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ROSE: development and demonstration of a "Mobile Response Observatory" prototype for subsea environmental monitoring.

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Abstract: **ROSE project was aimed at defining and studying a system for monitoring polluting wrecks based on the deployment of a set of subsea stations integrated in an acoustic network and communicating with shore through a wireless link. The project scope also comprised the building of a prototype system intended for a near shore demonstration of limited duration. This system comprises: two floating measuring stations anchored at sea bottom, a relay buoy and the operating shore station. Station sensors are shared in pollutant sensors and environmental parameter sensors. The prototype system is fitted with: hydrocarbon fluorometer, CTD sensor, back scattering meter, dissolved O2 sensor and ADCP profiler. The system was deployed in Bay of Douarnenez, at 25 meter during 2.5 months in summer 2006. This deployment enables to draw experience return on at sea operations and system behaviour, data acquisition by the various sensors and operation of the communication system.**
Keywords: pollution, wreck, marine environment, subsea observatory, acoustic network.

I. INTRODUCTION

Scope of the ROSE project (Acoustic Network for Polluting Wreck Monitoring) was to define and study a system for monitoring polluting wrecks. The system is based on a set of sea bottom stations integrated in an acoustic network and communicating with the shore thanks to a relay buoy and a wireless link.
The project has been labelled in December 2003 by RITMER (Technology and Innovation Network on accidental sea pollutions) and was financially supported by the French Ministry of Research. The project was coordinated by Ifremer and carried out by the enterprises Atlantide, NKE instrumentation and Sercel with the contribution of Cedre and Ecole Nationale Supérieure de Télécommunications de Bretagne (Brittany Telecommunication School).
The work was started mid 2004 and was organised along three axes: Operations, System and Sensors. The project comprised also the building of a prototype system intended for a coastal and limited duration demonstration performed during summer 2006.
The paper will successively deal with : functional definition of the system, technical description of the prototype system, on shore equipment tests in laboratory and seawater tank and demonstration at sea.

II. FUNCTIONAL DEFINITION OF THE SYSTEM

The system definition resulted from numerous debates between project partners in order to get a good knowledge of operational requirements. The definition is notably based on an event analysis performed by Cedre, which comprised:
. a review of past accidents at sea and an inventory of potentially harmful wrecks along the French coasts
. an inventory of sensors and more complex equipment for detection and measurement of pollutions and an assessment of their adequacy to the operation conditions of ROSE system.
The functional specifications prepared by Ifremer at the end of the debate and analysis phase define the system objectives and its architecture. They do an inventory of the foreseeable conditions of system applications. Based on this information Atlantide carried out the study of the methods, logistic means and operation assistance tools required for deploying the system.

1. Destination and architecture of the system

ROSE system is intended to be deployed around a polluting or dangerous wreck in order to:
. detect pollution leakages and as much as possible evaluate their importance
. measure environmental parameters of interest to predict the dispersion of the pollution, to evaluate the environment actions on the wreck and to define the requirements on the means for a future intervention.

The system is composed of (Fig.1):
. several autonomous sea bottom stations, fitted with sensors, which constitute the nodes of an underwater acoustic communication network
. a buoy moored within the area of station deployment and communicating acoustically with the stations
. a shore station to operate the system, which communicates by a wireless link with the buoy

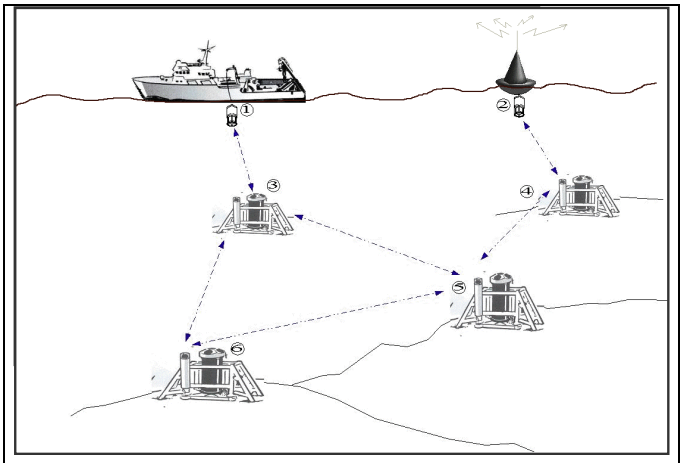


Figure 1. ROSE system scheme

2. Functionalities

System functionalities are of three types:
. acquisition and recording of measurements by sea bottom stations
. communication with the stations through the acoustic network and wireless link
. system and data management by the shore station

