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ESONET News
European observe the deep sea

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Project Coordinator: Roland PERSON
Coordinator organisation name: IFREMER, France
Work Package #6
Networking Participant #1 and #23
Lead Authors: Roland PERSON (Ifremer)
Jorge Miguel MIRANDA (FFCUL)

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EXECUTIVE SUMMARY

The issues of ESONews were planned for month 26, 29 and 32 of ESONET project, meaning three issues during the third year of the project. Two issues were gathered in one volume.

The content reflects the life of the Network of Excellence through the Demonstration Missions.

The issue due on month 35 is slightly delayed. An effort is made by the WP6 leader and the PESOS group to promote the insertion of equipment description by European SMEs in the next issues.
I. Introduction

Hydrothermal circulation at mid-ocean ridges is a fundamental process that impacts the transfer of energy and matter from the interior of the Earth to the crust, hydrosphere and biosphere. The unique faunal communities that develop near these vents are sustained by chemosynthetic microorganisms that use the chemicals in the hot fluids as a source of energy. Environmental instability resulting from active mid-ocean ridge processes can create changes in the flux, composition and temperature of emitted hydrothermal fluids and thus influence the structure of hydrothermal communities. Approximately 10 years ago, the InterRidge Program initiated the MoMAR project (Monitoring the Mid-Atlantic Ridge) to promote and coordinate long-term multidisciplinary monitoring of hydrothermal vents on the Mid-Atlantic Ridge (Figure 1a). The goal of this multidisciplinary project is to study vent environmental dynamics from geophysics to microbiology. In 2006, this area was chosen as one of the 11 key sites of the ESONET NoE (coordinator: R. Person, Ifremer).

In 2008, a MoMAR/D proposal (PI’s: Sarradin, PM, Ifremer; Colaço, A., University of Azores) was submitted to the ESONET committee as a candidate demonstration mission in the frame of WP 4. This project was selected and granted 500k€ to deploy and manage a multidisciplinary observing system at Lucky Strike vent field during one year (Figure 1b). This large hydrothermal field is the focus of several pluridisciplinary studies since the mid-90’s. It is located in the center of one of the most volcanically active segment of the MAR.

The scientific objectives of the MoMAR/D proposal are to link the temporal variability of active processes such as hydrothermalism, volcanism, seismicity and ground deformation to better understand the dynamics of mid-ocean ridge hydrothermal systems and their impacts on the faunal assemblages. To achieve this, the challenge is to deploy a multidisciplinary observing system, with satellite connection to shore, and to demonstrate its management during 12 months.
The SEAMON technology (Blandin & Rolin 2005) will be used on two nodes acoustically linked to a surface buoy which will ensure satellite communication to a land base station at Ifremer, Brest center. The first node will be dedicated to large scale geophysical studies and will be moored in the center of the Lucky Strike lava lake. The second node will be deployed at the base of the Tour Eiffel edifice to study the links between faunal dynamics and physico-chemical factors. Temperature probes will be moored on the buoy line to give insights on the local water circulation.

2. Description of the operational system

The MoMAR/D experimental design combines autonomous instruments which will store data over the duration of the mission (1 year), and instruments that will be connected to shore via the SEAMON system.

2.1 The SEAMON / BOREL technology

The SEAMON system includes a set of long-term, non-cabled sub-sea observatory components, initially developed by Ifremer during the EU ASSEM project (2002-2004). These components have since been upgraded and made more reliable. SEAMON is the generic name of the seabed stations serving a local set of sensors, whereas BOREL (Bouée relais) is the surface data transmission relay. The SEAMON stations are rated for 4000 mwd operations and each node can provide 8 kWh, allowing for the sensors operation and for a daily data transmission of ca. 40 – 400 kbytes. The main components of SEAMON include:

a. **COSTOF** (Communication and Storage Front-end). This electronic unit serves a set of local sensors by providing them with data storage, communication channels and optionally energy. COSTOF communicates with the ROV via CLSI (see below), and the BOREL buoy via acoustic modems. The COSTOF robustness and modularity rely on the use of a low power field bus (CAN) linking a set of simple identical boards, each board devoted to one sensor. The measurement sequencing is left to each sensor to insure that a COSTOF failure does not prevent data acquisition at the sensor level. Conversely, data duplication at the COSTOF level is a safety factor in case of sensor damage. SEAMON can duplicate this data storage for a volume up to 2 Gbytes per year.

b. **CLSI** (Contact-Less Serial Interface) is a small device made of two parts, allowing serial communication between two units, without electrical connection. If one part is connected to a ROV, and the other part to the COSTOF, communication can be established between the ROV and any connected sensor. This methodology will be used after deployment to check or fine tune a sensor functioning before the ROV leaves the area.

