TEMPO: a new ecological module for studying deep-sea community dynamics at hydrothermal vents

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***Abstract*— The major goal of this project, elaborated in the frame of the STREP Exocet/D European project, was to design a first autonomous long-term imaging module equipped with a deep-sea video camera, adequate lightning and sufficient energy storage while taking advantage of most recent progress in imaging and photonics. The new ecological module TEMPO was tested and deployed during the Momareto cruise held from August 6 to September 6, 2006 on the new French oceanographic vessel Pourquoi pas?, with the ROV Victor 6000. The scientific objectives of the Momareto cruise were to study the spatial and temporal dynamics of hydrothermal communities colonizing the MoMAR zone, located on the Azores Triple Junction.**

***Index Terms*—Community dynamics, deep-sea, imagery, monitoring**

I. Introduction

THERE is world-wide recognition for the need of long term in situ monitoring of the marine environment. While the intertidal zone and coral reefs have retained much attention because of their accessibility and because their most common species make them well suited to manipulative experiments, technological limitations have delayed observational studies of community structure in the deep ocean. Only recently are we beginning to understand some of the dynamics of deep-sea communities. Even more important, most of the traditional techniques used to evaluate the influence of biological interactions are not yet applicable in subtidal or deep-sea habitats. As a result, our knowledge of the influence of biotic and abiotic factors in these remote ecosystems is extremely limited compared to shallower environments.

Particularly lacking in the study of abyssal benthic communities are time-series data. Regular visits to the deep-sea are prohibitively costly and ecologists have been slow to develop monitoring instruments to study community dynamics and patterns of succession in distant habitats. Time-series studies in remote ecosystems will give fundamental insights about the reaction of the benthos to different environmental events -flow changes, food falls, catastrophic disturbances-, community succession [6] as well as on the role of biological interactions on community dynamics [3]. Short-term video recordings can also be used to describe and document faunal behaviour, including territorial interactions [4] and predation [5].

Understanding community dynamics is also an important prerequisite for management, conservation and protection of natural ecosystems. A great effort is now being invested by the international scientific community into developing new ways to study the temporal aspect of both environmental and biotic factors in the deep ocean. The goal of seafloor observatories (c.f. NEPTUNE, MoMAR, ESONET) is to develop multidisciplinary long-term experiments for observations and monitoring of seafloor active processes through the provision of communications and power to scientific instruments. The development of new autonomous scientific tools, suited for long-term deployment, is an essential step to insure the success of these future observatories.

The major goal of this project, elaborated in the frame of the STREP Exocet/D European project, was to design a first autonomous long-term imaging module –AIM- equipped with a deep-sea video camera, a digital video recorder, adequate lightning and sufficient energy storage while taking advantage of most recent progress in imaging and photonics. The AIM is able to pilot the projectors and to record digital video sequences on a hard disk. A biofouling protection was set on the camera port hole and on the lights. A CHEMINI Fe in situ analyzer and three temperature probes (NKE) were coupled to the imagery module to monitor environmental changes in parallel to community dynamics. The whole system, called TEMPO, is powered by a Sea-Monitoring Node (SEAMON) [1]. TEMPO was tested and deployed during the Momareto cruise. It was left operating on the MoMAR hydrothermal site, for a year-round collection of data.

Manuscript received March 30, 2007.

The development of TEMPO was funded by the EXOCET/D European project, contract # GOCE-CT-2003-505342.

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1-4244-0635-8/07/$20.00 ©2007 IEEE

II. Development

TEMPO is composed of 2 main aluminum alloy structures (Fig. 1). The first one (main structure) hosts the energy container, the COSTOF (SEAMON master electronics), a CLSI link (Contact-Less Serial Interface from NKE, used for underwater local communications) and a junction box. The dimensions of this structure are 110*110*100 cm for a total weight in water of 78 kg. During the mooring, it held a sensor module and a 15 m coiled cable.