Measurement acquisition and recording

These two functions are carried out by the sea bottom stations thanks to the sensor set and the station electronic unit. The sensor set can be easily adapted to the encountered situation; this adaptability has been obtained by a simple mechanical interfacement between sensors and station structure and at the electronic level by modular integration of the sensors. Measurement acquisition parameters, mainly periodicity and duration, are tailored to the needs of each sensor.
Availability of sensors to detect/measure pollutants in subsea environment is rather limited. Inversely measurement of environment parameters takes advantage of the wide range of oceanographical sensors.
Pertinent environment parameters are primarily: temperature and salinity, visibility and current profiles.
Station operation status is monitored by measurement of several technical parameters: battery voltage, consumed energy and water ingress detection in pressure resistant containers.
Acquired data are integrally recorded by station electronics. They are recovered at the end of deployment.

Communication with the stations

A near real time bi-directional link relates the bottom stations to the shore station. This link is based on the acoustic network between the stations and the buoy, which is prolonged by the wireless link from the buoy to shore.
Additionally the communication with the stations can be established from a ship on site thanks to a portable system comprising a computer, an acoustic modem and an acoustic transducer.
The type of the wireless link depends primarily on the class of deployment areas corresponding roughly to the link coverage capabilities : GSM or GPRS phone, VHF radio or satellite link.
The information conveyed by the communication system are classed in: command messages to activate station equipment, sensor data messages and technical data messages, and finally alarm messages emitted in case of special event detected by a sensor or an abnormality of a technical parameter.
The stations can be fitted with “Messengers”; they are floating beacons released by the station capable of storing a continuous sequence of data and a set of sampled data that can be transmitted on shore by Argos satellite system. Messenger unlatching can activated at a programmed time, on command reception or alarm detection.
A contacless inductive link, CLSI (ContactLess Serial Interface), allows local communication with the station.

System management

The system management is performed at a shore station comprising : a computer unit and the end station of the wireless link. The station equipment can easily be conditioned as a portable system. The shore station is designed so that the received information can be integrated in a wider crisis management system.

Deployment zone classification

Deployment zone categories are defined on the basis of two criteria: the deployment site water depth and the coverage of the various wireless links.
Three depth classes are defined:
. Coastal : depth < 100 m
. Continental shelf: 100 m < depth < 400 m
. Great depths: 400 m < depth < 4000 m

Three classes of wireless link coverage correspond to the type of operable link: GSM or GPRS phone, VHF radio or satellite link.
These classes are rather correlated with the site distance to shore. Depth and coverage categories are not systematically in coincidence, depending on the sea bottom profile.

III. DESCRIPTION OF THE PROTOTYPE SYSTEM

The prototype system was designed for a demonstration in coastal area and small water depth. It is composed of two stations, one of them fitted with two Messengers, a relay buoy and the shore station.

1. Bottom stations
A new concept of buoyant bottom station has been developed. It allows to position sensors at the convenient height above sea bottom by adjustment of the station mooring line length. Thanks to the hydrodynamic action on rear plates, the station orientates itself in the direction of current. An horizontal deflector compensates the current drag and maintains the station in the horizontal plane. The station is latched to its mooring by an autonomous acoustic release.

Structure

It is an assembly of welded tubes in corrosion resistant aluminium alloy. The objective was to build a robust and compact structure to facilitate handling at sea while maintaining its mass as low as possible. Dimensions of the constitutive elements have been kept under the limits authorizing ordinary road transportation.
Station buoyancy is provided by fishing net floats for continental shelf deployments, which can be replaced by syntactic foam blocks in case of deep-sea deployment (Fig.2).

