ESO NEWS

The Newsletter of the European Sea Observatory Network

Volume 2 Issue 3

"Dear Colleagues

We wish you an Happy New Year and all the best for 2009!

As you know a new ESONET year will also start soon. Indeed, we are ending the second year with the preparation of the yearly reporting and a reporting workshop will be held near Paris the 26 Jan09. After good results of 2008 : selection of 4 demonstration missions, working groups constitution, and the organization of 3 main ESONET Workshops and of the General Assembly meeting, we can tell that a a first important step toward ESONET integration has been really done. We greatly thank all the ESONET community for the efforts made.
Our wish for 2009 is of course to make a second important step toward integration with a specific highlight to the sustainability of this integration. Indeed, the third year of ESONET, starting from the 1st of March 2009, aims at preparing a permanent ESONET organization with the Virtual Institute VISO to be defined and discussed, the definition of the ESONETLabel (definition of rules and procedures to define an ESONET Regional Observatory) and the launching of ESONET legal integration bodies jointly with EMSO PP. During the second All Regions workshop in Oct 2009 the regional observatory networks around Europe will be better defined, a complete business plan and the first result of demonstration missions will be presented. The ESONET Label will be delivered for the Esonet Nodes to the groups issued from the regional implementation committees which will build up the corresponding ESONET RLEs with EMSO PP.
We wish the needed synergy will be present."

Roland Person and Ingrid Puillat

GEOSTAR Technology

PAOLO FAVALI and LAURA BERANZOLI

The Early Years

The European experience on seafloor monitoring started in early 1990s with the EC MAST Programme. Feasibility studies commissioned by EC were addressed to identifying the scientific requirements (Thiel et al., 1994) and to establishing the possible technological solutions for the development of seafloor observatories (Berta et al., 1995). In parallel, other studies and activities, such as DESIBEL (Rigaud et al., 1998), were carried out at EC level, aimed at defining needs and expectations for long-term investigations at abyssal depths. Meanwhile, USA, Canada and Japan, the most technologically advanced countries, have launched a large number of projects and programmes addressed to long-term and multiparameter seafloor monitoring (Favali and Beranzoli, 2006; Frugoni et al., 2006).
Since 1995, Istituto Nazionale di Geofisica e Vulcanologia (INGV) ran a scientific and technological program for the development of deep-sea observation systems for geophysics, oceanography and environmental sciences. This programme, called GEOSTAR (GEophysical and Oceanographic STation for Abyssal Research), was initially funded by the European Commission (EC) within the 4th and 5th Framework Programme, through the GEOSTAR (1995-1998) and GEOSTAR 2 (1999-2001) (Jourdain, 1999; Beranzoli et al., 2000; 2003; Beranzoli, Favali and Smriglio, 2002; Favali et al., 2002; 2006b).
Two paths were followed after the GEOSTAR experience: the development of other single-frame observatories devoted to specific applications and the enhancement of GEOSTAR as principal node of a network of seafloor observatories. These paths have led to the availability of other five GEOSTAR-class observatories and to the first European prototype of a deep seafloor observatory network.
SN1 (Submarine Network 1) is addressed to seismological, oceanographic and environmental measurements, and was initially developed between 2000 and 2002 within an Italian project. In 2005 it has become part of the cabled underwater infrastructure off Eastern Sicily (NEMO-SN1) (Favali et al., 2006a). GMM (Gas Monitoring Module), built within the EC ASSEM project (2002-2004) (Blandin et al., 2003), is devoted to seafloor gas monitoring (Marinaro et al., 2004; 2006). Another single-frame system, MABEL (now SN2), was developed for polar sea applications within the framework of the Italian PNRA (National Programme for Antarctic Research) (Calcara et al., 2001).
Within the framework of the EC ORION-GEOSTAR-3 project (2002-2005) (Favali et al., 2006b), GEOSTAR was implemented to act as the main node of an underwater network of deep-sea observatories of GEOSTAR-class with the capability of (near)-real-time

communication. In addition to this main node, two more observatories, with the function of satellite nodes (SN3 and SN4), were built and equipped with geophysical and oceanographic sensors.
The parallel running of the EC ORION-GEOSTAR-3 and ASSEM projects has given us the chance to integrate one of the ORION nodes (SN4) in the shallow water ASSEM system during the pilot experiment in Corinth Gulf. This integration was to demonstrate the compatibility of the two seafloor networks and the chance to operate a “coast-to-deep-sea” monitoring system in the near future.
The information on the size, weights and depth rates for all the developed observatories is shown in the following table.