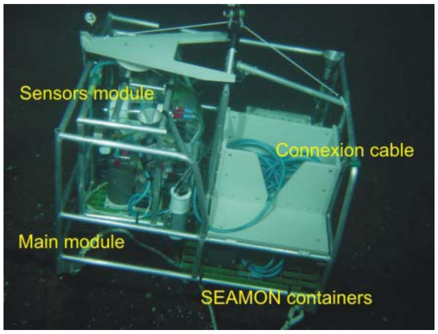

Fig. 1. The TEMPO main structure on the seafloor prior to the deployment of the sensor module during the MoMARETO cruise, 2006.

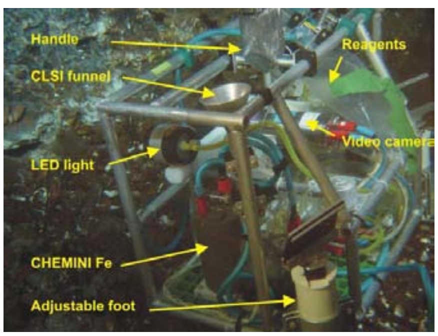

Fig. 2. The TEMPO sensor module will monitor the temporal dynamics of a mussel assemblage at the base of the Tour Eiffel hydrothermal edifice.

The sensor module measures 0.85*0.70*0.65 cm for a weight of 28 kg in water. It includes the AIM (autonomous camera and 2 Led projectors), a CLSI link, autonomous temperature probes, and a CHEMINI Fe analyzer with its 10L bags of reagents (Fig. 2). This frame can be handled by underwater vehicles and is equipped with 2 adjustable feet.

A. *Camera and lights*

The AIM is composed of a color video camera and a digital recorder integrated in a titanium resistant housing and two LED projectors (Fig. 3). The AIM is powered by the energy container, and has a fully autonomous operation. The SONY EX980 camera incorporates a 18x zoom lens and a ¼” super HAD CCD. The main functions include zoom, iris and focus that can be controlled via an RS232C serial link during the deployment. The video camera can be mechanically adjusted to the target by the submersible. A compact low power digital video recorder has been developed (Shaktiware/Ifremer). This unit is based on a MPEG2 compression module, which acquires the composite video, encodes it and stores the obtained digital signal on a 40 Gigabyte compact hard disk. The algorithm used for compression allows a full D1 resolution (720x576) at 25 frames per second. A low power controller schedules the operations of the different parts of the AIM (camera, recorder, lighting, remote links). Two operational modes are available: recording and sleeping. A fast Ethernet link allows downloading of the video sequences when the AIM is recovered at the surface. A 38,4kbds CLSI (Contact Less Serial Inductive Link, NKE/Ifremer) allows activation of the camera, control of the settings, and the streaming of a lower resolution image during the deployment. Two 35W light heads --which are based on seven white LEDs – have been developed and marinized by DYNASUB. They have a very short warm up delay to reduce energy consumption. Ultimately, the color of the lights could be optimized for underwater imaging.

Fig. 3. Camera outside its titanium housing.

B. *Anti-fouling system*

Surprisingly, 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 for preventing bio-fouling lies on localized microchloration. The portholes of the video camera and the projectors were coated with a thin conductive and transparent film of metallic oxide. The application of a defined potential allows sea water electrolysis and the generation of hypochlorite on the surfaces. This method has two main advantages: it does not modify the image and the concentrations of chemicals released are negligible. The method was successfully tested on a photo camera during the Exomar cruise (2005) on active hydrothermal vents of the Mid Atlantic Ridge (MoMAR area).

C. *Chemical analyser*

The development of *in situ* analysers to make chemical measurements in marine environment is essential to allow the chemical characterisation of habitats prevailing in vent ecosystems. CHEMINI constitutes the new generation of analysers for the *in situ* measurement of sea water chemical parameters (Fig. 3a). It is based on flow analysis and colorimetric detection. Much of the development effort has focused on miniaturisation and reliability. The deep-sea version of CHEMINI allows the *in situ* calibration and determination of iron and sulphide with analytical performances similar to lab spectrophotometers (Table I).