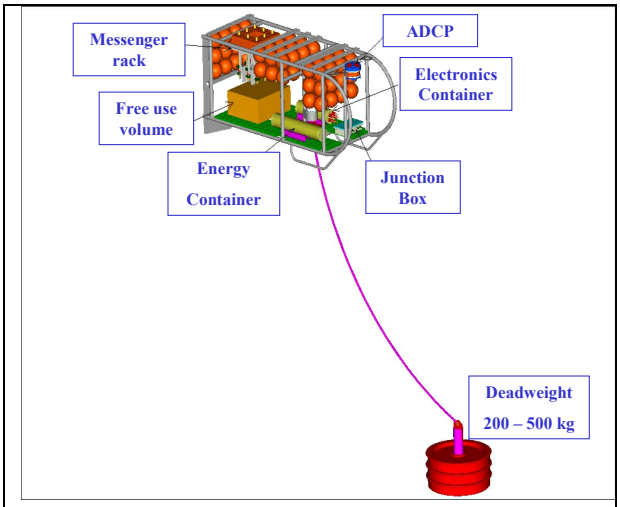


Figure 2a . ROSE bottom station

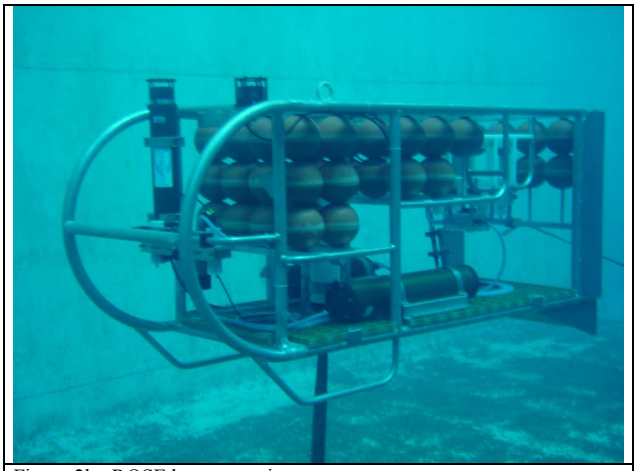


Figure 2b . ROSE bottom station

Main characteristics of a station fully equipped

. Over all dimensions: length 2.70 m * width 1.00 m * height 1.30 m
. Mass : 300 kg ;
. Buoyancy : 25 à 30 daN

Energy
The station is powered by continuous 12 and 24 volt primary battery packs housed in standard pressure resistant containers. The station can be fitted with 1 or 2 containers.
The type of batteries and the size of battery packs are determined by energy needs of the mission. A standard container can contain up to 120 LSH 20 batteries.

Electronics
The operation of the station is piloted by the electronics named COSTOF composed of (Fig.3):
. the bottom basket board which can be connected to 8 bridge boards. Each bridge board can be coupled to a memory extension board of 64 Mbytes capacity
. 5 of the bridge boards are available to insure interface with a sensor
. the 3 other ones insure interface with: the Sercel acoustic modem MATS 200/Net, the electronics piloting the Messengers and the CLSI link.
Communication between bridge boards is insured by the field bus CAN (CANopen protocol). The CLSI bridge board is connected to the technical management board. Technical monitoring applies to:
. feeding tensions, instantaneous current intensities and cumulative consumed energy
. container internal depressurisation and detections of eventual water entries
. good operation of each bridge board.
The interconnections for energy and signals between pressure resistant containers are implemented by cables in oil filled equipressurised tubes and SUBCONN/Micro connectors.

