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# MoMAR-D: a technological challenge to monitor the dynamics of the Lucky Strike vent ecosystem

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## Abstract :

The MoMAR (monitoring the Mid-Atlantic Ridge) project was initiated in 1998 by the InterRidge programme to promote and coordinate long-term multidisciplinary monitoring of hydrothermal vents at the Mid-Atlantic Ridge (MAR). The major objective of the project is to study vent ecosystem dynamics using a multidisciplinary approach from geophysics to microbiology over a period of a few decades. MoMAR-D is a demonstration project of MoMAR, partially funded by the European network of excellence ESONET (http://www.esonet-noe.org/). MoMAR-D aims to deploy and manage a multidisciplinary observing system at the Lucky Strike vent field for 1 year. This large hydrothermal field is located at the centre of one of the most volcanically active segments of the MAR. The project has been set up to monitor this region to capture evidence of volcanic events, observe interactions between faulting, magmatism, and hydrothermal circulations, and to evaluate the potential impacts of these environmental factors on the unusual communities colonizing hydrothermal vents. The MoMAR-D infrastructure consists of two sea monitoring nodes (SEAMON) acoustically linked to a surface buoy with satellite communication to a land-based station. The first node will be mainly dedicated to geophysical studies, whereas the second will focus on ecological studies and chemical fluxes. The infrastructure should have been deployed in September 2010 during the MoMARSAT cruise.

**Keywords :** hydrothermal vents ; long-term studies ; Lucky Strike vent field ; MoMAR ; monitoring experiments ; ocean observatories ; technical infrastructure

# 1. 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 developing near these hydrothermal vents are sustained by chemosynthetic microorganisms that use reduced chemicals present in the hydrothermal fluid as an energy source. The Mid Atlantic Ridge (MAR) near the Azores comprises four known hydrothermal vent fields- Menez Gwen at 800m depth, Lucky Strike at 1650m, Saldanha at 2200m and Rainbow at 2300m (Figure 1)- each presenting specific geological, chemical, hydrothermal, and biological characteristics.

This region has been extensively studied for thirty years by both European and US investigators. The FAMOUS and AMAR projects took place in this region leading to some of the most detailed studies on the MAR segments. This area was also a focus of the FARA program which involved some twenty US and French cruises in the 1990's. Thus, several successive European programs (e.g. FARA, MARFLUX, AMORES, ASIMOV, VENTOX, EXOCET/D and MoMARNET) as well as national projects such as SEAHMA from Portugal have taken place in the last 20 years. The geophysical background of this region is therefore well described, as are the general characteristics of most of the known hydrothermal vents. The broad taxonomic diversity of the associated mega- fauna and macro-fauna has also been studied, but less is known about the smaller meiofaunal compartment. Data available include multibeam and survey module ROV bathymetry (Cannat *et al*., 1999, Ondréas *et al*., 2009), side scan sonar, gravity, magnetics and seismicity, geology, chemistry of water column, bottom waters and vent fluids, regional and detailed ecological studies including larval dispersal and subsurface deep-sea drilling. .

The Lucky Strike vent field is located at the summit of a central volcano (Langmuir *et al*., 1997), and is underlained by a recently-discovered axial magma chamber at mid-crustal depth (Singh *et al*., 2006). It is one of the largest hydrothermal fields found along the MAR, extending over ~1 $km^2$ around a relatively flat lava lake, and harbours numerous active and inactive vents and zones of diffuse flow (Fouquet *et al*., 1995). Vent fluid temperatures range from 330º C in black smokers, to 200-212ºC and even 20°C in diffuse emissions (Von Damm *et al*., 1998; Charlou *et al*., 2000; Cooper *et al*., 2000). While temperatures appear to be very stable over a time scale of a few years at some vents (i.e., Tour Eiffel, 324±1°C), others show relatively high temperature variability (Statue of Liberty, 202-185°C; Sintra, 176-215°C, [Charlou *et al*., 2000]). Fluid chemistry indicates that the vents located in the south-eastern Lucky Strike area have a distinct source (Charlou *et al*., 2000). This vent field shows sustained levels of micro-seismicity, and a possible magmatic diking event occurred in 2001 (Dziak *et al*., 2004). On most active sulphide edifices, faunal communities are visually dominated by extensive mussel beds of *Bathymodiolus azoricus* that are partially covered by microbial mats. The vicinity of active high-temperature chimneys, flanges and cracks are colonized by *Chorocaris chacei* and *Mirocaris fortunata* shrimp assemblages (Desbruyères *et al.,* 2001). *B. azoricus* live in symbiosis with microbial endosymbionts (sulphide oxidizing- and methanotrophic bacteria, [Fiala Medioni *et al*., 2002; Duperron *et al.,* 2006]) and seems to be able to use two of the energy sources present in the hydrothermal fluids ($CH_4$ and $H_2S$). These mussels can also take in particulate organic matter through filter feeding (Riou *et al.*, 2008). The faunal assemblages dominated by *Bathymodiolus* are present in the cold part of the mixing zone with limited hydrothermal inputs (Sarradin *et al.,* 1999).

