GEOSTAR deep sea mission

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Abstract. GEOSTAR (GEophysical and Oceanographic STation for Abyssal Research) is a scientific and technological project funded by European Commission in the Marine Science and Technology Program (MAST-III CT95-0007 and CT98-0183 contracts). This project has developed and tested the prototype of a deep sea multidisciplinary benthic observatory capable to carry out long-term (up to 1 year) scientific observations at abyssal depths (up to -4000 m) in geophysics, geochemistry and physical oceanography. GEOSTAR system includes two modules: the Bottom Station, that is the Observatory equipped with sensors and communication system, and the Mobile Docker which was designed and realised specifically to handle the Bottom Station from the sea surface during the deployment and the recovery.

GEOSTAR Observatory, successfully deployed last September 23rd, 2000 in Southern Tyrrhenian Sea (38 32'N; 12 46' E) at a depth of about 2,000 m, is now performing its first long term mission lasting till late Spring 2001.

1 Main characteristics of GEOSTAR

The main aspect characterising the GEOSTAR concept (see Fig.1) is the possibility to actively deploy to the sea-bed and then retrieve a Bottom Station (BS), designed to support operation of a wide range of sensors, able to collect multidisciplinary data on the same spot,. The BS contains also the battery vessel and the Data Acquisition and Control System to allow the management of a complete scientific mission (Gasparoni et al., 2001).

Accurate and safe positioning at seafloor, re-entry and recovery capabilities of the BS are ensured by a dedicated cable suspended thrustered module, hereafter referred as Mobile Docker (MD). This is a system able to carry heavy loads (up to 5 tons) at abyssal depths, deploy them within the range of 5% of the water depth and retrieve them at the end of a scientific mission.

The solution adopted overcomes typical limitations of other systems like the need of neutral asset in water, free-falling deployment (very imprecise and rough), short autonomy and limited payload.

Communication capabilities are ensured by three systems located on the BS and by a Near Real Time Communication System (Marvaldi et al., 2001):

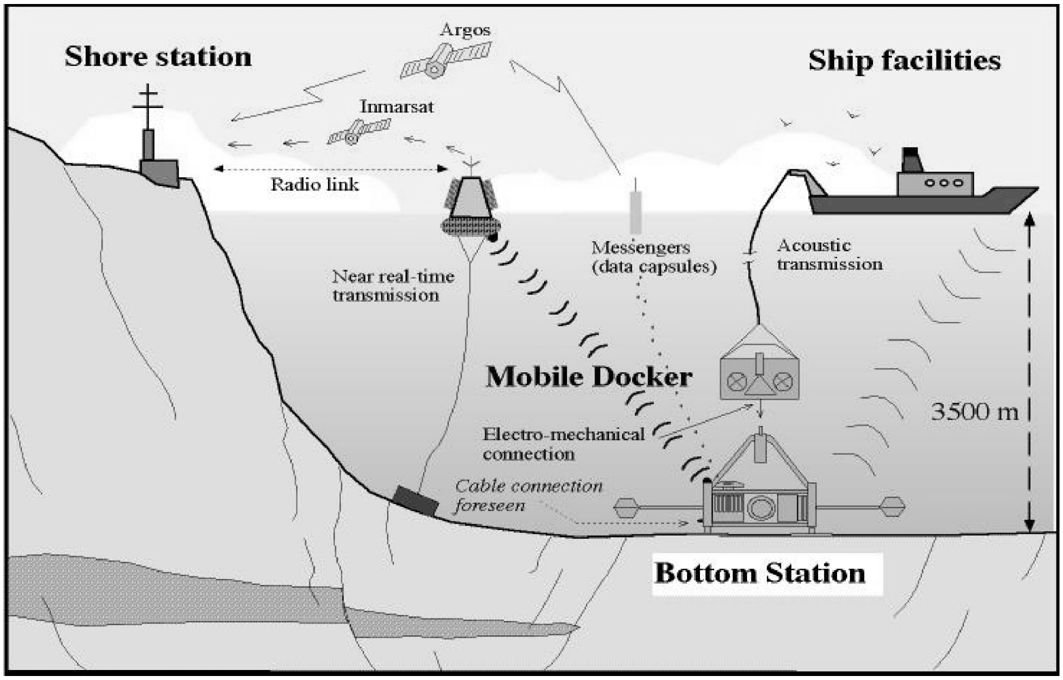

Fig. 1. GEOSTAR concept. Cable connection is an option not implemented in the prototype version.

