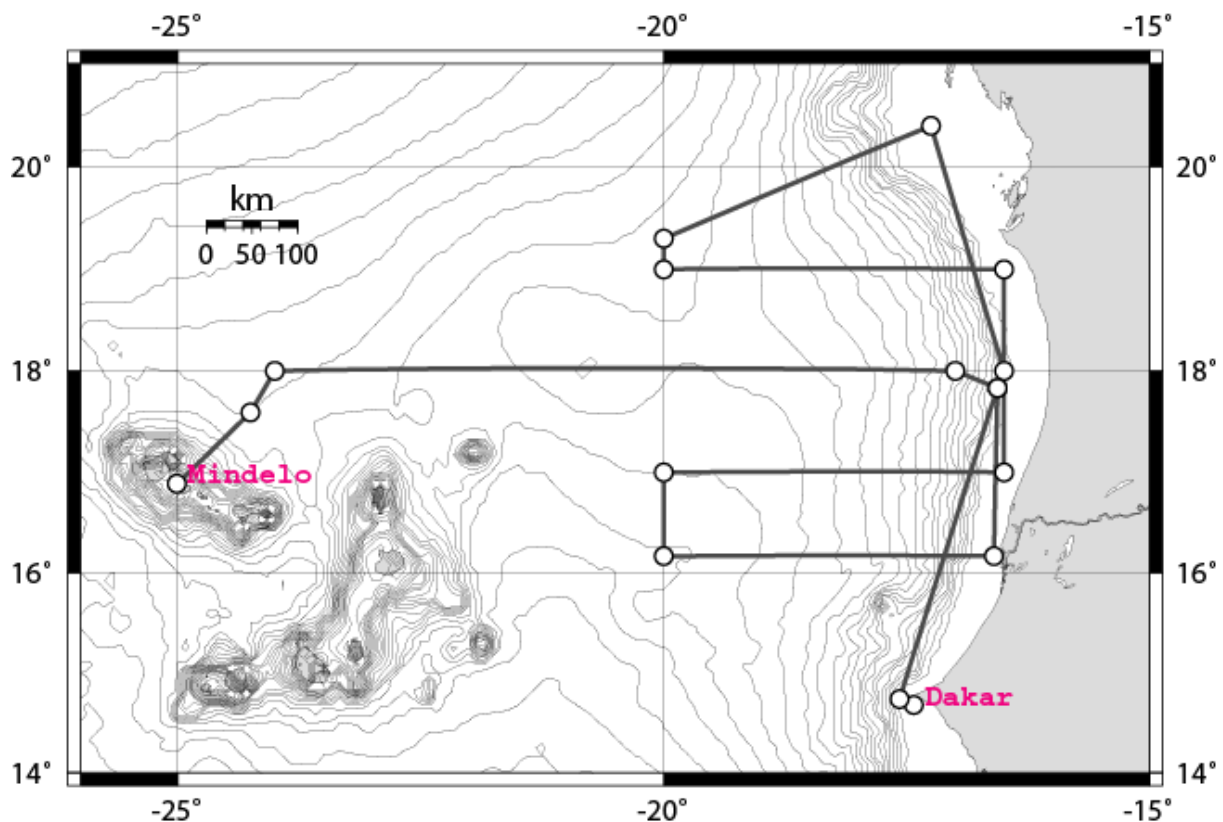


Figure 1: Bathymetric map of the study region with cruise track of R/V *L'Atalante* leg 3 from Dakar/Senegal to Mindelo/Cape Verde (Feb. 3 – 20, 2008).