Table I
Analytical performance of CHEMINI

	CHEMINI iron	CHEMINI sulphide
Range (µmol/l)	0 to 100	0 to 400
Duration / measure (min.)	2	2
Repeatability (6 µmol/l, n=5)	± 0,3	± 0,2
Detection limit (µmol/l)	0,3	0,12

The hydraulic module is a pressure-balanced tank filled with dielectric oil (Fig. 4b). Two peristaltic pumps and eight 3-port SMC solenoid valves are used for circulation of the different fluids. Two ways are devoted to sample and four ways for standards. Most of the manifold tubing is replaced by an engraved circuit in PMMA. The pumps and valves are integrated directly on the manifold limiting the use of tubing and connecting parts.

The detection module holds the electronic cards and the colorimeter in a pressure tank (Fig. 4a). The quartz flow cell, manufactured by HELLMA (France), is placed outside this tank (Fig. 5). The light is emitted by LED to the external quartz flow cell and returns to the detector via optic fibres and special waterproof titanium optic pass through (SEDI, France). The final signal is obtained using synchronous detection.

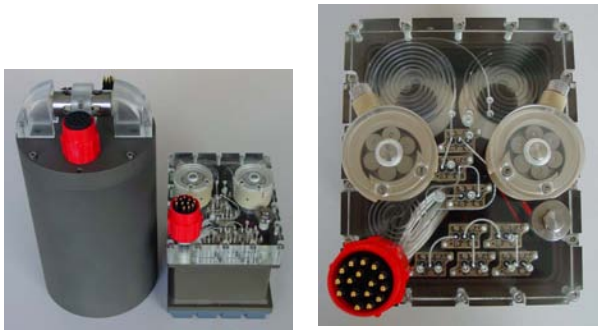

Fig. 4a.CHEMINI deep sea version with the detection and the hydraulic modules. 4b. Top view of the hydraulic module.

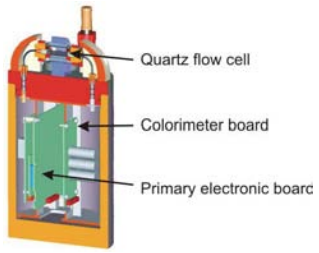

Fig. 4. Transversal cut of the detection module.

The electrical consumption of the whole system is quite low with 20mAh per measurement (12V). A low consumption board (ATMEL Atmega) pilots the electronic part of CHEMINI. This permits CHEMINI to be used either connected to a submersible or controlled by a SEAMON-like autonomous seabed station. The system is controlled on the surface by a specific software. Due to problems with reagent stability over time, only the Fe version was deployed on TEMPO. This issue should be resolved in the near future.

D. Power and controls

TEMPO is powered by a set of lithium cells that will provide 4 kW per hour during one year. The measurement sequencing and data acquisition are performed by a COSTOF (Communication and STOrage Front-end). It includes a series of simple, identical and low power electronic boards, each dedicated to one sensor and communicating through a CAN (Controller Area Network) field bus, providing maximum modularity and reliability to TEMPO. Both the power and control subsets are generic components from the so-called SEAMON technology, developed by Ifremer for non cabled long term observatories [1]. Two Contact Less Serial Inductive links were used to control and adjust the settings (camera and CHEMINI probe).

III. AT-SEA TRIALS

The MoMARETO cruise was held from August 6 to September 6, 2006 on the new French oceanographic vessel Pourquoi pas?, with the ROV Victor 6000. The main objective of this cruise was to study the spatial and temporal dynamics of hydrothermal communities colonizing the MoMAR zone, located on the Azores Triple Junction [7]. The first leg of the cruise was dedicated to the final integration and validation phase of different prototypes, including TEMPO, developed during the European EXOCET/D project. The proposed approach for the second leg was to study the response of different hydrothermal species to their environment at two temporal scales: a very short-term response of organisms to habitat micro-variations (hours-days) and a longer observatory-type scale where the dynamics of faunal assemblages was to be linked to broader-scale habitat variations (months-years).

