ESO NEWS

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2008 Cruise Report

LOOME

ESONET DEMONSTRATION MISSION

20-10-08 to 24-10-08

Tromsø – Longyearbyen

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Introduction and Objectives

The Håkon Mosby Mud Volcano (HMMV) is one of the most active cold seep systems documented, and intensively investigated during the last decade (Ginsburg et al., 1999, Vogt et al., 1999, Mienert et al., 1999, Mienert et al., 2003, Sauter et al., 2006, Niemann et al., 2006 and Garcia-Perez, 2009). Since 2001 the HMMV was investigated by a collaboration of Norwegian, French and German scientists at least once per year. The research was aimed to describe physical phenomena, the chemistry of the seep, and the habitat distribution for microorganisms, and meio- and macrofauna. The three disciplines were highly integrated to obtain a coherent concept of the volcano. Data on topography dynamics, fluid and gas flow, hydrate distribution, temperature distributions, geochemical analyses, microbial rate measurements and microbial community descriptions, together with habitat descriptions using meiofauna and video mapping have lead to a coherent view of the system.

Yearly cruises by particularly Norwegian, French and German teams have greatly contributed to understanding the heterogeneity and diversity of its associated life habitat, and to the fluid transport phenomena within the cold seep. During these visits the seep gave the impression of a quiet and continuous process. However, we have strong evidence from micro bathymetric images, and from a unique continuous temperature record spanning 9 months that irregular outbursts of mud volcanism occur in the central area. During such outbursts large amounts of mud must get suspended, driven by a large outflow of methane. This will have at least local consequences for the sediment structure and life in the eruption area; a large amount of methane is released into the seawater, possibly reaching even the atmosphere.

During LOOME deployments, we carry out detailed investigations of the dynamics within the sediment surface, to follow the sequence of eruption events. Measuring the effects of the eruption on the geology, topography, meiofauna and microbiology of the seafloor allow to evaluate natural environmental impacts. For this, we must measure various physical, chemical and biological parameters in the HMMV at the surface during long term observations at the hot spot, and determine essential parameters in the water phase.

The RV Jan Mayen cruise is the 1st part of the LOOME ESONET demonstration mission at the Nordic margin. We plan to make long-term observations and the measure a range of parameters that are important to understand the phenomena occurring before, during and after an eruption. The complete observatory will be equipped with dedicated instruments that can measure autonomously and reliably for at least 12 months. The observatory will integrate a carefully selected number of sensing devices to optimally record eruptive phenomena. Technical descriptions of the units that are more detailed can be made available. The units will either be partially purchased by the partners, custom made for this project, or are in possession of the partners.

The 1st part of the observations included:

1) a temperature Lance in the sub seabed (Figure 1 and 6). Ifremer owns the unit.
2) a multicomponent ocean bottom seismometer, with 3 channels for seismometers and 1 for a hydrophone, to detect mud and fluid eruption events, and its precursory phenomena, like mud movement at depth (Figure 5). The Department of Geology at University of Tromsø (UiT) owns the unit.
3) a Piezometer to measure the pore pressure in the sub seabed (Ifremer owns the unit).
During the 2nd part that will take place on the RV Polarstern cruise in July 2009:

Fig.1 - T-Lance

1) a string of 24 temperature sensors which will be laid out over the hot spot and measure temperature every 15 minutes. The IfM-Geomar will purchase this unit.
2) an array of sensors that will measure DO, pH and OPR at 6 positions at the sediments surface, with an interval of 15 minutes. The MPI will purchase this unit.
As the rising fluids will be warm, anoxic, acidic and have a low OPR, we expect that the latter 2 units will record the actual eruption at the surface.
3) Acoustic sensors to record the plume, i.e. an Acoustic Doppler Current Profiler (ADCP) that scans vertically over a distance of 100 m and a scanning sonar that can image over a horizontal distance of ca 50 m. MARUM at the University of Bremen (Germany) owns these units.
4) a digital camera. The Alfred Wegener Institute (AWI) owns this unit.
5) a methane sensor
6) an acoustic flare.

In addition a redeployment of the 3 instruments from the 1st part of LOOME is planned.

Instruments 1), 2) and 3) can operate autonomously during the planned 1st period. During the 2nd part, the acoustic sensors and the camera must record most actively during the eruption with high frequency. As such intensive operation is not possible during a year, we consider the use of the seismometer to give early warnings, as a wake-up call for these instruments.

The data generated by all instruments will be regularly down-loaded in three data-cylinders, via optical fibres. Each of these data cylinders can be released by a passing ship, and data can become available at regular intervals during the year of deployment.

To assess the effect of the eruption, before and after events, geochemical and biological analyses of the sediments in and near the hot spot will be made. Colonization experiments will also be conducted, by deploying pieces of wood, near which continuously pH and sulphide will be measured, by an additional set of sensors. Furthermore, the change in topography will be followed by recording a bathymetric map before and after the observation period.

Working Area

The HMMV is at approx. 1250 m water depth, has a diameter of approx. 1200 m, and has a height of max 10 m at the outer rim. The volcano connects to the deep geosphere at over 3000 mbsf (meters below the seafloor), from where warm methane-rich fluids slowly are pressed upwards towards the

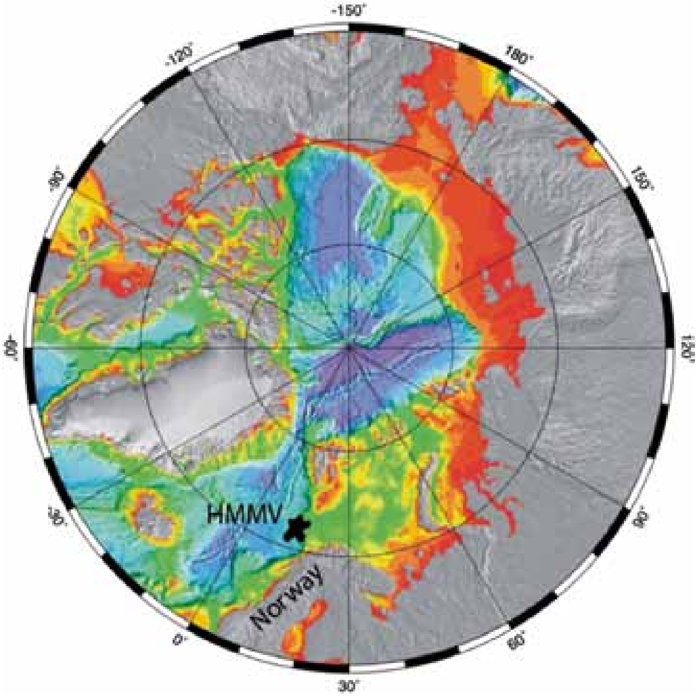

Fig.2 - Location map HMMV site (after).

At the surface, the Håkon Mosby consists of several more or less concentric domains. By using the microbathymetry of a sonar system on the French ROV Victor, two highly detailed maps were produced, one in 2003 (Figure 3) and one in 2006 (Figure 16). The existence of an outer ring of approx. 300 m width is supported by gas hydrate sampling (Figure 19), and colonized areas of symbiotic Pogonophora worms. This is the most irregular surface. Patches of gray mats occur (Figure 4), where hydrates have eroded. Further to the centre large areas are covered by Beggiatoa mats. The centre is smooth and consists of gray mud. Using high resolution video mapping, large parts of the surface were mapped for ecological habitats.

