

# EMSO-Azores: six years of continuous monitoring of a deep sea hydrothermal vents – Technical results

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**Abstract** - Since 2010, the EMSO Azores non-cabled deep sea observatory acquires scientific data on the Lucky Strike vent field on the mid Atlantic ridge. This paper presents the marine infrastructure of EMSO Azores observatory needed to acquire and transmit data in near real time 24/day during six years. It details technical results obtained during this period.

**Keywords** – non-cabled observatory, near real-time, COSTOF, EMSO, long-term subsea monitoring

## I. INTRODUCTION

The MoMAR “Monitoring the Mid-Atlantic Ridge” project [1] was initiated by InterRidge in 1998 to study the environmental instability resulting from active mid-ocean-ridge processes at hydrothermal vent fields south of the Azores. EMSO-Azores observatory is now a part of the European Research Infrastructure Consortium EMSO (European Multidisciplinary Seafloor and Water Column Observatory - <http://www.emso-eu.org>) European programs, which coordinates eulerian observatory initiatives in European seas. The non-cabled EMSO-Azores observatory, deployed in October 2010 on the Lucky Strike vent field at 1700 m depth, focuses on two main questions: what are the relations between volcanism, deformation, seismicity, and hydrothermalism at a slow spreading mid-ocean ridge and how does the hydrothermal ecosystem couple with these sub-seabed processes?

The marine infrastructure consists of two Sea Monitoring Nodes (SEAMON) placed on the sea floor and fitted with the scientific sensors [2]. A surface buoy (BOREL) relays the acoustically received seafloor measurement data to the shore, via satellites.

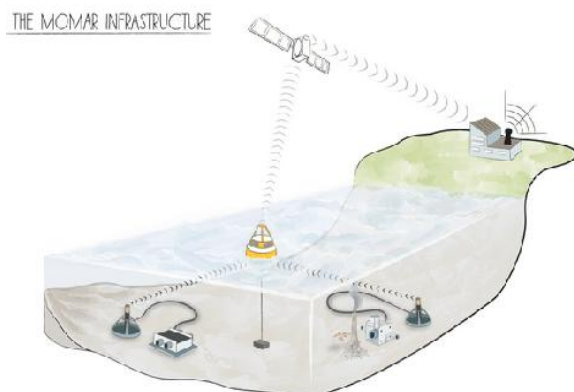


Fig.1. The EMSO Azores infrastructure is made up of two Sea monitoring nodes and a relay buoy

An array of autonomous sensors (OBSs, pressure probes, temperature probes in selected smokers, current meters and temperature probes in the water column) and colonization devices complete the infrastructure. A site studies program contributes to increase the set of accessible parameters and to extend the spatial coverage of the study.

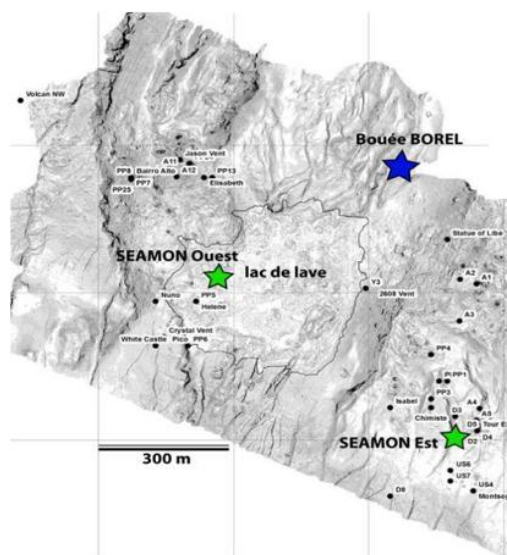


Fig.2. SEAMON and BOREL positions on the Lucky Strike vent field

## I. SEA MONITORING NODES

The two SEAMON nodes have the same architecture and include a set of components designed for long-term, non-cabled sub-sea monitoring, initially developed by Ifremer during the EU ASSEM project (2002-2004) and upgraded. The main components of SEAMON are:

### A. COSTOF

The COSTOF (Communication and STorage Front-end) is the electronic unit serving a set of connected sensors by providing them with energy, sequencing, data storage, time stamping, local data transmission for the installation phase, remote data transmission, and active protection against bio-fouling. The COSTOF is designed with a distributed architecture including a series of simple, identical and low power electronic boards built around an 8-bits microcontroller (ATMEL® ATmega128), each dedicated to a specific function and communicating through a CAN

(Controller Area Network) field bus, providing maximum modularity and reliability to the observatory.