Platform	Overall dimensions (m) (L x W x H)	Weight (kN) (in air)	Weight (kN) (in water)	Depth rated (m)
GEOSTAR	3.50 x 3.50 x 3.30	25-04-09	14-02-09	4000
SN1	2.90 x 2.90 x 2.90	14.0	08-05-09	4000
SN2 (MABEL)	2.90 x 2.90 x 2.90	14.0	08-05-09	4000
SN3	2.90 x 2.90 x 2.90	14.0	08-05-09	4000
SN4	2.00 x 2.00 x 2.00	06-06-09	03-04-09	1000
GMM	1.50 x 1.50 x 1.50	01-05-09	0.7	1000

The Geostar System

GEOSTAR system is designed as a stand-alone autonomous seafloor observatory, based on three main sub-systems (Beranzoli et al., 1998): a) the Bottom Station (BS), which is the frame equipped with sensors, power and communication systems; b) the Communication Systems (CS), hosted by BS; c) MODUS (MObile Docker for Underwater Sciences), which was specifically designed to handle the BS from the sea surface during the deployment/ recovery operations, and operates like a simplified ROV. GEOSTAR is capable of long-term (more than one year) multidisciplinary monitoring at abyssal depths. At present, the maximum operative depth is 4,000 m.

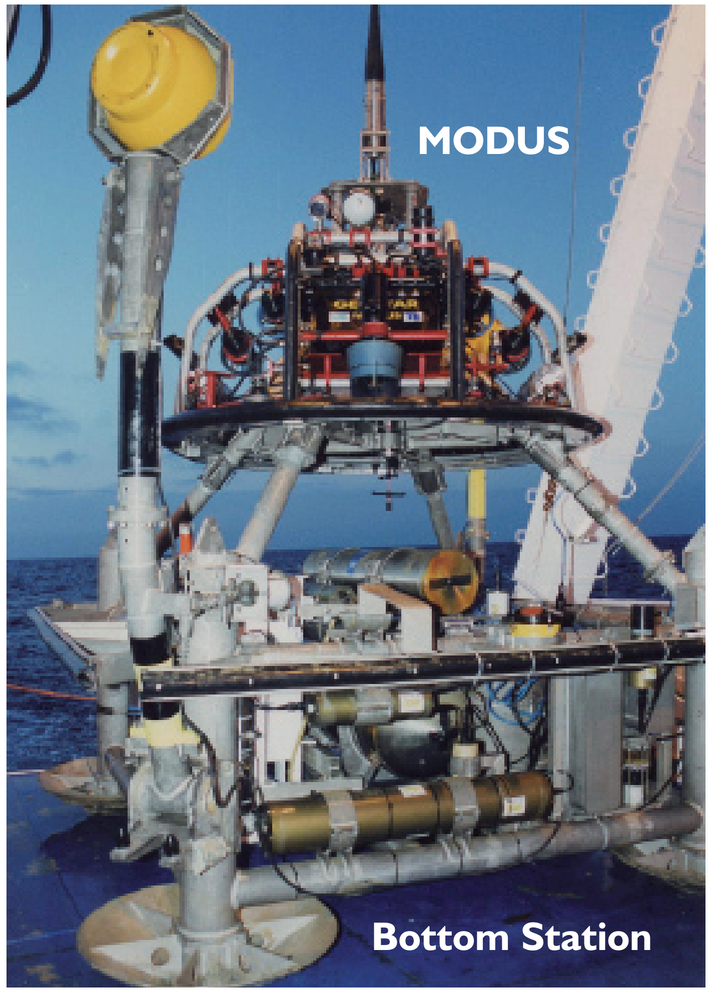

Figure 1 – GEOSTAR system: Bottom Station (bottom), MODUS (top)

Bottom Station

The Bottom Station (BS), a four-leg marine aluminium frame (Fig. 1, bottom), hosts a wide range of sensors, able to collect multidisciplinary data on the same spot. It also contains the battery pack (primary lithium), electronics mounted inside titanium vessels, hard disks for data storage and the underwater part of the communication systems. The BS mission is driven and controlled by a central Data Acquisition and Control System unit (DACS) to allow the management of a complete scientific mission with a wide set of data streams and tagging each measurement according to a unique reference time provided by a central high-precision clock (stability 10-9 ÷ 10-11) (Gasparoni et al., 2002).