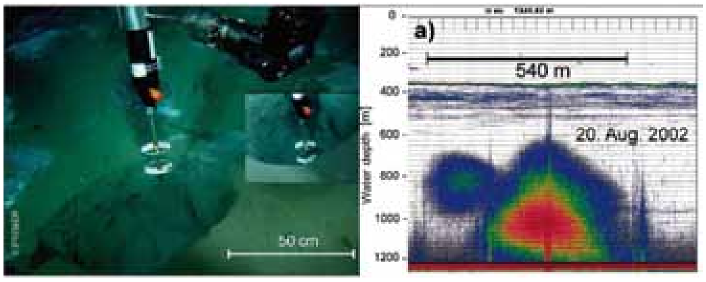

Fig.4 - Methane plume in the water column (right) and a seep seen on the seabed (left).

cold seafloor. If the opening of the HMMV is cool enough to allow methane hydrates to form, a ring with an outer diameter of 1200 m and a wall thickness of 200-300 m forms. This hydrate-rich ring is lighter than the surrounding sediments, thus lifts the volcano edge to 10 m above the seafloor. It erodes patch-wise and intermittently at the surface, while growing at the base due to inside supplies apparently subside of methane from rising fluids. Sediments apparently subside in a ring of ca 100-200 m outside the HMMV.

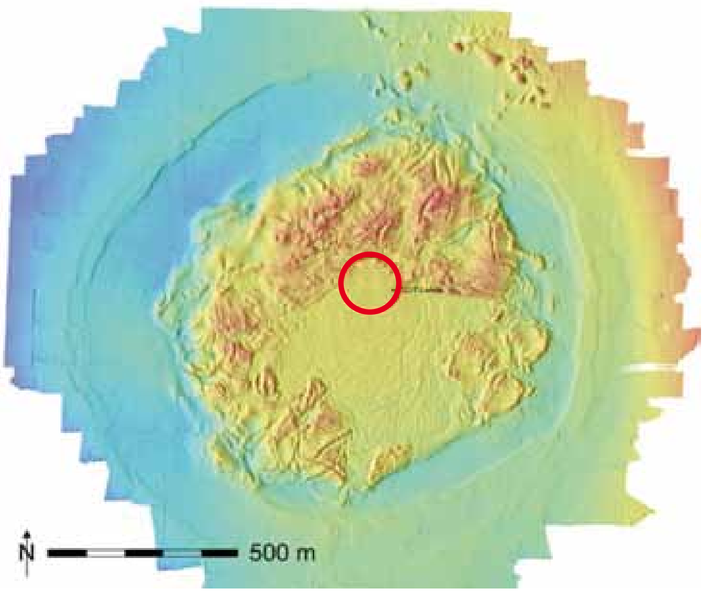

Fig.3 - Bathymetry map of the HMMV from 2003 (courtesy, J.-P- Foucher, Ifremer). The position of the previous temperature lance is indicated by a star. The three instruments of LOOME 1st part are all located in the northern part of the HMMV caldera (red circle). The volcano is surrounded by a slight depression. The hilly area is the hydrate perifiy. The central area has few features

The water column above the HMMV is enriched in methane, and fishery sonar images suggest the presence of a methane plume extending from the seafloor to ca 600 m below the sea surface (Fig. 4, right). Occasionally, methane bubbling was observed at the seafloor (Fig. 4, left). Such seepage will very strongly contribute to the methane release. However, mysteriously, these seeps are very rarely found, often disappear, whereas the tentative methane plume is a constant phenomenon. Possibly, the source for the plume is more diffuse.

By combining temperature measurements and geochemical and microbiological studies a close relation between geochemistry and habitat developments was observed. Assuming this relation is controlled by mass transfer phenomena, upflow velocities could be inferred from modelling. The highest flow velocities occur inside the HMMV but gradually decrease outwards, and are probably close to zero in the hydrate zone. The higher flow velocities in the centre are reflected in the highest surface temperatures, and more precisely, in steeper near-surface temperature gradients. The distribution of biological habitats and upflow velocities are closely related. In the centre, the upflow velocities are too high (3-6 m/year) to allow sulphate to penetrate the sediments. Thus no anaerobic oxidation of methane (AOM) can occur, and thus no sulphide is formed, which is the basis of the rich deep-sea chemoautotrophic ecosystems. Only aerobic methane oxidation was observed, a low-yield metabolic process. Much of the methane rising up in the central area escapes into the water column possibly contributing to the plume. Further outwards the flow velocities decrease (0.3-1 m/year, de Beer et al.; 2006), allowing sulphate to penetrate into the sediment and methane is oxidised efficiently by AOM under production of sulphide. The sulphide is oxidized anaerobically and aerobically by Beggiatoa, leading to a rich biological community. On the outer hydrate zone the upward flow is largely blocked by the hydrates and here the Pogonophora worms mine deep into the sediments, pumping sulphate to the hydrates, thus stimulating AOM at over 50 cm depth. The worms, gardeners of AOM, obtain energy by aerobically oxidising the formed sulphide.

Recently, a significantly different 4th domain was recognized. A detailed study using temperature probes showed local extremely steep T-gradients, and thus extremely high upflow velocities, in an area of ca 40 m in diameter near the northern side of the central area. The upflow velocities may exceed 40 m/year, which is above the stability threshold. At such velocities, channelling of the sediments will occur, as indeed is observed near this area. The seafloor presents a rather regularly distributed pattern of small 1-2 cm diameter pockmarks, 10-15 cm apart. Secondly, eruptions may occur. During a 9 month deployment of a temperature lance, equipped with 8 temperature sensors over a length of 15 m, dramatic temperature fluctuations occurred. The lance was deployed just next to the hot spot as documented by measurements of temperature (T) - sticks. The first three months of the deployment only a gradual decrease in temperature at the deepest point was seen. Then a drastic change in the temperatures occurred. Within 36 hours, the temperature increased suddenly, and then the temperature along the whole lance decreased rapidly, leaving an inverted T-profile, with lower temperatures near the sediment surface. Such a drastic change and inversion of the sediment structure over a depth of 15 m is caused by a major eruption. This eruption will have lead to a major loss of methane, exposure of previously deeper buried sediment layers and horizontal transfer of mud. It is this phenomenon that we aim to document in detail, and its consequences for benthic life and chemistry. In the same period, short T-sticks were inserted in the north of the central area. Two of the five inserted were never found. The three found were placed outside the hot spot. Upon close inspection of the photos made by the ROV, the area that we suspect to be very active has some distinct surface features: small cracks and frequent small pockmarks of 2 cm diameter. All these observations allow a rather precise localization of the hot spot area (Figure 26). These observations strongly point to the hot spot as a site of regular eruptions, which therefore is a key area for long term multidisciplinary observations.

Technology

Long term seismic observation

During this cruise a multi-component Ocean Bottom Seismometer (OBS), was deployed to record seismic recordable events from October 2008 to July 2009. The multi-component OBS was deployed in approx. 1257 m water depth at the northern area inside the HMMV. The OBS system used during this survey of the HMMV is a KUM design and was purchased by the Department of Geology of the University of Tromsø (Figure 5). It is an autonomous sea floor recording platform, designed to record both compressional and shear waves reflected and refracted through the sediments. It consists of a titanium frame with buoyancy made of syntactic foam, a KUMQUAT acoustic release system2, and a digital data recorder3 in a separate pressure case1. A hydrophone and a 3-component geophone1 are used to record the seismic wavefield. The Tromsø OBS has a 4.5 Hz geophone attached. While the hydrophone is fixed to the frame of the OBS, the geophone is detached from it. This design insures that the geophone is mechanically decoupled from the frame, to avoid noise generated by the frame being recorded by the geophone. The whole system is rated for a water depth of up to 6000 m. The OBS is attached to a ground weight via the acoustic release system, to make it sink to the sea floor after deployment. When the seismic experiment is completed, the OBS is released from its ground weight by sending an acoustic code, and it rises to the sea surface by its buoyancy.

Fig.5 - The Ocean Bottom Seismometer (OBS) system (UiT including geophone, buoyancy, recorder, acoustic releaser, sender and flash light, and weight.

The Marine Longtime Seismocorder (MLS) manufactured by Send GmbH is optimised for acquisition of seismic signals in marine long term applications. Up to four input channels may be processed. Each channel is digitised using a sigma-delta A/D converter producing a 16-bit signed digital data. After application of a digital decimation low-pass filter and data compression, the samples are saved on PCMCIA storage cards together with timing information. Up to 12 storage cards may be used, which leads to presently up to 12 GB of memory. The data logger contains a time oscillator with accuracy better than 10-7. The time oscillator is synchronised at the beginning and end of each experiment via the DCF77 code from a GPS receiver, thus enabling to measure any time drift of the oscillator. A sample rate between 1Hz and 200 Hz can be selected which leads to a recording time of at least 87 days at a sampling rate of 200 Hz with 12 GB of memory using four channels, data compression not taken into account. The MLS recorder has a power consumption of 230-250 mW during recording.