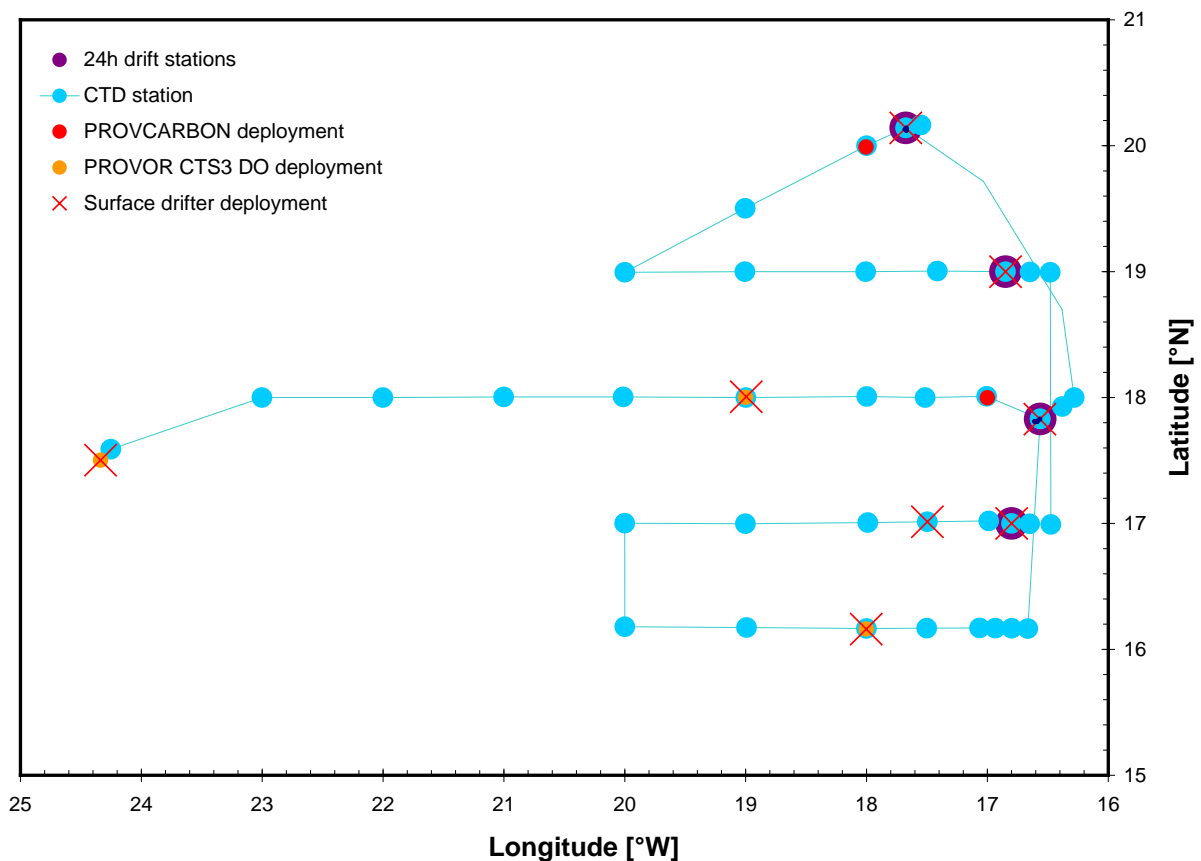


Figure 2: Cruise track of R/V *L'Atalante* leg 3 from Dakar/Senegal to Mindelo/Cape Verde (Feb. 3 – 20, 2008) with the locations of hydrographic stations, 24h Lagrangian drift stations, deployment sites of profiling drifters (PROVOR CTS3 DO, PROV CARBON), and deployment sites of surface drifters.

At the first station (17°50'N/16°34'W), a short-term mooring for high resolution current measurements was deployed in the morning of Feb. 5 at a water depth of about 260 m. The mooring was equipped with an upward looking 300 kHz ADCP (range 200-50 m), a downward looking 1200 kHz ADCP (range 207-220 m) and four Microcat temperature and conductivity meters at depths of 206, 225, 230 and 235 m (see Fig. 3). The mooring was recovered after 11 days on Feb. 16.