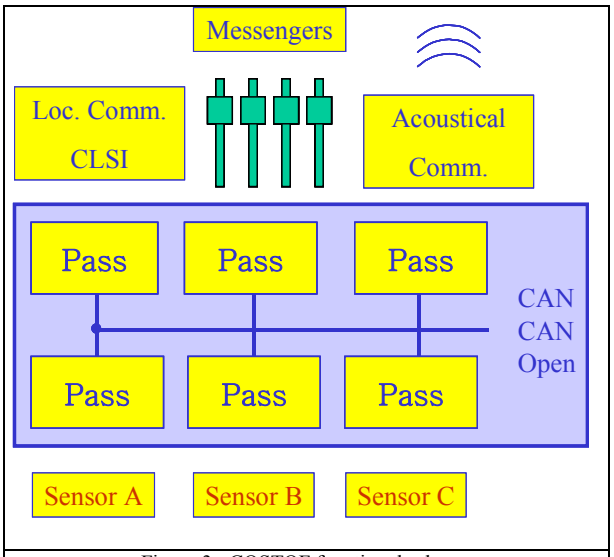


Figure 3 . COSTOF functional scheme

2. Sensors

The prototype stations were fitted with the following sensors :

. Station N°1 :
Back scattering meter Wetlabs BBRTD-226 and O2 Optode Aanderaa

. Station N°2 :
Hydrocarbon fluorometer Trios EnviroFlu , CTD sensor SBE 37 SMP and ADCP RDI 300 kHz

Glasses of optical sensors are protected against biofouling development by electrolysis chlorine generation.

3. Communication system

The system is composed of :
. a Sercel MATS 200/Net acoustic network between stations and the buoy
. a GPRS phone link between the buoy and the shore station.

Acoustic network
It operates at 12 kHz frequency. Data flow ranges from 20 to 200 bits/s depending on the selected modulation type. Three modulation types with fair robustness against multiple paths are implemented . Three power emission levels are available from 173 to 185 dB/µPa . Acoustic modems are equipped with an omnidirectional transducer attached to the container and are 4000 m depth rated.

Wireless link and shore station
In the case of coastal deployment GPRS phone constitutes an efficient link. The relay buoy is equipped with the GPRS antenna and modem. The modem is connected to an electronic unit insuring interface with the acoustic network.
On shore the system comprises a data server accessible through a MMI dedicated to data treatment, visualisation and exportation for further user oriented treatments

4. Messengers

The stations can be equipped with a set of 8 Messengers. A Messenger can store 4 Mbytes of continuously recorded data and 10kBytes of sampled data, which can be transferred to shore by Argos satellite. Messengers are stored in a rack.
Data transfer to Messengers is done through a miniaturised CLSI link. The data pre-treatment and transfer as well as Messenger release command are managed by the Messenger bridge board.
Messengers are attached to the rack by an Inconel wire, which is consumed by electrolysis upon the release command. Messengers are 4000 m depth rated.

Messenger main characteristics (Fig. 4):

. Titanium tube : Diam. 38 mm * Length. 460 mm
. Float: Section 154 * 154 * Height 150 mm
. Mass : 3.2 kg Buoyancy : 0.6 daN

Figure 4 . Messengers in rack

5. Relay buoy

The buoy (Fig.5) is composed of a foam toroidal float, an underwater galvanised steel keel structure with steel stabilising deadweight at the foot and an aerial aluminium superstructure. On the superstructure planking are placed two watertight containers for batteries and the electronics. At the periphery 4 groups of 2 solar panels (totalising 4 m2) insure battery refuelling. The buoy superstructure is fitted with the GPRS antenna, a radar reflector and regulatory flash light.

Buoy main characteristics :

. Toroidal float : Diam. 2.20 m * Height. 0.90 m
. Overall buoy height : 5.10 m
. Mass fully equipped: 870 kg

For 30 m water depth the mooring line comprises: 12 m of 28 mm diameter steel cable, 1 m of tension damping polyamide cable, 40 m of 14 mm galvanised steel chain and a 750 kg steel anchoring deadweight

Figure 5a . Relay buoy

Figure 5b . Relay buoy

IV. ON SHORE LABORATORY AND SEA WATER TANK TESTS

In addition to functional tests carried out at the successive integration stages, environmental tests have been performed on several subsystems. System tests have carried out in Ifremer seawater test tank. Several sensors have been calibrated in laboratory.

Environmental tests have been performed on various station subsystems and on Messengers. Station pieces of equipment are either already proven custom built parts or on the shelf equipment. Simple control pressure tests are carried out. Messengers that were a new product have undergone an in depth test program both in NKE and Ifremer facilities comprising : functional tests under temperature from 0 to 40 °C, pressure qualification tests on Messenger tube and end closures, vibration tests, Inconel wire electrolysis tests.