c. **A BOREL buoy** – This buoy is the data transmission relay between the SEAMON seabed stations and the Iridium satellite constellation (Figure 2). It is moored within acoustic range of the SEAMON stations and is composed of two identical independent data transmission channels. Channel 2 can be activated from shore in case of a failure of channel 1. Each data transmission channel is powered independently and comprises an acoustic modem, control electronics and an Iridium modem. The communication is bi-directional and BOREL supports three data transmission modes: periodic (typical rate 6 hours), triggered by events detected on the seabed, and triggered from shore. BOREL has now been used for two years in the Mediterranean Sea, where it was moored at 2000 m depth. The Mediterranean mooring will be modified for MoMAR/D to take into account the sea conditions prevailing in the mid-Atlantic ocean. Its position and the local sea/wind state will be monitored throughout the experiment. The robustness of this mooring is clearly one of the technical challenges of the MoMAR/D experiment.
2.2 Acoustic data transmission

For five years now, successive SEAMON/BOREL systems have been using the same type of acoustic modems. Their reliability has now reached a satisfying level, but their energy requirement per transmitted bit (a key parameter for non-cabled observatories) can probably be significantly lowered. Ifremer is currently working on this issue. This work started in 2007 with a selection of five modems available on the world market. Among the selection criteria, the lowest energy necessary to transmit 1 bit at a given distance was sought. In 2008, three of these five modems were tested at sea, between a sub-sea station at a depth of 2200 m, and the research vessel L’Europe. This test demonstrated that the more recent modems required at least 15 times less energy to transmit one bit than the ones used on SEAMON until now.

Longer term tests of the two best modems are planned in 2009, between the 2200 m-deep subsea station and a relay buoy. The MoMARSAT experiment will directly benefit from these improvements. Only a subset of data will be periodically transmitted to shore via the BOREL buoy. The subsampling step will be designed specifically for each sensor. Simple subsampling operations can be performed by SEAMON such as temporal subsampling, simple statistics or thresholding (Figure 3).

2.3 Location and configuration of the nodes

Two SEAMON nodes will be deployed in the Lucky Strike vent field. The BOREL buoy will be moored at acoustic range of the 2 nodes, on the volcano heights. The geophysical node (Seamon Ouest) will be moored in the lava lake on a flat surface. The photomosaic of the area obtained by Escartin et al. (2008) will be helpful to find a convenient place. Finally, the ecological node (Seamon Est) will be located at the base of the Tour Eiffel active edifice, to continue the study started by the TEMPO module in 2006 (Sarrazin et al. 2007, Figure 4).
SEAMON-Ouest will be primarily devoted to thematic experiments 1 (Seismicity and hydrothermal activity) and 2 (Seafloor deformation). It will connect the pressure probe and one OBS. This second node will be moored in the western part of the lava lake, near the present location of the pressure probe installed since 2006.

2.4 Underwater connection devices

To ease the deployment, the OBS will be connected to SEAMON underwater using a low cost connection device (CdC,) specially developed and validated during the ASSEM project (Figure 5).

2.5 Data storage

Each connected sensor will independently store data over the 12 months duration of the project. When possible (volume < than 2Gbytes per year), the data storage will be duplicated by SEAMON. The Ecology package (TEMPO) and the pressure gauge have already tested operational SEAMON connections. Development will be carried out for the connected OBS (IPGP), the NOCS chemical flow analyzer and the CTD/ADCP mooring. Other sensors will be deployed as autonomous instruments, storing data that will be recovered at the end of the 1 year experiment.

2.6 Biofouling

Biofouling is a major issue in the vent ecosystem. Biofilms form on every available surfaces and trap the mineral particles emitted by the hot fluids. The method used successfully for preventing bio-fouling on the lens of the TEMPO video camera and on an Aanderaa oxygen optode relies on localized microchlorination (Exomar, 2005 and MoMARETO, 2006 cruises). This method does not modify the image, and the concentrations of chemicals released are negligible.

3. The sensors

The project relies on the mooring of various sensors to acquire time series related to the seismic activity of the system, floor deformation, chemical fluxes, faunal dynamics and physical oceanography. Part of the sensors will be connected to the SEAMON nodes and will transmit a subset of data to the BOREL buoy and the DMAS on shore. The complete data set will be stored in the sensors and in SEAMON when possible. The other sensors will be used in an autonomous mode. The complete set of data will be downloaded at the end of the experiment when the sensors are recovered. All the sensors will be synchronized at the beginning of the experiment. The drift will be measured after the recovery of each sensor against the GPS clock.

4. Planning

The project planning is described in Figure 6. The instruments adaptation phase correspond to the modification of the instruments prior to their connection to SEAMON. The SEAMON adaptation phase will allow the development of specific drivers for each instrument. During the instruments integration to SEAMON, the sensors will be integrated (mechanically and electrically) to SEAMON. The system test will be performed on shore using the complete system: from the sensor to the DMAS. Ultimately, the MoMAR/D observatory should be deployed in 2010 during the MoMARSAT cruise (PI’s: Cannat, M, Blandin, J., Sarradin, PM).