The OBS system was prepared and programmed prior to deployment. A sampling frequency of 50 Hz was chosen for

[1]www.kum-kiel.de, [2]www.oceano-instruments.fr, [3]www.send.de

the measurement leading to a recording time of 289 days using 10 GB of PMCIA storage capacity. A lithium battery pack was used to ensure a sufficient power supply during the measure period of about 10 months. The first channel records the hydrophone data, while channel two, three and four are connected to horizontal and vertical components of the geophone. The location was selected based on previous investigations (see Figure 3) and on the results from previously collected temperature profiles.

Long term temperature observation

The mud temperature at a mud volcano is anomalously high as a result of the freshness of a mud eruption or more frequently as a consequence of warm fluids rising through the mud volcano feeder conduit from depth. Monitoring the mud temperature therefore provides important information on time changes in the activity of the volcano.

A 10m lance specifically designed to measure temperature in the soft erupted mud of the Håkon Mosby mud volcano was deployed as part of the Jan Mayen LOOME cruise (Figure 6). The lance comprises a core barrel on which thermometers were attached on outriggers at regular intervals of 1.40 m (Figure 6). Thermometers are self-recording NKE-manufactured thermistor temperature sensors accurately calibrated in the Ifremer laboratory prior to the cruise. Measurements have an accuracy of a few milli-degrees. A corer head of 400 kg drives the lance into the mud. A total of seven thermometers are mounted along the lance itself (Figure 6) and one at the top of the corer head.

Fig.6 - T-lance equipped with thermometers mounted on outriggers along the external wall of the pipe at intervals of 1.40 m. Picture taken on-board the RV Jan Mayen prior to deployment.

Long term pore fluid pressure observation

Long term pore fluid pressure observation
The piezometer (P-lance) is designed to measure the differential fluid pressure between the mud and the bottom sea water (Figure 7). Monitoring the pore fluid pressure at HMMV aims to detect fluid events affecting the mud volcano. By fluid event, is meant a rapid change of the pore fluid pressure in the mud of the volcano that may indicate a major mud and/or fluid movement, including a mud eruption or mud flow activity, or a fluid outburst.

The Ifremer P-lance deployed during the LOOME cruise at the centre of the Håkon Mosby mud volcano measures the differential pressure at 5 depths below the seafloor, namely 0.5, 3.5, 5.0, 6.5 and 8 m below the seafloor. Each sensor has its own data logger, thus making measurements at each sensor electronically decoupled from measurements at other sensors. A low resolution thermal sensor is included inside the lance at each depth of pressure measurement. The temperature data is also sampled by the logger of the pressure data at this depth. The total weight of the P-lance is 750 kg. Pore fluid differential pressures and temperatures at the five depths of measurements are sampled every 4 minutes.

1 - Pressure sensor specifications

Range of measurement (differential pressure)	0-350 KPa
Maximum in situ fluid pressure at measurement site	60 MPa
Resolution	± 0,2 KPa
Cumulated repeatability, hysteresis, non-linearity	± 0,18 KPa

Temperature sensor:

Range of measurement	0-35°C
Resolution	0.01°C

Fig.7 - Picture captions from top left to bottom right: 1. P-lance being assembled in its rotating frame prior to deployment. 2. P-lance head in its rotating frame. 3. P-lance soon to be deployed. 4. P-lance being deployed from the RV Jan Mayen.

Kongsberg SIMRAD 18kHz "plumefinder"

The echosounder provides an echogram that contains information about the acoustical values, which are given in color scales. The color allows to visualize the echo strength. Distinct changes in echo strength allow to detect plumes in the water column though the size of individual bubbles is unknown. A quantification of plumes and their gas content may be feasible in the future but not at present. However, the plume detection in the water column already helps to infer gas releases and target areas at the seabed.

Preliminary Results

The Plume of the HMMV

Acoustic imaging of gas plumes at the HMMV (see Figures 8 and 9) allows to trace gas in the water column. The 18 kHz echo sounder indentified a gas plume that exists in the northern part of the HMMV over a period of several years from 1998 to 2008 (Figure 8 shows the plume of July 2005). The plume of 2005 is bowed because appreciable bottom water currents are likely to influence its shape. In addition, a plume was separated from the major plume, and was drifting within the water mass. The plume of 2008 is different; it has a cigar-like shape that can be followed easily from the seabed at 1257 m to a height of 400 m above the seabed (Figure 9). The plume width of approx. 300 m indicates a large but focussed outflow from the seabed. The area where it penetrates the seabed shows no particular sign of disruption but this may depend on the acoustic resolution.

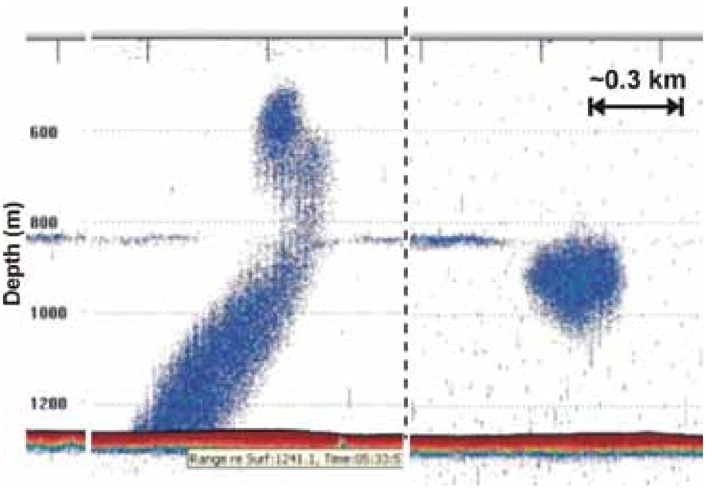

Fig.8 - Gas plumes above the HMMV in July 2005 as seen in the 18kHz fishfinder echolot. Note the bow of the plume and the floating separated plume due to the currents.

The next LOOME cruise will take place on RV Polarstern (July 9th-August 4th) of the AWI (Germany).

Acknowledgements

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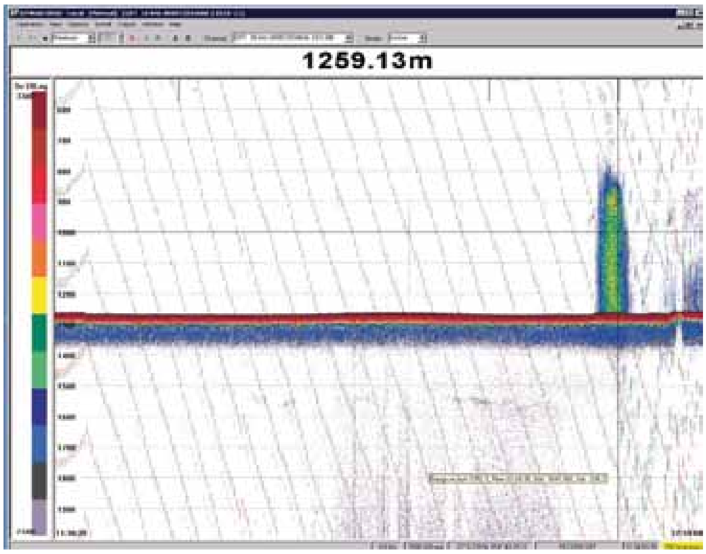

Fig.9 - Gas plume above the HMMV in October 2008 as seen in the 18kHz “plumefinder” echolot. Note that the plume has no horizontal deviations indicating weak currents during the time of the recording.

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Station list of observatory locations with an uncertainty of +- 50m.