MODUS

Accurate and safe positioning at seafloor, re-entry and recovery capabilities of the BS are ensured by the dedicated cable suspended module MODUS (Fig. 1, top), developed and built at the Technische Universität Berlin (TUB), and the Technische Fach-Hochschule (TFH) Berlin (Clauss and Hoog, 2002). MODUS is a sub-sea intervention shuttle operating in deep seas while it is connected to a surface vessel with an umbilical, which provides power, bi-directional data-transfer via F/O telemetry and carries the load induced by the system during operation.
MODUS was conceived to be driven by a ship-board operator and initially could be moved only horizontally by means of two thrusters as needed during the BS recovery. For deep-sea missions the MODUS was enhanced with the inclusion of four more thrusters to power the horizontal (two additional thrusters) and the vertical (two thrusters) movements, one transponder and one altimeter to check MODUS location at depth from the sea surface, and sonar to identify the BS location during the recovery. The MODUS frame is also equipped with video cameras for visual seabed inspection. This system is able to carry up to 30 kN at abyssal depths.

Communications

Two independent Communication Systems (CS) were originally developed for GEOSTAR, based on different principles (Marvaldi et al., 2002). The first one consists of buoyant data capsules, named Messengers (MES), releasable upon surface command or automatically, when filled of data or in case of emergency. Two types of MES are available: a) expendable (data storage capacity 64 Kbytes); b) storage (data storage capacity larger than the expandable, 40 Mbytes). The capsules can transmit via ARGOS satellites their position at sea surface and small quantities of data. The second CS is based on a bi-directional vertical acoustic link with a ship of opportunity or moored buoy. A surface relay buoy, equipped with a telemetry unit and radio/satellite transmitters, assures the (near)-real-time communication between a shore station and the observatory on the seafloor.
The most recent communication link implemented on the GEOSTAR-class observatories was through the cabling: a proper interface between platforms and electro-optical cables was implemented on the SN1 observatory. This determined the realisation of the first real-time seafloor observatory in Europe, NEMO-SN1 off Eastern Sicily (Favali et al., 2006a). This area was identified as one of the key-sites for the nodes foreseen in the EC projects ESONET-CA (Priede et al., 2005) and ESONET-NoE (http://www.esonet-emso.org/esonet-noe/) and in the EC-FP7 Research Infrastructure Project EMSO (Favali and Beranzoli, 2008).

Geostar-Class Observatories And Experiments

Adriatic demonstration mission

In 1998 the first demonstration mission was carried out and GEOSTAR observatory was firstly deployed in Adriatic Sea, 40 km East of Ravenna (Italy), at a depth of 42 m (Jourdain, 1999; Beranzoli et al., 2000). During the 3-week mission the acquisition system recorded 440 continuous hours (97.8% of the total time). The analysis of the data demonstrated the complete reliability of the whole system, including MODUS functionality, and in particular demonstrated the scientific potentiality of unique time-referenced multiparameter data (Beranzoli et al., 2003).

GEOSTAR-2 deep-sea mission

The first GEOSTAR long-term deep-sea mission was performed between September 2000 and April 2001 at about 2000 m w.d. in Southern Tyrrhenian Sea (Favali et al., 2006b). The communication system was enhanced with the support of a surface moored buoy, equipped with the interface of the acoustic system and a radio/satellite link for (near)-real-time transmission between the Bottom Station and on-shore sites. Data acquired, 4160 hours corresponding to about 174 days, amount to more than 65 Mbytes. Also in this long-term experiment, the data quality was high, as demonstrated by De Santis et al. (2006; 2007), Iafolla et al. (2006), and Etiope et al. (2006) that pointed out ocean-lithosphere interactions at Benthic Boundary Level (BBL).

SN1 Observatory

SN1 was the first observatory based on the GEOSTAR technology. Initially, it was funded by Italian agencies during the period 2000-2004. Mainly addressed to seismology and oceanography, it was designed as a reduced-size version of GEOSTAR, using the same features of GEOSTAR in regard to deployment/recovery procedures, the data acquisition system and the special device for seismometer installation developed in the GEOSTAR projects.
From October 2002 to May 2003 SN1 successfully completed the first long-term experiment off-shore Catania (Southern Italy, Eastern Sicily) at 2105-m depth in autonomous mode without any permanent acoustic or physical connection with the sea surface. SN1 was equipped with a vertical acoustic link to allow the remote request of the observatory data from a ship of opportunity and the retrieval of segments of acquired time series. During this

