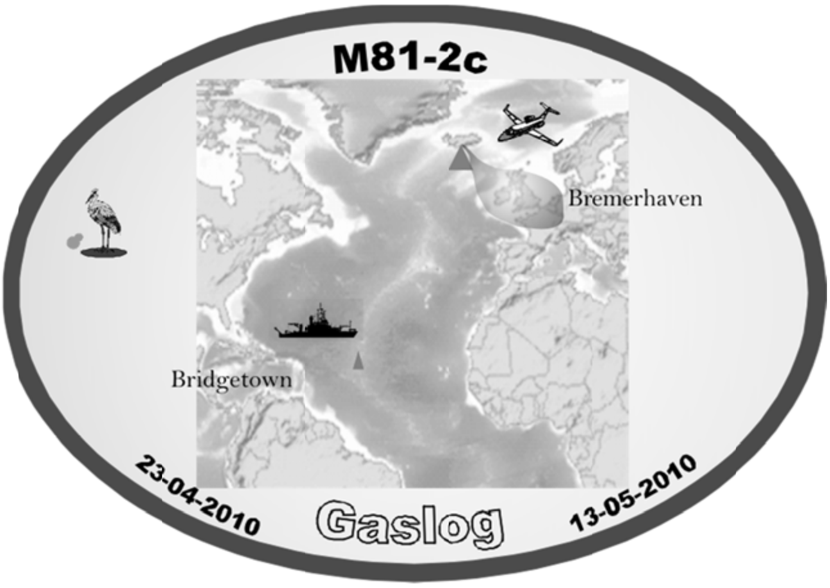
METEOR-Berichte

Methane and Helium Investigations in the Water Column of the Hydrothermal Vent Field Logatchev

Cruise No. 81, Leg 2c

April 23 – May 05, 2010
Bridgetown (Barbados)-Bremerhaven (Germany)



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1 Summary

The main goal of M81/2c GASLOG was to investigate the water column around the 'Logatchev' hydrothermal vent field (LHF) on the mid-Atlantic ridge at 14°45'N. This site is known to permanently release hot vent fluids into the water column. These fluids are highly enriched with metal and gases namely hydrogen, methane, and helium. The latter two gases were sampled and analyzed for concentration measurements and later isotope analysis. Moreover, turbidity sensors during CTD casting were used to gather online information about the hydrothermal plume in the water column.

Overall a total of 17 CTDs could be conducted around LHF within the three days of station work. One background CTD was conducted one day before reaching LHF approximately 380nm west of the working area. The sampling strategy was to first complete a section south of LHF, then to sample directly above Logatchev I/II, and finally to conduct a N-S section.

All stations around LHF (max. distance 6.5nm) show elevated methane concentration in form of a gaussian plume peaking around 2900 m water depth with a vertical plume extension of 400 m. In the nearfield of Logatchev I methane concentration values reach values up to 119nM around 2900 m. Correspondingly, the optical backscatter data plot here with higher values and show three spatially separated plumes at various depths. The data indicate a correlation between optical backscatter and methane concentration. Moreover, the LHF plume clearly plots in TS diagrams. Further analysis of the plume will be possible after interpretation of the ^{3}He und δ ^{13}C-CH_4 hydrographic sections.

Two lowered ADCP were attached during each CTD cast to constrain the currents and a predominant direction towards the north was present close to the seafloor and plume area, respectively. Later processing will allow to derive an integrated water mass flux and the corresponding dissolved gas flux and source strength of the hydrothermal vents. By means of comparing the conservative tracer concentration ^{3}He and CH_4 under consideration of the δ ^{13}C-CH^4 isotopic signature, the hitherto unknown microbial methane oxidation rate can be constrained.

Zusammenfassung

Die METEOR Reise M81/2C GASLOG hatte zum Ziel die Wassersäule über dem hydrothermalen Vulkanfeld ‚Logatchev' (LHF) auf dem Mittelatlantischen Rücken bei 14°45'N zu untersuchen. Geplant waren gaschemische Untersuchungen von Methan und Helium in bestimmten Wassertiefen, sowie die kontinuierliche Aufnahme von Trübewerten mittels eines Spezialsensors um die Ausbreitung des hydrothermalen Plume quantitativ zu erfassen und deren geochemische Signatur anhand diskreter Beprobung zu bestimmen. Während der dreitägigen Stationsarbeiten konnte das geplante Program erfolgreich durchgeführt werden. Insgesamt wurden 17 CTD Stationen im Nahfeld sowie eine Hintergrund CTD 380 nm westlich des Logtchev-Feldes gefahren. Die Stationen wurden in zwei Schnitte, einen nördlich und einen südlich von LHF, unterteilt. Weitere Stationen wurden direkt über Logatchev I/II und in N-S Erstreckung gefahren.

Die CTD Stationen dienten außer der Aufnahme von Temperatur, Salinität, Trübe und Eh dazu Wasserproben zu gewinnen, die an Bord auf deren Methankonzentration untersucht wurden. Alle Stationen im Umkreis von LHF (max. Entfernung 6.5 nm) zeigen mehrfach erhöhte

Methankonzentrationen mit einem Maximum um 2900 m Wassertiefe und einer Vertikalerstreckung bis 400 m. Im Nahfeld von Logatchev I steigen die Methankonzentrationen bis 119 nM in den Tiefen um 2900 m. Die kontinuierliche Aufnahme von optischer Rückstreustärke zeigt hier ebenfalls deutlich erhöhte Werte mit drei voneinander getrennten Maxima. Die Ergebnisse deuten an, dass die kontinuierlichen Sensordaten mit der Methankonzentration korrelieren. Des Weiteren zeichnet sich der LHF Plume in TS Diagrammen ab. Weitere Ergebnisse über den Plume werden nach der Interpretation von ^{3}He und δ^{13}C-CH_4 Werten möglich sein.

Gleichzeitige Strömungsmessungen wurden erfolgreich mit LADCP durchgeführt und eine bevorzugte Strömung nach N festgestellt. Über die Auswertung der Strömungsdaten soll der Massentransport von Methan und Helium im Logatchev-Feld abgeschätzt werden. Anhand eines Vergleichs des konservativen ^{3}He Tracers und reaktivem Methan unter Berücksichtigung von δ^{13} C-CH_4 kann letztendlich die bisher kaum untersuchte mikrobielle Abbaurate des Methans in der Wassersäule während des Transports ermittelt werden.

2 Participants

Table 2.1. Scientific crew participants during M81/2c.

Name	Discipline	Institution
Dr. Jens Schneider v.D.	Chief scientist, CH_4 analysis	IOW
Dr. Robin Keir	Senior scientist, CH_4, He analysis	IFM- GEOMAR
Klaus-Peter Wlost	Scientist, CTD operation	IOW
Haugen Grefe	Assistent student (bio-physics)	FB1 Uni Bremen
Anna Fiedrichs	Assistent student (oceanography)	Uni Hamburg IFM- ZMAW
Gregor Halfmann	Assistent student (oceanography)	Uni Hamburg IFM- ZMAW
Julia Köhler	Assistent student (oceanography)	Uni Hamburg IFM- ZMAW
Andreas Raeke	Technician, weather station	DWD, Hamburg

IOW	Institut für Ostseeforschung Warnemünde, Germany
DWD	Deutscher Wetterdienst, Germany
IFM- ZMAW	Centre for Marine and Atmospheric Sciences, University of Hamburg, Germany
IFM-GEOMAR	Leibniz Institut for Marine Sciences, University Kiel, Germany
FB1	Fachbereich 1, University Bremen, Germany

Figure 2.1. Group picture from scientific crew of M81/2c. From left to right namely: Peter Wlost, Gregor Halfmann, Haugen Grefe, Anna Friedrichs, Julia Köhler, Jens Schneider v. Deimling, and Robin Keir.

3 Research Programm

The cruise to the Logatchev hydrothermal vent field at 14°45‘ N / 44°58.8’ W on the Mid-Atlantic Ridge is part of the DFG SPP 1144, which investigates the links between geophysical, geochemical and biological processes in hydrothermal vent areas. The Logatchev field represents one of the main study areas within the SPP 1144 and was already intensively studied on previous cruises (e.g. MSM03/2, MSM10/3). The Logatchev hydrothermal field is characterized by a broad spectrum of fluid compositions (Schmidt et al., 2007), hydrothermal deposits (Petersen et al., 2009), and a highly specified fauna (Petersen et al., 2011). Methane, hydrogen, and 3-helium are important components of submarine hydrothermal fluids of the Logatchev field (Schmidt et al., 2007).

Our objective during METEOR cruise M81/2c was to characterize the transport of methane and 3-helium within the hydrothermal plumes emitted from the vent field into the water column (Keir et al., 2009; Marbler et al., 2010). Through an intensive investigation of the gas dispersion in the water column the concentration distribution within a distance of a few kilometers away from the sources (Fig. 3.1, data from cruise MSM04-3, Fig. 3.2, stationwork M81-2c) can be described. Coupled current measurements (LADCP, Lowered Acoustic Doppler Current Profiler) provide a description of the current regime, which strongly influences the plume dispersion. The combination of gas chemical and oceanographic datasets will provide a basis for a quantitative assessment of the gas- and fluid-emission from the field. The plume dispersion and concentration pattern will provide additional information about mixing processes and microbial CH_4-consumption rates within the plume waters. The investigation of the stable isotope composition of methane ($\delta^{13}C$-CH_4) allows for an estimate of the microbial carbon isotope fractionation in hydrothermal plumes (Keir et al., 2009).

The results of the cruise are an integral part of the SPP1144 and will help to generate a mass balance to describe the transport of matter from the crust into the hydrosphere (see German et al., 2010). The hydroacoustic records during the transit and at the Logatchev field complement existing bathymetric datasets and are used to map the hydrothermal particle plume in the hydrothermal field.