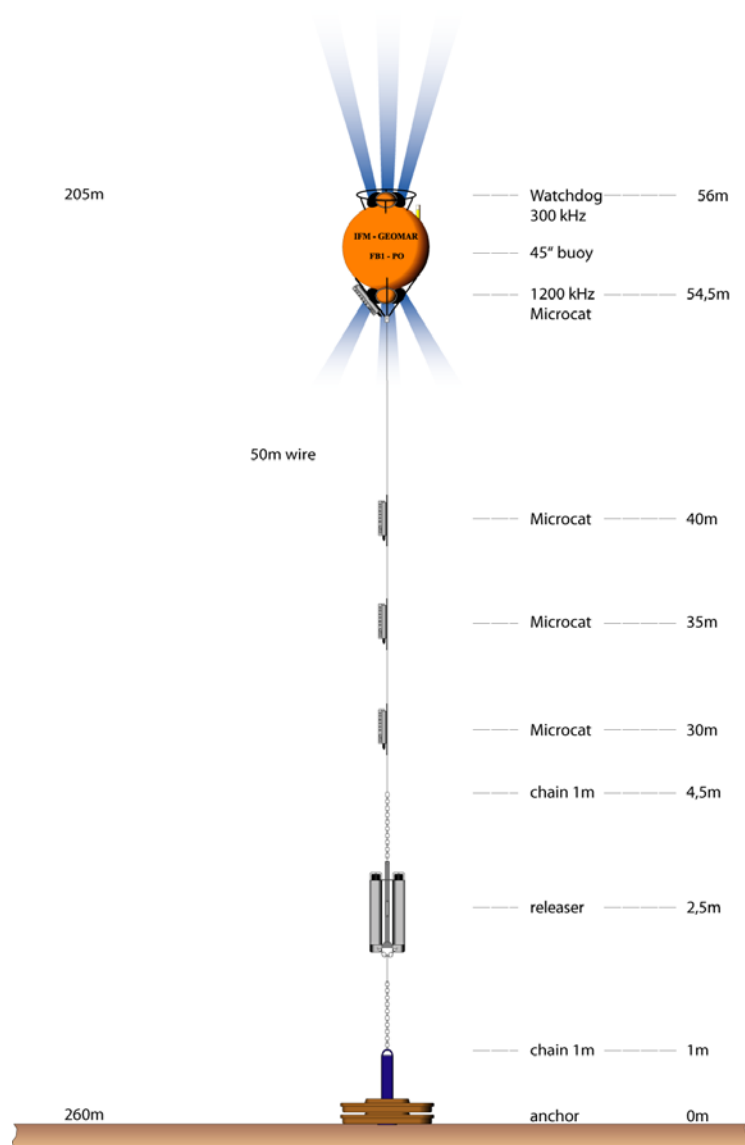


Figure 3: Schematic drawing of short-term mooring deployed for 11 days at 17°50'N/ 16°34'W.

After the mooring deployment, regular hydrographic work started along hydrographic sections at 16°10'N, 17°N, 18°N, 19°N, and ~20°N. Except for the 18°N hydrographic section, which extended as far west as ~24°W, all sections ran from shallow coastal waters to 20°W. East of 18°W, stations were carried out at 1/2°-spacing in deeper waters and a more dense spacing of approx. 10' near and above the shelf break. Stations west of 18°W were spaced a 1° intervals. A Seabird (SBE) 9 plus CTD system with additional oxygen (SBE 42) and chlorophyll fluorescence sensors as well as a Chelsea Instruments Alphatracka transmissometer (25 cm, 660 nm) was used. The CTD-rosette system was also equipped with upward and downward looking LADCP systems. Typically CTD profiles extended down to 2000 m depth (or just above seafloor if shallower than 2000 m). Only at the site of Cape Verdean long-term ocean observatory (17°35.39'N/ 24°15.12'W) a deep full water depth hydrocast to 3500 m was carried out. Table 1 provides a list of all 61 CTD profiles carried out at the 40 hydrographic stations of R/V *L'Atalante* leg 3.

Table 1. List of all CTD stations carried out during R/V *L'Atalante* leg 3.