- Expendable data capsules (Messenger/E) periodically released by the BS and able to transmit their data to a shore station over a satellite link; the E-type, with capacity of 32 Kbytes, is used to store and transmit about 30 Summary Messages, generated daily, whose maximum size is 640 bytes. The Summary Messages are composed by data blocks containing the basic statistics of measurements and a set of technical operating parameters of the BS.
- Recoverable high storage capacity capsules (Messenger/S) released by the BS on request of user from surface ship; the S-type, with capacity of 40 Mbytes, contains about 40 Data Records of maximum size of 850 Kbytes generated hourly. The Data Records contain the complete data volume produced by all the sensors.
- Two-way acoustic communication system to allow data exchange between users, on board a surface ship, and the BS.
- The Near-Real-Time Communication System (NRTCS) includes the surface buoy, the antenna and transducer, and the energy source to communicate data through the satellite link. The communication between the observatory, the buoy and the shore station occurs in a interactive way.

The characteristics of the main subsystems of GEOSTAR developed within the project and the actual scientific payload, hosted by the BS, are summarised:

- **Bottom Station**
  - Dim. 3500 x 3500 x 2900 mm
  - Weight 3100 kg (in air), 1475 kg (in water)
  - Material Al 5083, Ti grade 5
  - Battery pack 24 V, 2400 Ah
  - Mass memory 4 Gbyte (hard disk), 144 Mbyte (PCMCIA)

- **Mobile Docker**
  - Dim. 2878 x 2348 x 1540 mm
  - Weight 1050 kg (in air), 850 kg (in water)
  - Material Al, Stainless Steel
  - Power 25 kW
  - Thrust 2x2000 N (lateral), 2x700 N (vertical)
  - Telemetry 2 video, 12 RS232 lines
  - Video 3 b&w, 1 color
  - Lighting 4 x 250 W (+ 1 optional)
  - Sonar, Altimeter

- **Communication System**
  - 3 Expendable Messengers (32 kByte memory, ARGOS transmitter)
  - 2 Storage Messengers (40 Mbyte memory, ARGOS positioning)
  - Multimodulation Acoustic Modem (12 kHz, up to 2400 bit/s bidirectional link with a ship of opportunity and a buoy equipped with a satellite transmitter for connection to shore)

- **Scientific Payload**
  - Three axis broad-band seismometer
  - Scalar (proton) magnetometer
  - Fluxgate (x-y-z) magnetometer
  - 300 kHz Acoustic Doppler Current Profiler (ADCP)
  - Conductivity, Temperature and Depth sensor (with pump) (CTD)
  - Transmissometer
  - Gravity Meter
  - Space seismometer (three axis broad-band)
  - Single point current meter (3D)
  - Chemical Package (NH_3, pH)
  - Water sampler

A high precision clock ensures a long-term highly stable and accurate time reference for all sensors, mainly required by the seismic measurements.

2 GEOSTAR 1

The GEOSTAR project develops in two phases. The first phase (1995-1998), named GEOSTAR 1, was aimed at designing and realising the prototype and at verifying its performances and reliability (Favali et al., 1998, Jourdain, 1999). GEOSTAR observatory was deployed in Adriatic Sea from August 13th to September 2nd, 1998 at about 40 km East of Ravenna (Italy) and at a depth of 42 m. During the 3 week mission the acquisition system recorded continuous 440 hours (97.8% of the total time). A magnetic observatory and three broad band seismic stations were installed on land to integrate the geophysical measurements. The mission demonstrated reliability, both of the MD, and of the sensors and efficiency of the communication system BS-surface user.

The recorded data during the first mission in Adriatic Sea (Fig. 2) gave the opportunity to verify the quality of the installation procedures selected in the design phase for specific sensors (Beranzoli et al., 2000).

