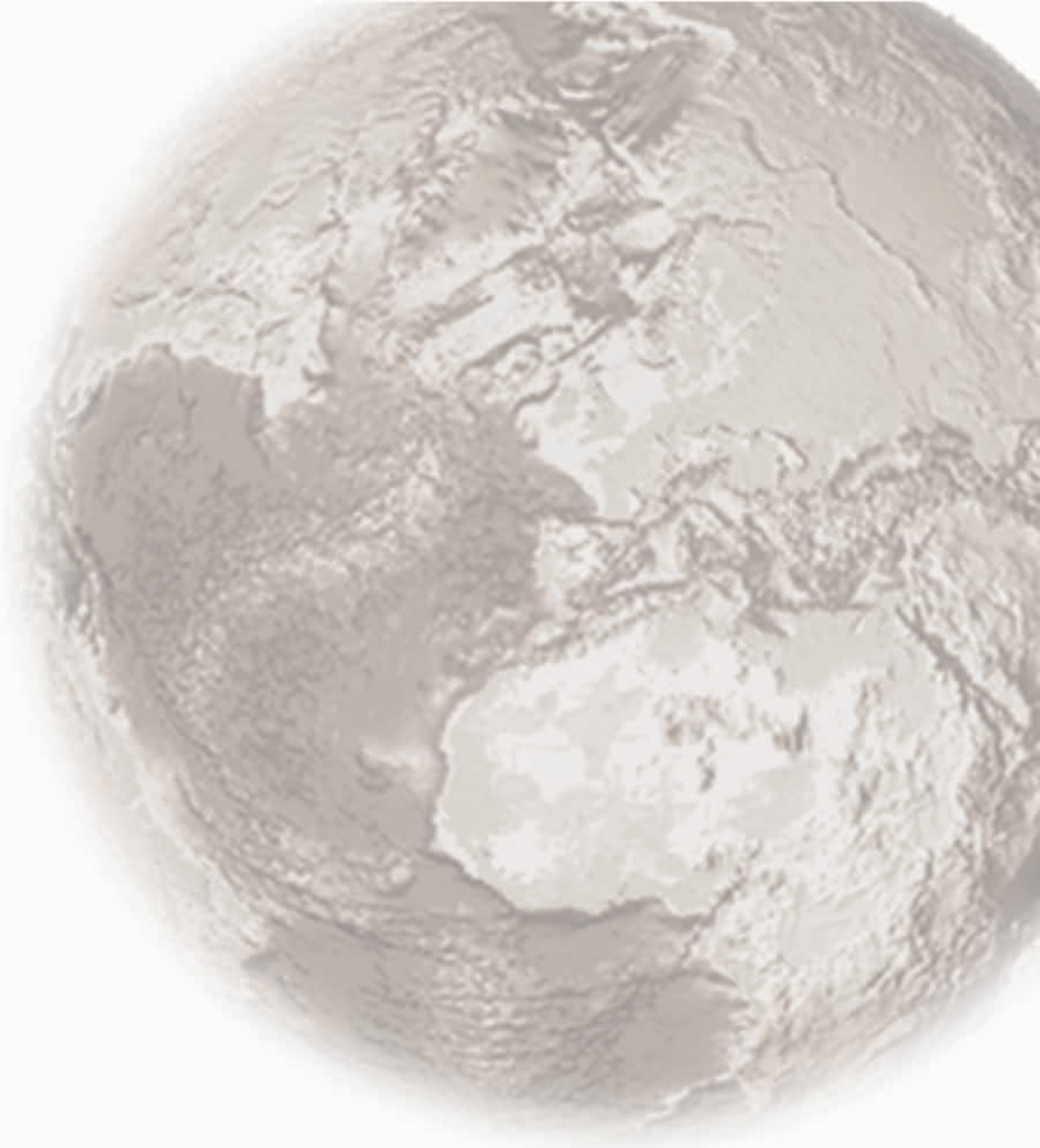
Rapporti Tecnici INGV



2008

First long time OBS campaign in the Ionian Sea

G. D'Anna, G. Mangano, A. D'Alessandro, R. D'Anna, G. Passafiume, S. Speciale

n. 72

Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata 605 - 00143 Roma
tel 06518601 • fax 065041181
www.ingv.it

FIRST LONG TIME OBS CAMPAIGN IN THE IONIAN SEA

G. D'Anna, G. Mangano, A. D'Alessandro, R. D'Anna, G. Passafiume, S. Speciale

Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti – OBS Lab Gibilmanna

Index

Introduction

The INGV started its interest to extend the seismic monitoring network to the sea in 1995 with GEOSTAR (Geophysical and Oceanographic Station for Abyssal Research) project, coming out with the realization of the first multidisclipinary observatory for deep-sea monitoring [Favali et al. 2002].