The MoMAR “Monitoring the Mid-Atlantic Ridge” project was initiated by the international InterRidge Programme in 1998 to study the environmental instability resulting from active mid-ocean ridge processes, the changes in the flux, composition and temperature of emitted hydrothermal fluids and its effects on dependant hydrothermal fauna at the slow-spreading MAR. The initial goal of this project was to promote and coordinate long-term multidisciplinary monitoring of hydrothermal ecosystems in this region (Santos *et al.*, 2002). The ultimate objectives of the MOMAR project are to provide answers to the following scientific questions:

- What are the feed-backs between volcanism, deformation, seismicity, and hydrothermalism at mid-ocean ridges?

- How does the hydrothermal ecosystem couples with these sub-seafloor processes?

- What are the mass, energy and biological fluxes at ridge hydrothermal vent fields?

MoMAR includes a multi-scale approach, ranging from the regional (>100 km) scale for seismicity, oceanography, and biological dispersion studies, to a local (<10 km) and very local (<1m) scales for the study of specific vent sites and associated biological communities. The regional scale approach addresses: 1) the relationships between intermediate depth hydrothermal fields, seamount ecosystems, and the evolution of fishing resources in the Azores area, 2) seismic and volcanic risks to populated areas in the Azores Islands, 3) the movement of deep water masses and the consequences of thermohaline circulation changes in the North Atlantic on climate and biodiversity.

## 2. The MoMAR:D project

In 2003, the MoMAR area was chosen as one of the 11 key sites of the ESONET concerted action (Priede *et al*., 2005) and successively confirmed by ESONET Network of Excellence (Ifremer, http://www.esonet-noe.org/). This led, in 2008, to the submission of the MoMAR-D proposal to the ESONET committee to propose the MAR as a candidate site for a demonstration mission. The project was selected by ESONET and complements existing activity. The scientific objectives of MoMAR-D are: i) to evaluate the temporal variability of active processes such as hydrothermalism, volcanism, seismicity and ground deformation, and ii) 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 for 12 months. The MoMAR-D demonstration mission will address the objective of MoMAR by integrating time-series data from a multidisciplinary range of sensors, and by implementing technological solutions required for near real-time transmission of a significant sub-set of these data. The demonstration will also aim to develop, in conjunction with ESONET : i) interoperability and standardization of sensors and observatory infrastructure, ii) adapted approaches to data distribution and archiving, iii) appropriate site management policies, iv) link with economic users, v) an effective public outreach program.

## 3. Planned experiments

The experiments that will be deployed at local scales at the Lucky Strike vent field belong to 5 thematic packages exploring the dynamics of the hydrothermal ecosystem: (1) seismicity and hydrothermal activity, (2) seafloor deformation and its impact on hydrothermal fluid composition, (3) chemical fluxes and their impacts on the associated fauna, (4) ecology as changes in the structure of faunal assemblages and local environmental conditions and finally, (5) physical oceanography as exchanges with the surrounding ocean. The philosophy of the project is to integrate data from the widest range of sensors and disciplines. The operational system will be build around two Sea monitoring nodes -SEAMON (Blandin and Rolin, 2005) and a BOREL buoy (relay-buoy) for data transmission. Many scientific teams already have experiments on the seafloor at MoMAR sites and we expect that the new capability for data transmission through the SEAMON/BOREL technology will help us promote this integrated approach even further. The demonstration project also includes a component of numerical modelling of hydrothermal circulations at small scales. This modelling will also promote data integration, because all thematic subgroups will contribute with supporting data.

### 3.1 Thematic Package 1: Seismicity and hydrothermal activity

Seismic monitoring of hydrothermal fields and their surroundings is an efficient method to monitor the tectonic and magmatic events that likely control hydrothermal dynamics. Changes in the dynamics of hydrothermal circulation, on the other hand, are expected to result in variations in the temperature and chemistry of vent fluids. Statistical correlation between variations of the vent fluids and seismic activity is expected if seismicity play a role to maintain high permeabilities, allowing for hydrothermal circulation at and near the faults which connect to the crustal melt lens. The link between seismicity and vent fluid temperatures has been used before as a powerful constraint on numerical models of permeability distribution at hydrothermal sites in the Pacific (Sohn *et al*., 1998; Wilcock, 2004). The experimental design for this thematic package consists in arrays of Ocean Bottom Seismometers (OBS) coupled to temperature probes to monitor fluid temperature. Lucky Strike is a large vent field and it is important to be able to verify whether the temperature variations detected affect the chemical composition of fluids throughout the area, or just locally. Deep-sea autonomous temperature probes are cheap and reliable. This, and the paucity of operational chemical sensors, justifies our choice of temperature as the parameter to monitor at this wider scale. The link between temperature time series and chemical signature of the fluids obtained locally using chemical sensors and discrete fluid sampling was yet studied (Sarradin *et al*., 1999, 2009) and will be examined further in the thematic package 3.

Although this experiment will use “off the shelf” technology, it requires some work to adapt and modify OBS’s for SEAMON connection and deployment by a ROV. We will use a standard 3-axis short period instrument, with one processor for data acquisition and storage on a hard drive. A Persistor micro processor is added to interface the SEAMON monitoring node. This interface has been used during the ASSEM experiment (Blandin and Rolin, 2005) and is currently being adapted to OBS specifications.

Although the MoMAR-D project is mainly dedicated to local scale studies on the Lucky Strike volcano and vent field, a regional scale component is included by integrating seismicity data from an array of autonomous hydrophones (Goslin *et al*., 2004) to reinforce the interpretation of local seismicity record. A continuous record of seismic events (M > 2.5), occurring over the whole 300 km of ridge of the MoMAR area, will then be added.