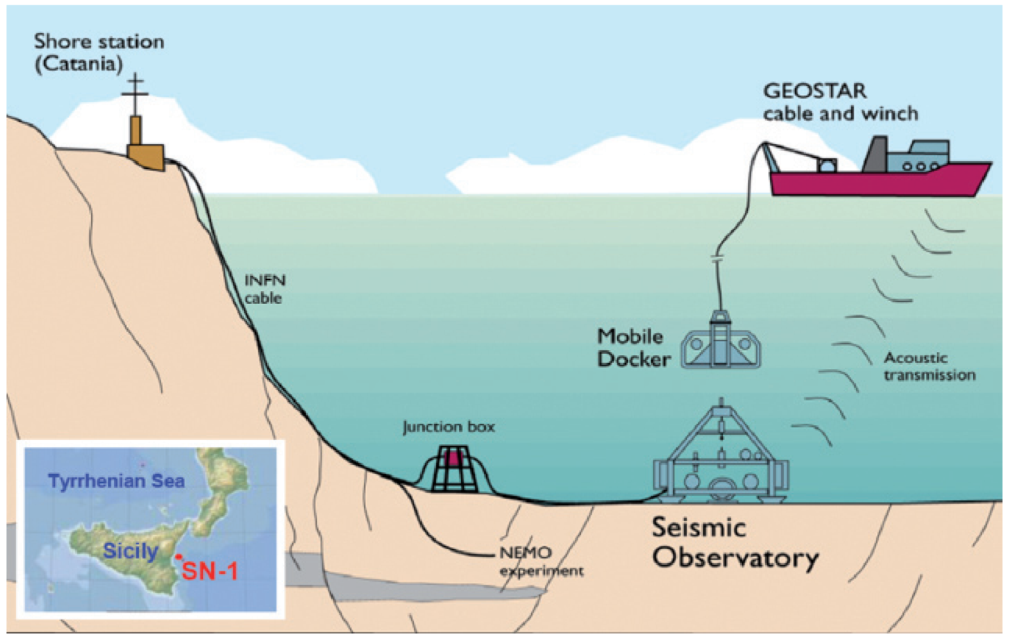

Figure 2 – Layout of the NEMO-SN1 underwater infrastructure in Sicily

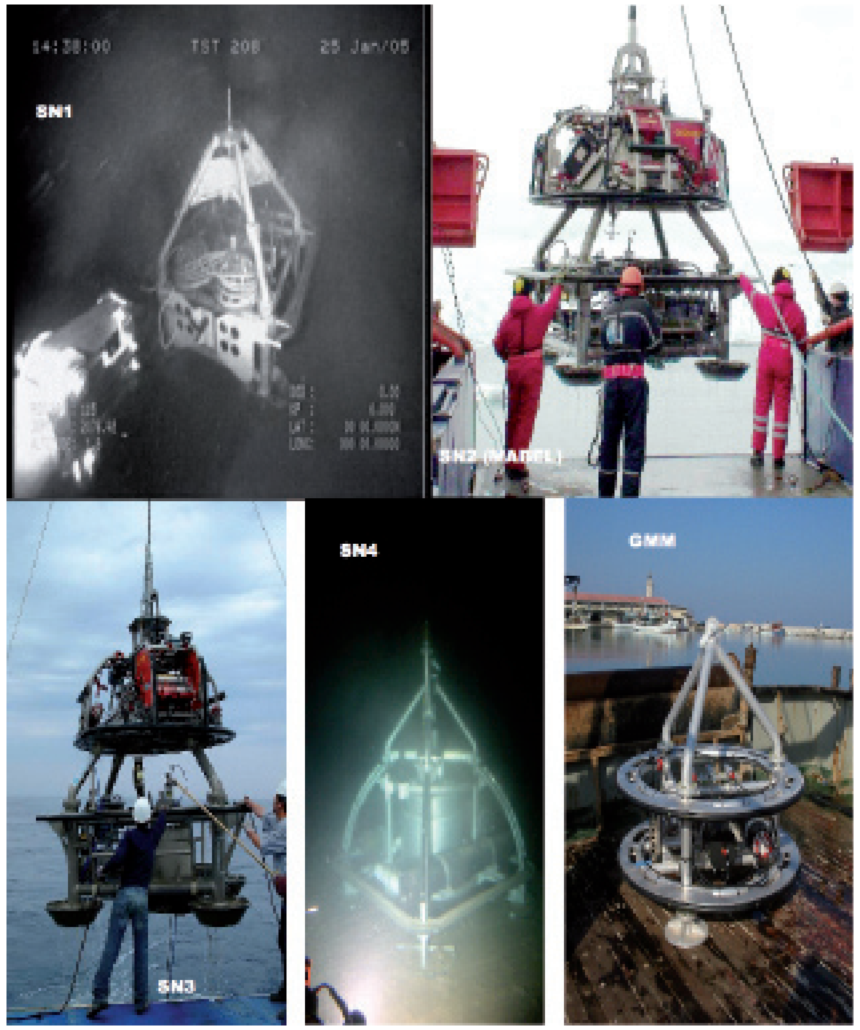

Figure 3 – GEOSTAR-class observatories: SN1, off-shore Eastern Sicily, ROV connects SN1 to the cable (January 2005); SN2, Weddell Sea (Antarctica) recovery on board R/V Polarstern (December 2008); SN3, Tyrrhenian Sea, recovery on board R/V Urania (May 2005); SN4, on the seafloor of Corinth Gulf /April 2004); GMM, Patras Gulf, before deployment (April 2004).