At the end of 2004, the National Earthquake Center (CNT) of INGV decided to provide a pool of Ocean Bottom Seismometers to be employed as a submarine mobile network and to study submarine faults and volcanoes. This was possible thanks to an agreement between the INGV and the Italian National Civil Protection Department (DPC). On July 2006, the *Gibilmanna OBS Lab*, tested the first OBS prototype for nine days on the flat top of the Marsili submarine volcano [D'Anna et al. 2007] and in early 2007 other seven OBS's were ready to be deployed on the seafloor.

In May 2007, within the European project NERIES (activity NA6), the Gibilmanna OBS Lab of the INGV has deployed three Broad Band Ocean Bottom Seismometers (BBOBS) in the southern Ionian Sea at 3500-4000 meters of depth.

This area has been chosen during the NERIES – "NA6-BBOBS net" meeting in Rome, on the 11th of September 2006 because at first, there are at the moment few seismological data [Scrocca et al., 2003] to construct a reliable model for the Ionian lithosphere and also the rate and features of the seismicity in the area between the Hyblean-Malta fault system and the accretionary prism of the Calabrian Arc are largely unknown [Catalano et al. 2002].

The Ionian Sea is indeed one of the most seismically active area in the Mediterranean region with several destructive earthquakes sometimes followed by tsunamis [Tinti et al. 2004]. The seismicity occurring in the Ionian basin is characterized by large location uncertainties due to the lack of seafloor seismic stations. In 2002, the quality of the seismic sensing and the location of earthquakes have been improved by the deployment of the real-time submarine observatory SN-1, about 25 km offshore Eastern Sicily [Sgroi et al, 2007]. However, the SN-1 location only allows to characterize the seismicity in the area offshore the eastern Sicily.

Two of the three OBS's were successfully recovered on the 2nd of February 2008; the last one was recovered on the 15th of March 2008 and another OBS was deployed on the same location to accomplish the continuous long-term seismic monitoring task (until May 2010) as planned in NERIES project.

1. Instruments description

The three OBS's (*Fig. 1*) employed in this experiment, were entirely developed at the Gibilmanna OBS Lab of the INGV National Earthquake Center (CNT) and are part of a pool of eight instruments ready to deploy. They are the first Italian OBS's taking part in a long term experiment.

Figure 1 INGV Ocean Bottom Seismometer ready to be deployed in the Ionian sea.

The instruments deployed in the Ionian sea were equipped with a **Nanometrics Trillium 120P** seismometer, installed in Nautilus gimbals for the levelling, and a **Cox-Webb** 500s-2 Hz **Differential Pressure Gauge** (DPG). A 21 bits four channel data logger (**SEND Geolon MLS**) recorded data at 100 sps.

The OBS's were also equipped with two different acoustic release systems, one backup of the other, installed in two different canisters.

In case of unintentional rising of the OBS to the surface, a GPS based tracking system will give information about the OBS position through a web platform, allowing its recovery.

Tab. 1 shows a summary of the instrumentation on board of the OBS's and some their features.

(a) *(b)*

Figure 2 *a)* Trillium 120P installed in the Nautilus gimbals *b)* Cox-Webb Differential Pressure Gauges.

Seismic sensor gimballed	Nanometrics Trillium 120P (3C seismometer with a flat response between 120s and 175Hz) housed in a 17" pressure glass sphere on a Nautilus gimbals for the levelling (*Fig. 2.a*)
Pressure sensor	Cox-Webb Differential Pressure Gauge 500s-2 Hz; gain 1 mV/Pa at 1 Hz (*Fig. 2.b*)
Digitizer	SEND Geolon MLS 21 bits digitizer, 4 channels (3 for the seismometer and 1 for the hydrophone or DPG). Sampling rate up to 200 sps (set at 100 sps)
Clock	Seascan Precision Time base. Drift rate is 3-5 x 10^{-8} (<0.5 ms/day drift)
Storage Capacity	12 PCMCIA slots, up to 24 GB with 2GB flash cards.
Battery Packs	2 Primary Lithium-Thionyl Chloride battery packs of 14,4 V and 350 Ah
OBS weight	501/42,5 Kg in air/water
Electronic canister	ERGAL (7075 T6 aluminium alloy) canister, with hard anodizing.
Release system	IXSEA AR861S-MR and C980102 ORE-Offshore acoustic release system.
Emergency localization system	ELSACOM Guardian Sentinel, which can transmit the OBS positions every 3 hours for more than one month, if it comes back on the surface.
OBS dimensions	1200x800x1500 mm

Table 1 Technical specifications of the INGV-OBS.