The temperature lance has a beacon for ROV detection (table1)

Date	Station type	UTC-time	StNR.	Latitude	Longitude	Depth (uncorr.)
21.10	CTD	11:40	450	72º 00.592’ N	14º 42.936’ E	1256
21.10	Pressure Probe	19:55	451	72º 00.299’ N	14º 43.587’ E	1256
21.10	Temperat. Lance (with beacon)	21:40	452	72º 00.308’ N	14º 42.571’ E	1256
21.10	Ocean Bottom Seismometer	22:19	453	72º 00.314’ N	14º 43.523’ E	1263
21.10	Plume	23:00		72º 00.268’ N	14º 42.712’ E	1256-850

Table 1

In this ESONEWS issue we present the latest devolopments of the July-August 2009 recent cruise, starting with part of the weekly reports from Michael Klages followed by a final preliminary report from the team coordinated by Dirk de Beer. The 2008 cruise report was for the first set of deployments of 3 instruments that were to be integrated in LOOME. The actual LOOME deployment and redeployment of 2 of the instruments from 2008, occured this summer.

2009 CRUISE REPORT

First report from ARK XXIV/2 [10.07. – 17.07.2009]

Friday afternoon 50 scientists, engineers, technicians and students embarked in Longyearbyen, coming from seven nations and participating the second cruise leg of RV „Polarstern“ during her 24th Arctic expedition. RV „Polarstern“ left the Adventfjord of Longyearbyen as planned at 20:00 o’clock in the evening. This cruise leg will have two main regional areas of operation with different scientific objectives. For the first nine days we will work in the so called “Hausgarten”, a deep-sea observatory west of Svalbard at 79 degrees northern latitude. “Hausgarten” *comprises 16 sampling stations covering a depth range of 1000 to 5500 meters. The planned research programme contributes to long-term time-series studies at this deep-sea observatory where we investigate the impacts of climate change on the Arctic slope ecosystem through field studies, observations and models since 1999. A special feature of the "Hausgarten" observatory is its full system approach, covering physical, chemical, biological and geological processes, and including observations from the ice cover to pelagic photosynthetic production to the deep sea bacterial life. This year, we will also service a variety of deep water experiments which include different disturbance scenarios from starvation to slope erosion.*

The second half of the cruise will take place further south at 72 degrees northern latitude where the Hakon Mosby Mud Volcano (HMMV) is situated at 1250 meters water depth. The HMMV is a famous chemosynthetic ecosystem of the Northern margin, where methane fuels a diverse benthic community.

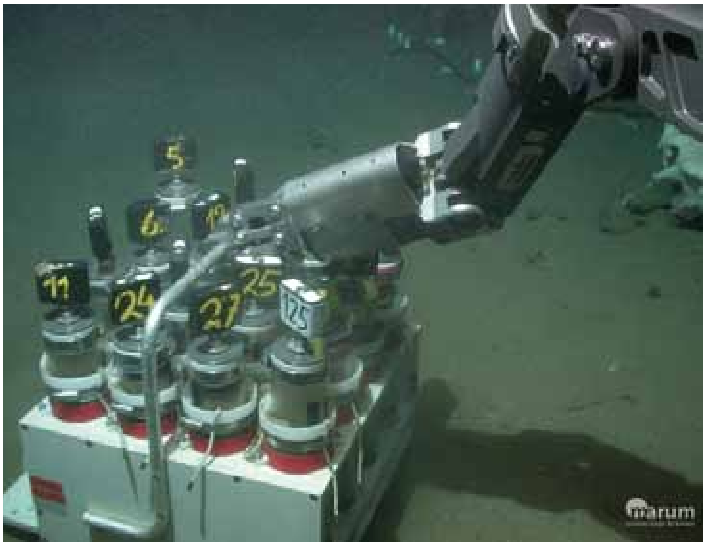

Fig.10 - The push core rack

The dynamics of the emission of the potential greenhouse gas methane at this mud volcano are poorly understood. Thus, one aim of this part of the mission ARK XXIV/2 is the implementation of a long-term observatory on the Norwegian margin to study mud volcano eruptions. The work at both sites serves as contributions to various European research projects such as ESONET (European Seas Observatory NETwork), EMSO (European Multidisciplinary Seafloor Observatories), HERMIONE (Hotspot Ecosystem Research and Man's Impact on European Seas), HYPOX (In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies) and CHEMECO/DIWOOD (Colonization processes in CHEMosynthethic ECOsystems) EUROCORES EURODEEP). For our work we use the ROV QUEST owned by the Centre for Environmental Sciences (MARUM) at the University of Bremen. This 4000 m depth rated vehicle is equipped with several cameras including a very modern HDTV system, two manipulator arms and other scientific tools for deep-sea intervention.

On the 11 July „Polarstern" reached our most westerly station of this campaign in the Molloy Deep, a 5600 m deep depression in Fram Strait, our deepest Hausgarten station. Here we sampled the water column and the deep-sea sediments by means of CTD, water sampler and multicorer at different water depths along an easterly course towards Hausgarten central station. On Monday morning a free falling lander was ready for deployment there and is now doing it's pre-programmed mission over the coming twelve months. Scientists of the new EU project HYPOX are joining the cruise to continue long term oxygen measurements at the "Hausgarten". Although the water column is far from hypoxia, the "Hausgarten" was selected as one of the HYPOX observatories: Previous oxygen data seemed to indicate a significant decline of oxygen concentrations in the bottom water that may be related to climate induced changes in deep water formation in the North Atlantic - Arctic Ocean transition. Within HYPOX, research related to dynamics in oxygen concentrations and fluxes in the Arctic will be fostered by adding long-term optode oxygen sensors to moorings, and by additional measurements of various oxygen consumption parameters in the water column and sediments. The techniques applied include in situ chamber incubations and microprofiling as well as flux measurements in retrieved cores (Figure 10 and 11).

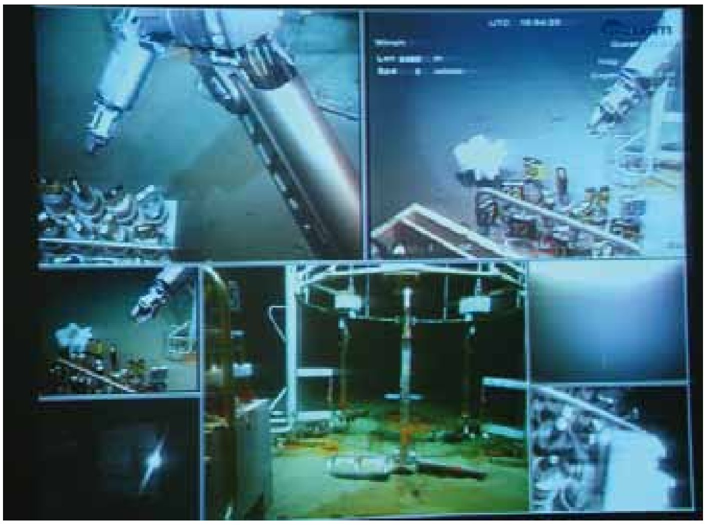

Fig.11 - Viewing from the underwater camera

Fig.12 - The Hypox Lander

At 2500 m water depth the ROV QUEST was used to take samples around different experiments, which were initiated last year. These investigate the responses of benthic communities to different disturbance scenarios. We managed to look at changes in biomass, diversity, and remineralization rates using the ROV three times this week.

On Wednesday we reached our northernmost station at 79° 44´ N and 4° 30' E. We had to release a 2.5 km long mooring at this location from an area widely covered by ice floes. Unfortunately our mooring was trapped in the ice and moved away in southern direction with the drifting ice. After several hours we finally succeeded to localize the ice floe under which the releaser unit was supposed to be and "Polarstern" crushed this one into two big pieces.