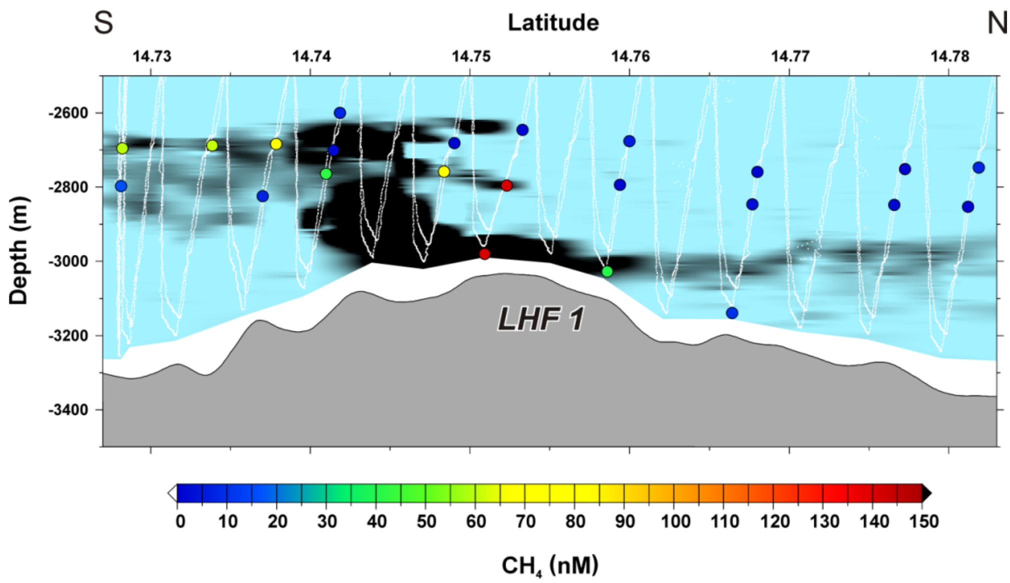


Figure 3.1. Results of the plume mapping (optical backscatter) in the Logatchev field (LHF-1) on cruise MSM04-3. The figure shows the particle cloud above the field and the increased methane concentrations in the plume (color-coded).

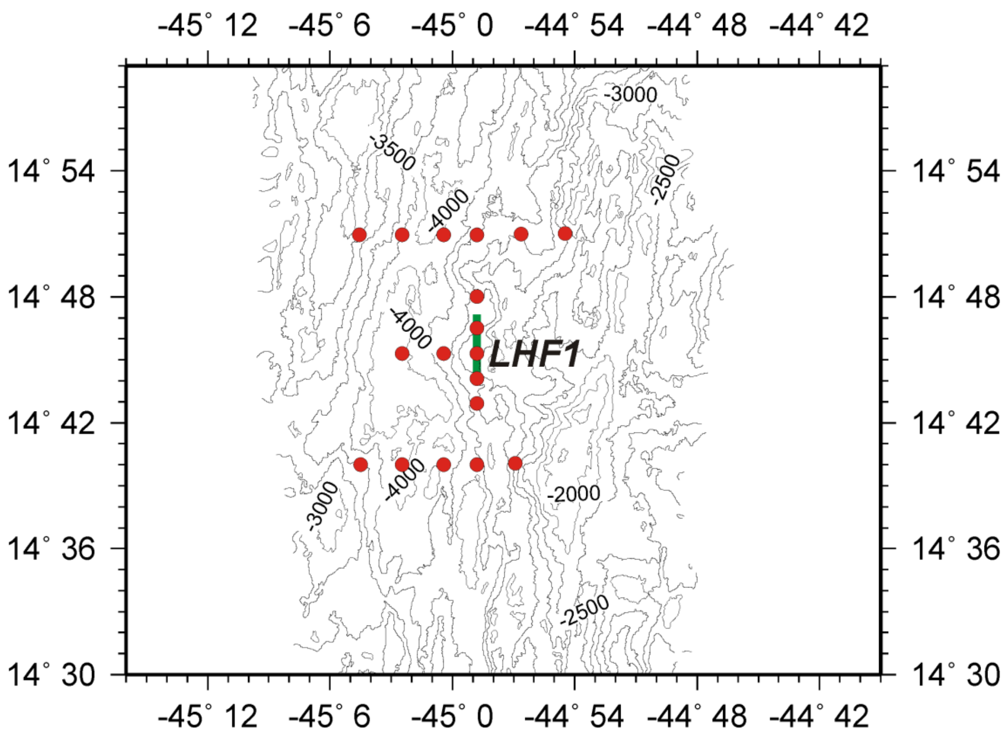


Figure 3.2. The working area of cruise M81/2C, Logatchev field on the Mid-Atlantic Ridge, and the locations of the planed water station (red dots). The green line indicates the N-S transect displayed in Figure 5.15.

4 Narrative of the Cruise

The cruise M81/2c (Fig. 4.1) served as an alternate cruise to compensate former technical failure during R/V MS MERIAN 10/02 and R/V Poseidon 380 in 2009. Thus the formerly planned transit of R/V METEOR from Bridgetown/Barbados to Bremerhaven was a chance to gather data for the project SPP 1144 in the Logatchev hydrothermal field (LHF). This third attempt seemed to fail in the very last moment. Even though the scientific equipment was already loaded on METEOR, 4 of 7 scientists haven't arrived yet at the vessel in the evening of the 22th of April. With an over 50% cut in man power, the previously planned scientific program would not have been possible to be carried out. The reason for the delay was the explosive eruption of volcano Eyjafjallajökull that caused a several days lasting shutdown of virtually all European airports. Only through very much personal effort from Julia Köhler, Anna Friedrichs, Gregor Halfmann and Robin Keir, a transfer from Germany to Barbados succeeded in the very last moment before the ship had to leave the harbor of Bridgetown. At 08:00 in the morning of the 23th of April, METEOR left the harbor of Bridgetown heading east towards the Mid Atlantic Ridge. A maximum of 4 engines were used to reach the working area as early as possible while steaming with 10 knots against the trades. Meanwhile the scientific equipment was installed in the labs and thoroughly tested. A very limited station work time required maximum efficiency once we had arrived in the area of interest. Thus we decided to drive a test CTD station with 4200 m depth 36 hours before reaching the working area to have some extra time for troubleshooting and for training of our four assistant students. This guaranteed the later smooth operation of day and night shifts once we had arrived at LHF. All sensors worked properly, and water samples were successfully analyzed for methane concentration in the clean lab.

After 3.5 days of fairly calm steaming we arrived at the Logatchev hydrothermal field (LHF) at 14°45'N und 44°58'W at 27.04 00:15 UTC and began the sampling in the southwestern part of the working area. Long-periodic swell from the North together with wind from the East caused heavy roll over 20° during station work, especially as the thruster of METEOR wasn't working and maneuvering/steering the vessel into a better orientation to the swell was not possible. Nevertheless, CTD operation and careful analytical work in the lab could be successfully conducted. Thus water samples were taken from the Niskin CTD bottles and subsequently analyzed for methane concentration. Respective gas samples were gathered for later onshore lab measurements of $\delta^{13}C\text{-}CH_4$. Moreover the autonomously measuring MAPR system was attached to the CTD frame for continuous measurement of temperature, turbidity and Eh at respective depths to identify hydrothermal venting. The sampling strategy was to start with a southern cross-section from west to east including seven CTD casts. Afterwards two CTD casts were conducted in the vicinity of Logatchev I and II. Finally a northerly section comprising 6 casts from east to west and two additional casts were performed to complete the sampling. The wind and swell dropped after the first night and following we could stick to the original research plan and a total of 18 CTD casts was including the background station. On the 29^{th} of April Meteor started at 18.00 local time for the transit to Bremerhaven/Germany. Until the 5^{th} of May the deep-water multibeam system EM120 was logging bathymetry to spot potential new seamounts until entering the EEZ of the Azores. Logging was then restarted after leaving the EEZ of the Azores in the morning of the 7^{th} of Mai and could be successfully continued.

Until Saturday, R/V METEOR was in time in regard to reaching Bremerhaven on the 13th of May. However, the weather had significantly worsened with up to 45 knots wind gusts and high waves (Fig. 4.2). The vessel was heavily pitching and speed dropped occasionally below 4 knots. Even though the multibeam was logging, the data is very much disturbed by heavy movement of the vessel and gas bubble entrainment underneath the transducer during the recordings from Saturday and Sunday.