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Fig.6 - Planning of the development and integration of the MoMAR/D observatory on the Lucky Strike vent field in 2010.
5. Recent news

A first meeting took place in Brest March 18-19 and gathered engineers and scientists from 4 different European countries (France, Germany, Portugal, United Kingdom). The objectives of this meeting were to present the scientific objectives of the different participants, to plan the land integration and trials of the instruments in Brest (coordinator: J. Blandin) and finally, to work on the communication plan and data management policy. The next “rendez-vous” is given in Brest next fall.

References


ESONEWS - Spring 2009


J. Sarrazin, responsible for the MoMAR/D communication plan

MARMARA-DM PROJECT

A demonstration mission to establish a deep sea observatory, with emphasis on fluid and seismic activity interaction, in a major transform plate boundary

Namik Çagatay, Louis Gelli and MARMARA-DM team

Fig. 1 - Map the Sea of Marmara, based on the bathymetry collected by Le Pichon et al. (2000). Red stars indicate the 5 cabled seafloor observatories that are planned to be deployed in 2009 by KOERI as part of the Turkish national seismological network. observatories to monitor fluids and seismicity within the ESONET MARMARA-DM project. Yellow stars indicate those sites selected for implementing multi-disciplinary seafloor.

Scope and Objective

Marmara-Demonstration Mission (DM) project, funded by the ESONET-NoE, aims at collecting long-term multi-disciplinary data in the Sea of Marmara (SOM), with special emphasis on the fluid- and seismic-activity interactions. The ultimate objective of the project is to establish the most suitable sites and parameters for permanent multi-disciplinary earthquake observatories in the SOM.

Geohazard Risks

The SOM is located on the North Anatolian Fault (NAF) zone in NW Turkey, a major transform-plate boundary that has produced devastating historical earthquakes along its 1600 km length (Ambraseys & Jackson, 2000). After the 1999 Izmit and Düzce earthquakes, the next large (Mw>7) earthquake is expected in the SOM close to Istanbul, an important cultural centre and a mega-metropole with 15 million inhabitants (Parsons, 2004). The SOM has three ~1250 m-deep strike-slip basins that are separated by NE-trending transpressional highs (Fig. 1). The slopes leading to the deep basins are steep (>18°) with unstable areas on the upper slope that may slide during future seismic events. The future earthquake and tsunami (Yalçın et al., 2002) hazards would have devastating effect not only in Istanbul, but also in the whole of the SOM coastal areas in which more than Turkey’s 20% population and 50% of industry are located. Hence, the high tectonic activity with geohazard risk, as well as the special oceanographic setting as a gateway between the Mediterranean and Black Seas, makes the SOM a natural laboratory for multidisciplinary seafloor observations for geohazards and oceanographic monitoring, with unique specificities concerning the relationship between fluids and seismicity.
Fluids and Seismicity

In the deeper parts of the SOM, fluid outflow sites manifested by carbonate crusts, black patches, and bacterial mats are commonly observed along or near active faults (Armitage et al., 2005; Zitter et al., 2008). Free gas emissions are common and appear to be influenced by earthquake occurrence. In the Gulf of Izmit, repeated surveys showed that the intensity of methane emissions increased after the August 17, 1999 earthquake (Alpar, 1999). The distribution of gas seeps in the main part of the SOM has been found to be unevenly distributed, with less activity on the linear fault segment crossing the Central High, which has not ruptured since 1766 (Gélí et al., 2008). In contrast, bubbling was observed above a buried transtensional fault zone along the southern edge of the Çınarcık Basin, which displayed micro-seismic activity after the 1999 events (Karabulut et al., 2002). While the hydrocarbon (HC) gases emitted from the Çınarcık basin is predominantly of relatively shallow origin, the gases expelled from faults cutting the highs are of deep thermal origin (Bourry et al., 2009).

Observatory Sites and Sensors

To determine whether there is a hydrogeologic connection between some gas seeps and the seismogenic zone, seafloor observatories with specific sensors, such as seismometers, flowmeters (Tryon et al., 2001), piezometers, acoustic stations for gas bubble monitoring and in-situ geochemical sensors, will be deployed at 4 selected sites.

- **Site 1** is located in the eastern Çınarcık Basin (Fig.1), which is presently affected by aseismic slip on faults resulting in extension rates of the order of 10^{-7} yr^{-1}, not accounted for by interseismic loading models (e.g., Ergintav et al., 2007).

- **Site 1a** is where active gas emission sites have been found during the 2000 and 2007 surveys, above a buried transtensional zone extending in the prolongation of the fault that ruptured during the 1999 İzmit earthquake (Figs. 1, 2a).

- **Site 1b** is located at the entrance of the Gulf of Izmit, where the principal deformation zone of the North Anatolian Fault is less than some tens of meters wide.