Fig.13 - The oxygen microprocessor

Seconds later one of the orange floating units popped up and we were able to pick this end of the mooring to safely recover the entire array. We were more than happy about this final result of our efforts because all measurement devices worked properly over the past twelve months, and both sediment traps (one attached close below the sea surface the other close to the seafloor at 2500 m water depth) collected sinking particles over the entire deployment period. We have finished our research activities for 2009 at Hausgarten observatory on Sunday afternoon 19 July to start our 430 miles long transit to the Hakon Mosby Mud Volcano, for the ESONET demonstation mission LOOME.

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ARK XXIV/2 [26.07. – 02.08.2009]

3. Weekly Report

Last days at Håkon Mosby and the return voyage begins !

Fig.14 - The ROV QUEST release

The last week onboard ! But again wind and waves influenced our station work. After safe recovery of the ROV QUEST on Sunday noon, another dive was impossible due to wind speed of 6-7 Beaufort. Instead we deployed the temperature lance which had been recovered the week before for another one year period in the center of the Håkon Mosby. Afterwards the lift system „Colossus" (this name has been given because of it's enormous dimension and weight) was lowered to the seafloor in preparation of the scheduled next dive of the ROV. Monday afternoon QUEST was deployed because wind and sea – state had significantly decreased. During the night numerous samples were taken and instruments placed at the seafloor.
Early in the morning a piezometer, measuring pore water pressure in the sediments, which had been deployed the year before by the Norwegian research vessel "Jan Mayen", was fortunately localized by the ROV pilots. The subequent recovery was supported by relatively calm sea-state. However, not only our French colleagues from IFREMER were more

than happy that this expensive device was back onboard. Tuesday afternoon the Autonomous Underwater Vehicle

Fig.15 - Alfred Wagener Institute AUV recovery

(AUV) of AWI (Figure 15)*, equipped with a newly developed water sampler system was launched. Although the planned mission had still the characteristics of a sea trial the launch and recovery procedures had considerably improved through various discussions between scientists and crew so that a very good mission followed. In contrast to underwater vehicles like the ROV QUEST AUVs are independet from the surface vessel after deployment. They are self-propelled, have their own batteries and a pre-programmed mission file in their control computer. Because they have to react autonomously once underway these systems are rather complex and each mission is always a challenge for the vehicle and the operators. After receiving sufficient GPS information about it's actual position the vehicle started to dive to a water depth of 500 m which needed approximately 15 minutes. At this depth the water sampler started to collect discrete samples along a straight transect towards the final waypoint where the AUV started to ascend. All systems did work properly so that scientists and engineers of the AUV team were eager to launch a second mission immediately afterwards, but unfortunately we had no time slot to be allocated as a reserve for such additional station work.*

Instead the lift system was lowered for the last time during our cruise leg, the ROV QUEST followed afterward. While the final tasks were done at 1250 m water depth, we expected the Norwegian research vessel „Jan Mayen" which made a brief stop-over on her way from Longyearbyen to Tromsø. The scientists onboard had to release an ocean bottom seismometer (OBS) which was deployed last year at Håkon Mosby. This work was a further contribution of the University of Tromsø as partner institution in ESONET to the LOOME demonstration mission. This meeting was planned and organised long before we started our cruise leg so that neither the master of „Polarstern" nor the chief scientist were excited about a vessel at such close distance to our position which we could not leave because the ROV was still at depth. However, such meetings at high sea occur relatively seldom, thus the radar systems of „Polarstern" classified the „Jan Mayen" as a „dangerous target" because of her comparatively close distance to us. The release command had been sent to the OBS by our Norwegian colleagues and soon after the orange floating unit was seighted by the seaman on watch onboard „Polarstern" at first. The device was than safely recovered and the collected seismometer data stored on shipboard computer.

Wednesday morning the OBS had been re-deployed at a position proposed by the LOOME coordinator onboard „Polarstern". Afterwards the „Jan Mayen" continued her transit to Tromsø and after a while her silhouette disappeared at the horizon and we were alone again at the Håkon Mosby Mud Volcano.

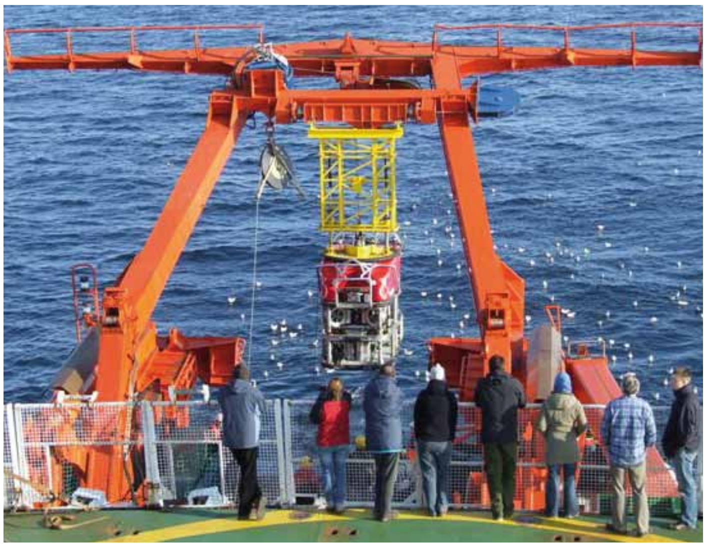
In the meantime we did not count days but remaining hours of station time during our cruise leg. The very last activites were the recovery of a free falling lander, a final CTD cast and another temperature lance transect to further improve our knowledge about the heat regime of this active mud volcano. On Thursday morning at 2 o'clock the Temperature-lance was back on the main working deck and our station work formally closed. We immediately started our transit to Reykjavik with southwesterly course. All onboard are actually packing their scientific equipment, stowing it into containers and starting to clean-up their laboratories and cabins.

We will arrive on Monday morning the 3rd of August at the bunker pier of the harbour of Reykjavik to take over some hundred tons of fuel for the coming cruise leg of „Polarstern". Afterwards we will move to our regular berth at Skavabaken until „Polarstern" will leave at the 5th of August for her last cruise leg into the Arctic for 2009.

Most of us – crew and scientists – will return home either on 4th or 5th of August. All of us are looking forward to meet our families and friends – we have a lot to talk about !

On behalf of all scientists, engineers, technicians and students onboard I would like to thank the master of „Polarstern" and his crew for all their competent help and assistance during this cruise leg !

Michael Klages (Cruise Leader)



LOOME

ESONET DEMONSTRATION MISSION

10-07-09 to 02-08-09
Dirk de Beer, LOOME team coordinator*
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Long-term Observatory On Mud-volcano Eruptions

A demonstration mission to establish a long term observatory on a methane emitting deep-sea mud volcano.

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Introduction

LOOME DM is a networking action for the long-term observation of a major site of methane emission from the deep European margin, the Håkon Mosby mud volcano (HMMV). The HMMV is a cold seep ecosystem located at a water depth of 1250 m on the SW Barents Sea slope off Norway, in an area with a history of seabed slides and tsunamis, and under exploitation for hydrocarbon resources and fisheries. The Barents Sea slope is a target area for sustainable management and monitoring of global change effects. Previous work of the partners at HMMV yielded evidence of several eruptive events, indicated by strong gas ebullition and abrupt temperature changes of almost 10°C within a few days. High-resolution bathymetric maps and video observations of the seafloor before and after this event clearly showed changes in the morphology of HMMV. Only by detailed continuous observations, recording a wide variety of parameters, we can learn about the mechanics of such eruptions and their early signals, estimate the amount of gas released and the consequences for
geochemistry and local communities as well as for seafloor stability, which are main scientific objectives.
Furthermore, methane is a powerful greenhouse gas and therefore the global budgeting of sources and sinks is of great importance. Searches for marine sources of methane are focused on deep-sea seepage through mud volcanoes and gas hydrate bearing sediments (Figure 19). It is thought that in these areas most methane transported towards the oxic biosphere is removed by anaerobic methane oxidation coupled to sulfate reduction (1-3, 5, 6). The efficiency of methane transport and oxidation in the seafloor are, however, still poorly constrained due to lack of understanding of the controlling factors. Special conditions, for example by high pore water flow or gas ebullition by excessive methane accumulation, enable the methane to escape up through the sulfate barrier (4).