Station No.	CTD Profile No.	Date UTC	Time UTC	Latitude Degrees	Latitude Minutes	Longitude Degrees	Longitude Minutes	Water depth [m]	max pressure [dbar]
1	1	05.02.2008	15:16	17° N	49.9'	16 °W	33.7'	258	259
2	2	06.02.2008	02:22	16 °N	9.9'	16 °W	39.9'	55	51
3	3	06.02.2008	04:25	16 °N	10.0'	16 °W	48.0'	97	100
4	4	06.02.2008	05:56	16 °N	10.1'	16 °W	56.1'	707	697
5	5	06.02.2008	07:44	16 °N	10.0'	17 °W	4.0'	1258	503
6	6	06.02.2008	12:11	16 °N	10.1'	17 °W	30.1'	2578	502
7	7	06.02.2008	16:45	16 °N	10.0'	18 °W	0.0'	2835	2012
8	8	07.02.2008	01:40	16 °N	10.2'	18 °W	59.5'	3361	2013
9	9	07.02.2008	09:43	16 °N	10.8'	19 °W	59.9'	3630	2013
10	10	07.02.2008	17:42	17 °N	0.0'	20 °W	0.0'	3414	2013
11	11	08.02.2008	02:05	16 °N	60.0'	18 °W	59.9'	3337	2013
12	12	08.02.2008	10:35	17 °N	0.4'	17 °W	59.5'	2831	2010
13	13	08.02.2008	16:25	17 °N	0.7'	17 °W	29.7'	2350	503
14	14	08.02.2008	22:00	17 °N	1.2'	16 °W	59.3'	1537	502
15	15	09.02.2008	00:25	17 °N	0.0'	16 °W	48.0'	584	580
15	16	09.02.2008	04:00	16 °N	58.5'	16 °W	48.3'	746	202
15	17	09.02.2008	08:05	16 °N	57.3'	16 °W	48.6'	774	62
15	18	09.02.2008	12:09	16 °N	56.0'	16 °W	48.8'	773	63
15	19	09.02.2008	16:05	16 °N	54.7'	16° W	49.2'	853	203
15	20	09.02.2008	20:05	16 °N	53.4'	16 °W	49.5'	888	202
16	21	09.02.2008	22:20	16 °N	59.8'	16 °W	39.0'	92	95
17	22	10.02.2008	00:36	16 °N	59.5'	16 °W	28.5'	45	46
18	23	10.02.2008	13:23	18 °N	59.7'	16° W	28.8'	32	32
19	24	10.02.2008	15:53	18 °N	59.8'	16 °W	38.8'	95	91
20	25	10.02.2008	18:42	18 °N	60.0'	16 °W	51.0'	445	443
20	26	10.02.2008	22:00	18 °N	58.1'	16 °W	50.6'	433	202
20	27	11.02.2008	02:01	18 °N	55.7'	16 °W	50.2'	488	202
20	28	11.02.2008	06:00	18 °N	53.4'	16 °W	49.8'	417	202
20	29	11.02.2008	10:03	18 °N	51.0'	16 °W	49.3'	398	130
20	30	11.02.2008	14:17	18 °N	48.6'	16 °W	48.8'	414	202
20	31	11.02.2008	17:58	18 °N	46.3'	16 °W	48.4'	426	202
21	32	11.02.2008	23:20	19 °N	0.3'	17 °W	24.8'	2129	2012
22	33	12.02.2008	04:51	18 °N	60.0'	18 °W	0.0'	2259	2013
23	34	12.02.2008	12:50	18 °N	59.8'	19° W	0.2'	3011	2014
24	35	12.02.2008	20:55	18 °N	59.7'	20 °W	0.1'	3264	2015
25	36	13.02.2008	05:39	19 °N	29.9'	19 °W	0.0'	2983	2012
26	37	13.02.2008	14:22	19 °N	59.9'	18 °W	0.1'	1848	1859
27	38	13.02.2008	19:19	20 °N	8.5'	17 °W	40.5'	449	445
27	39	13.02.2008	21:57	20 °N	7.7'	17 °W	40.2'	402	202
27	40	14.02.2008	01:58	20 °N	6.4'	17 °W	39.6'	350	202
27	41	14.02.2008	06:03	20 °N	5.1'	17 °W	39.1'	339	201
27	42	14.02.2008	10:20	20 °N	3.9'	17 °W	38.4'	356	346
28	43	14.02.2008	12:04	20 °N	10.0'	17 °W	32.9'	109	48
27	44	14.02.2008	13:56	20 °N	2.5'	17 °W	38.0'	537	204
27	45	14.02.2008	18:00	20 °N	1.1'	17 °W	37.5'	440	202
29	46	15.02.2008	08:08	18 °N	0.0'	16 °W	17.0'	41	40
30	47	15.02.2008	10:27	17 °N	55.7'	16 °W	22.9'	100	96