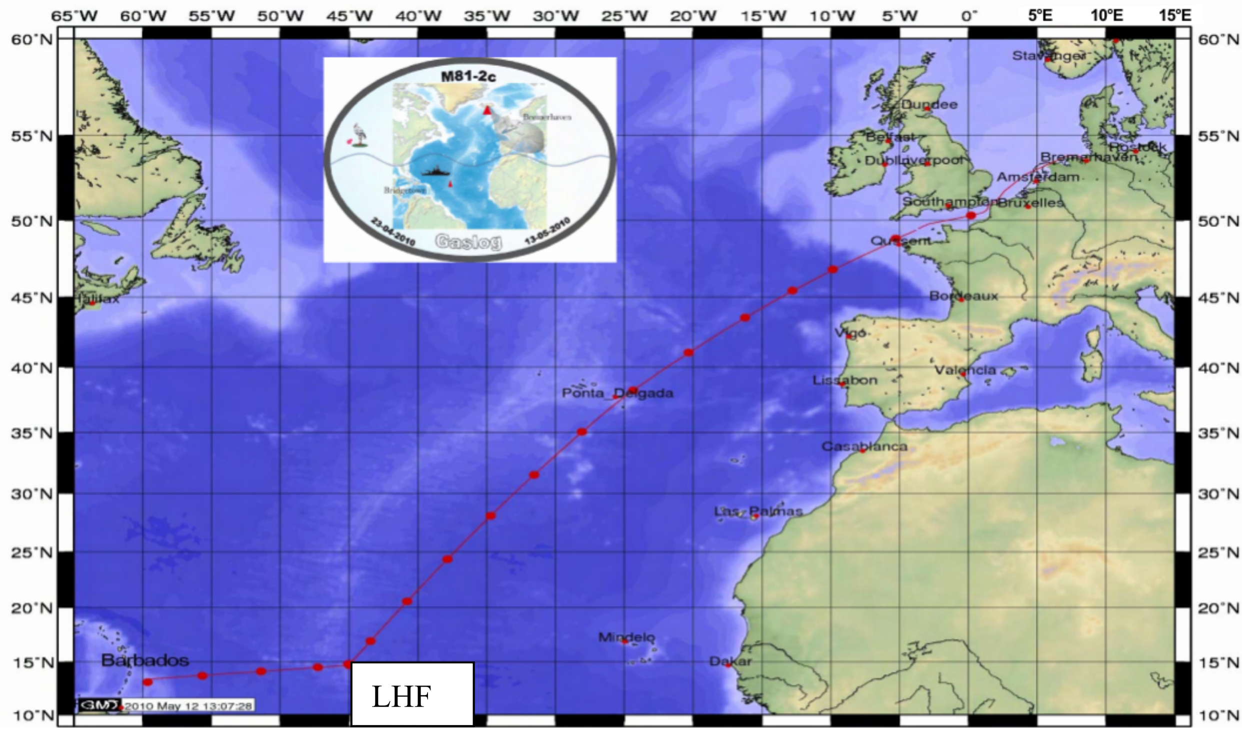


Figure 4.1. Trackplot of Leg M81/2c from Bridgetown (Barbados) to Bremerhaven. Bathymetric chart (GEBCO 08) showing the working area at the Logatchev Hydrothermal Field (LHF) on the Mid Atlantic Ridge.

On Sunday, the storm intensity ceased and METEOR entered the French EEZ and the European continental slope. Thus, the last mapping station 309 was finished and METEOR could steam with over 10 knots to reach the final destination Bremerhaven Port on the 14th of Mai. During the transit the entire team was processing the data with much effort on board and was discussing the results.

Figure 4.2. METEOR on Sunday 9th of May 2010.

5 Preliminary Results

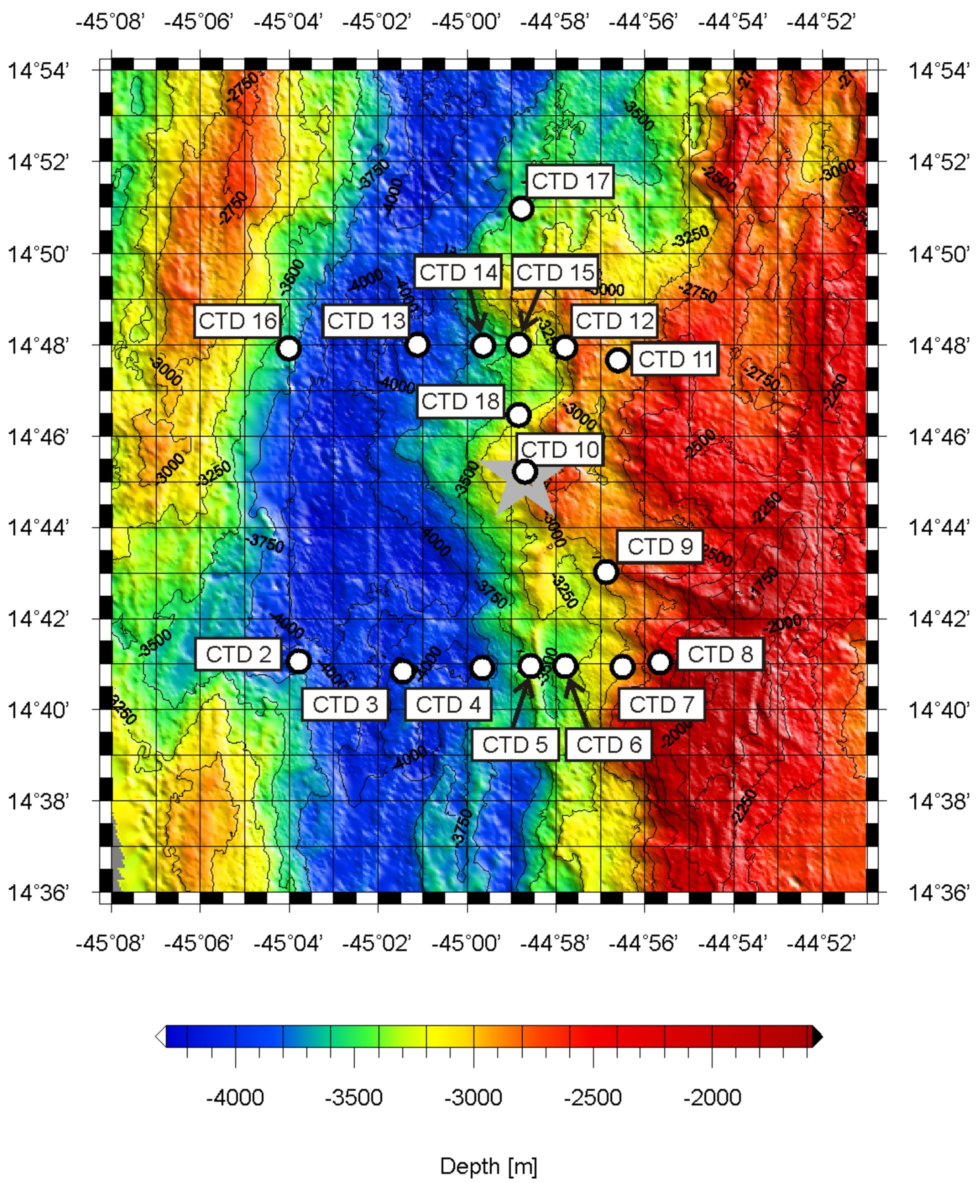


Figure 5.1. Station map of M81/2c CTD stations except for CTD 1, which plots approximately 380 nm to the west of LHF. Bathymetry is provided by courtesy of Niko Augustin (IFM-GEOMAR). The star indicates the position of LHF 1.

5.1. Oceanography

5.1.1. Methods

5.1.1.1. CTD

CTD casts were conducted to cover two hydrographic sections (Fig. 5.1), one 4 nm south of LHF (CTD 2-8), and one 3 nm north of LHF (CTD 11-16). Additionally, the near field of LHF-1 and 2 was investigated by CTD 9, CTD 10, CTD 18 and one CTD approximately 6 nm north of LHF.

A total of 18 CTD deployments at 18 positions were carried out, using a Seabird Electronics, Inc. standard SBE 911plus CTD system (IOW).

Figure 5.2. The mounted LADCP system.

Figure 5.3. Picture of the Rosette/LADCP system (Monika Rhein, Uni-Bremen) used during M81/2c deployments.

This unit had been additionally equipped with 22 x 10 l Niskin bottles, fired by a SBE32 carousel sampler (Uni Bremen). Besides standard sensors for conductivity, temperature and pressure measurements, the system was additionally equipped with a Seabird oxygen sensor SBE 43 (IOW), a 2-channel fluorometer (WETLABS ECO FLNTU, 700 nm optical wavelength, IOW) for measuring chlorophyll concentration and turbidity (Seapoint Turbidity Meter, 880 nm optical wavelength; Uni Bremen). For current measurements a self-contained lowered ADCP bloc (two LADCP, one upward, the other one downward looking, and a centered battery box all placed instead of two Niskin bottles at positions nr. 23 and 24; Uni Bremen). Below the Seabird sensors a MAPR (Fig. 5.5, Miniature Autonomous Plume Recorder, hired from NOAA/PMEL) was mounted below the Seabird 911 for measuring and recording temperature, pressure, turbidity and Eh.

All CTD casts have been acquired and processed by the use of the IOW-Cruise-Assistant-system (Fig. 5.4), which uses a little network of one small sized server (interfacing to METEORs DSHIP data system and realizing all centralized services like data logging and archiving) and two Cruise Assistant-Laptops. One was used for cruise management and the other for all necessary CTD work, including data acquisition, chart generation (Fig. 5.6), cast journal creation and off-line data processing.

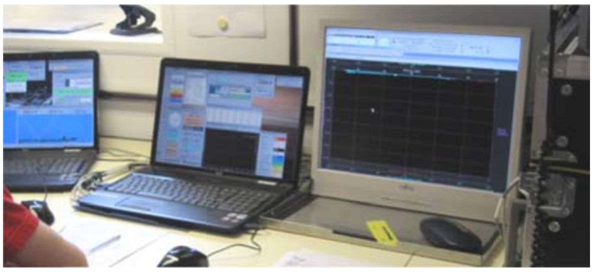


Figure 5.4. CTD control center: The CTD operator's working place, equipped with two IOW-Cruise Assistant-laptops and an extra screen for CTD-online-diagrams.

Figure 5.5. Downward 'looking' mounted extra 'Seapoint' turbidity sensor.

It worked properly throughout the entire cruise except for some pronounced spikes most likely caused by high temperature difference between deck 35°C and more and deep water (3°C).

In general all CTD casts were measured at down- and upcast speeds of 1 m/s. The upper 100 m downcastwas operated at a speed of 0.5 m/s.

A total number of 310 bottles have been fired at all. The shot depth strategy was to sample in addition to bottom and surface a certain number of nearly equidistant standard horizons from the deepest point to a depth of 1800 m and, depending on the measured downcast turbidity, a limited number of extra bottles.

To minimize hydrodynamic influences to the data quality only CTD data lines from the downcast parts were selected to be processed for the depth bin averaged physical profiles (bin size = 1 m), while all bottles had been closed manually without winch stops during upcast (except the bottom and the surface bottle, these were fired after the CTD-winch had been stopped before).

To avoid bringing additional, seldom used equipment on board, the conductivity calibration check will be done at home. Therefore salinity samples have been periodically collected at two standard depths (2000 m and surface) and bottled for transfer to the IOW's calibration laboratory.