### 3.2 Thematic Package 2: Deformation of the seafloor at the Lucky Strike volcano

Vertical deformation on active terrestrial volcanoes varies with the type of volcano and with its state in the eruptive cycle. In dyke injection crisis such as the recent one in Ethiopia (Kendall *et al.*, 2005) or the 1978 crisis in the Afar rift (Ruegg *et al.*, 1979), vertical deformation was in the order of 1 meter or more. The tectonic setting at Lucky Strike presents many similarities with that of the Ethiopian-Afar rift system. The primary hypothesis to verify if is vertical motions at a volcanically active mid-ocean ridge have the same order of magnitude than those observed on the Ethiopian-Afar system. Secondly, to investigate the links between vertical motions, tectonics and hydrothermal activity by integrating the vertical ground motion information with seismic, fluid temperature and chemical data. A pressure gauge moored at the volcano summit will be connected to the SEAMON system for near real time data transmission. Data from an autonomous GPS station installed on the BOREL buoy will also be collected in order to get the best continuous estimate of sea surface height above the volcano. This will be obtained after kinematics processing of the data, using a land based GPS station in the Azores. A series of temperature sensors along the mooring line of the BOREL buoy will be used to convert the sea level variations (buoy vertical movements) into pressure changes and to discriminate in the pressure signal a vertical motion from a sea level change.

Pressure data will be complemented by seafloor tilt and vertical acceleration data acquired with the OBM (Ocean Bottom Motion meter) of the University of Bremen. This instrument is an integration of existing parts of the Bremen Ocean Bottom Tiltmeter and the Ocean Bottom Accelerometer, which have been deployed for a year at the Logatchev hydrothermal vent field on the MAR (Fabian and Villinger, 2008). The OBM to be used at Lucky Strike includes a high resolution absolute pressure-gauge and a temperature data logger. It will monitor long-term seafloor deformations caused by processes like tectonics, magmatics, hydrothermal activity or slow mass movements nearby. The data will be collected by a low-power high-resolution data logger and stored locally.

### 3.3 Thematic Package 3: Chemical fluxes at Lucky Strike vents

The behaviour of chemical species in hot hydrothermal fluid end-members provides critical information on the conditions of fluid rock interactions in the hydrothermal cell (e.g., Charlou *et al*., 1991, 2000). These are susceptible to change with time, due to geological processes (volcanism, tectonics, thematic package 1), or to instabilities inherent to the hydrothermal convective system (Baker *et al*., 1995). The planned experimental design aims at a good integration between fluid characteristics and their evolution through time at the scale of the vent field (~1 $km^2$) on one hand, and the ecological approach developed at the scale of a few meters on the Tour Eiffel edifice on the other hand. Two slightly different chemical *in situ* analyzers will be deployed in the area. The first was developed at NOC (Southampton) for the measurement of Fe and Mn species in the hydrothermal plume (Statham *et al.*, 2005), and the second, called CHEMINI (CHEmical MINIaturized analyzer) was developed at Ifremer (Vuillemin *et al*., 2009) and will measure total dissolved Fe concentrations and temperature in the vicinity of hydrothermal organisms (see thematic package 4). To improve the link between the vent site-scale approach described above, and the meter-scale approach of the ecology experiment an innovative fibre optic temperature sensor array will be deployed and tested, based on Fibre Bragg Grating sensing technology. This temperature sensor system will allow the monitoring of fine scale variations in fluid temperatures, the actual fluid chemistry being monitored at discrete locations within the array.

Repeated sampling of the hot vent and diffuse fluids and analyze their composition (traces and major elements, stable and radiogenic isotopic ratios, gases) will also be performed on board the ship or back on shore. Time-series data and geochemical data on discrete fluid samples will be analyzed jointly in order to link the variability in hydrothermal fluid composition with other parameters like fluid temperature, and seismicity.

### 3.4 Thematic Package 4: Ecology at Lucky Strike vents

Deep-sea hydrothermal ecosystems are extreme habitats, driven by microbial chemosynthesis and characterized by strong endemism. The vents harbour faunal assemblages dominated by complex animal associations with microbial producers and secondary consumers that have co-evolved in a constraining environment. Several studies have shown that hydrothermal communities are shaped by dynamic, small- and large-scale geological processes which vary substantially in time and space. The spatial distribution of the fauna can be linked to fluid characteristics including concentrations of chemicals (methane, sulphide, metals) and fluid flow, to the type of substratum and also, to water depth (Sarrazin *et al*., 1997, 1999, Sarradin *et al*., 1999, 2009; Desbruyères *et al*., 2000, Colaço *et al.*, 2002, Le Bris *et al*., 2003, Cuvelier *et al*., 2009).