With this multi-master architecture, by running specific software based on a common kernel, each board is totally independent from the others and a failure on one of them does not have any effect on the others. Furthermore, this architecture facilitates the integration of a new sensor and avoids software interference.

The choice of a CAN field bus has been motivated by its standardization level, its low power consumption, its multi-master capability and its wide use in the industry, especially in automotive, offering reliable service. Data, alarms and synchronization messages are sent through the CAN bus.

Each board consumes 1.5 mW in sleep mode and 860mW in active mode. A complete COSTOF consumes 12mW in sleep mode and 7W in active mode if all the boards awakes synchronously.

In addition to scientific data, COSTOF records and transmits technical data such as internal pressure, voltages, instantaneous current, remaining energy and water intrusion detection. Its titanium housing is 4000m deep rated.

The COSTOF has proved its reliability during this six years period of experiment with a very good behavior. Only a harmless issue concerning energy measurement has been noticed.

## B. COMMUNICATION LINKS

A local inductive serial modem allows an operator to configure the system before the deployment in air, and during the deployment in water, through the ROV, without any physical electrical connection, with a 57600 bits/sec maximum baud rate. Noise interferences caused by the ROV hydraulic engine have been overcome by replacing the RS232 serial link by an RS422 (NKE<sup>®</sup> CLSI - ContactLess Serial Interface).

A second type of modem developed by Ifremer is used to establish a local Ethernet link. This underwater 802.11g Wi-Fi link allows the user to stream HD video during the camera installation through an ROV without electrical connection, and to download files during the deployment. It is also very useful for configuration on deck to have a wireless remote access to the camera. The modem, switched on and off by the COSTOF, has a power consumption of 2.1W and provides a 10Mbits/sec bandwidth that will be improved by the use of a type 802.11n modem.

Finally, an acoustic modem offers a near real time bidirectional link to the observatory. Four times a day, data collected by the COSTOF are transmitted through this acoustic link to the surface buoy connected to shore via IRIDIUM satellite communication. The acoustic modems have been chosen after short and long term trials (COMMODOC experiment, 2008-2010) confronting several manufacturers of the world market. The energy efficiency (number of correctly transmitted bits per joule) was a crucial factor for the choice. EvoLogics<sup>®</sup> S2CR12/24 underwater acoustic modems were selected as the most efficient and reliable solution. The bottom modems are composed with a

6000m rated titanium housing containing the electronics and a directional transducer with 60 degrees beam to optimize the efficiency/power level ratio. Daily transmitted data is around 100 kilo-bytes for the SEAMON East node (technical data, scientific data and a snapshot per day) and around 3.5 kilo-bytes for the SEAMON West node (technical and scientific data). Their mean consumption is 17mW. The mean bitrate observed on EMSO-Azores is around 1500 bits/sec depending of the sea state and the buoy position. The power efficiency is around 70 bits per joule. The source level used is 178 dB ref 1 $\mu$ Pa corresponding to an electrical power of 15W (6000m range).

During the six years, the four modems of the network have been very reliable. Indeed, only one issue has been encountered during the second deployment. It concerned wake-up difficulties, remotely corrected by the manufacturer during the 2011 cruise.

## C. ACTIVE ANTI-FOULING PROTECTION

Biofouling is a major issue in the highly productive vent ecosystem environment. Biofilms forms on every available surface and traps the mineral particles produced by the hot fluids. Localized micro-chlorination is used for preventing the portholes of the video camera, projectors and dissolved oxygen sensor from biofouling.

A specific COSTOF board drives an electronic device generating a current between two electrodes. This allows sea water electrolysis generating hypochlorite on the surfaces. Programmed to run between two measurement periods, this system does not affect sensors data and the amount of chemicals released are negligible. The chlorination cyclic ratio, initially of 50%, has been lowered to 10% to save energy, without any difference.

## D. ENERGY

SEAMON is powered by one or several energy containers composed with ten sets of twelve 3.6 V primary lithium-thionyl chloride (Li-SOCI<sub>2</sub>) cells, each container providing 4 kWh. Voltages and instantaneous consumed currents are monitored and transmitted with other technical data. Energy containers are 4000m rated aluminum housing fitted with a security overpressure valve.

## E. CONNECTION/DISCONNECTION SYSTEM

A specific mechanical system has been developed by Ifremer to allow underwater connections and disconnections of sensors and batteries. The SEAMON can be fitted with several devices to allow the ROV to perform the installation of a new sensor or to change batteries without recovering the node. These devices have been used from 2010 to 2014 to install OBS and pressure gauges on SEAMON WEST.