31	48	15.02.2008	13:40	17 °N	49.8'	16 °W	33.8'	260	258
31	49	15.02.2008	18:35	17 °N	47.9'	16 °W	36.0'	327	325
31	50	16.02.2008	00:24	17 °N	45.5'	16 °W	38.5'	400	203
31	51	16.02.2008	06:05	17 °N	43.2'	16 °W	41.2'	510	203
31	52	16.02.2008	10:04	17 °N	40.7'	16 °W	41.8'	625	202
32	53	16.02.2008	17:41	18 °N	0.7'	17 °W	0.3'	1751	1508
33	54	16.02.2008	22:36	18 °N	0.0'	17 °W	30.9'	2534	2001
34	55	17.02.2008	03:47	18 °N	0.3'	17 °W	59.9'	2788	2013
35	56	17.02.2008	12:22	18 °N	0.6'	18 °W	59.9'	3139	2006
36	57	17.02.2008	19:55	18 °N	0.3'	20 °W	0.4'	3200	2004
37	58	18.02.2008	02:00	18 °N	0.2'	20 °W	51.5'	3071	2012
38	59	18.02.2008	10:45	18 °N	0.3'	22 °W	0.5'	3299	2001
39	60	18.02.2008	18:22	18 °N	0.1'	23 °W	0.2'	3506	2008
40	61	19.02.2008	03:11	17 °N	35.7'	24 °W	14.1'	3600	3634

Water samples were drawn from up to 21 depths per CTD cast. Measurements performed on these water samples include the following parameters (list not exhaustive):

- Salinity
- Nutrients (Nitrate, nitrite, phosphate, silicate)
- Dissolved oxygen
- Dissolved inorganic carbon (DIC)
- Total alkalinity
- Dissolved organic carbon and nitrogen (DOC/DON)
- Particulate organic carbon and nitrogen (POC/PON)
- Triple oxygen isotopes (^{16}O , ^{17}O , ^{18}O) of dissolved oxygen
- $\delta^{15}\text{N}$ of nitrate/nitrite
- Chromophoric dissolved organic matter (CDOM)
- Suspended organic matter
- Chlorophyll a
- Nitrous oxide (N_2O)
- Methane (CH_4)
- Hydrogen (H_2)
- Helium isotopes
- Dimethylsulphide (DMS), Dimethylsulphoniopropionate (p/d DMSP)
- Hydrogenperoxide (H_2O_2)
- Flow cytometry
- DNA/RNA

During R/V *L'Atalante* leg 3 a microstructure profiling system manufactured by Sea and Sun Technology (Trappenkamp, Germany) was used to collect microstructure shear and temperature profiles. The system consists of a profile, a mobile winch and data interface. The profiler operates 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, resolution of all channel is 16 bit. The profiler is equipped with two shear probes (airfoil type PNS98, 4 ms response time), a fast-responding temperature sensor (microthermistor FP07, 12 ms response time), an acceleration sensor as well as conductivity, temperature, depth sensors that sample at a lower

frequency (24 Hz). Additionally the profiler was equipped with two tilt sensors, an oxygen sensor and a turbidity probe. 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 500 m. Shear fluctuations recorded due to vibration of the profiler while sinking can be diagnosed from the acceleration sensor. From these measurements the dissipation rate of the turbulent kinetic energy and temperature variance over time intervals of 1 s (~depth interval of 0.6 m) can be calculated. In total, 172 microstructure profiles were collected at 32 stations (Table 2).

Table 2. List of all microstructure stations carried out during R/V *L'Atalante* leg 3.