The long-term dynamics of the fauna and environmental factors at Tour Eiffel were first assessed through the deployment of the TEMPO during the MoMARETO cruise in 2006 (Sarrazin *et al*., 2006). TEMPO is an ecological observatory module that aims at studying community dynamics in relation to environmental variations (Sarrazin *et al*., 2007a). TEMPO was equipped with a deep-sea video camera and two LED lights, protected by an anti-fouling system. A CHEMINI Fe in situ analyzer (Vuillemin *et al*., 2009) and 3 temperature probes were coupled to TEMPO module to monitor environmental changes in parallel to community dynamics (Figure 2). Data process is in progress and the preliminary results show no major change in mussel community structure over the 49 days of the experiment. On the other hand, a significant increase of microbial coverage was observed and seems to be linked to a local modification of hydrothermal influence (Sarrazin et al. unpublished data). Processing of the data methodology will be used as a model to refine our sampling strategy (e.g., acquisition frequency, duration of video sequences, data processing) for MoMAR-D, and to build a robust data treatment protocol especially concerning video imagery. An ecological module, similar to TEMPO, will be deployed and connected to the SEAMON East node at the base of the Tour Eiffel edifice. Near real-time connection to shore, will allow transmission of a subset of the data (mainly chemical data), with the possibility of modifying sampling rates during the experiment. The bandwidth limitation of acoustic transmission will only limit video imagery transmission. Therefore, the transmission of still images and environmental data will be tested at a low frequency. All video sequences will be stored locally to be recovered during the second cruise in 2011.

Biofouling is a major issue for long-term studies in the vent ecosystem. Biofilms form on every available surface and trap the mineral particles emitted by the hot fluids, making optical systems opaque. The method used successfully for preventing biofouling on the lens of the TEMPO video camera and on an Aanderaa oxygen optode relies on localized microchloration

(Exomar, 2005 and MoMARETO, 2006 cruises (Sarrazin *et al*., 2006). This chemical anti-biofouling method, developed at Ifremer, does not modify the image, and the concentrations of chemicals released are negligible.

### 3.5 Thematic Package 5: Physical oceanography

Lucky Strike, as most of the MAR segments south of the Azores, is a site of active internal wave generation, as well as complicated local circulation influenced by bathymetry and mixing, both near the central volcano, the prominent rift valley walls, and in the semi-enclosed deep nodal basins. Oceanographic data collected in 2006 and 2007 during the GRAVILUCK and BB-MoMAR cruises provide an interesting first view of the internal waves in the area, the flow between the deep basins, and the areas where mixing takes place, in particular in the channel to the east of the Lucky Strike volcano. It is planned to equip the surface BOREL buoy with a GPS (this data set will also be used for geodesy), and the SEAMON mooring infrastructure with a set of temperature and pressure autonomous probes, recording at relatively high frequency (1 sample per minute), and current measurements at lower frequency (sampling each 30 minutes). Current meter data, which are being recorded near NERIES BBOBS1, will be used in view of cleaning seismic data from noise associated with baroclinic tides. An autonomous CTD/ADCP instrument package has been assembled to that purpose during the EXOCET/D project (Sarradin *et al*., 2007). It is planned to upgrade the system for autonomous deployment over a longer period (6-12 months). This includes (i) extending the capability of the existing data logger, (ii) augmenting the energy supply, and (iii) improving the synchronization between the CTD and the ADCP. Special care will also be taken in regard to corrosion and biofouling issues.

## 4. Description of the operational system

The MoMAR-D experimental design combines autonomous instruments which will store data over the duration of the demonstration mission (1 year), and instruments that will be connected to the SEAMON system and will transmit subset of data via the BOREL buoy (Figure 3).

The SEAMON technology (Blandin and 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. The BOREL buoy will be moored at acoustic range of the 2 nodes, on the volcano summit. The geophysical node (SEAMON west) 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 East) will be located at the base of the Tour Eiffel active edifice, to continue the study started with the TEMPO module in 2006 (Sarrazin *et al*., 2007a).

### 4.1 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 is the surface data transmission relay. The SEAMON stations are rated for 4000 m depth operations and each node can provide 8 kWh of energy, allowing for the sensors operation and for a daily data transmission of *ca.* 40 – 400 kilobytes.

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 a CLSI (Contact-Less Serial Interface), and the BOREL buoy via acoustic modems. The measurement sequencing is left to each sensor to insure that a COSTOF failure does not prevent data acquisition at the sensor level. SEAMON can duplicate this data storage for a volume up to 2Gbytes per year.

b. CLSI 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 tested methodology will be used after deployment to check or “fine tune” a sensor before the ROV leaves the area.

c. BOREL buoy – This buoy is the data transmission relay between the SEAMON seabed stations and the Iridium satellite constellation (Figure 4). It is moored within acoustic range of the SEAMON stations and is composed by two identical independent data transmission channels. The second channel can be activated from shore in case of a failure of the first one. 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. A BOREL buoy 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.

### 4.2 Acoustic data transmission

For five years now, 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 French RV “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 currently on-going and the MoMARSAT experiment will directly benefit from the results of these tests. Only a subset of data will be periodically transmitted to shore via the BOREL buoy. The sub-sampling step will be designed specifically for each sensor. Simple sub-sampling operations can be performed by SEAMON such as temporal sub-sampling, simple statistics or thresholding.

### 4.3 The sensors

The project relies on the mooring of various sensors to acquire time series related to the seismic activity of the system, seafloor deformation, chemical fluxes, faunal dynamics and physical oceanography. Part of the sensors will be connected to the SEAMON nodes (Table 1) and will transmit a subset of data to the BOREL buoy and to the Data management system DMAS on shore. The complete data set will be stored in the sensors and in SEAMON when possible. The other sensors (Table 2) will be used in an autonomous mode. The complete set of data will be downloaded at the end of the experiment when the sensors will be recovered. All the sensors will be time-synchronized at the beginning of the experiment. The drift will be measured after the recovery of each sensor against the GPS clock.