Because of the extremely limited time window at LHF no extra casts, using reversing thermometers for temperature sensor checks were conducted. Instead of this method we decided, to compare the CTD-temperature value of the deepest measured depth bin against the deepest simultaneously stored temperature of the self-contained MAPR, which was mounted very close to CTD's temperature sensor.

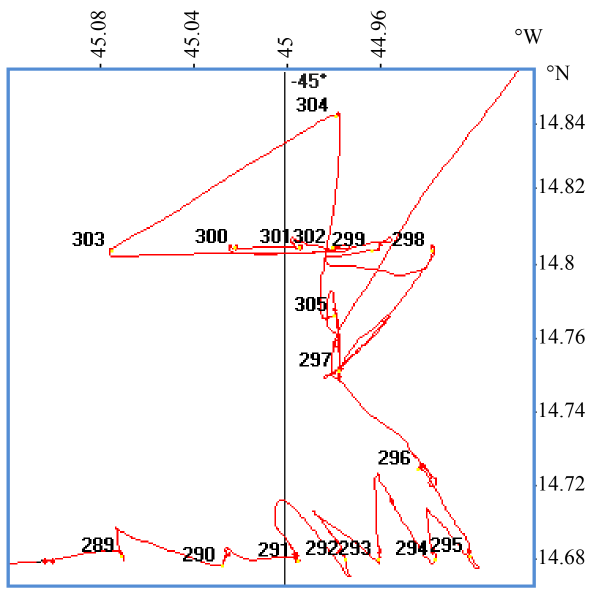


Figure 5.6. All worked stations around LHF. See station list for respective CTD numbering.

The following table shows the complete summary of all these comparisons between CTD and MAPR temperature:

Table 5.1.: Comparison between the temperature measured by the CTD and the MAPR system, respectively.

Nr.	Date	(timemapr)	File(CTD)	p(mapr)	p(CTD)	D(mapr)	D(CTD)	T(mapr)	T(CTD)	deltaP	deltaD	deltaT
6	27.04.2010	19:40:21	0006H01	3465,6	3452,8	3417,4	3405,0	2,591	2,578	12,8	12,4	0,012
7	27.04.2010	23:17:56	0007H01	3016,8	3003,5	2978,0	2965,0	2,749	2,736	13,3	13,0	0,013
8	28.04.2010	02:20:16	0008H01	2674,5	2662,1	2642,1	2630,0	2,902	2,886	12,4	12,1	0,016
9	28.04.2010	05:35:16	0009H01	2963,1	2950,5	2925,3	2913,0	2,764	2,749	12,6	12,3	0,015
10	28.04.2010	10:42:31	0010H01	3086,7	3073,9	3046,4	3034,0	2,716	2,709	12,8	12,4	0,007
11	28.04.2010	15:25:51	0011H01	3001,3	2988,2	2962,7	2950,0	2,793	2,778	13,1	12,7	0,014
12	28.04.2010	19:07:51	0012H01	3100,2	3086,2	3059,7	3046,0	2,718	2,705	14,0	13,7	0,013
13	28.04.2010	22:51:46	0013H01	4013,1	3998,3	3952,4	3938,0	2,545	2,533	14,8	14,4	0,013
14	29.04.2010	02:32:41	0014H01	3680,3	3665,5	3627,3	3613,0	2,546	2,534	14,8	14,3	0,013
15	29.04.2010	07:05:31	0015H01	3419,8	3406,8	3372,5	3360,0	2,570	2,556	13,0	12,5	0,014
16	29.04.2010	10:48:51	0016H01	3707,7	3693,1	3654,0	3640,0	2,512	2,500	14,6	14,0	0,013
17	29.04.2010	14:25:56	0017H01	3488,8	3474,3	3440,1	3426,0	2,590	2,573	14,5	14,1	0,017
18	29.04.2010	17:49:31	0018H01	3309,4	3295,5	3264,5	3251,0	2,650	2,638	13,9	13,5	0,012
	with…							mean values:		13,6	13,2	0,013

Nr. cast index

Date/time timestamp in mapr-memory

File(CTD) CTD-cast-filename

p(mapr) deepest pressure value of the mapr-registration [dBar]

p(CTD) deepest pressure mean value (of deepest depth bin) [dBar]

D(mapr) deepest calculated depth value of the mapr-registration [m]

D(CTD) deepest calculated depth bin center value of the CTD-cast [m]

T(mapr) temperature value of the deepest mapr-registration line [K]

T(CTD) temperature mean value of the deepest CTD-cast depth bin [K]

deltaP pressure difference **p(mapr) – p(CTD)** [dBar]

deltaD depth difference **D(mapr) – D(CTD)** [m]

deltaT temperature difference **T(mapr) – T(CTD)** [K]

5.1.1.2. LADCP

The ADCP used was a RD Instruments 300 kHz Workhorse Monitor, powered by an external battery supply that consisted of 35 commercial quality 1.5 V batteries assembled in a pressure resistant Aanderaa housing (Fig. 5.2, 5.3). Bins were set to 20 with a bin length of 10m, and 1 second ping rate. The overall performance of the instrument was very good. Only at CTD 13 the slave failed to record data, most likely due to wrong initialization. After this cast, the slave was replaced with the spare ADCP of the same type. The range was typically very good and bottom track was successful.

The Lowered ADCP data quality was considerably decreased by the scarcity of scatter in the deeper parts of the water column. For depths exceeding 1000 m, the range was reduced to 4 good bins per instrument; occasionally only 2-3 good bins were achieved. The poor range in combination with the sometimes relatively heavy ship motion led to a relatively large error in the depth mapping of the individual measurements and the resulting velocities. The data will be reprocessed using the pressure from the finalized CTD data to improve this problem.

5.1.1.3. MAPR

A MAPR (Miniature Autonomous Plume Recorder SN 63; Baker and Milburn, 1997; Baker et al., 2001) with an optical backscatter sensor (OBS, NEPH SENSOR SN 1156) for turbidity measurements, pressure, temperature and Eh was attached to the CTD cage. Its orientation was downward looking with a minimum distance of 20 cm of the light beam emitter to any surrounding obstacles. Attachment to the ship's wire was rejected given the heavy weather in the beginning. For consistency reasons and to later compare the relative backscatter units, we decided not to change the position of the MAPR after the first casts. For conversion of the raw data into e.g. temperature the manufacturer processing scheme was applied to all data and a MATLAB median filter was applied. A final reprocessing will be carried out by Sharon Walker (NOAA, Seattle, USA).

5.1.2. Results

5.1.2.1. Temperature and Salinity

Over the depth range of 0 to 4000 meters, the profiles of temperature (Fig. 5.7) and salinity (Fig. 5.8) are practically identical within the Logatchev working area. They exhibit well known water mass structure, with Upper North Atlantic Deep Water (UNADW) at the salinity maximum at about 1500 m grading to Lower NADW around 3800 meters. Small scale perturbations to these profiles occur due to the injection of vent fluid into to water column. These perturbations can be seen in the T-S diagrams (Fig. 5.9) of the deep waters surrounding the vent field. The T-S segment within them normally appears as a nearly straight line produced by the vertical gradient between warmer, saltier UNADW and colder, less salty LNADW. The admixture of vent fluid perturbs this line as deviations “to the right”, i.e. toward warmer temperature (Marbler et al., 2010). These perturbations coincide with increased particle concentration, as detected in the optical back scatter (Fig. 5.10).

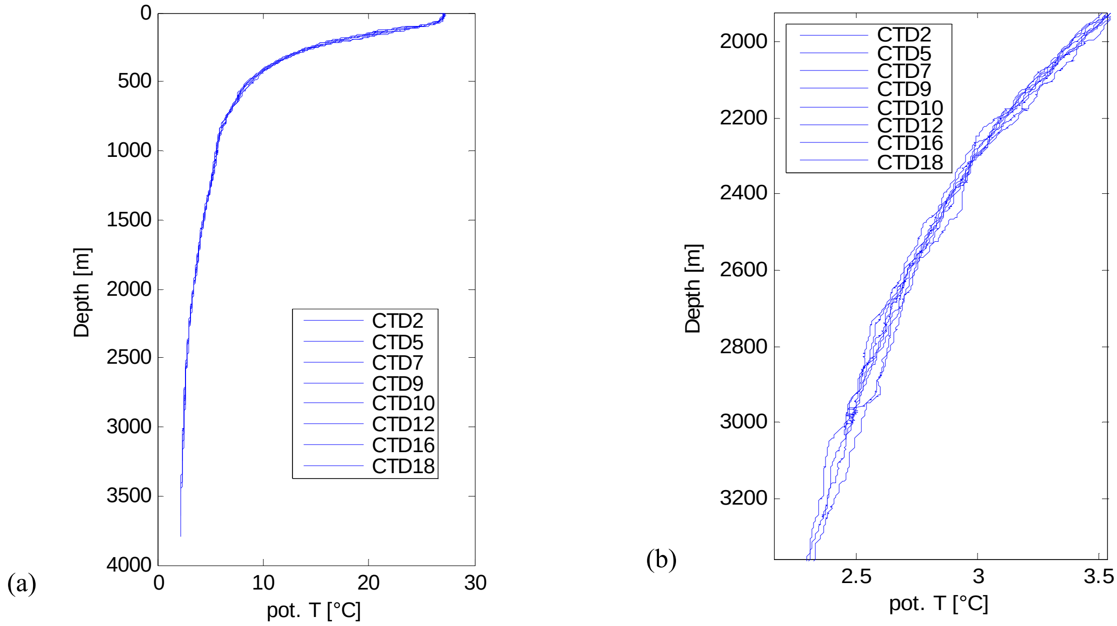


Figure 5.7 Temperature-depth profiles covering (a) the entire water column at LHF and (b) the plume depth.