Ecology and Transport

Liquefied mud, gas, and geofluids rising from a depth of at least three kilometers, form a highly active mud volcano withpermanent gas emission. The Haakon Mosby is ca 1200 m in diameter, has max 10 m height and consists of several more or less concentric habitats. It is a site of unique chemoautrophically driven faunal and microbial communities, fuelled by the oxidation of methane by sulfate and further oxydation of sulfide by oxygen and nitrate. An outer hummocky area of ca 300 m width is shaped by gas hydrates, and covered with Pogonophora worms. Gray bacterial mats occur above highly gassy sediment patches where hydrates have eroded. Further towards the center one finds large mats of Beggiatoa, large filamentous bacteria that oxidise sulfide with oxygen or nitrate.

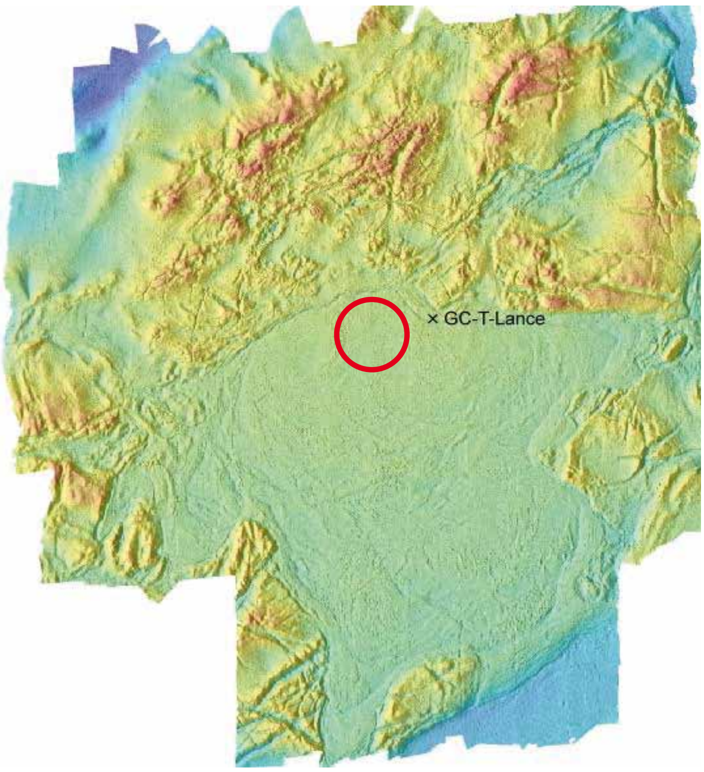


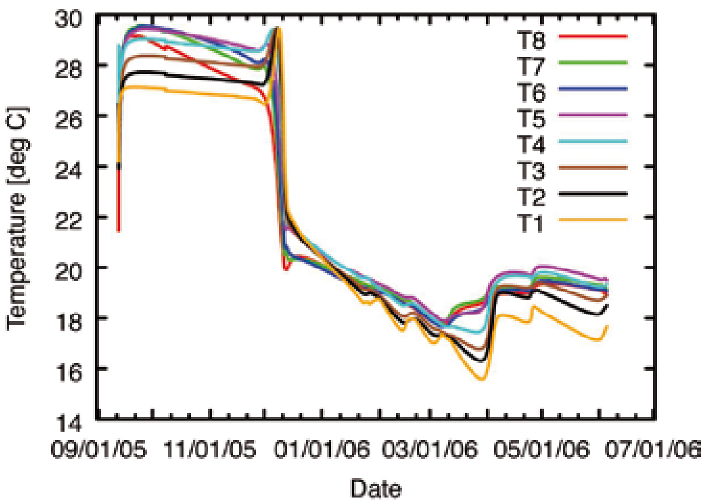
Fig. 16 - Hot spot area. Microbathymetric map from 2006 (Source IFREMER), with a 10 times higher resolution. The hot center is indicated with a red circle. The X indicates the position of the graviticorer with attached temperature probes.

The center is flat and consists of gray mud. Here the highest flow velocities occur, that gradually decrease outwards, and are probably close to zero in the hydrate zone. This ecological structure can be understood from the differences in porewater seepage (2).

The higher flow velocities in the center are reflected in the higher surface temperatures, and more specifically, in steeper near surface temperature gradients. A detailed study using temperature probes, showed that the steepest gradients, and thus the highest upflow velocities, are present in an area of ca 80 m in diameter near the north side of the central area, characterized by highly disturbed, gas saturated sediments.

We obtained evidence from a year long temperature record, that the HMMV is not in a continuously seeping vent. In December 2005 and April 2006 drastic temperature changes were observed, occurring in one day. These spectacular phenomena show that the center of the HMMV is active and has irregular eruptions. The disturbance caused by these eruptions will affect biogeochemistry and local fauna. Thus the ecological zones can be understood from a steady state model and from temporal local perturbations. To assess which phenomena are the dominant shaping factors is fascinating from fundamental scientific point of view.

The site forms thus a natural laboratory for ecologists and geologists. It was selected to be included in the Norwegian Margin cable network. The HMMV is a priority target within the ESONET/EMSO project, and a key site of the EU projects HERMES/HERMIONE, MARBEF as well as the ESF EuroDeep program CHEMECO.



The Observatory

We proposed LOOME as demonstration mission within ESONET, to deploy a long term observatory with a large variety of sensors to prepare for a node connected measuring system. In 2008 we were granted k□300 as encouraging support for this plan, totaling k€1300. The scientific aims of LOOME are to document physico-chemical phenomena before, during and after an eruption, and to study its effects on gas hydrate stability, seafloor morphology, geochemistry and the distribution and colonization patterns of benthic communities.. The technological aims are to integrate many sensors and to define best parameters for further long term observation of mud volcanism, to optimize integrated ways of underwater data storage and retrieval, and to develop technology for wake up calls.
We aimed for a combination of sensors that measure

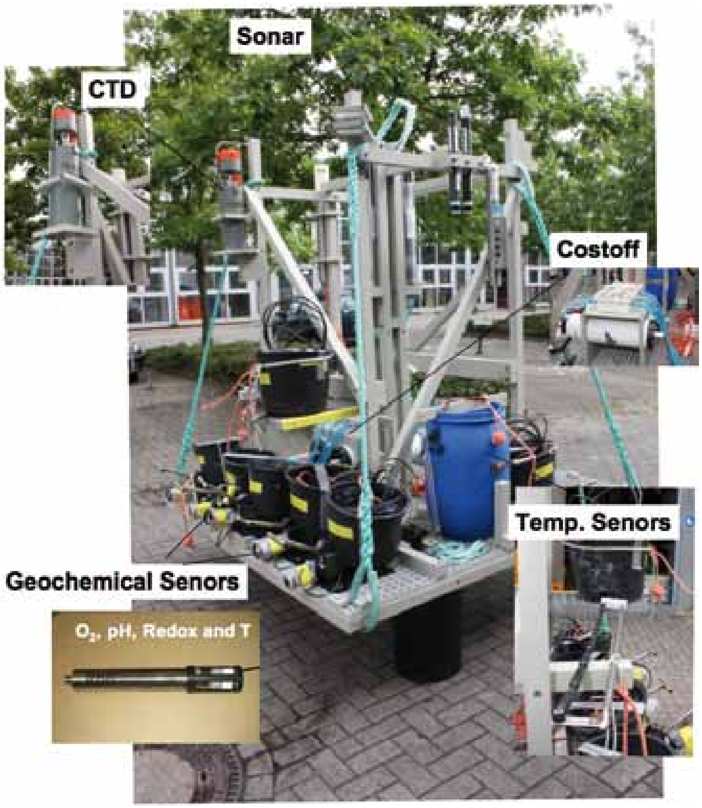


Fig.17 - LOOME in Bremen

phenomena deep into the volcano, at the surface and in the water column. Moreover, as the system must be autonomous, the boundary conditions for the choice of sensors were determined by data storage and power consumption. Most essential is that a possible eruption would not result in data loss, therefore all data measured at the eruption site will be stored in the frame of the LOOME observatory on a safe adjacent location 15 m away from the hot spot.