After a first operational trial, TEMPO was deployed at the base of an active hydrothermal edifice at 1700m depth. The system was moored from the vessel by free falling mode on the Lucky Strike vent field. In addition to TEMPO, the mooring included buoyancy, one acoustic transponder and dead weights. On the bottom, the ROV Victor was used to carry TEMPO as close as possible to the targeted study site. The sensor module was extracted from the main structure and the submersible precisely positioned it near a *Bathymodiolus azoricus* mussel assemblage located at the base of the Tour Eiffel edifice (Fig. 6).

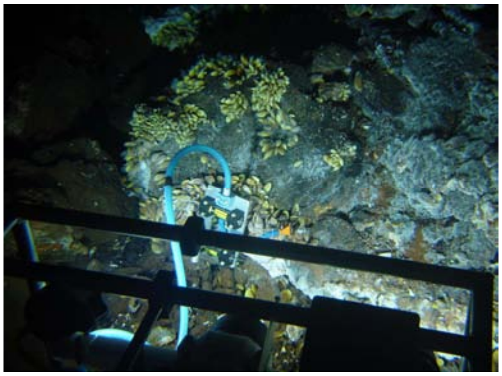

Fig. 6. The sample inlet (orange) of CHEMINI associated to two temperature probes were deployed in the mussel assemblage.

Diffuse fluid flow was observed in the vicinity of the mussels and several mobile animals (shrimps, crabs, amphipods) were crawling nearby. The CHEMINI sample inlet, associated to two autonomous temperature probes (NKE), was deployed within the target mussel assemblage. A third probe was left on the frame of the sensor module. To verify the point of view of the camera, a low-resolution still image was brought to the surface via a CLSI link (Fig. 7).

The module will record 2 x 3 minutes of high-quality video footage and take four *in situ* Fe measurements per day during one year. Temperature will be continuously recorded every 15 minutes in the vicinity of the assemblage.

Fig. 7. A view of the scene that will be observed by TEMPO during its year deployment as brought to the surface via the CLSI link.

IV. Conclusions

TEMPO will be hopefully recovered during summer 2007. Acquired imagery and environmental data will be analyzed to study the links between environmental changes and biotic factors, including composition, density, biomass and growth of visible species (mussels, shrimps, crabs), behaviour and, biological interactions such as predation. This first set of data will be used to adapt and refine future temporal experiments on the same area. Therefore, from 2008 on, it is foreseen to up-date TEMPO with a near-real time link (through a surface relay buoy) from the MoMAR zone to shore. A second node, dedicated to geophysical studies, will be installed in the vicinity of TEMPO, allowing multidisciplinary long term observations of the site.

A new version of TEMPO will also be deployed and connected to NEPTUNE – a deep sea observatory network located on the Juan de Fuca Ridge in the North-East Pacific Ocean. TEMPO will be adapted to communicate with a cable network which not only allows real time monitoring but also, interaction with the instrument. This study will allow a comparison of the dynamics of vent ecosystems from two different regions: the Mid Atlantic Ridge and North East Pacific Rise. These hydrothermal systems differ mainly by their spreading rates, their geology and their seismic activity.

Long-term experiments on the deep-sea floor will provide important insights on temporal variability of chemosynthetic ecosystems and will constitute the basis for the management and protection of these remote “hot spots”.

Acknowledgment

We would like to thank Captain Philippe Guillemet of the R/V *Pourquoi pas?* and his crew for their never-failing collaboration to the success of this cruise. We also acknowledge the Victor 6000 ROV team for their patience and constant support. The authors also express their sincere thanks to all members of the EXOCET/D team for their hard work towards the development of the instruments tested and the methodologies used during this cruise.

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