The good quality of the magnetometers recordings is revealed by the comparison with the time series of Castello Tesino (CT) observatory (300 km far from GEOSTAR 1 site), and of the temporary station of Bosco Mesola (BM) (Ferrara, about 57 km far from GEOSTAR 1 site). It was also possible to grossly estimate the magnetic influence of the GEOSTAR observatory frame and of the other equipment to the magnetometers. The results in terms of the geomagnetic deep sounding technique applied to the time variations of the horizontal and vertical components of the

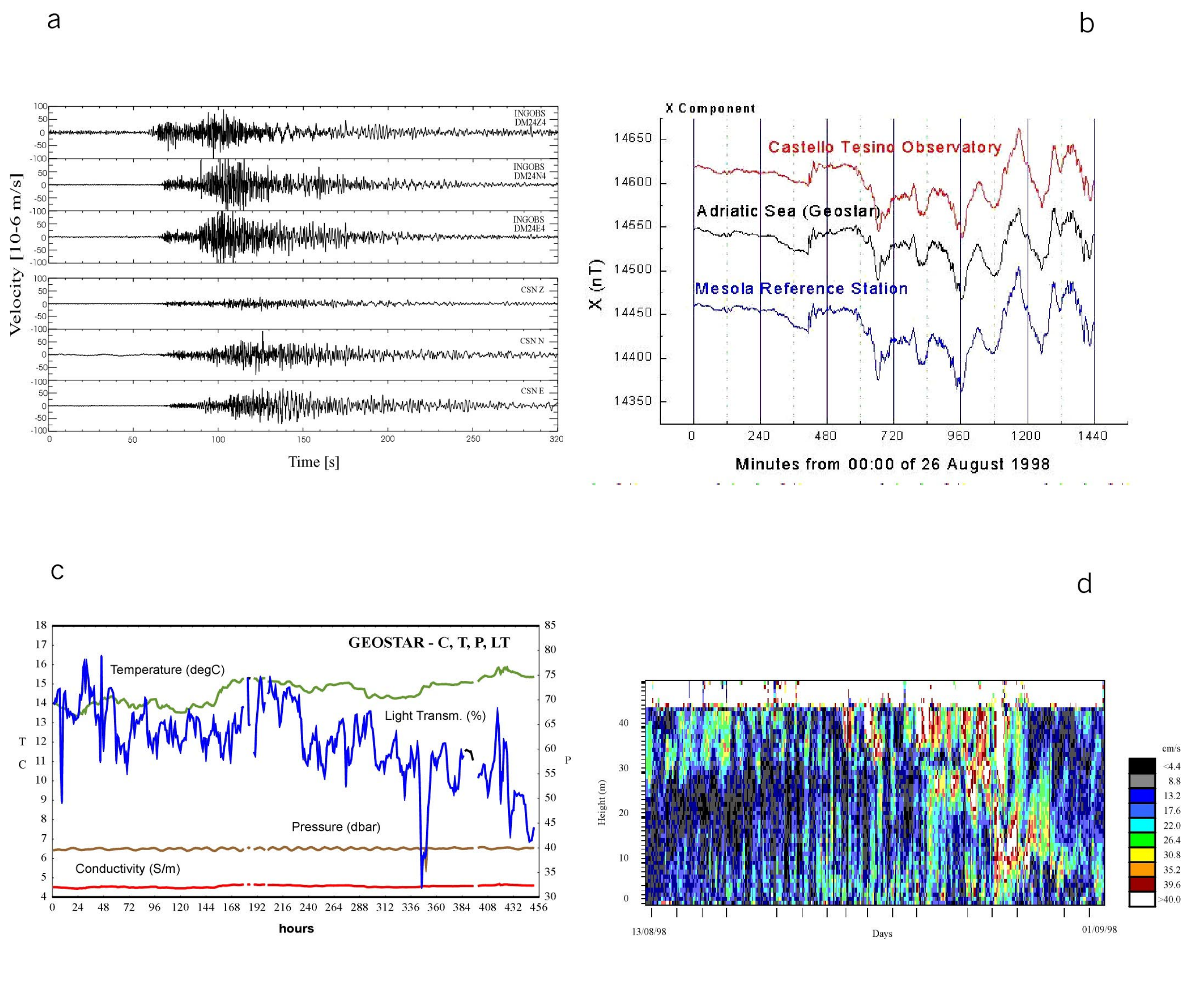

Fig. 2. a) Recordings of the Slovenia earthquake (31/8/1998, Ml 4.9, Δ= 232 km.) at one land temporary station (CSN) and GEOSTAR observatory. b) Recordings of the GEOSTAR scalar magnetometer during a disturbed day compared with the data of the Casatello Tesino ground Observatory, located 300 km far from GEOSTAR site, and of the Bosco Mesola temporary station. c) Time series collected with the CTD (water, temperature and pressure) over the days of mission. d) Absolute velocity of the water: current in cm/s versus depth from the seafloor, over the duration of the mission.