### 4.4 Data management

The data sets acquired during the MoMAR-D project will have two main origins: the time series and the data acquired during the cruise (site studies). The time series obtained will be transferred to the data centre at the end of the experiment after the recovery of the sensors and after validation by the experimenters within accepted time frame. A subset of data (telemetry data) will be periodically transmitted (each six hours) via the BOREL buoy to the data Centre in Ifremer Brest and validated during the experiment. The site studies data will include water, rock and faunal samples as well as experimental studies performed during the two cruises. These data will also be transmitted to the data centre. The SISMER data centre (Ifremer) will collect and distribute the validated metadata. All data passing through the MoMAR-D data processing stream will be deemed releasable unless specifically registered in the project Data management policy agreement is a work in progress. The project is committed to comply with the policies set out in the EU INSPIRE directive.

## 5. Site management

The growing interest and the increased number of science activities at the MoMAR vent fields have led the Portuguese and Regional administration to propose, in 2006, the area as a Marine Protected Area (MPA) within the OSPAR network. This followed on a special workshop organized in Horta in 2002 (Santos et *al.,* 2003), to reconcile the requirements for an MPA, with the constraints of the MoMAR project and other on-going research activities. The Lucky Strike vent field in particular, is identified in the MPA proposal «with the aim of promoting knowledge, monitoring and conservation of an area that best represents species, habitats and ecological processes in deep-sea hydrothermal vents in the OSPAR area, while enabling sustainable scientific research and promoting education and environmental public awareness and interest».

The MoMAR-D project will comply with the MPA recommendations and develop a coherent site management plan. This plan will include a set of rules for PI's, based on the MPA, InterRidge and OSPAR codes of conduct. These rules will aim at minimizing the impact of research on the environment, and at making sure that the work of one team does not compromise monitoring activities led by other researchers. In this context, we plan to devote one dive to clean the area around the two Lucky Strike SEAMON nodes of the non-native material left there over the years of scientific work (unused ballast and cables, and unfortunately discarded items thrown overboard ships).

## 6. Public outreach

Near real time transmission of data (and still images) from the vents will open new opportunities for public outreach. The plan for the MoMAR-D demonstration is to fully use these opportunities, both in the direction of the general public, and toward school and university students. The public outreach strategy will include press conferences before the cruises, maintenance of a cruise web site, and organization of a live event from the vessel, with video conferences and transmission of live images from the seafloor (Sarrazin *et al*., 2007b), participation of journalists interested in making a movie out of this seafloor observatory adventure. A permanent exhibit, with access to the most recent data and images from the seafloor, will be established first at the Oceanopolis aquarium in Brest. In the future mirror sites and exhibit material can also be set in other aquariums in Europe. The production of a didactic kit, on hydrothermal vents and seafloor observatories for multiple school levels, is also foreseen.

## 7. Conclusions

The deployment of the system is scheduled in the summer 2010 for a recovery in 2011 (MoMARSAT cruises using the French ROV Victor 6000, PI's: Cannat, M, Blandin, J., Sarradin, PM). This deployment step will be preceded by a phase of development, adaptations and testing of the sensors. There will be an on shore integration of the whole system followed by a final shore trial before the deployment of the system.

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## Figures

Figure 1: Location (white stars) of the 4 known hydrothermal vent fields near the Azores Triple Junction.