- **Site 1c** is located at the base of the northern escarpment of the Çınarcık Basin, where cold seeps were observed, near the base of a steep slope exposing cliffs of Paleozoic rocks (Fig.1).

- **Site 2** is located on the Central High, 15 km SW of Istanbul (Fig. 2). This site is situated on a fault segment constituting the “seismic gap” that did not rupture since at least 1766. There is little evidence for fluid emission along the fault itself, but there is thermal HC gas outflow from an anticlinal axis, a few km south of the main fault trace (Bourry et al., 2009). It is therefore of critical importance to deploy instruments such as seismometers and piezometers on top of the Central High and within the fault valley, in order to establish comparisons between these two different environments.

- **Site 3** is centered on the Western High, an area where gas hydrates have been discovered during the 2007 Marine Naut cruise onboard R/V L’Atalante (Bourry et al., 2009; Figs. 1, 2a, b, d). HC gases from this site have gas and isotopic compositions similar to those of the gases from the Thrace Basin. This suggests that that the fault is acting as a conduit for the transfer of gases from the deep HC reservoirs. Hence, this site is particularly suited to address the question on the hydrogeologic connection between the gas seeps and the seismogenic zone of the NAF.

- **Site 4** is located on a secondary fault at the base of the Ganos slope in the Tekirdağ Basin, where strong gas bubbling with 70% mantle helium (3He) and deep crustal seismicity are observed (Figs. 1, 2a,c; Burnard et al, 2008). Combined geochemical sampling and monitoring of gas flux and microseismicity is important at site 4.

Marine Operations

The following activities will be carried out under MARMARA-DM project:

- **a)** From August 23rd to October 2nd, 2009, site surveys will be conducted with R/V Le Suroit for micro-bathymetry (EM-2000) and acoustic bubble detection (EK-60) using an AUV at all sites. A 3D, high resolution seismics is planned at Site 2 and a prototype instrument for the acoustic monitoring of gas bubble emissions in the Çınarcık Basin.

- **b)** In September-October 2009, six piezometers and 10 short-period (4.5 Hz) OBSs will be deployed for 6 months (October 2009 – March 2010) with R/V Urania. The SN-4 station (Favali et al, 2006) will be deployed at Site 1b in the entrance of the Gulf of İzmit. SN-4 will be equipped with several sensors, including a broad-band, three-component seismometer and CONTROS-type methane sensor.

- **c)** An additional seismic site survey will be conducted at Site 3 with R/V Piri Reis in October 2009.

Other Activities

Other planned MARMARA-DM activities include:

KOERI Initiative

Marmara Sea Bottom Observatory (MSBO) project of by the Kandilli Observatory and Earthquake Research Institute (KOERI) is funded by the Turkish Telecom, independently of ESONET. It plans to deploy a total of 5 cabled seafloor observatories in the year 2009 (Fig. 1). The observatories will be operated by the Kandilli Observatory and Earthquake Research Institute (KOERI) as part of the Turkish national network for earthquake and tsunami hazards monitoring. The planned seafloor observatories consist of three-component broad band velocity sensor with a natural period of 360 s and digitizers, three component accelerometer, differential pressure meter, hydrophone, temperature meter, three-D current meter, camera, Flux Gate Compass and a tiltmeter sensor.

Each seabottom observatory will be connected to land by a fibre optic cable and be fully integrated to the land seismic network, providing capability for:

a) early warning of earthquake related tsunami,

b) detailed earthquake source studies and tomography of the source,

c) determination of the crustal structure,

d) highly accurate determination of the earthquake magnitude and epicentre,

e) reduction in the earthquake location treshold less than M=1.0,

f) determination of the source of noise and nature of deformation and faulting.

References


Fig.2a - Bathymetric map of the Sea of Marmara and active fault trace over a Landsat image of the area. The Nautilie dive sites explored during Marnaut are shown in red dots where fluid seepage were observed, and in white dots otherwise. Numbers refer to dive sites and follow the definition of dive targets in the cruise plan.

http://cdf.u-3mrs.fr/~henry/marmara/marnaut_web/meeting1.html
Fig.2b - Bacterial mat (white) and polychaetes tubes colonizing black sulphidic sediments.

Fig.2c - Mantle He bubbling from tensional fracture, western Tekirdağ Basin

Fig.2d - Gas Hydrate burning on ship deck, which was recovered from Kullenberg core located on Western High
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:

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 downloaded 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

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![Fig.1 - T-Lance](Image)
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.

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.

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 disappears, 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 chemautotrophic 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 system, and a digital data recorder in a separate pressure case. A hydrophone and a 3-component geophone 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.

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 PC-MCIA 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 1 Hz 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
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.