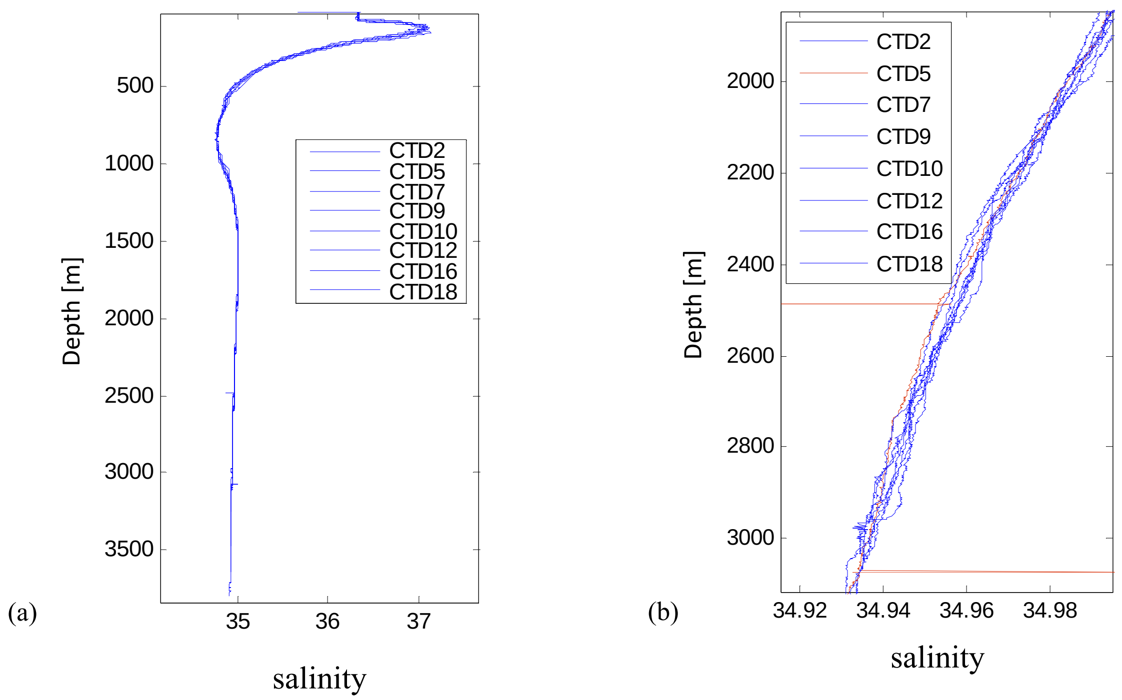


Figure 5.8. Salinity-depth profiles covering (a) the entire water column at LHF and (b) the plume depth.

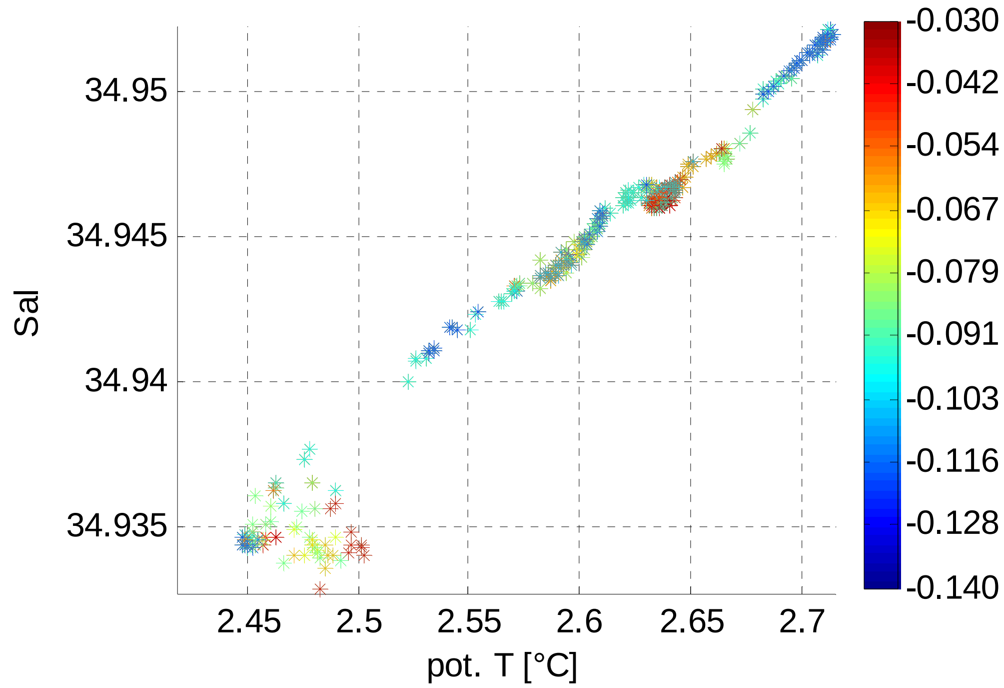


Figure 5.9. TS plot of CTD 10 with color coded optical backscatter (OBS) data.

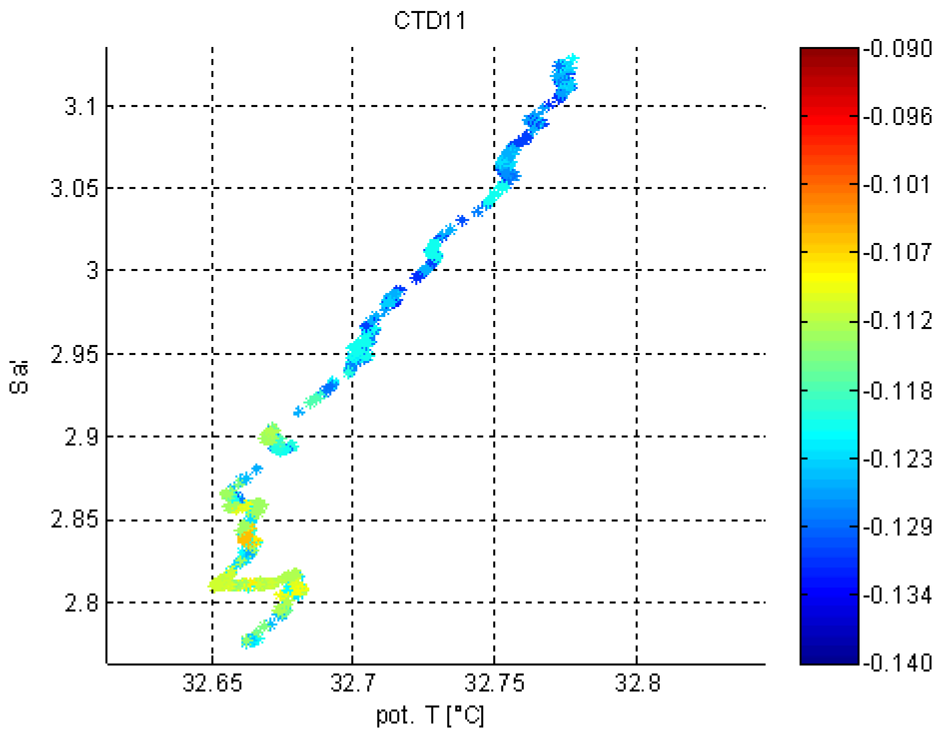
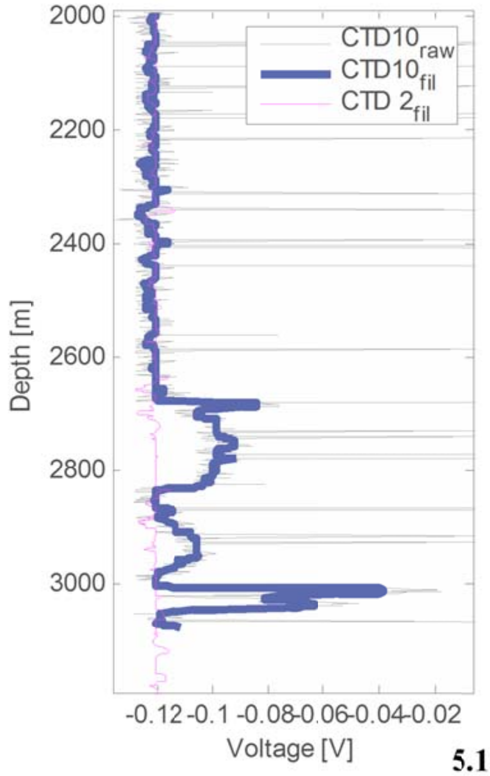


Figure 5.10. TS plot of CTD 10 with color coded OBS data.

5.1.2.2. Turbidity



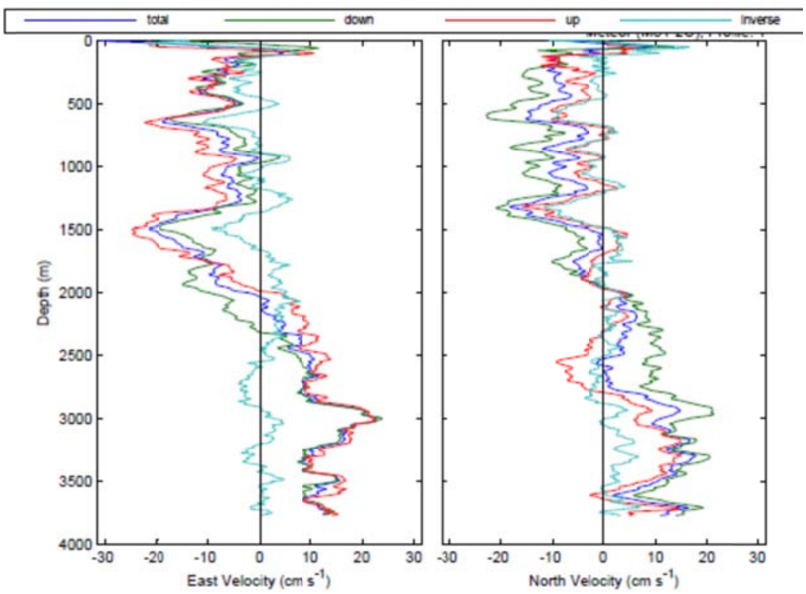
The turbidity sensor attached to the CTD showed strong scatter and spikes (Fig. 5.11, CTD10_raw). During deployment and online CTD registration, plume signals were hardly observed. However, after application of a median filter with 15 bins window size (*medfilt1*; MATLAB signal processing toolbox) the data redraw three plume-like structures (Fig. 5.11, $CTD10_{fil}$). Further positive turbidity values were found in CTD 6 and CTD 11 (not shown). Some nautical miles away from the LHF, e.g. at CTD 2, the voltages plot as an unchanged vertical line from 2000 until depth (Fig. 5.11, $CTD2_{fil}$) is shown. In contrast elevated methane was found at CTD2 and consequently, methane seems to be the more accurate tracer than turbidity, as will be shown later.