experiment SN1 recorded about 15 Gbytes of data, mainly seismic. Monna et al. (2005) showed the high quality of the acquired data, definitively validating the procedure to deploy seismometer, de-coupling its housing from the frame coupling the instrument with the seabed. The seismic events recorded only by SN1 opened new insights on the knowledge of the Ionian Basin seismicity (Sgroi et al., 2007).
After this experiment, SN1 was fitted with a fibre-optic telemetry interface so as to be compatible with the electro-optical cable owned and deployed off-shore from Catania by INFN (Istituto Nazionale di Fisica Nucleare) and related with particle physics experiments. In January 2005, the observatory was deployed by MODUS in the same site of the first mission (about 25 km East of Catania at 2060 m w.d.) and connected to the submarine cable thus becoming part of the underwater infrastructure NEMO-SN1 (Fig. 2). These activities were performed under an agreement between two major Italian scientific institutions, INGV and INFN (Favali et al., 2006a).
SN1 (Fig. 3) receives power from the shore, can communicate in real-time with the shore station inside Catania harbour, and is integrated in the INGV land based networks. SN1 is the first real-time seafloor observatory in Europe and one of the few in the world. It is also the first operative seafloor observatory in one of the «key-sites» planned in ESONET and EMSO.
At the end of April 2008, SN1 has been recovered after 3 years and 3 months. The observatory will be refurbished, adding sensors and functionalities, particularly taking into account geo-hazards and bio-acoustics. It is planned to be re-deployed and re-connected to the cable in 2009. These activities are performed in the frame of the PEGASO project (2005-2008, funded by "Regione Siciliana") and the LIDO (LIstening to the Deep Ocean) demonstration mission (2008-2010, funded by ESONET-NoE).

GMM

GMM (Gas Monitoring Module), a light benthic circular tripod of aluminium alloy, was designed for continuous and long-term measurements of gas concentration (especially methane) in seawater at the benthic boundary layer (Fig. 3).
In spring 2004 GMM was deployed within an active gas-bearing pockmark in the Gulf of Patras (Greece) at a water depth of 42 m. Recordings were carried out in two successive campaigns over the periods April-July 2004, and September 2004-January 2005, amounting to a combined dataset of about 6.5 months. This represents the first long-term monitoring ever done on gas leakage from pockmarks by means of CH4+H2S+T+P sensors. The results show frequent T and P drops associated with gas peaks, more than 60 events in 6.5 months, likely due to intermittent, pulsation-like seepage. This seepage "pulsation" can either be an active process driven by pressure build-up in the pockmark sediments, or a passive fluid release due to hydrostatic pressure drops induced by bottom currents cascading into the pockmark depression (Marinaro et al., 2004; 2006).
In 2008, in the frame of the PEGASO project GMM has been refurbished to perform an on-going pilot experiment off-shore Panarea (Aeolian Islands) at 23 m w.d. in the area where a long-term degassing episode occurred in 2002. Data from the seafloor are transmitted in real time through a cable connection with a surface boy and a radio link to the INGV site in Palermo.

ORION-GEOSTAR-3

In the framework of EC ORION-GEOSTAR-3 project, GEOSTAR Bottom Station, the surface relay buoy and MODUS were upgraded in order to be able to manage a network of GEOSTAR-class observatories in a network environment. Two additional observatories were developed (SN3 and SN4, Fig. 3) able to communicate via acoustics with GEOSTAR BS. To achieve the new required functionality also GEOSTAR DACS has been enhanced. A set of new functionalities were introduced: automatic event detection on the seismometer and hydrophone data, transmission of seismometer waveforms (Favali et al., 2006b).
The long-term mission of this deep-sea network started in December 2003. The deployment site lies in the Southern Tyrrhenian Sea at more than 3300 m w.d. at the NW base of the Marsili volcanic seamount, one of the largest seamounts of the Mediterranean basin. The network configuration for this mission includes GEOSTAR as main node and one satellite (SN3) in horizontal acoustic communication with GEOSTAR deployed 1 km apart. A surface buoy enables the connection with GEOSTAR via vertical acoustics and the radio/satellite link with the on-shore station located at the INGV observatory of Gibilmanna (northern coast of Sicily). Due to a malfunctioning in the acoustic communication link with the nodes (underwater part), they were recovered at the end of April 2004 and re-deployed at the same site at the middle of June until the final recovery in May 2005, always using the R/V Urania of CNR. One of the ORION node (SN4) was integrate in the ASSEM system. Accordingly, common communication protocols were defined and implemented in the nodes of both networks with respect to the data communication.
The magnetic data of this experiment in comparison with the other acquired in previous ones have allowed to study the different properties of the conductivity of the Tyrrhenian and Adriatic Basins (De Santis et al., 2007).