**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**

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<th>Specification</th>
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<td>Maximum in situ fluid pressure at measurement site</td>
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<tr>
<td>Resolution</td>
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<td>Cumulated repeatability, hysteresis, non-linearity</td>
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**Temperature sensor:**

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<tr>
<td>Resolution</td>
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</tbody>
</table>

**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
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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.

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

Acknowledgements

We are grateful to the captain and the crew of RV Jan Mayen for their support during the 1st phase of the ESONET LOOME seafloor observatory deployment. We thank Benedicte Ferre for her review and revision of the document. The research was funded by the European Union project ESONET (contract no 036851). Links to the ESONET website kindly find at http://www.esonet-emso.org/.

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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.

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.


Station list of observatory locations with an uncertainty of + - 50m.
The temperature lance has a beacon for ROV detection (table I)

<table>
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<tr>
<th>Date</th>
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<th>Longitude</th>
<th>Depth (uncorr.)</th>
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<td>14° 42.936’ E</td>
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<tr>
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<td>Temperat. Lance (with beacon)</td>
<td>21:40</td>
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Table 1

In this ESONEWS issue we present the latest developments 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.

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).

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 CHEMEO/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.

Fig.10 - The push core rack

Fig.11 - Viewing from the underwater camera
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.

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 demonstration mission LOOME.

...
than happy that this expensive device was back onboard. Tuesday afternoon the Autonomous Underwater Vehicle (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 independent 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 sighted 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 activities 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*

*Max-Planck-Institute for Marine Microbiology,
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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 with permanent gas emission. The Håkon 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 chemosynthetically driven faunal and microbial communities, fuelled by the oxidation of methane by sulfate and further oxidation 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.

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**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 gravitricorer 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 ESP EuroDeep program CHEMICO.

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 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
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.

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.

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
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).

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).

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).

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.

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.

Further Literature


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 Çağatai)
On Tuesday 8 December 2009, NEPTUNE Canada went live, allowing people everywhere in the world to access realtime and archived data via the Internet. This is a major step on the development of Ocean Sciences. NEPTUNE Canada is building the world’s first regional-scale underwater ocean observatory that plugs directly into the Internet. People and Ocean Scientists will be able to run deep-water experiments from labs and universities anywhere around the world, reinventing Ocean Science for the 21st century!

The text below was adapted from Neptune-Canada Website.

A new approach to Ocean Science

NEPTUNE Canada is designed by scientists for scientists to address some of the key challenges and questions in the oceans. With continuous data, interactive laboratories and remotely operated vehicles (ROVs) positioned in multiple sites spanning a full range of marine environments, the NEPTUNE project’s unique design allows researchers to study processes previously beyond the capabilities of traditional oceanography. The wide array of instruments allows direct study of geological, physical, chemical and biological systems in the ocean. This interdisciplinary approach will enable researchers to answer some of the most complex and pressing questions of ocean and earth science today.

Dynamics of a tectonic plate

The Juan de Fuca Plate, smallest of Earth’s 13 major tectonic plates, is ideally suited for study because of its size and close proximity to Vancouver Island. The NEPTUNE Canada network will span this plate with instrumentation at strategic locations on the plate’s active edges and relatively stable interior.

The Climate and greenhouse gas cycling

NEPTUNE Canada will advance our understanding of climate change by enabling the study of processes involving carbon dioxide and methane cycling in the ocean.

Ocean productivity

Scientists will be able to monitor physical, chemical and biological interactions involved in primary productivity over a period of decades. This in turn drives bio-chemical cycling through the rest of the food chain.
**Marine mammal and fish stocks**

Population modeling and resource management will benefit from real-time tracking of migration patterns, behaviors and health indicators.

**Non-renewable marine resources**

NEPTUNE Canada will enable more accurate assessments of metal deposits, hydrocarbon distributions, and slope stability in our coastal regions.

**Episodes, events and catastrophes**

Long-term, continuous observations will make it possible to capture data for significant episodes as they occur. Resulting research will help scientists improve forecast and warning systems. Examples include:

- extreme weather events
- earthquakes
- volcanic activity
- tsunamis
- submarine landslides
- algal blooms

**Origins and limits of life**

A great diversity of extremophile life-forms are found in harsh deep-sea environments like the super-heated waters surrounding hydrothermal vents and submarine volcanoes. NEPTUNE Canada will help researchers study life’s adaptations to extreme and primitive earth habitats.

**Marine Life and Climate Change**

Some of the world’s most productive bio-zones are found in the mid-latitudes along continental west coasts, where prevailing winds and ocean currents combine to lift deep-sea water toward the surface. Upwelling nutrients support a rich and diverse profusion of marine life. One such area exists off southwestern Vancouver Island. This region plays a critical role in the life cycles of several important fish stocks, including Pacific salmon.

NEPTUNE Canada’s seafloor sensor array and vertical water column profiler at the continental shelf break and slope will observe oceanic conditions and their variations as never before. Acoustic and optical sensors will open an unprecedented real-time window to a wide range of physical, chemical and biological processes in the water column. Over time, we will also be able to monitor their evolution related to climate change.