Figure 5.11. OBS data from the online sensor over depth. Raw and filtered data are presented.

5.1.2.3. Currents

The LADCP data were processed with the MATLAB software LADCP Processing provided by courtesy of Christian Mertens (Uni-Bremen). Raw master and slave data were imported to derive the north and east components at the respective depths. Roll and pitch values during deployment showed only minor tilt angles of the device of a few degrees. Standard processing parameters provided in LADCP Processing were used to derive velocity profiles (Fig. 5.12).

In the depth range of interest between 2000 m and the seafloor, a significant current change over time from north-easterly towards more westerly direction was found with a general tendency to the North. Furthermore, significant shear was found in several locations (not shown).



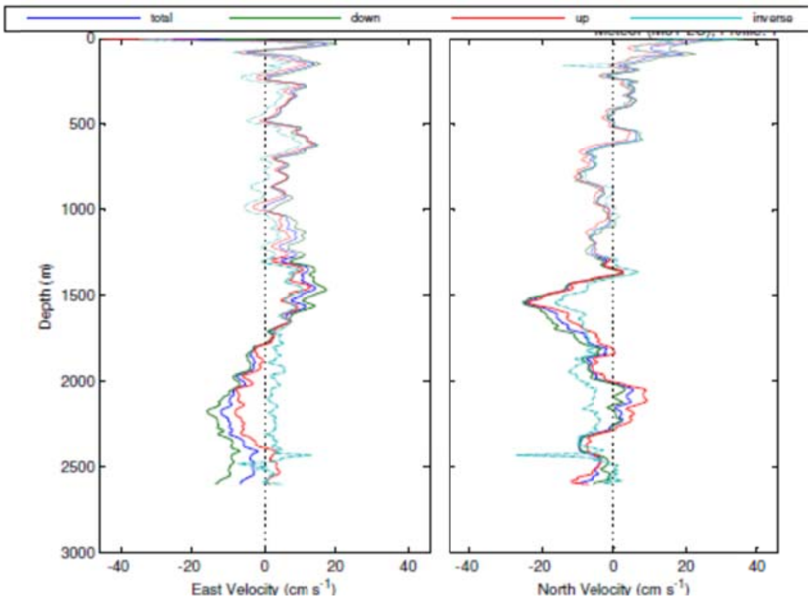


Figure 5.12. Velocity over depth gathered during ST. 289 and St. 295 showing data from up- and downcast and the total.

5.1.2.4. MAPR

For hitherto unknown reason, the MAPR failed during the first CTD stations and no data could be gathered. After resetting the MAPR, data was successfully recorded during stations CTD 6 – CTD 18 with a sample interval of 5 seconds.

Observations with the MAPR's optical backscatter sensor (OBS) are of specific interest, because previous studies have shown, that the elevated OBS data are very useful to continuously trace the LHF plume in the water column (Keir et al. 2009; Marbler et al., 2010). A compound plot of all data is provided in Fig. 5.13a showing raw OBS voltage signals over depth. A pronounced anomaly plots in the raw voltage data around 3000 m water depth together with high methane concentrations. Solitary high voltage values at depth are interpreted as spikes. The clustered positive anomaly occurs at the depth, where LHF releases its fluids into the water column, and it is most likely caused from the hydrothermal LHF plume. A closer inspection of the data below 2000 m of CTD10 directly above LHF indicates three separated plumes with center depths of 2700 m, 2900 m and 3000 m water depths. The data virtually redraws the CTD online OBS sensor data from Fig. 5.13b. Obviously the sensor's sensitivity resembles each other and the CTD-OBS could be used to fill the MAPR data gap in CTD1-5. Fig. 5.13c demonstrates, that the MAPR is capable to detect plume signals even several miles north of LHF visible through a pronounced peak around 2800 m in CTD11. This peak correlates to the high methane concentration found in CTD11 at this depth. In CTD 13 methane concentration was low and no elevated OBS signal could be detected.

After data post processing, the OBS plume signals will be –if possible– correlated with CH_4 and He. This would allow mapping the overall extent of the plume with a 5 m vertical resolution.

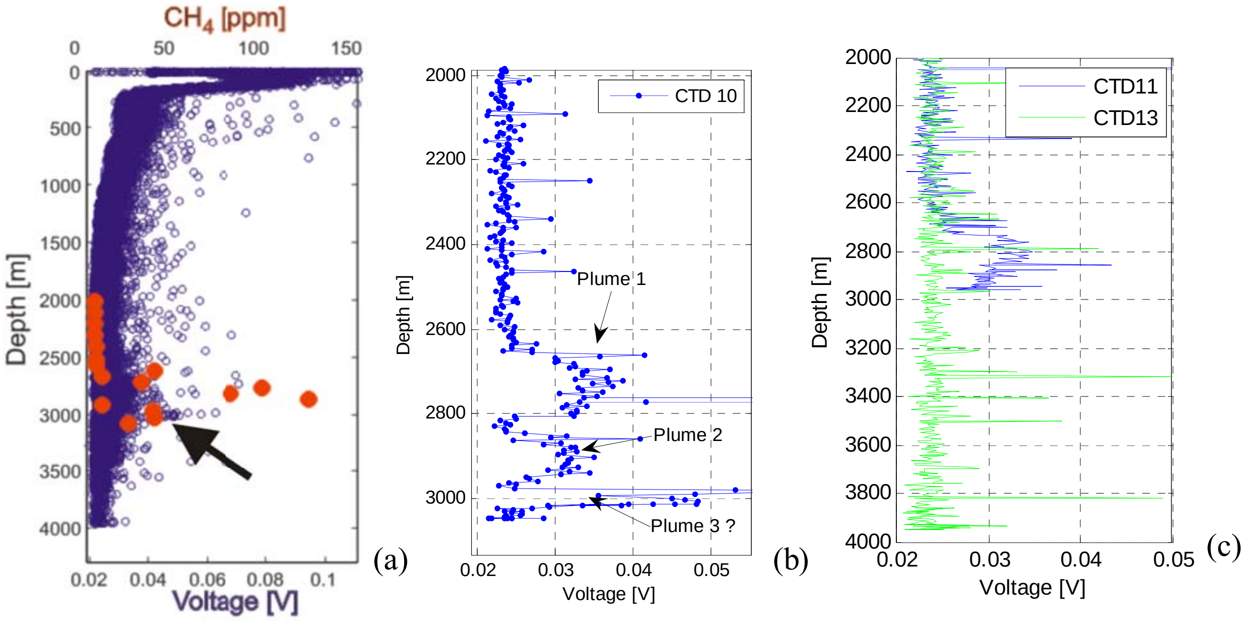


Figure 5.13. Raw MAPR OBS voltages and CH_4 ppm values over water depth (a) shows data gathered during CTD6-CTD18 down- and up casting. Methane concentrations are shown from CTD10 directly above LHF. The arrow indicates the positive OBS anomaly at depth. (b) and (c) show OBS data in deep water recorded during respective CTD's (downcast).

5.2. Gas chemistry

5.2.1. Methods

5.2.1.1. Methane concentration and $\delta^{13}C$-CH_4

A 22 bottle rosette water sampler was used to gather a total of approximately 220 water samples predominantly between 1800 and 3500 m water depth at each CTD cast to trace the LHF plume. The water samples were analyzed within 2 hours after the sampling.

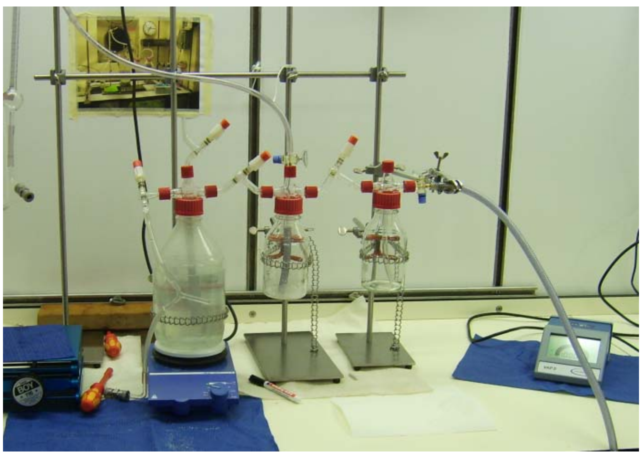


Figure 5.14 Picture of the vacuum degassing system installed in the clean lab of R/V METEOR.

1400 ml of water was filled from the Niskin bottles into pre-evacuated 2000 ml glass bottles, which were closed with valve caps to avoid any air contamination caused by leakage. A calibrated flow meter (ENGOLIT Flow-Control 100S DMK) was used to control the flow into the glass bottles. The transfer of the sample water into pre-evacuated bottles leads to 90% degassing (Keir et al., 2009). For CH_4 analysis a modification of the vacuum degassing method described by Lammers and Suess (1994) was used (Rehder et al., 1999) to extract the gas out of the sample bottle into a syringe and glass vial without contamination (Fig. 5.14).

Subsequently, a 1ml gas sample was injected with a syringe into a gas chromatograph to detect methane by means a THERMO Trace GC equipped with a flame ionization detector. Integration was performed with the ChromCard software.

Isotopic analyses ($\delta^{13}C$-CH_4) could not be conducted on board, but the extracted gas from each sample was stored in pre-evacuated crimp cap glass vials and sealed with a butyl rubber septum. 4 ml of supersaturated salt solution was added into each vial before and the sample stored upside down to protect it for contamination from atmospheric gases during the storage.