MABEL

MABEL (Multidisciplinary Antarctic Benthic Laboratory) is another deep-sea multiparameter seafloor observatory based on GEOSTAR technology (SN2, Fig. 3) addressed to the acquisition of geophysical, geochemical, oceanographic and environmental time series in Polar Regions (Calcara et al., 2001). MABEL is sponsored by the Italian PNRA, is designed to operate autonomously and is the first seafloor observatory deployed in Antarctica. Its mechanical and electronic behaviour at low temperatures was firstly tested in simulated polar conditions (air: −15°C, and icy waters: −2°C). The first Antarctic MABEL experiment started at the end of the 2005 having deployed the observatory in the Weddell Sea at over 1800 m w.d. and it has been recovered middle December 2008, always with the logistic support of the R/V Polarstern, managed by Alfred Wegener Institute.

Cadiz Observatory

The EC NEAREST project (Integrated observations from NEAR shorE Sources of Tsunamis: towards an early warning system, http://nearest.bo.ismar.cnr.it/), proposes to place the sensors directly on the tectonic source to be able to monitoring the movements and to immediately recognise a tsunami. During this project, GEOSTAR was installed in August 2007 south-west of Cape St. Vincent, in the Gulf of Cadiz (Portugal), at over 3200 m w.d. and recovered in August 2008 using R/V Urania. In this experiment, GEOSTAR was equipped with geophysical instruments and oceanographic instruments, and with a new "tsunameter". This tool has been appositely designed to operate in areas that generate tsunami waves in order to send automated alert messages. The tsunameter is based on a double check of seismic and pressure signals and keeps into account the seafloor movements. It is planned to continue this experiment re-deploying GEOSTAR in the same site in late Spring 2009 using the new Spanish ship Sarmiento de Gamboa, thanks to the LIDO demonstration mission.
The Gulf of Cadiz is a key area defined by ESONET/EMSO as the future location of a permanent deep-sea observatory and NEAREST missions are considered a pilot implementation of this node.
The experiments (1998-2008) described above are summarised in Figure 4.