**Infrastructure**

NEPTUNE Canada’s infrastructure is uniquely designed to support real-time cabled observation from multiple instruments and locations distributed across a broad region. Major components of the network are manufactured and installed under a contract with Alcatel-Lucent submarine networks. Junction boxes, produced by OceanWorks, are connected to the network nodes via extension cables and ODI wet-mate connectors. Each junction box can support multiple instrument platforms, individual instruments and sensors. In addition, power, communications and data processing are handled at our shore station and headquarters facilities.

**Sensors & Instruments**

The sensors and instruments deployed across the NEPTUNE Canada network will evolve over time. Old instruments can be removed and new instruments added, often by “plugging in” via wet-mate connectors on nodes and platforms at the seafloor.

Instrument types include:

- conductivity-temperature-depth
- current meters
- hydrophones, sonars, echosounders
- acoustic Doppler current profilers
- bottom pressure sensors
- chemical and gas sensors for measuring carbon dioxide, oxygen, methane, nitrates, etc.
- seismometers, gravimeters and accelerometers
- high-resolution still-frame and video cameras with lights
- microbe and plankton samplers and microbial incubators
- turbidity sensors, transmissometers, sediment traps
- benthic flow simulation chamber
Instrument Platforms

Most instruments in the observatory are either affixed to platforms or connected to them by extension cable. Using platforms, instruments can be kept off the seafloor and out of the sediment. Platforms also greatly simplify instrument deployment and recovery, as they are transported between ship and seafloor as single units. During Summer 2009 installation cruises, 9 fixed and 2 mobile instrument platforms were installed. (The mobile platforms are the Vertical Profiler System and Hydrates Crawler.)

Junction Boxes

The heart of each platform is its junction box, which provides power and communications to the instruments. Incoming 400V DC power can be passed through to secondary instrument platforms or it can be converted to lower voltages (15V, 24V or 48V) required by many instruments. Data streams from the instruments are handled by the junction boxes using either serial or ethernet protocols.
Instrumented Locations

NEPTUNE Canada’s backbone delivers power, Internet access and accurate time to five (possibly six) nodes, from which the network will extend via junction boxes to a wide range of instruments. Locations and community experiments were selected after much debate and review to address the key scientific questions within the major research themes for this project.

The NEPTUNE Canada observatory includes five instrumented locations:

1. Folger Passage (Inshore Shelf)

Folger Passage is located on the continental shelf near the entrance to Barkley Sound. Here, instruments will be positioned in two clusters. Folger Passage Deep (95m) on the seafloor and Folger Passage Pinnacle on a rocky pinnacle that reaches up to 17m below the surface.

Main research objectives of this node include (1) the identification of factors controlling biological productivity both within the water column and at the seafloor; (2) the evaluation of the effects that marine processes have on fish and marine mammals and (3) to provide learning opportunities for students, researchers and the public, many of whom will be working and studying at the nearby Bamfield Marine Sciences Centre.

Instruments include at Folger Passage Deep: oxygen sensor, ADCP (300 kHz), echosounder (38, 120, and 200 kHz); bottom pressure recorder; hydrophone (5 Hz - 300 kHz) and CTD. At Folger Passage Pinnacle the following sensors are planned: current meter (2 MHz); light sensor; ADCPs at 600 kHz, 1200 kHz (looking upward), and 2MHz (looking downward); transmissometer; video camera; 3-D 8-camera array with lights.

2. ODP 889 (Continental Slope Subduction Zone)

This node is equipped mainly with geophysical instruments. Main Research objectives include the monitoring of changes in hydrate distribution, depth, structure, properties and venting, particularly related to earthquakes, slope failures and regional plate motions.

Instruments installed are the following: controlled source electromagnetic (CSEM) system; seafloor compliance (SFC) apparatus; broadband seismometer (to help pinpoint movements associated with Juan de Fuca subduction zone below); bottom pressure recorder (BPR).

3. Barkley Canyon (Continental Slope Subduction Zone)

Barkley Canyon node was designed to study nutrient and sediment transport from the shelf/slope break through a submarine canyon to the deep sea. In addition, a prominent mid-canyon outcrop of gas hydrates can be studied by marine biologists, geologists, geophysicists, and climatologists.

A multi-sensor vertical profiler system was installed at the canyon head. This system consists of a seafloor platform (400m) and a tethered float. A winch on the platform raises and lowers the float through the water column, which bristles with instrumentation for monitoring salinity, temperature, dissolved gases and nutrients, currents, plankton and fish concentrations and marine mammal movements. This system will help scientists examine the influences of complex currents on plankton life cycles. Scientists will be able to study benthic (seafloor) ecology using instrument suites at four study sites along the shelf break, mid-canyon, and canyon axis. A variety of instruments, both on a fixed platform and carried by a remotely operated crawler, will allow detailed study of gas hydrate outcrop accretion and dissolution. Data are now accessible through the Internet.