First Installations in 2008

In autumn 2008 the first autonomous moorings were deployed by a joint mission of the University of Tromso and IFREMER with RV Jan Mayen (Norway). The moorings included an OBS system, a temperature lance and a piezometer. These moorings were recovered during our recent expedition with POLARSTERN (ARK XXIV-2, 10.07.09 – 04.07.09) and redeployed (Figure 18).
The frame of LOOME (Figure 17 and 23) is constructed

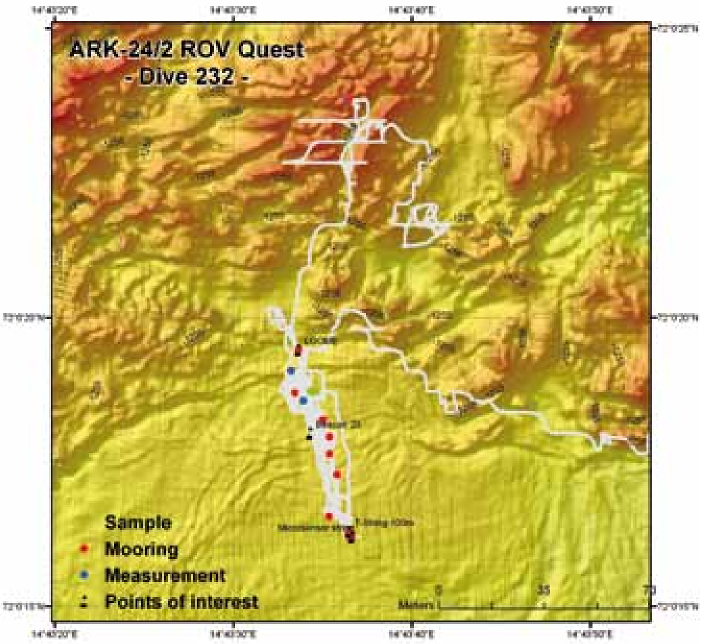


Fig.18 - map of LOOME and sensor strings

of light weight non-corrosive and flexible materials. It can be recovered autonomously or by ROV. Summarizing the LOOME observatory measuring from depth to watercolumn:

The sensors measuring in depth are a Ocean Bottom Seismometer (OBS), a 8 m piezometer, and a T-lance of 13 m.
1) The OBS measures acoustics from the seafloor. The sounds from the seafloor are corrected with the sounds from the water column to obtain a clear image of the geosounds indicating seismic activity of the mud volcano. The data should give an early warning of an eruptive event.
2) The piezometer measures subtle changes in porewater pressure, thus indicative for changed porewater flow.
3) The T-lance will measure changes in the temperature profile, induced by changed porewater movement.

Fig.19 - Sampling the gas hydrate field

At the seafloor we will measure with a series of chemosensors and T-strings across the hot spot, and a 1 m T-lance in the middle of the hot spot (Figure 26).
1) The chemosensors are 6 units each measuring pH, DO and ORP. We hope to detect increased upward flow of the acidic, anoxic and low ORP porewater.
2) The T-string includes 24 thermometers, laid out across the hot spot. With these strings we hope to obtain a picture on the dynamics of surface phenomena.

In the water column we measure with three CTDs (conductivity, T, salinity, turbidity) mounted at the bottom, middle and top of the frame of LOOME, and a scanning sonar (Figure 17 and 20).
1) With the two CTDs we hope to detect the vertical extent of the effect of the seismic activity of the active site.
2) With the sonar we will detect gas flares up to a distance of 300 m, and can quantify the emissions to a distance of 50 m. The power consumption of the sonar and the data storage capacities do not allow the sonar to operate at sufficient intensity during 1 year, thus the sonar will switch on and off automatically.

Sensors:

- **Water column**
  - **2.5m above seafloor:**
    gas flare imaging
    current speed + direction
    Oxygen, Conductivity, Turbidity, Temp.
  - **1.5m above seafloor:**
    Conductivity, Temp.
  - **0.5m above seafloor:**
    Oxygen, Conductivity, Temp.
- **Sediment surface**
  - **Geochemical Sensors (O_2, pH, Redox, T) as 17, 34, 50, 67, 89 and 100m strings**
  - **Temperature-chain with 24 surface T-logger**
  - **Temperature string (60m) with short T-lance (8 T-logger**

As a first step towards the integration of these various sensors into an observatory, some of them are connected to a COSTOF (Communication and Storage Front-end), a low-power consumption modular electronic unit that provides the following services: synchronization of the measurement data with a common clock, local duplication of some sensor data and a common access channel to all connected sensors via a CLSI (Contact-Less Serial Interface) allowing the installing ROV to fine-tune and check the functioning of the sensors on the seabed. First, the COSTOF was planned to be used to trigger the activation of the sonar for 24 hours when an eruption is predicted. This is done by running an algorithm that analyses the T-lance data as and when acquired, to predict the occurrence of an eruption. The prediction algorithm was developed on the base of past temperature data series analysis. Unfortunately, the sonar crashed, could be repaired, but can no longer communicate with COSTOF, and is now programmed to record autonomously 23 scans every 12 hours. We expect still interesting data.

Fig. 20 - LOOME just before deployment, left panel, Backside with central data storage, CLSI (funnel) and Costof, right photo: front side with T and chemosensor strings, sonar and CTD. The white blocks are flotation material.

Finally, 10 m away from the LOOME frame we positioned an autonomous camera that will at regular intervals takes video streams of gas bubble emissions from the fresh mud flow and the local fauna browsing bacterial mats.

In summary, the OBS, the 8 m piezometer, the 10 m T-lance and the camera are autonomous devices positioned near the hot spot. They are deployed and recovered separate from LOOME. The surface chemo and T sensors, the CTDs and sonar are connected to or placed on LOOME, and all data will be stored on LOOME. The T-sensors are integrated by COSTOF (Figure 21).

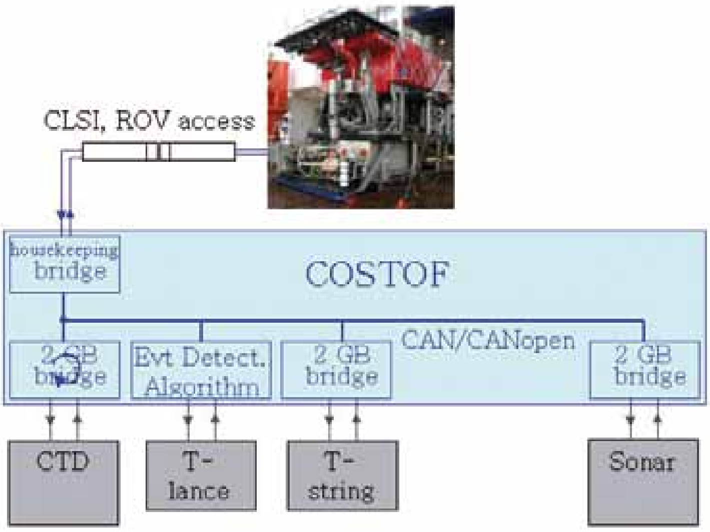


Fig. 21 -Costof implementation on the Loome observatory

In this preliminary report we can already present the first Thomas Feseker's data from the T-string of 100m long, with 24 sensors, on 3 hot spots (Figure 22).