The OBS deployed on the 15th of March 2008, after the recovery of the OBS named A2 (see paragraph 3), was equipped with a Guralp CMG40T-OBS seismometer with a frequency band of 60s-50Hz *(Fig. 3)*. This seismometer was chosen for this new deployment for its low power consumption and for its self-levelling system case, housed in a 15 cm of diameter glass sphere.

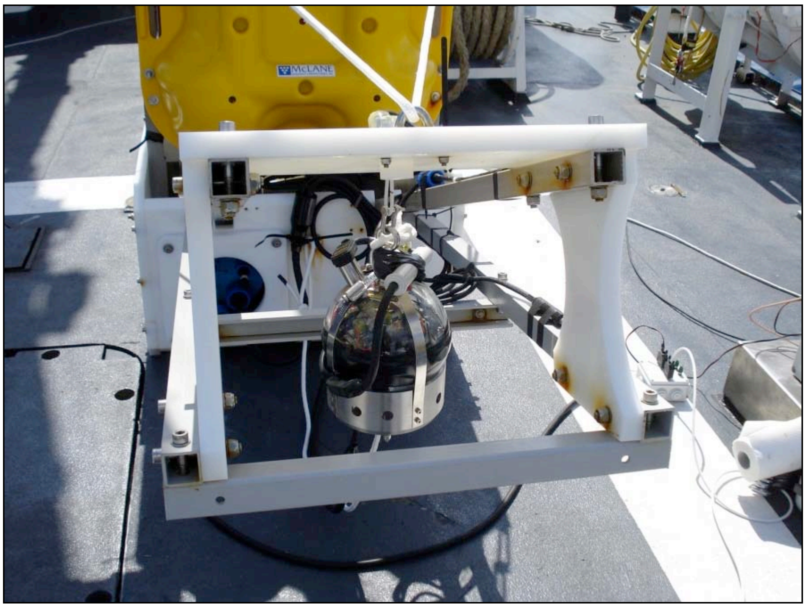


Figure 3 CMG40T-OBS installed on the OBS deployed on the 15th of March 2008.

2. The deployment

The deployment cruise was carried out with the 82,70 meters Italian Navy vessel "**Ammiraglio Magnaghi**" of the *National Hydrographic Institute*.

The three OBS's with serial numbers A1, A2 and A3, were deployed on the 15th May 2007 in three different locations arranged in a roughly equilateral triangle of about 60-70 nautical miles as shown in *Fig. 5*.

Tab. 2 shows the coordinates of the three OBS's (as estimated after a triangulation with the acoustic transponder on a circle with a radius of 0.5 Miles), their depths and the UTC time of the deployments.

Figure 4 Vessel Ammiraglio Magnaghi.

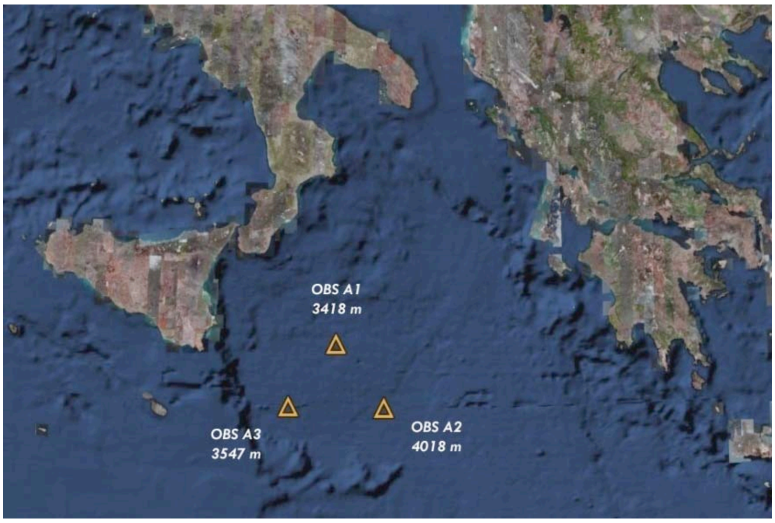


Figure 5 INGV OBS's locations in Southern Ionian Sea.