The 50 m * 12.5 m area and 10 m deep Ifremer water tank allows to carry out a wide range of tests on full scale equipment including:
. hydrodynamic behaviour tests of stations in current by underwater towing and test of free ascent after release
. release and ascent tests of Messengers and behaviour tests in swell
. partial acoustic communication tests.

Sensor calibrations have been carried in the Cedre or Ifremer laboratories:
. TRIOS hydrocarbon fluorometer, with naphthalene, styrene and xylene solutions by Cedre
WETlabs back scattering meter, with formazine solutions and Aanderra O2 optode by Ifremer.

V. DEMONSTRATION AT SEA

1. System deployment

A demonstration at sea of the prototype system has been carried out during 2.5 months in summer 2006 in the Bay of Douarnenez in Brittany on a site with 25 m map depth that is from 26 to 33 m according to tide amplitude.
The operation was carried out using the Ifremer 25 m long coastal oceanographic ship “Thalia” with Douarnenez as port of operation.
The two ROSE stations have been completely mounted and tested in Ifremer workshop prior to be embarked at Brest harbour on “Thalia”. As the buoy is too big to be handled with the ship A-frame, it had been to be transported by truck to Douarnenez and then towed to deployment site by “Thalia” in about 1 hour.
The buoy was first put in place. Then the ship made its way to the first station position. With the ship going very slow ahead the station was lowered towards the bottom with “Thalia” deck gear and cable, the station 3 m long mooring line and deadweight hanging below it. When hanging deadweight was about 1 m from the bottom the station was unlatched from ship cable by acoustic release.
In addition to the two ROSE moored buoyant stations a simplified station was laid on sea bottom to be a third node in the acoustic network. The three stations were positioned in an Y pattern with the buoy at crossing point, at distances of 750 m for ROSE stations and 1000m for the simple node.
The whole deployment operation took about 1.5 hours.

2. System operation

Programmed operating mode

Environment sensors take a measure every 15 minutes. The station technical parameters are monitored every hour. Every 4 hours the stations send the latest recorded data to the buoy through the acoustic network, with a time lag of 30 minutes between stations. The message sizes are: 430 bytes for station-1 and 2 500 bytes for station-2 due to the ADCP data volume. Emitting acoustic power was set at 179 dB/µPa. The Messengers were programmed to be released 15 days and 2 months after deployment.
If needed these parameters could be changed from the shore station terminal. At the end of the deployment the whole sequences of recorded data are extracted from the station electronics.

Operation of the stations

The technical parameters received during deployment allow to monitor the good operation of the station in spite of some unpredictable acoustic communication perturbations . The recovery of the complete time series at the end of deployment allows to check it completely.
During the demonstration the technical parameters were controlled to be nominal:
. stability of feeding tensions
. decrease of battery energy in conformity with station consumption forecasts
. stability of pressure inside watertight containers
. no water entry alarms

Operation of the communication system

The operation of the system is visualised on the graphs of the number of “No error messages” received per day.
Fig.6 gives the results for the hourly technical messages during 1.5 month for each of the 3 stations. Results are comparable as regards sensor data messages.
The graphs indicate successful transmission rates ranging from about 90% for the node on bottom to 50-65 % for ROSE stations. The lower performance is deemed to be

caused by interferences between the acoustic modem beam and buoyancy air filled spheres. Preliminary assessment of remedial solutions has been carried out regarding the position of the acoustic modem and acoustic protection on buoyancy spheres.