Station No.	MSS Profile No.	Date UTC	Time UTC	Latitude Degrees	Latitude Minutes	Longitude Degrees	Longitude Minutes	Water depth [m]	max pressure [dbar]
2	1-3	06.02.2008	02:56	16 °N	10.0'	16 °W	40.0'	58	58
3	4	06.02.2008	04:50	16 °N	10.1'	16 °W	48.0'	98	100
7	5-7	06.02.2008	18:31	16 °N	10.0'	18 °W	0.0'	2837	225
8	8-10	07.02.2008	00:56	16 °N	10.0'	18 °W	60.0'	3364	240
9	11-13	07.02.2008	08:55	16 °N	10.1'	20 °W	0.1'	3613	370
10	14-16	07.02.2008	16:44	16 °N	59.6'	20 °W	0.0'	3414	262
11	17-19	08.02.2008	01:15	16 °N	60.0'	19 °W	0.2'	3340	212
12	20-21	08.02.2008	09:34	16 °N	59.7'	17 °W	59.8'	2826	235
13	23-25	08.02.2008	15:26	17 °N	0.2'	17 °W	30.0'	2353	228
14	26-28	08.02.2008	21:05	17 °N	0.2'	16 °W	59.6'	1570	208
15	29-31	09.02.2008	03:00	16 °N	57.8'	16 °W	48.1'	700	206
15	32-34	09.02.2008	07:00	16 °N	56.6'	16 °W	48.3'	744	210
15	35-37	09.02.2008	11:07	16 °N	55.4'	16 °W	48.7'	757	220
15	38-40	09.02.2008	15:02	16 °N	53.9'	16 °W	49.2'	836	205
15	41-43	09.02.2008	18:58	16 °N	52.6'	16 °W	49.5'	750	205
16	44-46	09.02.2008	21:50	16 °N	59.3'	16 °W	38.9'	92	93
17	47-52	09.02.2008	23:57	16 °N	59.6'	16 °W	29.0'	48	46
19	53-55	10.02.2008	15:30	18 °N	59.6'	16 °W	38.7'	91	93
20	56-58	10.02.2008	21:01	18 °N	57.7'	16 °W	50.8'	439	235
20	59-61	11.02.2008	01:02	18 °N	55.1'	16 °W	49.7'	401	267
20	62-64	11.02.2008	05:00	18 °N	52.8'	16 °W	49.6'	409	219
20	65-67	11.02.2008	09:00	18 °N	50.4'	16 °W	49.2'	394	223
20	68-70	11.02.2008	13:04	18 °N	51.2'	16 °W	48.5'	376	223
20	71-73	11.02.2008	16:55	18 °N	45.9'	16 °W	48.1'	421	192
21	74-76	11.02.2008	22:35	18 °N	59.4'	17 °W	24.9'	2118	205
22	77-79	12.02.2008	04:09	18 °N	59.4'	18 °W	0.0'	2560	228
23	80-82	12.02.2008	12:12	18 °N	59.4'	19 °W	0.5'	3013	199
24	83-85	12.02.2008	20:04	18 °N	59.4'	20 °W	0.4'	3263	212
25	86-88	13.02.2008	04:55	19 °N	29.3'	19 °W	0.1'	2984	215
26	89-91	13.02.2008	13:41	19 °N	59.4'	18 °W	0.2'	1847	215
27	92-94	13.02.2008	21:04	20 °N	7.3'	17 °W	40.2'	418	187
27	95-97	14.02.2008	01:06	20 °N	5.7'	17 °W	39.6'	372	207
27	98-100	14.02.2008	05:02	20 °N	4.5'	17 °W	39.2'	373	212
27	101-103	14.02.2008	09:00	20 °N	2.9'	17 °W	38.6'	334	192
27	104-115	14.02.2008	15:23	20 °N	1.1'	17 °W	37.4'	429	204
30	116-118	15.02.2008	09:54	17 °N	55.3'	16 °W	22.9'	91	92
31	119-134	15.02.2008	20:34	17 °N	45.8'	16 °W	26.7'	98	153
31	135-149	16.02.2008	02:14	17 °N	46.1'	16 °W	28.3'	140	197

32	150-152	16.02.2008	16:51	18 °N	0.2'	17 °W	0.1'	1718	238
33	153-155	16.02.2008	21:43	18 °N	0.1'	17 °W	30.0'	2514	217
34	156-158	17.02.2008	03:04	18 °N	0.1'	18 °W	0.0'	2802	223
35	159-161	17.02.2008	11:00	18 °N	0.2'	19 °W	0.0'	3138	222
36	162-164	17.02.2008	19:25	17 °N	60.0'	20 °W	0.1'	3201	96
39	165-167	18.02.2008	19:45	18 °N	0.5'	23 °W	0.7'	3506	148
40	168-172	19.02.2008	05:54	17 °N	36.0'	24 °W	14.0'	3601	453