Name	Lat.	Long.	Depth (m)	Deployment Time UTC
A1	36° 47' 52.1" N	17° 14' 31.8" E	3418	15/05/2007 23:13
A2 (NERIES OBS)	35° 59' 44.7" N	18° 00' 17.2" E	4018	15/05/2007 13:14
A3	35° 59' 34.0" N	16° 30' 25.1" E	3547	15/05/2007 02:14

Table 2 Deployment data.

A sampling frequency of 100 Hz was set on the digitizer on board the OBS's (SEND Geolon MLS). The precision clock of the digitizer was synchronized with the GPS time few minutes before the deployment.

The release of the seismic sensor from the spacer harm was set as shown in *Tab. 3*. The levelling of the gimbals was programmed to begin 8 hours after the recording start (a few minutes before the deployment) and to be repeated every 30 days.

Name	Start recording	Sampling rate (sps)	Sensor release	Sensor levelling
A1	15/05/2007 22:52:33	100	16/05/2007 03:00:00	After 8 hours every 30 days
A2	15/05/2007 12:31:29	100	15/05/2007 18:30:00	After 8 hours every 30 days
A3	15/05/2007 01:52:14	100	15/05/2007 08:00:00	After 8 hours every 30 days

Table 3 Digitizer settings.

3. The recovery

The three OBS's were successfully recovered in two different cruises carried out with the patroller **U. Diciotti** of the Italian *Coastal Guard* (*Fig. 6*). On the 2nd of February we recovered the OBS's A1 and A3; on the 15th of March 2008 we recovered the OBS A2 located in the site selected by NERIES project and we replaced it by the OBS A1 with new batteries packs and a different seismic sensor (Guralp CMG40T-OBS).

Figure 6 The patroller U. Diciotti.

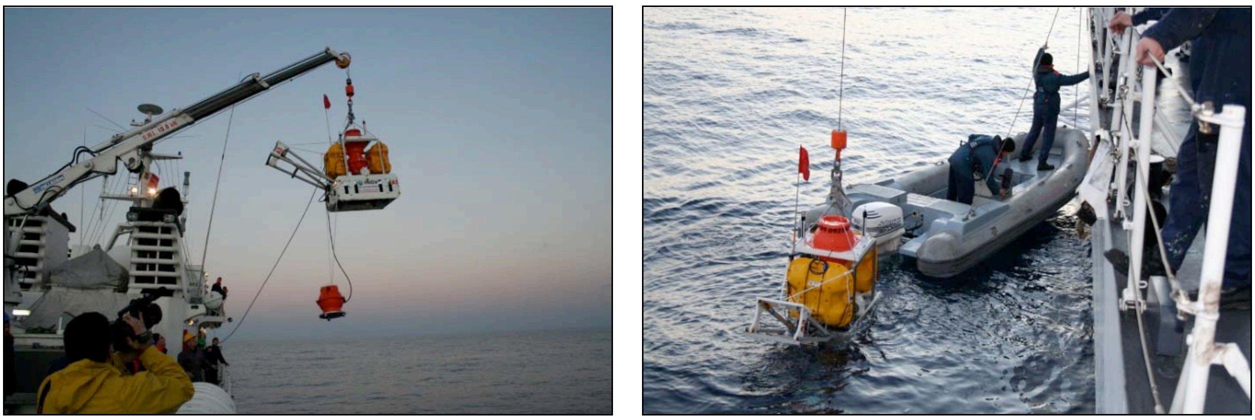


Figure 7 Recovery phases.

4. Preliminary data analysis

The three OBS's recorded a large volume of seismic data including local, regional and teleseismic events, but the data of the seismometers of OBS A2 and A3 are unusable (only electronic noise was recorded) because of a bad functioning of the Nautilus gimbals on those two instruments that had an insufficient levelling (Nanometrics Trillium 120P needs an almost perfect leveling with a +/- 0.2° accuracy). We are working to solve this problem by a new INGV auto-levelling system that will be ready for the first deployment within the end of June 2008. However the DPG's worked fine in all the three OBS's, providing us the data that will be presented hereafter.