5.2.1.2. CTD – Helium

For measurements of the ^3He concentrations water samples were taken at St. 287 and 289-303 from the Niskin bottles to gather a total of 174 samples. The samples were transferred into gas tight copper tubes (40 ml sample volume) without headspace for storage and transport (sample volume 40 ml). Helium isotope measurements were carried out at Univ. Bremen with a fully automated UHV mass spectrometric system. The sample preparation includes gas extraction in a controlled high vacuum system. Helium and neon are separated from permanent gases in a cryo system at 25 K. A split of the sample is analyzed for ^4He, ^{20}Ne and ^{22}Ne with a quadrupole mass spectrometer. At 14 K He is separated from Ne and released into the sector field mass spectrometer for analysis of ^3He and ^4He. The facility achieves about ± 0.2% precision for $^3He/^4He$ ratios, and ± 0.5% or better for helium and neon concentrations.

5.2.2. Methane concentration and $\delta^{13}C$-CH_4

The dissolved concentration of methane was measured in seawater samples collected on all 18 CTD stations taken during the cruise. These stations include 2 east-west sections across the rift valley, bounding the Logatchev hydrothermal fields 1 (LHF-1) and 2 (LHF-2) to the north and south. In the south section, the methane anomalies were surprisingly weak. The first 4 stations (CTD2–CTD5) showed only a weak maximum of about 1.5 nmol/L near 2900 m depth. CTD5 in particular is at the same position as Station 279 of M. S. MERIAN Cruise 04/3. At that time in 2007, a methane maximum of over 10 nmol/L existed at 2750 m (Keir et al., 2009). On the present expedition, the methane maximum increased to the east of CTD5, but only to about 3 nmol/L on the east wall bounding the rift valley (Station CTD8). It would seem as if the general transport may have been to the north at this time.

In addition, one station each was taken at the positions of the vent fields, and a final station about 3 km north of Logatchev Hydrothermal Field 1 was carried out. Both stations directly over the vent fields (CTD9 and CTD10) showed elevated methane anomalies. This was more or less expected, as LHF-2 is now known to be active (Fouquet et al., 2008). At LHF-1 (CTD10) we observed multiple maxima, as also found in previous expeditions (Sudarikov and Roumiantsev, 2000; Keir et al., 2009; Marbler et al., 2010). These multiple plumes were also seen in the optical backscatter, as discussed in the previous section.

The northern CTD section gave its own surprises. This section crossed the valley at 14°48'N, and Station 22 of the L'Atalante cruise in late 2007 lies on this section at a position 5.5 km directly north of LHF-1. At that time, methane at this station exhibited a maximum of 20 nmol/L at about 2800 m depth. CTD15 at this position, however, showed a much weaker maximum of 2 nmol/L at a similar depth. To the west of CTD15, the methane profiles remain almost constant with the same anomaly. To the east of CTD15, however, the methane concentration at this depth increases rapidly, reaching 40 nmol/L at the eastern boundary. One possibility is that the plume from LHF-1 was moving to the northeast at the time of this survey. Another possibility is that there is still another undiscovered vent near the position of CTD11, at the point of the "hook" of the ridge topography at that location.

Finally, the last Station (CTD18) was taken closer to LHF-1, only slightly farther north of it than L'Atalante Stations 25 and 28. Those two stations were taken on 2 consecutive days and show a large temporal variation. Both of the L'Atalante stations, however, show multiple peaks of at least 20 nmol/L with some much higher, up to 170 nmol/L on L'Atalante 28 (Keir et al., 2009). CTD18 of this expedition showed two methane maxima of about 2.5 and 5 nmol/L at 2600 and 3000 m respectively. This is clearly lower than those observed on the earlier stations, but is consistent with the results at CTD15, about 4 km north of CTD18. This seems to indicate that the direction of the plumes from LHF-1 varies widely in time.

Gas samples were extracted and conserved at all stations, and the stable carbon isotope ratio of methane in these gas samples will be analyzed in the isotope laboratory at IOW after the cruise.

Most of the CTD stations were positioned on two west-east lines across the rift valley, one north of LHF-1, and the other south of this vent field (Fig. 5.1). The two sections were positioned perpendicular to the main flow axis of the hydrothermal plume. A combination of the gas inventories calculated along the two axes and the current information will be used to estimate the fluxes from the Logatchev vent field. The sections displayed in Figure 5.15 indicate hydrothermal plume signatures that extend across the entire width of the rift valley. The methane concentration distribution indicates a plume center at about 2900 m water depth whereas the stable isotope data shows a center that is located about 200 m deeper. Along the ^{3}He sections the hydrothermal plume appeared as a "split-level" structure similar to the one observed on previous cruise. As described for the MSM 4/3 and L'Atalante data set, the regional methane gas distribution in that area is influenced by mixing and microbial oxidation that leads to decreasing methane concentrations and $\delta^{13}C$-CH_4 enrichment in the plume center with increasing distance to the vent field. At the upper and lower plume boundaries the decreasing methane concentration and the lighter values of $\delta^{13}C$-CH_4 point to mixing with open deep water. Apart from these general patterns, the new data indicates that an additional vent field exists at the eastern end of the northern section. High methane concentrations of up to 39 nM were measured at this station. The $\delta^{13}C$-CH_4 values in the bottom waters of about -14‰ are very similar to the source signature of vent fluids measured at LHF-1. This specific station is located in a valley that is separated from the main valley inhibiting a direct contact to LHF-1.

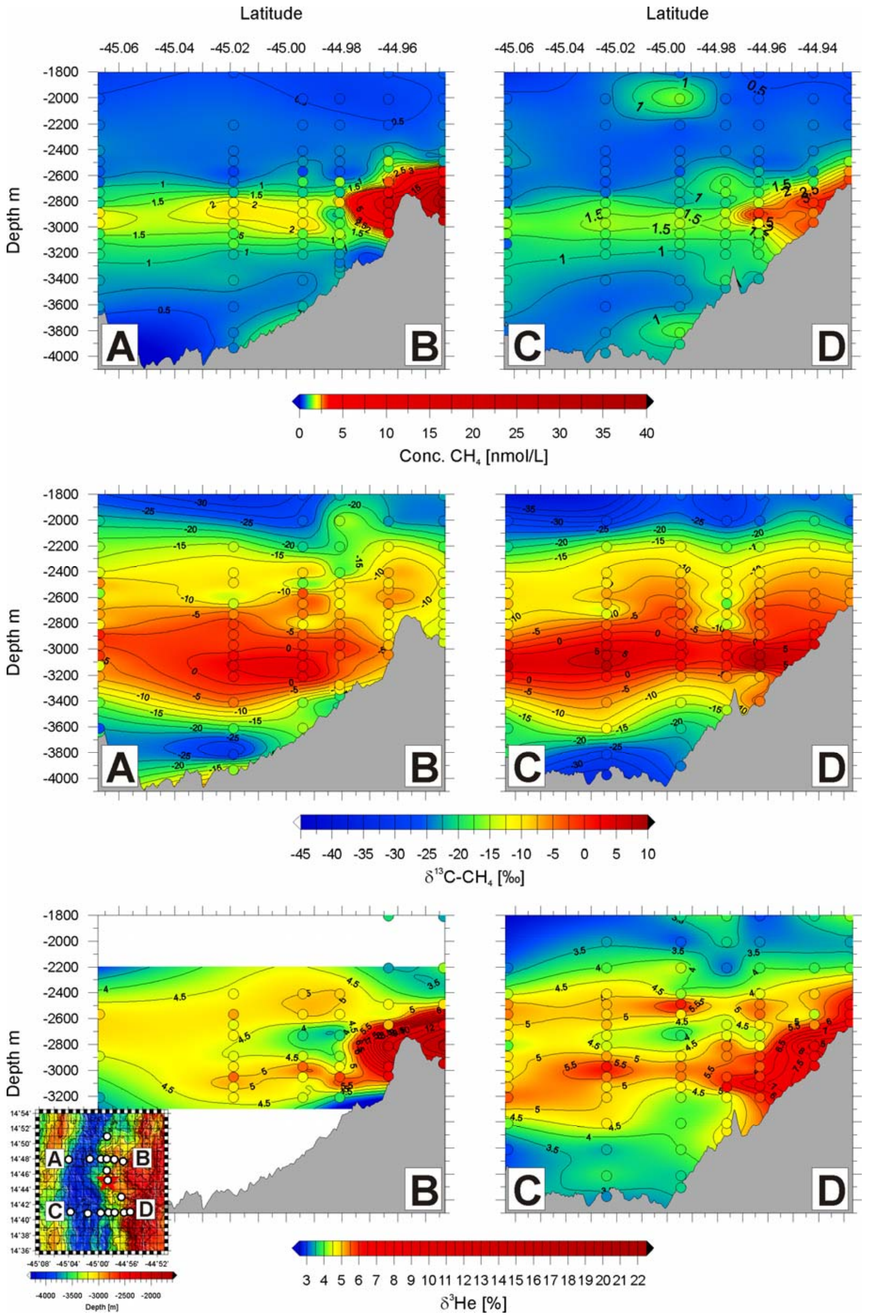


Figure 5.15. West-east section of CH_4 (top), $\delta^{13}C$-CH_4 (middle) and ^3He (bottom) near the Logatchev hydrothermal field adapted from Schmale et al. (2012). The northern section (A-B) is displayed on the left, the

southern section (C-D) is displayed on the right side. For the location of the two sections see the map in the left corner.

5.3. Acoustics

5.3.1. PARASOUND

The hull-mounted PARASOUND system on R/V METEOR was used to record sub bottom and water column data in regard to potential plume related backscatter anomalies.
To improve the signal to noise ratio (*S/N*), the ship was operated in the most silent way to avoid noise. This was achieved by shutting down all other sounders (e.g. Doppler Log, EM 120), reduced speed and shutdown of pumps. To account for the huge range in echo amplitude and to obtain maximum sensitivity in the online presentation, the gain was adapted manually to even resolve weak backscatter in the water column.