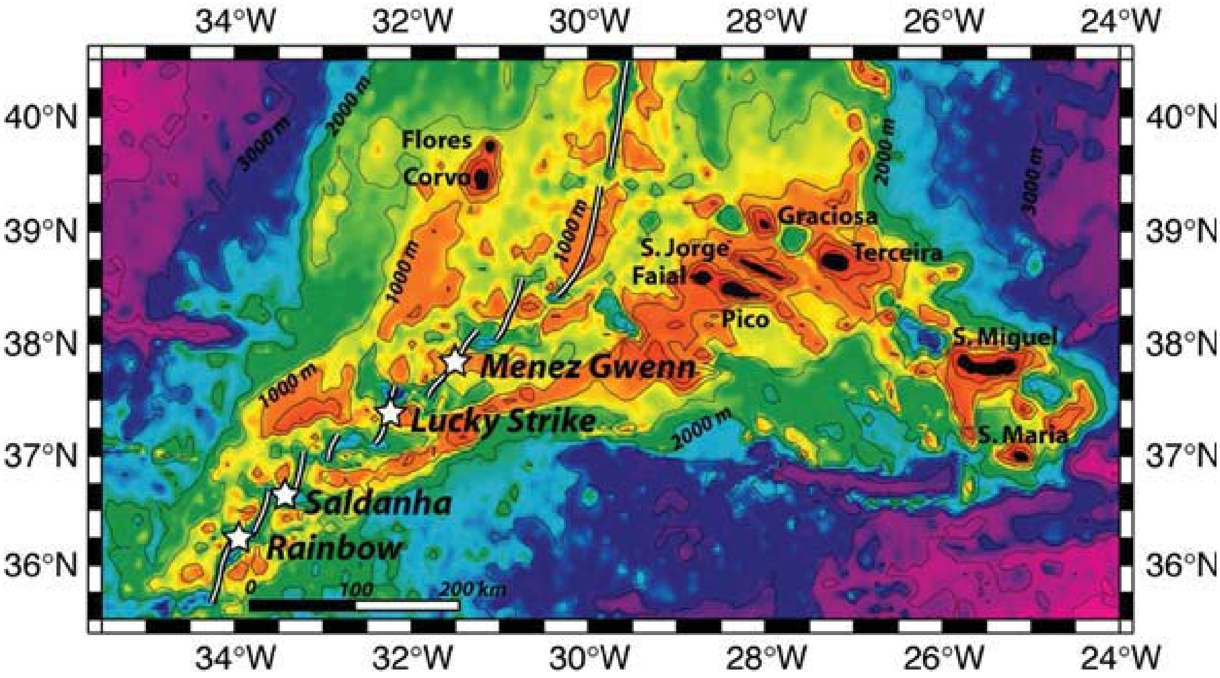


Figure 2: The autonomous module TEMPO (Sarrazin *et al*., 2007a) deployed at the base of the Tour Eiffel edifice, Lucky Strike vent field. MoMARETO 2006 and MoMARDREAM leg1 2008.

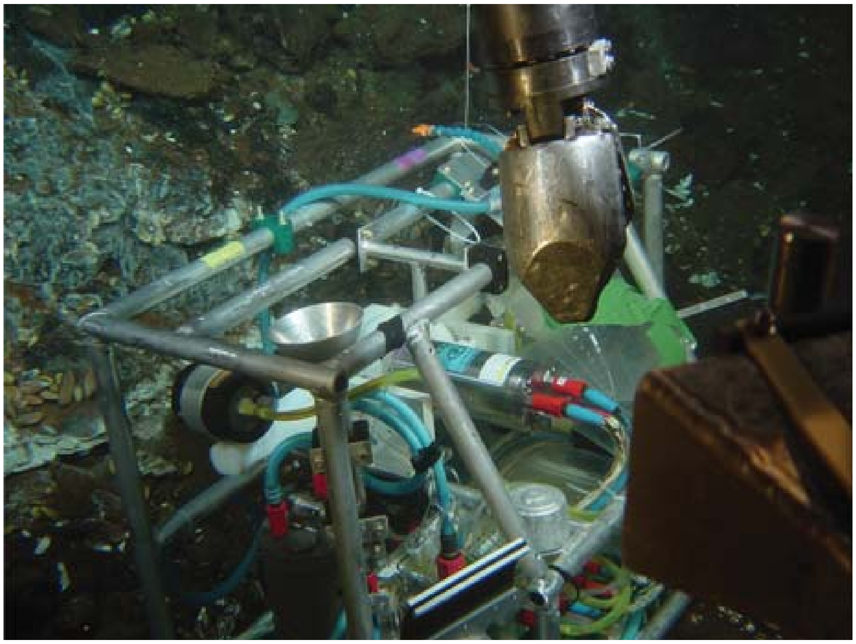


Figure 3: Sketch of the MoMAR-D experiment with the two SEAMON nodes on the bottom and the surface buoy at the sea surface. The surface buoy is the data transmission relay between the SEAMON seabed stations and the Iridium satellite constellation. Data are sent to a land base station at Ifremer, Brest.