OBS's data are often difficult to analyze for the different seismic noise level and spectral shape, compared to land signals, and for the presence of many kinds of seismic and acoustic waves travelling only through the water. Seafloor and continental noise spectra are basically different because the sea surface is an important source of broad band seismic noise [Webb, 1998]. *Fig 8* shows the acceleration and pressure noise Power Spectral Density (PSD) of 24 hours of signal without any events, recorded by the OBS A1. The PSD was calculated using the periodogram averaging method, with a signal length of 120 seconds (12000 samples). Signals analyzed were not deconvolved with the instrumental pulse response, therefore it is to be considered that DPG has a flat response only up to 2 Hz.

In comparison with the land *High Noise Model* (HNM) and the *Low Noise Model* (LNM) of Peterson [Peterson, 1993], the OBS PSD seems to be shifted forward in frequency. Acceleration and pressure noise PSD's have a very similar shape and show a very high level noise below 0.03 Hz and in the band between 0.3 and 3.0 Hz. Horizontal components noise is higher than the vertical component noise below 0.1 Hz.

This high level noise could induce a poor event detection for local and regional earthquakes. Low noise level in the bands 0.04-0.2 Hz and 3-7 Hz provides two windows for the detection of respectively teleseismic events and local earthquakes.

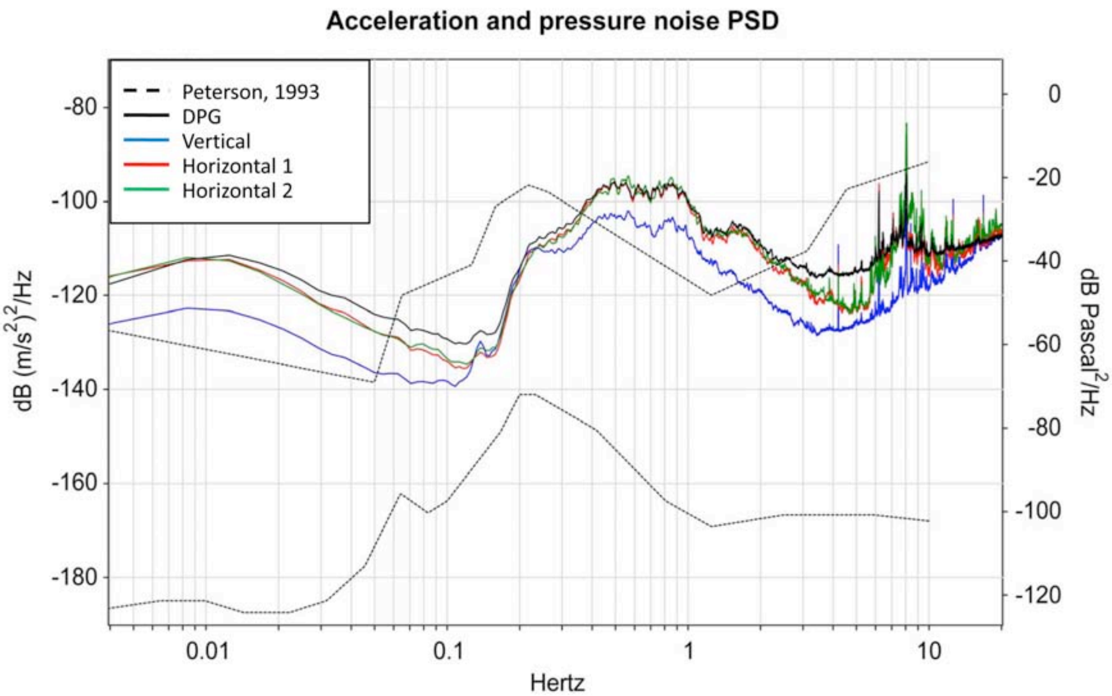


Figure 8 OBS A1 PSD of 24 hours of signal without events.

The magnitude frequency histogram of *Fig. 9* reports the number of events recorded by OBS A1 and A3, with 0.2 magnitude intervals, and shows few seismic events around magnitude 5, probably due to the seismic sources distribution around the OBS and to the magnitude recurrence.