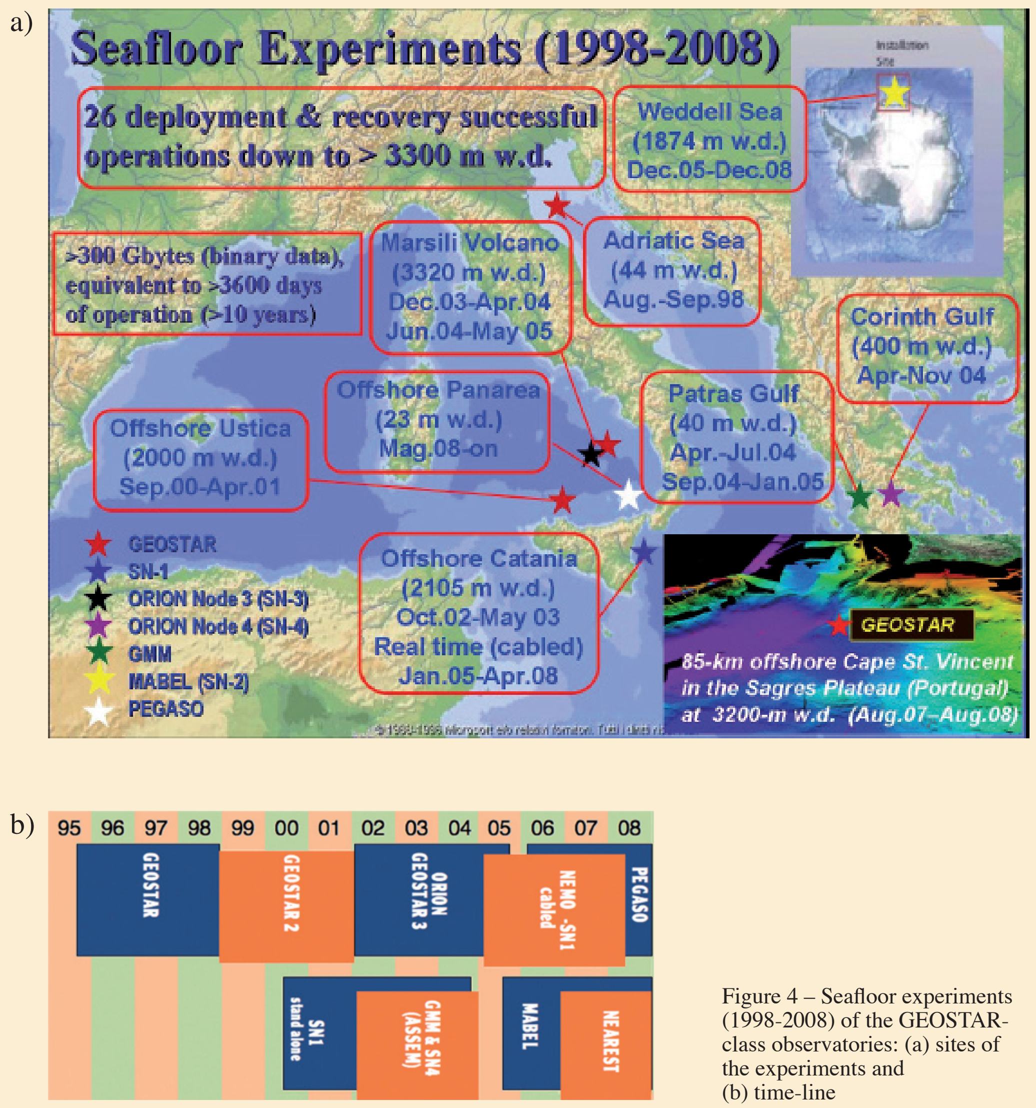

Figure 4 – Seafloor experiments (1998-2008) of the GEOSTAR-class observatories: (a) sites of the experiments and (b) time-line

Sensors And Data Examples

All the instruments have a unique time reference, given by the use of a single high-precision clock (stability 10-9 ÷ 10-11). From 1998 to 2008, many experiments have been performed using the following sensors, the typical sampling rates are also indicated:

Sensors	Typical sampling rates
3-C broad-band seismometer	100 Hz
hydrophone (geophysics)	100 ÷ 200 Hz
hydrophone (bio-acoustics)	96 kHz
gravity meter	0.1 ÷ 1 Hz
scalar magnetometer	1 sample/min
3-C fluxgate magnetometer	1 sample/s
absolute pressure gauge	1 ÷ 15 s
differential pressure gauge	1 ÷ 15 s
precision tilt meter (X, Y)	10 Hz
3-C single-point current meter	2 ÷ 20 Hz
ADCP (300 kHz)	1 profile/hour
transmissometer	1 sample/hour
turbidity meter	1 sample/hour
CTD	1 sample/10 min (or /hour)
nuclear spectrometer	1sample/4, 6, 8 hours (stand-alone) 1 sample/30 s (real-time)
CH4 sensor	1 Hz
H2S sensor	1 sample/10 min
O2 sensor	1 sample/10 min (or /hour)
chemical analyser (pH/eH)	1 sample/6 hours
water sampler (off-line)	1 sample/500 s ÷ 1week (48 bottles)

The total amount of data has exceeded 300 Gbytes (binary data), equivalent to > 3600 operative days (>10 years). Examples of recorded data are shown in Fig. 5.