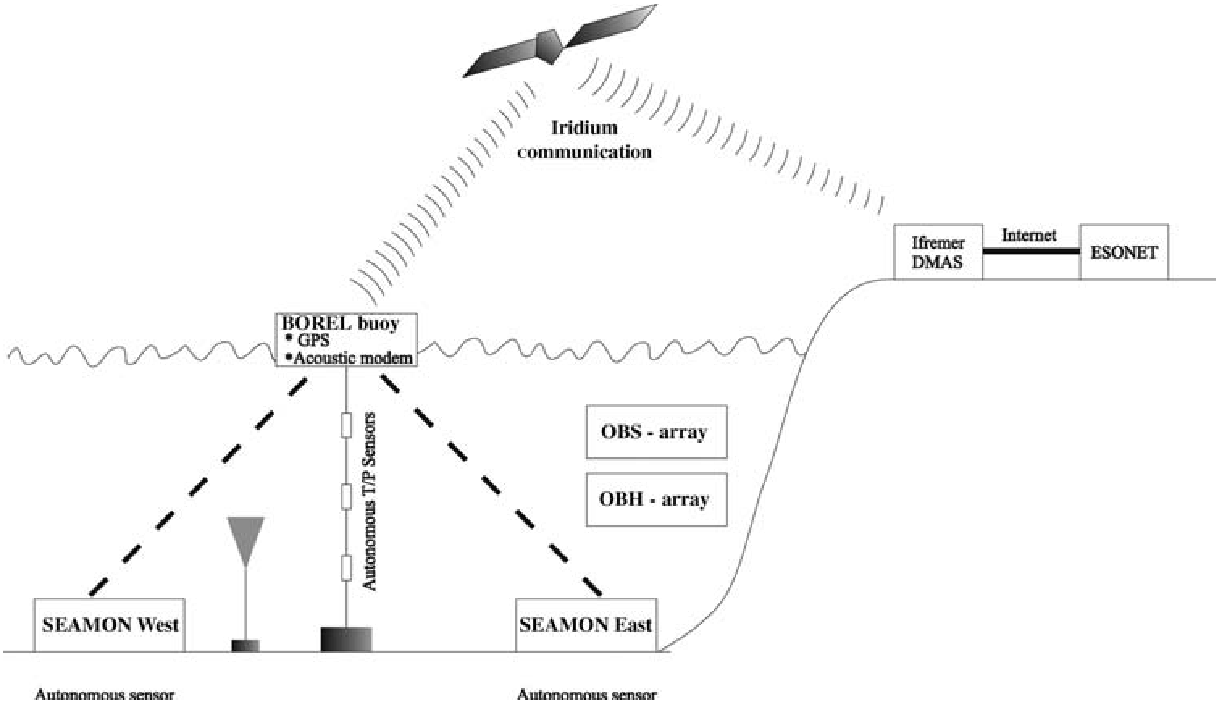
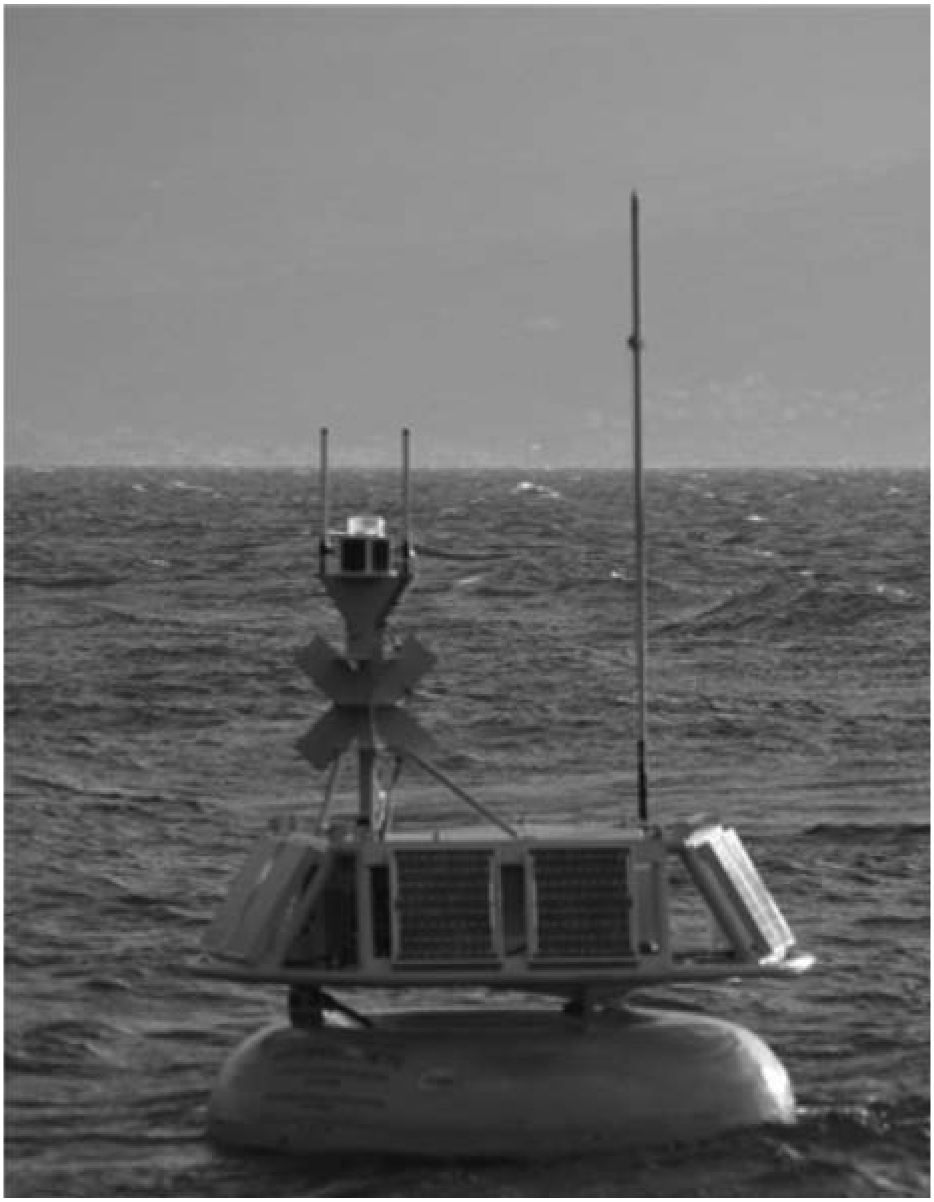
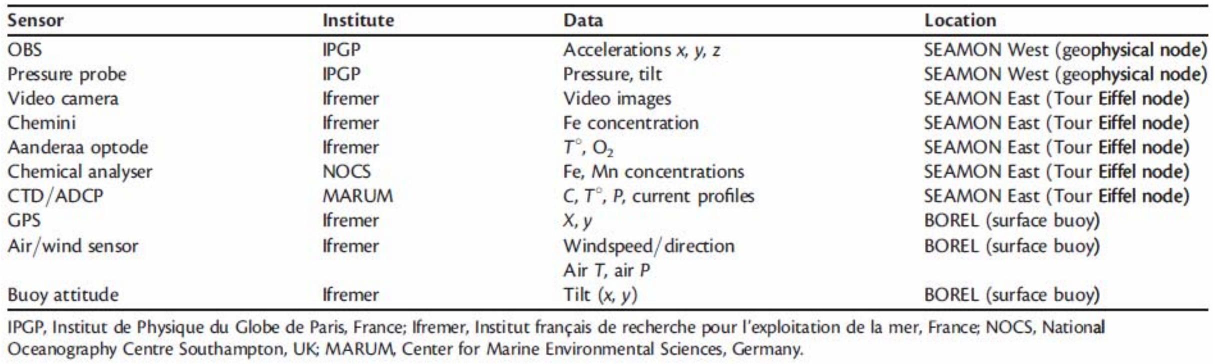