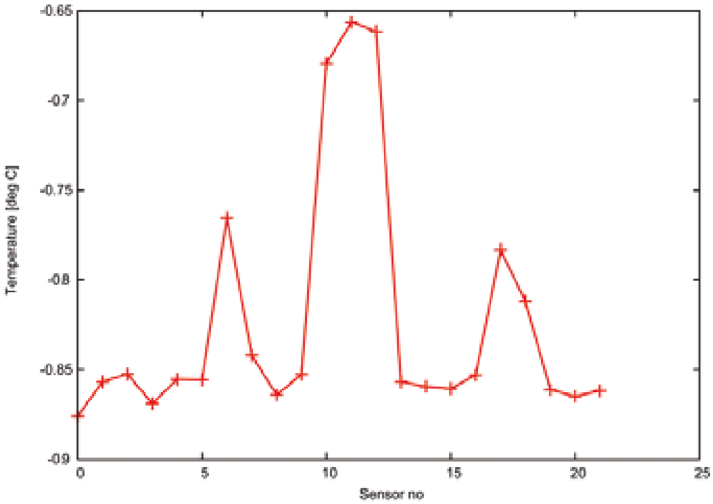


Fig. 22 - 1st data from LOOME, shortly after deployment.

Deployment and recovery

Deployment took place during the ARK-XXIV/2 FS Polarstern cruise (cruise leader M. Klages) in July 2009 using the ROV QUEST4000 of MARUM (Figure 14). LOOME was lowered to the seafloor by winch, and accurately positioned by the ROV Quest after the release of its deployment weights. We had chosen a stable sedimentary environment ca. 20 m away from the hotspot confirmed earlier by online T lance measurements from the ship. The ROV then positioned the sensors across the area of interest (Figures 24a, 24b and 25), from the temperature hotspot towards the edge of the most recent mud flow (close to the geographic center).

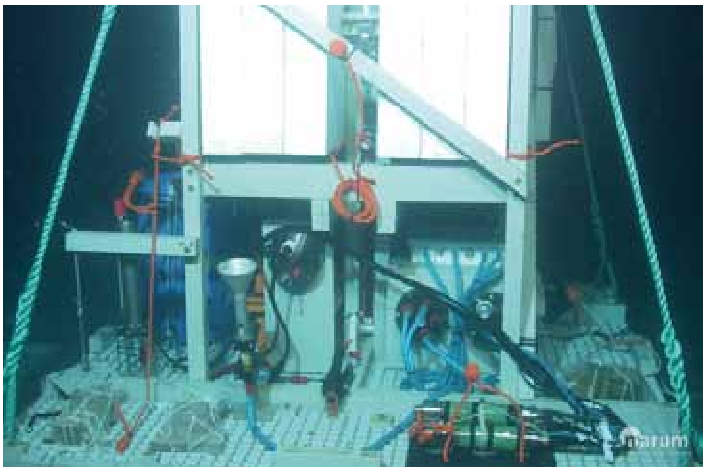


Fig. 23 - LOOME underwater view

Via CSLI the functioning of COSTOF, the T-sensors and the camera AIM was recorded and final program optimizations were made. The deployment was a complex operation that went fully according to plan. The CSLI was also used to optimally position the camera, which has been placed facing a bubble stream and abundant fauna (Ifremer Camera). Also there first temperature data were obtained. Recovery of LOOME, OBS and the T-lance will occur in autumn 2010, by a cruise with the FS Merian. The deployment of the long P- and T-lances was done by winch, and recovery was aided by the ROV, to hook on the ships winch.

Fig. 24a - Photos of deployment, UW photos of LOOME, made by ROV Quest, MARUM (Bremen, Germany).

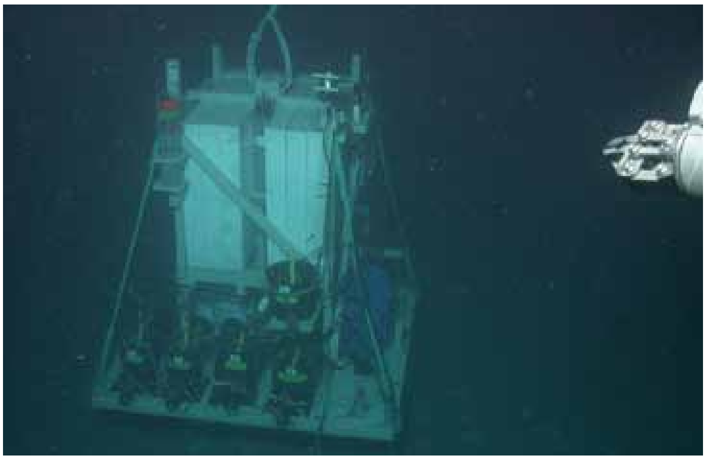


Fig. 24b - Photos of deployment, UW photos of LOOME, made by ROV Quest, MARUM (Bremen, Germany).

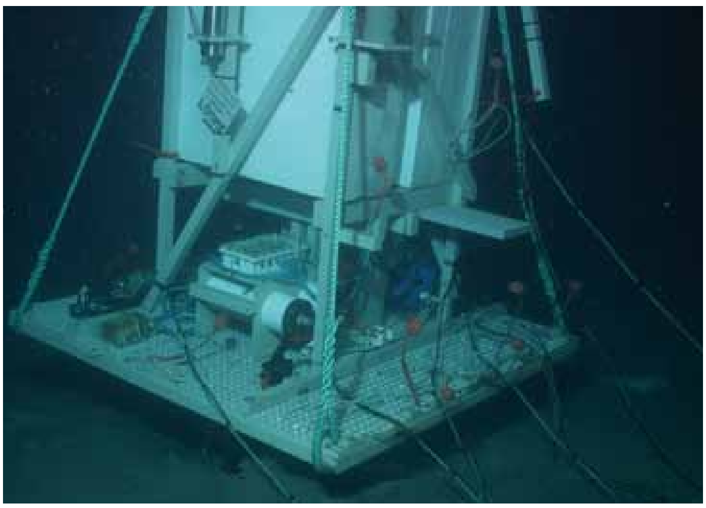


Fig. 25 - LOOME

On the Hakon Mosby we encountered the RV Jan Mayen, with our LOOME partner Jürgen Mienert as chief scientist, who recovered and redeployed the ocean bottom seismometer (OBS). The OBS was redeployed at the ideal position, at the edge of the most active area.

Fig. 26 - Hot spot sampling

Further Literature

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Debriefing of the VISO Workshop

ESONET and EMSO collaborate on long-term ocean observation from the Arctic to the Black Sea to better understand the processes driven by climate change. Over 80 scientists and engineers from around the world and from major marine research stake-holders, including industries, directly or indirectly related to deep-sea observatories, gathered for a workshop in Tromsø (Norway) on June 11-12, 2009, organized by the Department of Geology (University of Tromsø). The objective was to provide the planned marine large scale infrastructure, partner countries and interested organizations – such as fisheries and hydrocarbon industry – with strategies for ensuring the durability of observatory data.
The group discussions highlighted the urgent need to understand the effect of the climate change on the ocean which is turning more acidic, minimum oxygen zones that are expanding and anoxic dead zones that are appearing in formally rich fishing place, threatening ocean health and the ability of earth to support human life. The lack of deep-sea observations needs to be fulfilled, especially for decision makers trying to find better way to communicate with end-users. The education issue is also essential, with an increasing need of training of specialists with environmental background.
VISO will be a useful structure to interact with industry through the ESONET-EMSO community, and will also link ocean scientists and engineers into an international team. VISO will be a way to disseminate methods and equipment outside Europe (e.g. African zones, Indian Ocean, etc.) and to identify locations for observatories where the system installed satisfies the needs of industry as well as science. *(Bénédicte Férré)*

ESONET MARMARA-DM Training Course

Training course on "Seafloor Observatory Techniques for Marine Geohazard Monitoring" was held in Istanbul during 18-19 August 2009. The course followed a one-day symposium on "An overview of the research in the Sea of Marmara region over the last 10 years", on the 10th Anniversary of 17 August 1999 Izmit Earthquakes. More than 50 engineers and scientists from marine research institutes, and related governmental and private organizations participated. A total of 14 lectures was presented by different experts. The course was ended with a final exercise/discussion session involving participants and instructors. The symposium and the course were extensively covered by the Turkish media. The course programme, abstracts and presentations can be found at http://www.esonet.marmara-dm.itu.edu.tr/ under "ESONET Training Course". *(Namik Çagatai)*

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