Given the very limited man power during M81/2C only a few lines of surveying were possible. Thereby the vessel was more or less drifting directly over LHF-1 during relatively calm wind conditions (~7 knots) and small ship movements. The prerequisites of good water column imaging were achieved as visible by a clear signal caught from CTD-backscatter during the down- and up cast (Fig. 5.16. dotted line from down and up cast of CTD). Several suspicious features could be observed in the water column. However, interpretation of water column signals requires significant post processing to draw any conclusions.

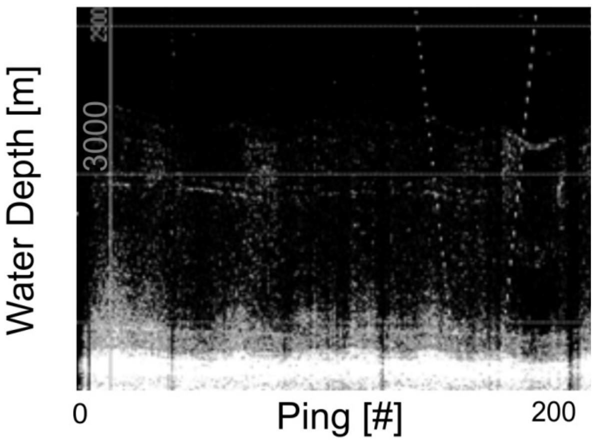


Figure 5.16. Stationary PARASOUND echogram (depth over time) recorded above LHF-1 showing a grey-shade coded backscattering strength. Bright grey-shade represents high backscatter/voltage. The seafloor plots white on the bottom and the CTD down- and up cast plots in the right side as a dashed line.

5.3.2. Multibeam

The hull-mounted multibeam system EM 120 (12 kHz) was used to record bathymetry and backscatter data during the transit (except within the EEZs) and during field work around Logatchev. The system parameters were set to automatic mode with a fix swath angle of 120°. After gathering CTD 1 the respective sound velocity profile was loaded into SIS for all succeeding multibeam recordings. The Logatchev area was not explicitly re-mapped because good bathymetry is already available and the time schedule was too tight for accurate surveying.

6 Ship's Meteorological Station during M81/2c

During the transit from Bridgetown to LHF, a high pressure zone located west of Gibaltar slowly moved eastward. Therefore, the weather was mostly characterized by easterly winds of Beaufort force 3 to 4, a sea of 1 to 1.5m and scattered low convective clouds. Just one single rain shower occurred on April 24th.

Winds of force 5 and north-westerly swell height of 2.5m temporarily complicated the scientific work in the night of the 27th. During the further station work weather was dominated by scattered cumulus clouds and persistent trade winds of force 4 to 5 being driven by a high southwest of the Azores.

Research activities ended in the evening of April 29th in order to reach Bremerhaven in time on May 13th. Due to the slowly eastward moving subtropical high, weather conditions during this leg turned out to be quiet calm with many sunny episodes until May 5th. Winds of variable direction and force 3 prevailed. Only for a while, Beaufort 5 was reached, with waves up to 2.5m.

Weather changed significantly in the evening of May 5th. An eastward moving low developed from the trough of a central low near Newfoundland. On the 6th and 7th, its frontal system affected the route of METEOR with south-easterly winds 6 to 7, wave heights up 3.5m, heavy cloud, rain or drizzle and haze as well. On May 8th, wind shifted northeast with unrelieved strength – directly against the heading of the ship. These strong north-easterly winds dominated all along the planned route to the English Channel. Following the advice of DWD and under consideration of fuel consumption it was not recommendable to circumnavigate the gale. It was therefore decided on May 7th to stay on the direct track to Bremerhaven.

On May 9th, when the low reached Cape Finisterre, METEOR experienced winds increasing to force 7 to 8 from Northeast, with gusts up to force 9 and significant wind waves up to 4.5m. On May 10th, the wind slowly decreased to force 5. Due to the past gale and the expected prevalence of strong north-easterly winds, the arrival at Bremerhaven had to be postponed to the afternoon of May 14th.

Actually, the gradient between the low and the ridge of the subtropical high weakened very slowly. In the English Channel winds finally ceased to 3 to 4 Beaufort from north while wave heights levelled off to 1 to 2 m.

The voyage ended in Bremerhaven by noon of May 15th.

7 Station List

Tabelle 7.1. Station List M81/2C.

Station	Date	Time UTC	PositionLat	PositionLon	Depth [m]	Gear/ deplo
ME814/286-1	24.04.2010	14:20	13° 46,14' N	55° 12,45' W	5234	MB 1
ME814/287-1	25.04.2010	11:30	14° 6,84' N	51° 23,05' W	5036	CTD 1
ME814/288-1	25.04.2010	14:31	14° 6,89' N	51° 22,93' W	5039	MB 2
ME814/289-1	27.04.2010	00:15	14° 41,05' N	45° 3,78' W	3786	CTD 2
ME814/290-1	27.04.2010	04:40	14° 40,83' N	45° 1,44' W	3935	CTD 3
ME814/291-1	27.04.2010	09:44	14° 40,91' N	44° 59,67' W	3916	CTD 4
ME814/292-1	27.04.2010	13:43	14° 40,95' N	44° 58,58' W	3474	CTD 5
ME814/293-1	27.04.2010	18:24	14° 40,96' N	44° 57,79' W	3423	CTD 6
ME814/294-1	27.04.2010	22:16	14° 40,94' N	44° 56,50' W	2944	CTD 7
ME814/295-1	28.04.2010	01:24	14° 41,03' N	44° 55,65' W	2616	CTD 8
ME814/296-1	28.04.2010	04:32	14° 43,01' N	44° 56,86' W	2944	CTD 9/PS 1
ME814/297-1	28.04.2010	09:40	14° 45,21' N	44° 58,70' W	3028	CTD 10/PS 2
ME814/298-1	28.04.2010	14:14	14° 47,66' N	44° 56,61' W	2911	CTD 11
ME814/299-1	28.04.2010	18:00	14° 47,93' N	44° 57,80' W	3119	CTD 12
ME814/300-1	28.04.2010	21:30	14° 47,99' N	45° 1,13' W	3945	CTD 13
ME814/301-1	29.04.2010	00:56	14° 47,98' N	44° 59,64' W	3629	CTD 14
ME814/302-1	29.04.2010	05:50	14° 48,00' N	44° 58,85' W	3383	CTD 15
ME814/303-1	29.04.2010	09:36	14° 47,91' N	45° 4,01' W	3660	CTD 16
ME814/304-1	29.04.2010	13:18	14° 50,96' N	44° 58,79' W	3469	CTD 17
ME814/305-1	29.04.2010	16:40	14° 46,46' N	44° 58,84' W	3266	CTD 18
ME814/306-1	29.04.2010	19:18	14° 45,57' N	44° 58,72' W	3131	PS 3
ME814/307-1	29.04.2010	20:15	14° 46,88' N	44° 58,99' W	3429	MB 3-PS4
ME814/308-1	29.04.2010	21:00	14° 45,53' N	44° 58,90' W	3083	MB 4

CTD: Conductivity-Temperature-Depth measurement
MB: Multibeam measurement
PS: Parasound measurement

8 Data and Sample Storage and Availability

Methane concentrations were measured on board M81/2C by Jens Schneider v. Deimling and Robin Keir. Subsamples of methane gas were taken by Jens Schneider v. Deimling and Robin Keir for home based stable carbon analyzes of methane by Oliver Schmale. Water samples were taken on board for home based helium analyzes by Jürgen Sültenfuss. The MAPR turbidity data was recorded in responsibility of Jens Schneider v. Deimling and will be reprocessed by Sharon Walker (NOAA, Seattle, USA) and stored by Oliver Schmale. The CTD and LADCP data was recorded in responsibility of Peter Wlost and will be reprocessed and stored by Maren Walter and Oliver Schmale.

Table 8.1. Dataset, responsibility and contact (in priority).

Dataset	Responsibility	Contact
Methane	Oliver Schmale	oliver.schmale@io-warnemuende.de
	Jens Schneider v. Deimling	jens.schneider@io-warnemuende.de
	Robin Keir	rkeir@ifm-geomar.de
Helium	Oliver Schmale	oliver.schmale@io-warnemuende.de
	Jürgen Sültenfuss	suelten@uni-bremen.de
	Robin Keir	rkeir@ifm-geomar.de
MAPR	Oliver Schmale	oliver.schmale@io-warnemuende.de
	Jens Schneider v. Deimling	jens.schneider@io-warnemuende.de
	Sharon Walker	Sharon.L.Walker@noaa.gov
CTD, LADCP	Oliver Schmale	oliver.schmale@io-warnemuende.de
	Jens Schneider v. Deimling	jens.schneider@io-warnemuende.de
	Peter Wlost	peter.wlost@io-warnemuende.de
	Maren Walter	mwalter@physik.uni-bremen.de

After data evaluation and publishing the total dataset will be stored in the database of the DFG Priority Program 1144 (http://spp1144.pangaea.de/). The data transfer is scheduled for the year 2012. The contact person for the data bank is Hans-Joachim Wallrabe-Adams (MARUM, hwallrabe@pangaea.de).

9 Acknowledgements

We gratefully acknowledge that this cruise was passed as an alternate cruise by the R/V METEOR advice committee, even though the time schedule was very tight in regard to the subsequent shipyard time in Bremerhaven. This enabled us to finally gather extra data for the project SPP 1144. The friendly and professional work of Captain W. Baschek, his officers and crew members supported us very much at any time. Once more we want to honor the great effort of our students to finally reach the vessel in time, which was very important for a successful cruise.

The work was supported by the priority program SPP 1144 of the German Science Foundation (DFG, funding number SCHM 2530/1-3) and DFG Koordinatorantrag M81 (project identification GASLOG).

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