Figure 4: BOREL buoy that will assure data transmission relay between the SEAMON seabed stations and the Iridium satellite constellation



# Tables

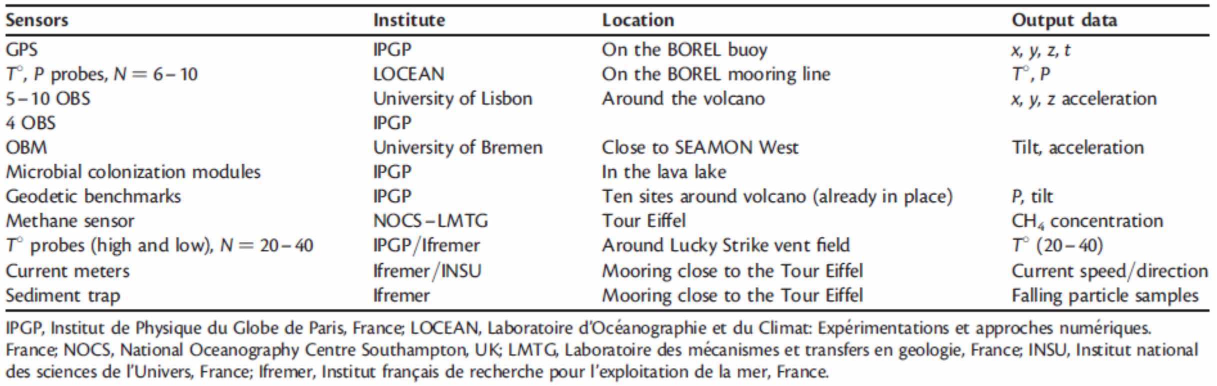
Table 1: Sensors to be connected to SEAMON as part of the MoMARD demonstration action



| Sensor | Institute | Data | Location |
|---|---|---|---|
| OBS | IPGP | Accelerations $x$, $y$, $z$ | SEAMON West (geophysical node) |
| Pressure probe | IPGP | Pressure, tilt | SEAMON West (geophysical node) |
| Video camera | Ifremer | Video images | SEAMON East (Tour Eiffel node) |
| Chemini | Ifremer | Fe concentration | SEAMON East (Tour Eiffel node) |
| Aanderaa optode | Ifremer | $T^\circ$, $O_2$ | SEAMON East (Tour Eiffel node) |
| Chemical analyser | NOCS | Fe, Mn concentrations | SEAMON East (Tour Eiffel node) |
| CTD/ADCP | MARUM | C, $T^\circ$, $P$, current profiles | SEAMON East (Tour Eiffel node) |
| GPS | Ifremer | $X$, $y$ | BOREL (surface buoy) |
| Air/wind sensor | Ifremer | Windspeed/direction<br>Air $T$, air $P$ | BOREL (surface buoy) |
| Buoy attitude | Ifremer | Tilt ($x$, $y$) | BOREL (surface buoy) |

IPGP, Institut de Physique du Globe de Paris, France; Ifremer, Institut français de recherche pour l'exploitation de la mer, France; NOCS, National Oceanography Centre Southampton, UK; MARUM, Center for Marine Environmental Sciences, Germany.

Table 2: Autonomous sensor to be deployed during MoMARSAT and that are part of the MoMARD demonstration action



| Sensors | Institute | Location | Output data |
|---|---|---|---|
| GPS | IPGP | On the BOREL buoy | $x$, $y$, $z$, $t$ |
| $T^\circ$, $P$ probes, $N = 6-10$ | LOCEAN | On the BOREL mooring line | $T^\circ$, $P$ |
| 5–10 OBS | University of Lisbon | Around the volcano | $x$, $y$, $z$ acceleration |
| 4 OBS | IPGP | | |
| OBM | University of Bremen | Close to SEAMON West | Tilt, acceleration |
| Microbial colonization modules | IPGP | In the lava lake | |
| Geodetic benchmarks | IPGP | Ten sites around volcano (already in place) | $P$, tilt |
| Methane sensor | NOCS–LMTG | Tour Eiffel | $CH_4$ concentration |
| $T^\circ$ probes (high and low), $N = 20-40$ | IPGP/Ifremer | Around Lucky Strike vent field | $T^\circ$ (20–40) |
| Current meters | Ifremer/INSU | Mooring close to the Tour Eiffel | Current speed/direction |
| Sediment trap | Ifremer | Mooring close to the Tour Eiffel | Falling particle samples |

IPGP, Institut de Physique du Globe de Paris, France; LOCEAN, Laboratoire d'Océanographie et du Climat: Expérimentations et approches numériques. France; NOCS, National Oceanography Centre Southampton, UK; LMTG, Laboratoire des mécanismes et transfers en geologie, France; INSU, Institut national des sciences de l'Univers, France; Ifremer, Institut français de recherche pour l'exploitation de la mer, France.