magnetic field provided interesting results in the framework of the regional tectonics (De Santis et al, 1999). The performances of the seismological package with respect to the detection of regional and teleseismic events, demonstrated that the seismometer deployment procedure and the coupling of the sensor with the sea bottom were fulfilled. The spectral analysis of the seismic background noise, showed that the effect of the thick sediment layer below the GEOSTAR 1 mission site reduced considerably the detection capabilities of local earthquakes. This fact was confirmed by the comparison with the seismic background noise of Cesena (CSN), the on land temporary station closest to GEOSTAR, sited on a ground with almost similar geo-technical characteristics.

During GEOSTAR 1 mission the oceanographic sensors (ADCP and CTD) recorded correctly. The CTD sensor demonstrated that the acquisition of temperature and pressure data worked properly, but conductivity and transmissometer data suffered for fouling due to sedimentation.

3 GEOSTAR 2

The second phase of the project – named GEOSTAR 2 and started in 1999 - has the purpose to perform the first long-term scientific mission at abyssal depths for a period of 6-8 months. The deployment site is located in the Southern Tyrrhenian Sea, 30 km WSW of Ustica island (Sicily) at about a depth of 2000 m. From a geological and environmental point of view this site represents an optimal observation point, in order to obtain relevant information about geodynamics and oceanography of the whole Mediterranean basin (Beranzoli et al., 1998).

The long term scientific mission started on 23 September 2000 (Fig. 3); the GEOSTAR observatory will be recovered during April 2001.

Objectives of the mission are:

- continuous, long-term acquisition of geophysical (seismic activity, earth magnetic field, earth gravity field) and environmental parameters (current, temperature, salinity, etc.);

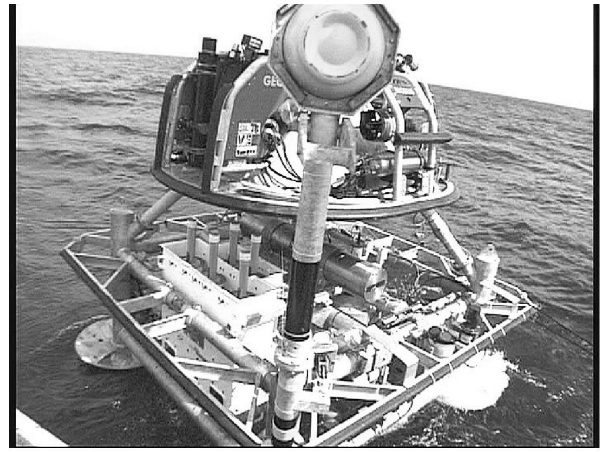

Fig. 3. GEOSTAR system during the deployment in the Tyrrhenian Sea. Top side: the Mobile Docker, the dedicated vehicle for surface assisted deployment/recovery of the observatory. Bottom side: The Bottom Station (BS) hosting the sensors, the data acquisition and control system and the battery vessel. The communication systems are located on the BS and include the messengers (their antennas are clearly visible), data capsules periodically released by the observatory. In the foreground a releasing arm with a benthosphere, containing a magnetometer.

- release and recovery of E-Type and S-Type Messengers, to verify the status of the observatory and to acquire scientific data samples.; till now 3 Messengers were successfully recovered.
- near-real-time communication with bi-directional connection between a shore operator and the BS, through the NRTCS buoy (Fig. 4). Various links were successfully established with the observatory, allowing the request of data from a shore station and a correct transmission of data from the observatory.

At the end of the GEOSTAR 2 phase, the observatory will be qualified and made available to the scientific community for other long-term scientific missions in deep-sea marine environments.

Fig. 4. The Near Real Time Communication System buoy

The partnership of the project includes:

Istituto Nazionale di Geofisica (Italy) Co-ordinator, Tecnomare s.p.a. (Italy), IFREMER (France), Laboratoire de Oceanographie et de Biogeochimie (France), ORCA Instrumentation (France), Institut de Physique du Globe de Paris (France), Technische Universitat Berlin (Germany), Technische Fachhocschule Berlin (Germany).

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