## F. SENSORS

SEAMON West is dedicated to geophysical monitoring. It serves two permanent pressure gauges as well as an ocean

bottom seismometer (OBS), both provided by the Institut de Physique du Globe de Paris and installed on a solidified lava lake.

SEAMON East is installed 600 m away from SEAMON West, at the base of the active Tour Eiffel edifice. It is dedicated to studying the links between faunal dynamics and physico-chemical factors. The node is composed with several elements such as an Ifremer SMOOVE (SMart Ocean Observatory Video Equipment) high definition video camera fitted with a solid-state drive and four pressure-balanced-oil-filled LED lights, an Aanderaa<sup>®</sup> optode, a Wetlabs<sup>®</sup> turbidimeter, an Ifremer Chemini *in situ* iron analyser and since 2013 and an Ifremer CISICS (Cabled *in situ* Instrumented Colonizer System).

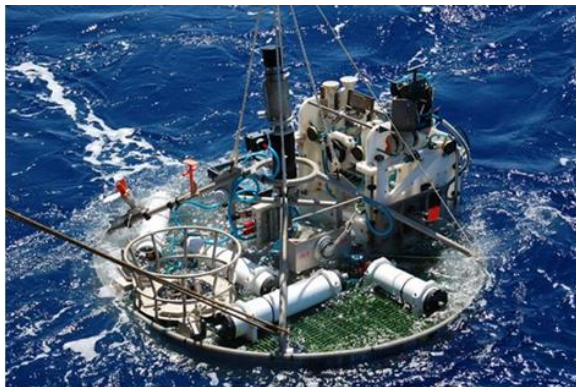


Fig. 2. The SEAMON EAST node during deployment

## II. RELAY BUOY

Moored within acoustic range of the two SEAMONs nodes on the ocean surface, the BOREL relay buoy transfers every six hours, the received acoustic data flow on the satellite link to the shore server decoding and archiving data.

Asynchronously, an operator can initiate a satellite session on shore and send remote configuration queries addressed to the buoy or a bottom station.

The energy is provided by solar panels coupled with a regulator and lead-acid batteries. To increase available energy, especially during winter periods, additional panels have been installed and a sleep mode has been implemented on the acoustic modems by their manufacturer.

The robustness of the buoy mooring is one of the technical challenges for the EMSO-Azores observatory. It is composed, from top to bottom, with 50m of steel cable (diameter 20mm), 700m of nylon cable (diameter 24mm) and 940m of polypropylene cable (diameter 28mm). Finally, a 1500kg steel ballast is connected to the line with a 10m chain (diameter 16mm) and an acoustic releaser for mooring recovery.

The Electronic unit named UGB (Buoy Management Unit) includes an application board built around an 8 bits microcontroller (Atmel<sup>®</sup> ATmega128). This board manages the acoustic modem, the satellite modem and sensors (weather station, IPGP precision GPS).

Two complete independent redundant transmission links are used on the buoy to optimize data transmission success

rate. In case of a material failure, we can remotely switch from a link to the other one and reestablish the data transmission channel. A preventive reset is done daily on the UGB to prevent from any software issue blocking data transmission.

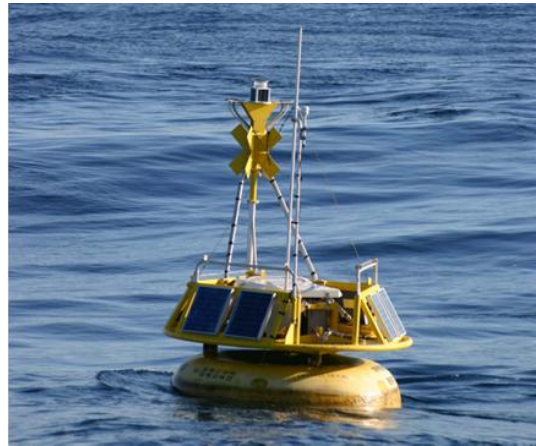


Fig. 3. The BOREL buoy after deployment

The acoustic modems are identical to the SEAMON ones except the housing which is stainless steel 200m deep rated. They are installed on the buoy keel with a baffle to optimize the signal-to-noise ratio.

The use of Iridium<sup>®</sup> RUDICS (Router-Based Unrestricted Digital Interworking Connectivity Solution) service on a Nal Research<sup>®</sup> A3LA-DG, associated to a specific data protocol allows efficient satellite transmission of a large amount of data.

The effective bitrate of the Iridium link is around 2000 bits/sec. Modem stability and reliability are considerable thanks to the RUDICS service having replaced the Direct Dial service. Connection time is around 15 seconds and cuts due to satellite connection loss are rare.