At the hydrographic stations also downward irradiance and upward radiance were measured using a free-falling Satlantic profiling system (SPMR) in the upper 30 to 70 m of the water column. The setup also included a floating surface reference (SMSR). The vertical resolution is on the order of 10 cm depending on the sinking velocity and the visible spectrum is covered by 13 channels between 400 and 700 nm. These vertical light profiling measurements at the stations were complemented by measurements of the downward irradiance and upward radiance above the sea surface made continuously at the ship's bow. For this, a TRIOS RAMSES system equipped with GPS and measurements of sky radiance for correction of surface effects was used. The RAMSES radiometers measure in the spectral range between 350 and 950 nm at 255 wavelengths.

A special focus of this cruise was to study diel cycles of biological, chemical and physical properties in surface waters. For this purpose four 24h drift stations (Fig. 2) were performed. At the beginning of each station a patch of surface water was marked by deployment of a Lagrangian surface drifter of the Surface Velocity Program (SVP) with Argos transmitter, thermistor, and holy sock drogue. The R/V *L'Atalante* tried to follow the surface drifter by means of an Argos direction finder. This turned out to be rather impractical, however. Instead the surface drift was estimated by logging the ship's GPS position when tracking the surface drifter visually at a fixed direction and distance for at least 30 min. This surface drift estimate was then used to calculate the locations of the CTD casts which were made at approx. 4-hourly intervals during the 24h drift periods. In some, but not all, cases the surface drifters were followed rather well by this approach.

During the entire cruise, surface seawater was sampled by means of the ship's seawater pumping system which also featured a thermosalinograph. The pumped seawater was used for:

- Continuous $p\text{CO}_2$ measurements using a classical flow-through headspace equilibrator system with NDIR CO_2 detection,
- Continuous O_2 measurements using an oxygen optode (by Aanderaa Instruments, Bergen/Norway),
- Continuous gas tension measurements using a GTD pro gas tension sensor (by Pro-Oceanus Inc., Halifax/Canada),
- Continuous chlorophyll measurements using a submersible MiniTracka fluorescence sensor (Chelsea Instruments, UK),
- Continuous methane (CH_4) measurements using a headspace equilibrator with subsequent measurement on a GC/FID system,

- Discrete sampling for other parameters (e.g. nutrients, DIC, total alkalinity, CDOM, chlorophyll etc.),

During R/V *L'Atalante* leg 3, a total of eight satellite-tracked surface drifting buoys of the Global Drifter Program (http://www.aoml.noaa.gov/phod/dac/gdp_drifter.html) were deployed successfully (Table 3). Four of these deployments were made in conjunction with the 24h Langrangian drift experiments.

Table 3: Surface drifter deployments (SVP – Surface Velocity Program)

Argos ID	WMO #	Date dd.mm.yy	Time UTC	Longitude	Latitude	Sensors
72024	13530	06.02.08	16:10	18 ° 0.13 ' W	17 ° 9.64 ' N	T
72020	13627	08.02.08	17:05	17 ° 29.80 ' W	17 ° 0.80 ' N	T
72023	13628	09.02.08	00:14	16 ° 47.98 ' W	17 ° 0.00 ' N	T
72025	13629	10.02.08	17:51	16 ° 50.99 ' W	18 ° 59.96 ' N	T
72021	13903	13.02.08	18:46	17 ° 40.50 ' W	20 ° 8.50 ' N	T
79019	13902	15.02.08	13:01	16 ° 33.93 ' W	17 ° 49.68 ' N	T
79018	13901	17.02.08	10:56	18 ° 59.70 ' W	18 ° 0.40 ' N	T
79022	13904	19.02.08	14:12	24 ° 20.23 ' W	17 ° 30.15 ' N	T

Additionally, five profiling floats were deployed successfully during R/V *L'Atalante* leg 3 (Table 4). These floats were either of the new PROVOR CTS 3 DO type which carries a Seabird CTD sensor and an Aanderaa model 3830 oxygen optode or of the PROVCARBON prototype which in addition to the Seabird CTD sensor and the Aanderaa model 3830 oxygen optode also carried a Wetlabs C-Rover transmissometer.