4. ODP 1027 (Mid-Plate Abyssal Plain)

The ODP1027 site is on the abyssal plain at a depth of 2660m. Here, NEPTUNE Canada reuses an existing Ocean Drilling Program borehole monitoring systems. CORK systems monitors changes in crustal temperature and pressure, particularly as they relate to earthquakes, hydrothermal convection or regional plate strain. This site will also form part of a plate-wide tsunami detection system that uses highly sensitive bottom pressure recorders to measure tsunami amplitude, propagation direction and speed. Data from this system will complement information gathered by other tsunami sensors around the North Pacific. ODP1027 readings are available at the Internet.

Instruments include: bottom pressure recorders (BPR), broadband seismometer (360s - 50 Hz); CTD; CORK pressure and temperature sensors.
5. Endeavour Ridge (Ocean Spreading Centre)

Endeavour Ridge node is located at the spreading boundary between the Juan de Fuca and Pacific plates. The region (approximately 300 km off the British Columbia coast), has been the site of intensive investigation for more than 20 years. NEPTUNE Canada’s real-time monitoring capability will benefit both ongoing and new experiments. Continuous data gathered before, during and after events like earthquakes and intrusions will be recorded across a coordinated suite of instruments both at the hydrothermal vents on the seafloor and within moorings extending 250m up into the 2,200m water column. A network of seismometers here and at other sites will provide high resolution information on tectonic processes such as earthquakes and strain across the Juan de Fuca plate. This node is still not operational. Tubeworms unfurl their plumes near a hot vent on Endeavour Ridge.

A sixth location will be established at Middle Valley (sedimented portion of the Juan de Fuca Ridge) if further supplementary funding can be secured.

Real-time Data Collection

NEPTUNE Canada is collecting data from 11 instrument platforms and over 50 instruments installed in 4 locations around our 800 km cable loop.

Science Topics

Earthquakes and plate tectonics

Subduction zones like the one along the eastern edge of the Juan de Fuca plate generate some of the world’s largest earthquakes, often associated with devastating tsunamis. NEPTUNE Canada’s array of sensitive instruments will augment other land-based seismic networks in Canada and the U.S., helping researchers better understand subduction processes and improve their estimates of seismic risk. Along the western edge of the Juan de Fuca plate, new seafloor is created through plate boundary spreading and volcanic activity. NEPTUNE Canada will install seismometers on the Endeavour segment of the Juan de Fuca Ridge to help pinpoint the many earthquakes that shake that region every year. Closely related phenomena like hot fluid venting and volcanic eruptions will also be studied in conjunction.

Hot vent

As tsunamis can move rapidly through the open ocean, a large earthquake off British Columbia could send a tsunami crashing into coastal regions in as little as 10-15 minutes. This computer simulation shows the main wave of the Cascadia tsunami as it crossed the mid-Pacific on 26 January 1700. Severe damage occurred both in coastal First Nations communities in British Columbia and Japan. A similar earthquake is expected sometime in the next 200 years.

Cascadia tsunami

Fig.9 - Mane location for deep seafloor monitoring along the 800kms long cable.

Fig.10 - Hot fluids vent from the seafloor in volcanically active Endeavour Ridge. Photo taken from ROPOS by Verena Tunnicliffe and Kim Juniper, 21 August 2002.

Fig.11 - Simulation of 1700 cascadia tsunami generated close to the location of Neptune canada network.
Fluid flow in the Seabed

When one tectonic plate pushes under another, sediments are scraped from it to create wedge-like formations along the continental margins. This is happening in western North America’s Cascadia Subduction zone, where unique physical and biological processes can be observed. As fluids seep up to the seafloor from deep within the crust, methane and other hydrocarbons in these fluids transmute into ice-like structures called gas hydrates. At some localities, such as along the edges of Barkley Canyon, gas hydrates outcrop at the seafloor as icy mounds populated by extensive bacterial mats and dense communities of large clams. Elsewhere, the shallowly buried gas hydrates release concentrated bursts of methane, bubbling upward through the water column.

Endeavour Ridge tubeworm community

At Endeavour Ridge, NEPTUNE Canada opens a new viewport into a captivating world of submarine pipes and castles. Here, volcanically heated fluids escape from the seafloor, surging upward into cold deep-ocean waters. As they emerge, the metals and minerals they carry precipitate, forming chimneys up to several tens of metres tall. Venting episodes can be traced to periods of volcanism and faulting. The chemically charged fluids support unique ecosystems, including unusual chemosynthetic bacteria, giant tubeworms, and eyeless shrimp that use photosensitive “patches” on their backs to “see” super-heated water coming from the vents. NEPTUNE Canada will help researchers further their long-term studies of this area’s chemistry, geology, geophysics and biology by monitoring the evolution of several vent fields. Ejection of large quantities of hot water from the ridge affects overlying waters.