Each BOREL independent link is powered with 4 solar panels associated to a regulator and to 2 lead acid batteries connected in series to deliver a 24V voltage to the UGB and to the modems. The average power consumption of each link is 3W, divided up almost fairly between UGB, Iridium modem and acoustic modem.

The voltage varies from 25V to 28V, between days and nights, depending of the cloud cover and the season.

## III. LOGISTICS

The observatory requires annual maintenance, carried out during a two week cruise from a research vessel equipped with a Remotely Operated Vehicle (ROV). During each maintenance cruise, each part of the observatory is recovered, reconditioned and re-installed.

The BOREL buoy is recovered after releasing its ballast. The buoy requires a thorough cleaning of its submerged parts. Sacrificial anodes are replaced. After one year of service, it is frequent to find one or several solar panels damaged by strong waves. The acoustic modems are replaced every year and sent back to the manufacturer. A



complete check of the electronics, batteries and external wiring is performed. Due to its critical role with regard to the whole observatory, a new mooring line is installed every year.



Fig. 4: cirripods on BOREL's keel after recovery in 2015

The two SEAMON seabed stations are recovered by lowering floatation devices, securing them to the stations with the ROV, then releasing a deadweight that triggers the ascent. Reconditioning consists in cleaning the stations, replacing the batteries and the acoustic modems, replacing the sacrificial anodes and upgrading the embedded software. The sensors are cleaned and calibrated or switched with lab calibrated units. Heavy data files that could not be sent to shore in real time (video footages and seismic data) are downloaded from the station. After a complete functional check, the stations are lowered to the seafloor with a cable. The final installation of the nodes and the precise installation of the sensors are performed by the ROV. The general functioning of the observatory, including acoustic and satellite data transmissions, is checked before leaving.

### III. DATA MANAGEMENT

All the data acquired by the EMSO-Azores observatory are stored in the National data bases, CORIOLIS, SEXTANT, BGM and BIOCEAN managed by the SISMER and RESIF. EMSO-Azores produces two flows of data.

Data acquired by connected instruments are at least partially transmitted to the shore in near real time (every six hours) through acoustic and satellite link. They are decoded, stored and made available without quality check. They are attributed a DOI (Digital object identifier) updated on a daily basis and can be downloaded or plotted using the portal <http://www.emso-fr.org/EMSO-Azores>.

The complete set of data is recovered annually during the maintenance cruises. This concerns the data for which the acoustic bandwidth is not sufficient for transmitting (video footages and seismic data for instance) and the data acquired by the autonomous instruments. These data are checked with respect to the quality process specified by EMODnet (European Marine Observation and Data Network). Each set of data acquired by each sensor during the deployment is also attributed a DOI and can be downloaded using the EMSO portal.

### IV. CONCLUSION

After six years of operation, the EMSO Azores infrastructure shows a good level of reliability. We learned a lot from the different issues encountered during the first years of deployment, especially concerning underwater manipulations. Deployment and recovery procedures have been adapted and improved to try to minimize operation duration. ROV interventions are now optimized thanks to the pilots experience and the Lucky Strike site knowledge.

The COSTOF proved that its modular architecture was perfectly adapted to this kind of observatory, allowing easy sensor changes. Its low power consumption and its communication capability have been demonstrated.

The data archiving and access step has been largely improved and standardized. The data can now be downloaded through a dedicated portal.

Nevertheless, during this deployment period, we pointed out some limits to the COSTOF. As each sensor board is dedicated to one sensor, only six sensors can be connected. The lack of Ethernet connectivity is also a limitation, more and more sensors needing a 100BASE-T link to transmit their data.

All these reasons convinced us to develop a new generation of electronic unit: the COSTOF2. The idea was to keep the COSTOF's benefits, improve some of its capabilities and add some new features.

COSTOF2 has been developed around a similar distributed architecture based on a CAN bus and an Ethernet network has been added in parallel. This new front-end allows to connect up to 16 sensors with a fully configurable interface to choose voltage and data link for each sensors.

Data storage capabilities, time stamping precision, user interface have also been considerably improved. A Sensor Development Kit has also been implemented to offer to any sensor provider a simple and convivial interface for coding each specific sensor driver.

The COSTOF2 will be deployed on both SEAMON nodes on the EMSO Azores observatory during next maintenance cruise in August 2016 and will equip the buoy the year after.

With this new innovative development, we start in 2016 a new period for the EMSO-Azores observatory with improved performances and new possibilities. Within the framework of the FixO3 Transnational access, the upgraded infrastructure will be able to welcome new sensors both on the SEAMON nodes and on BOREL buoy.

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