Table 4: Profiling float deployments (ARGO)

Argos ID	WMO #	Date dd.mm.yy	Time UTC	Longitude	Latitude	Float Type
80163	6900627	06.02.08	16:11	18 ° 0.11 ' W	16 ° 9.71 ' N	PROVOR CTS3 DO
-	6900631	13.02.08	13:34	18 ° 0.23 ' W	19 ° 59.37 ' N	PROVCARBON
-	6900632	16.02.08	16:00	17 ° 0.00 ' W	17 ° 59.91 ' N	PROVCARBON
80164	6900628	17.02.08	10:54	19 ° 0.01 ' W	18 ° 0.10 ' N	PROVOR CTS3 DO
80166	6900630	19.02.08	14:12	24 ° 20.23 ' W	17 ° 30.15 ' N	PROVOR CTS3 DO

The R/V *L'Atalante* leg 3 also carried a small atmospheric program. The overall objectives of this component was to characterize and quantify the atmospheric abundances of inorganic, reactive halogen species (RHS) of marine origin like ClO, BrO, IO, and OIO and to assess their impact on the marine atmospheric boundary layer. For this purpose two different Mini-MAX-DOAS devices were installed at the forefront of the ship's superstructure (Fig. 4): a VIS Mini-MAX-DOAS device measuring in the visible wavelength range from circa 540-630 nm and a the UV Mini-MAX-DOAS device, which takes spectra in the ultraviolet wavelength range from approximately 330 - 460 nm.

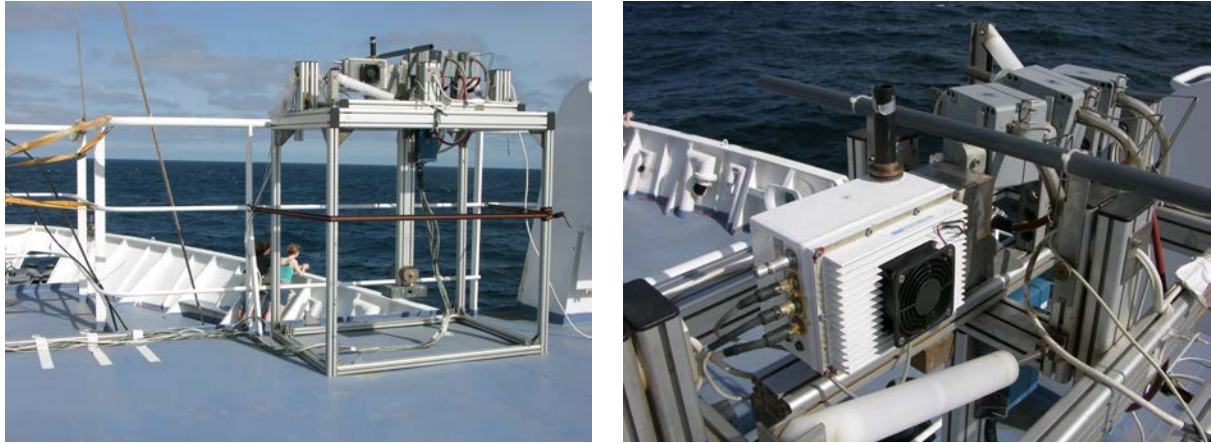


Figure 4: Photographs of the Mini-MAX-DOAS instruments installed on the forefront of the superstructure during leg 3.

Due to perfect performance of the CTD-rosette system, the winches, and last but not least the ship's crew the intended station program of R/V *L'Atalante* leg 3 was fully achieved. No down-time due to technical problems or bad weather had to be accommodated in the work program. All groups brought home a rich data harvest and mostly achieved their work plans. Overall the mission has been very successful and pleasant.

R/V *L'Atalante* reached Mindelo on the Cape Verdean island of São Vicente in the afternoon of Feb. 19 (~17:00L) and the usual container packing chaos quickly unfolded. The scientific party disembarked on Feb. 20.

I would like to conclude this short cruise report with my very best thanks to the Captain and crew of R/V *L'Atalante* for outstanding performance and cooperativeness well beyond the call of duty. This experience on a French research vessel was definitely a very pleasant one.