Figures

Fig.12 - A small fish eye ROPOS from its feeding grounds atop a methane hydrate outcrop in Barkley Canyon.

Fig.13 - Biologic community in the seabed

Platform

<table>
<thead>
<tr>
<th>Platform</th>
<th>On Barkley Upper Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>This platform is positioned in an area where the continental shelf begins to slope downward into the deep sea. Two other platforms, the Vertical Profiler System (Platform 3) and Barkley Benthic Pod 2 (Platform 8) are located nearby.</td>
</tr>
</tbody>
</table>

Instruments on this platform

- Seabird Microcat CTD (Conductivity Temperature Depth) sensor
- RDI Workhorse Long Ranger 75kHz ADCP (Acoustic Doppler Current Profiler)

Instruments positioned nearby

- Broadband seismometer
- BPR (Bottom Pressure Recorder)
- Naxys hydrophone
The Barkley Hydrates

This platform is positioned in the midst of the Barkley Canyon hydrates field, where it provides power and communications to Wally the Crawler and three other instruments platforms (Benthic Pods 1, 3, and 4).

The Vertical Profiler System (VPS) is a mobile instrument platform. It consists of a seafloor base unit and a tethered float. A winch on the base unit raises and lowers the float, which bristles with instrumentation for monitoring:
- salinity
- temperature
- dissolved gases and nutrients
- currents
- plankton and fish concentrations, and
- marine mammal movements

The Barkley hydrates crawler, nicknamed “Wally”, is one of two mobile instrument platforms in our network (the other is our Vertical Profiler System). Wally’s mission, crawling the hydrates fields in Barkley Canyon, is to help researchers carry out detailed investigations of processes influencing gas hydrates evolution at the seafloor.

Wally is connected to the Barkley Hydrates instrument platform via a 70m cable, which provides power and communications. The crawler “crawls” on dual tractor treads, which allow a full range of forward, backward and turning movement. Including its titanium frame, drive motors, sealed electronics chambers, wiring, lights, HD video camera, and sensors, the unit’s out-of-water weight is 275 kg. With syntactic foam floatation blocks attached, this is reduced to an in-water weight of 40 kg. One unique feature is its control interface, which plugs directly into the Web. If all works out as planned, you’ll one day be able to tune in to a live seafloor crawl on the NEPTUNE website.

Temperature Probes

The VPS base platform has two cameras and some other sensors associated with the mechanical assembly, but all scientific sensors are affixed to the profiler float unit.

NEPTUNE Canada is collecting data from 11 instrument:
- Satlantic upwelling radiometer
- Satlantic downwelling radiometer
- ASL acoustic water column profiler
- WETlabs Fluorometer
- Pro-Oceanus CO2 sensor
- Naxys hydrophone
- Seabird SBE19plus Conductivity-Temperature-Depth (CTD) sensor
- Nortek Aquadopp Acoustic Doppler Current Profiler (ADCP)
- WET labs ECO Backscatter Transmissometer/fluorometer
- Aanderaa oxygen optode
- Satlantic Nitrate Sensor
- current meter
- methane sensor
- tilt-compensated compass
- video camera

Connected to Barkley Slope/Canyon node on 26 Jul 2009 from the R/V Atlantis.
- Depth: 870.0m
- Lat: 48°18.7266’N
- Lon: -126°03.9480’W
- Heading: 253.0°

The VPS is positioned at a depth of 396m. Cable spooled on the platform is long enough for the float to extend to the surface, allowing scientists to capture data throughout the water column. Connected to Barkley Slope/Canyon node on 25 Aug 2009 from the R/V Thompson.
- Depth: 396.0m
- Lat: 48°25.6352’N
- Lon: -126°10.4457’W

Connected to Barkley Slope/Canyon node on 19 Sep 2009 from the R/V Thompson.
- Depth: 871.0m
- Lat: 48°18.7164’N
- Lon: -126°03.9529’W

NEPTUNE Canada is collecting data from 11 instrument.
Deep-sea ecosystems

Seafloor ecosystems and those in the overlying water column are intimately connected. NEPTUNE Canada will help researchers study:

- seafloor biological communities
- energy and nutrient pathways
- ecosystem evolution
- ecosystem responses to both short-term and episodic events

A number of sites will be instrumented with acoustic, chemical and optical systems, including video and still cameras, to help scientists learn how seafloor organisms are affected by phenomena like:

- large storms
- El Niño-Southern Oscillation (ENSO)
- Pacific Decadal Oscillation (PDO)
- long-term changes in ocean temperature and salinity
- seasonal upwelling
- canyon processes
- hydrothermal circulations
- Etc.

Fig.18 - Wally Hydrate Crawler in action