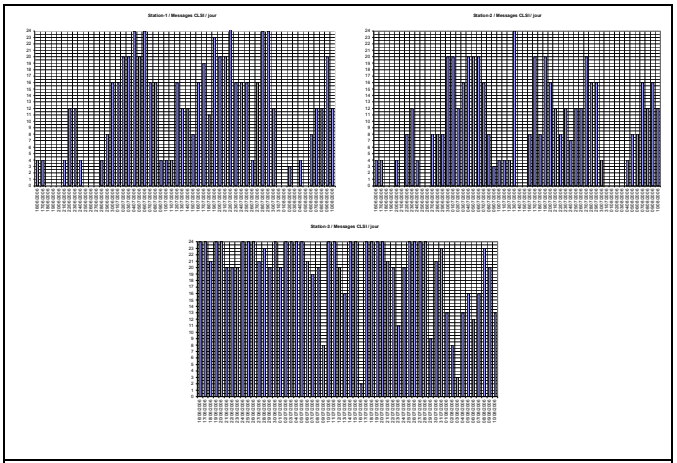
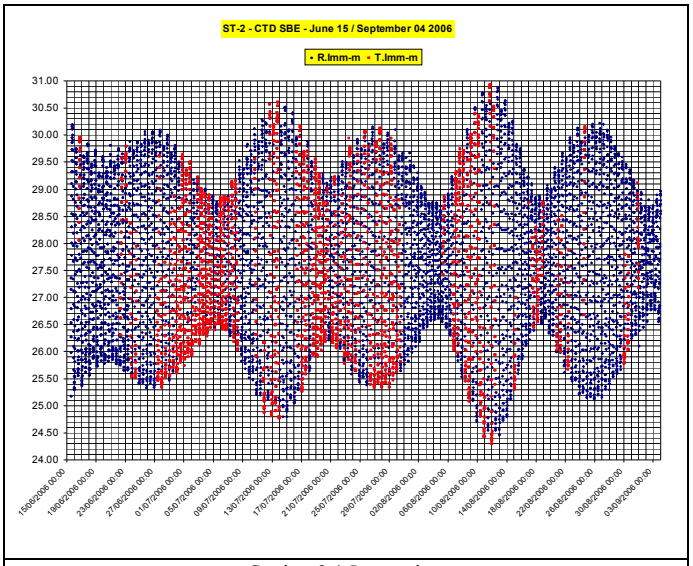


Figure 6 . Graphs of « No error messages » reception (100% success = 24 / day)

Operation of the sensors

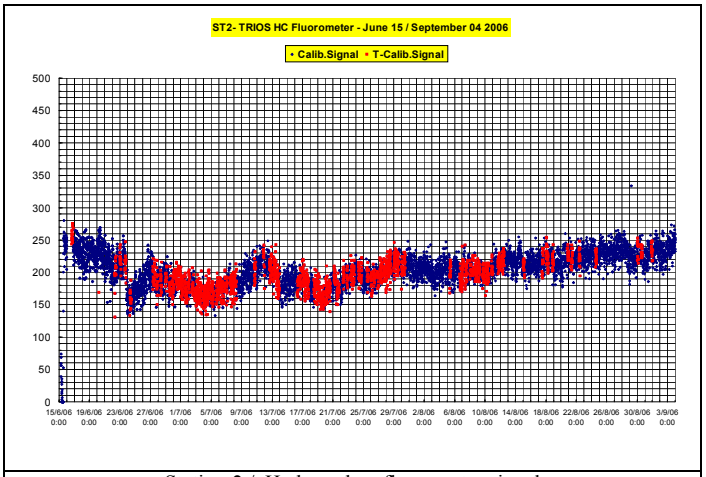
After the pre-treatment at the shore station, sensor data were periodically forwarded to potential end users for analysis of the environment evolution.
The evolution, which could be assessed rather satisfactorily along the deployment period in spite of interruptions in received data series, was confirmed after recovery of the full time series at the end of the demonstration.
Data analysis shows that the sensor set performed satisfactorily during the 2.5 month period of operation. In particular the prevention of biofouling on glasses of optical sensors was quite efficient in spite of the intense fouling development of the summer season .
Examples of recorded data are shown by the curves gathered in Fig.7.