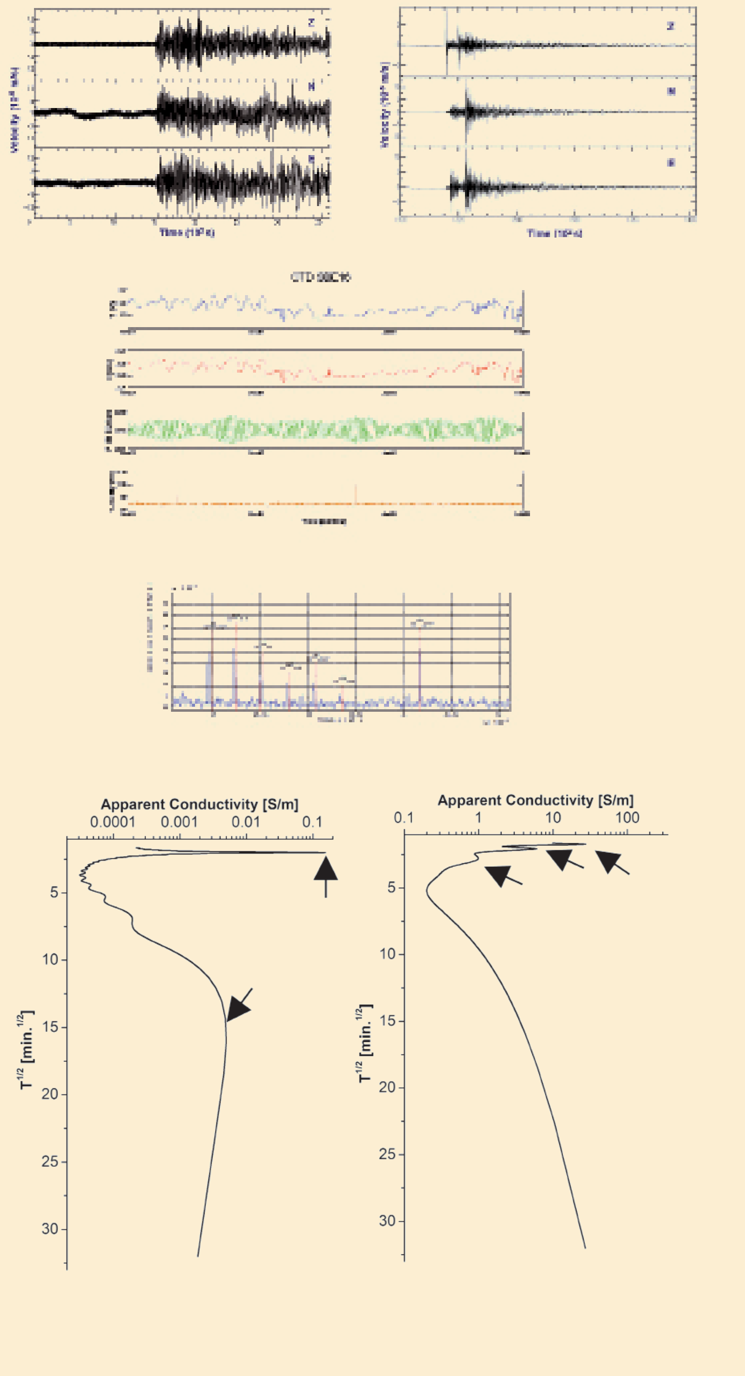

Figure 5 – Examples of acquired data during the 1998-2008 experiments: a) Santa Cruz Island event (2007.09.01, Mw=7.4) recorded by SN1observatory; b) Gulf of Cadiz event (2008.01.11, ML=4.4)recorded by GEOSTAR seismometer in the EC NEAREST experiment; c)temperature, conductivity, pressure and turbidity time series from November 2007 to February2008 recorded by GEOSTAR CTD and turbidity meter during the EC NEAREST experiment; d) Earth spheroidal modes excited by the Central Alaska event (2002.11.03, Mw=7.9)recorded by SN1 gravity meter; e) apparent conductivity vs magnetic time-series periods for GEOSTAR-2 (left) and ORION-GEOSTAR-3 (right) experiments in the Southern Tyrrhenian Sea inferring lithospheric depth in the area of Ustica Island and of the Marsili volcanic seamount

Conclusions

NRC (2000) outlined the characteristics of a seafloor observatory as a "…unmanned system of instruments, sensors and command modules connected either acoustically or via seafloor junction box to a surface buoy or a cable to land. These observatories will have power and communication capabilities…". GEOSTAR concept fulfils the definition with its capability of multidisciplinary, long-term monitoring providing time referenced data series, and the possibility to transmit data in (near)-real-time through a surface buoy or through an electro-optical cable.

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www.cnrm.meteo.fr/ama2009/

19-24 April
EGU, Vienna (Austria)
http://meetings.copernicus.org/egu2009/

27-30 April
ICES Deep-sea Symposium, Horta, Azores, Portugal)
www.turangra.com/deepocean

4-8 May
3rd international symposium on remote sensing of Environement, Stresa (Italy)
http://isrse-33.jrc.ec.europa.eu/welcome.html

May (to define)
Esonet Second Training workshop, Bremen (Germany)
www.esonet-emso.org

10 May
GEOSS Workshop XXV, Bremen, (Germany)
www.ieee-earth.org/Conferences/GEOSSWorkshops

11-14 May
Ocean's09 IEEE, Bremen (Germany)
www.oceans09ieeebremen.org/

15-16 June
ESONET VISO Workshop, Tromsoe, (Norway)
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OceanOBS'09, Venice (Italy
www.oceanobs09.net

24-25 Sepetember
1st International Conference on Sensor Networks Applications, Experimentation and Logistics, Athens, (Greece)
www.sensappeal.org

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OBS-Marine Seismology Workshop, Paris (France)
www.neries-eu.org/main.php/NERIS-ESONET-Workshop_request.pdf?fileitem=4112390

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