Station-2 / Immersion

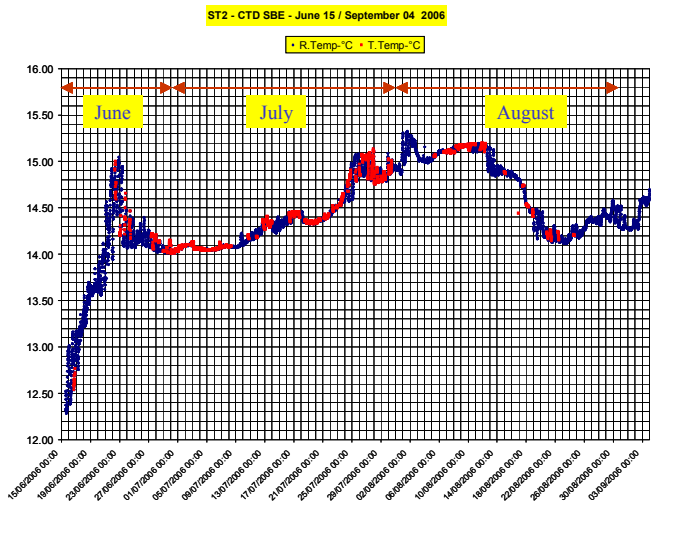
Figure 7a . Examples of sensor data
Douarnenez Bay – June 15 to September 05, 2006

Note : In blue : full time series recovered at end of deployment
In red : data telemetered during the demonstration



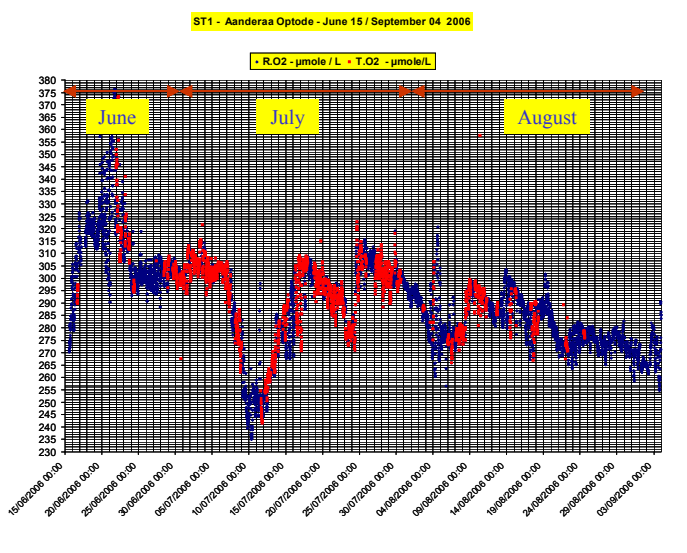
Station-2 / Hydrocarbon fluorometer signal

Figure 7b . Examples of sensor data
Douarnenez Bay – June 15 to September 05, 2006



Station-2 / Temperature

Figure 7c . Examples of sensor data
Douarnenez Bay – June 15 to September 05, 2006



Station-1 / Dissolved Oxygen

Figure 7d . Examples of sensor data
Douarnenez Bay – June 15 to September 05, 2006

Messenger operation

Some disappointment was encountered with the Messenger operation. A very simple system was adopted: Messenger escape is only driven by its own buoyancy once the retaining Inconel wire is dissolved. Buoyancy action revealed to be insufficient against blocking effect of fouling deposition on Messenger rack. An additional mechanical action has been conceived to solve the problem.

3. System recovery

The system recovery was performed using again the ship "Thalia". Stations were recovered firstly by activating the mooring acoustical release and letting the station ascend freely to surface. Operation was ended by the buoy recovery. The whole system recovery took 2.5 hours.

VI. CONCLUSION

The at sea demonstration has brought the proof of several positive features of the ROSE prototype system:

. easy deployment and recovery in shallow water configuration
. good mechanical behaviour and corrosion resistance
. good operation of station and data recording
. good sensor operation and efficient biofouling prevention

Some points need to be up-graded:

. success rate of "no error message" acoustic transmission
. Messenger extraction from their rack

Solutions have been identified and partly tested.

Beyond its original purpose of polluting wreck monitoring, application field of ROSE system can be broadly extended to environmental monitoring.

ACKNOWLEDGMENT

ROSE system development was carried out with support of the French Research Ministry within the frame of RITMER, Research and Technical Innovation Network on marine accidental pollutions