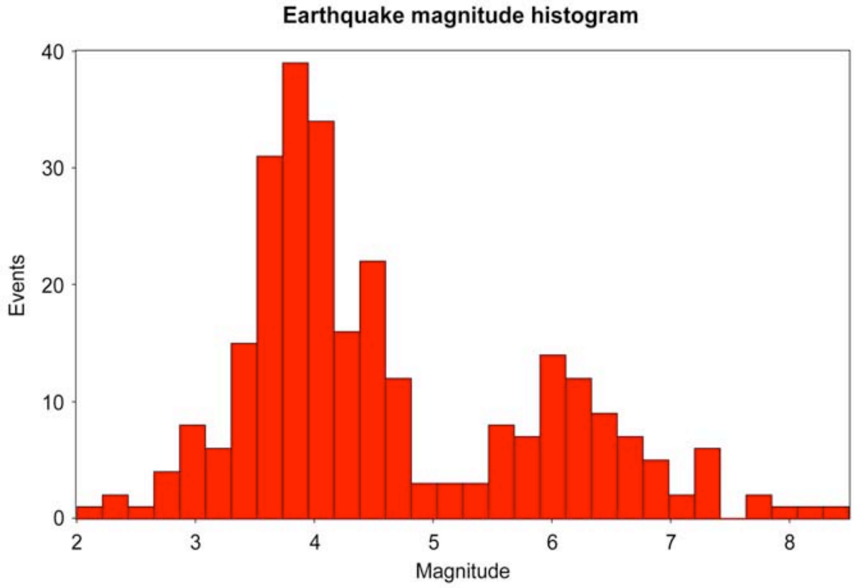


Figure 9 Number of seismic events recorded by OBS A1 (DPG and seismometer) and by the DPG of OBS A3, classified by their Magnitude.

During the almost nine months of the experiment, OBS A1 and A3 recorded altogether more than 300 local, regional and teleseismic events; data from the DPG of OBS A2 haven't been analyzed yet. *Fig. 10* shows all the earthquakes with magnitude larger than 5 recorded by OBS A1 and A3; the teleseismic events recorded are distributed in all the five continents, with special concentration in eastern Asia.

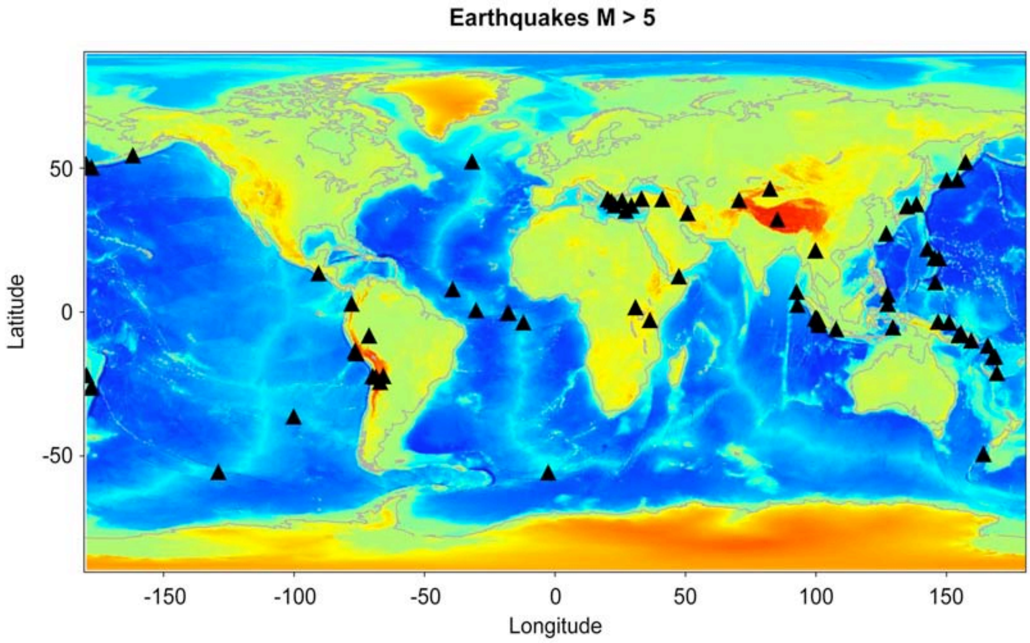


Figure 10 Earthquakes with magnitude larger than 5 recorded by DPG and seismometer of OBS A1, and by the DPG of the OBS A3.

Fig. 11 shows the M = 8.5 Sumatra teleseismic event of the 12th of September 2007, recorded by the DPG and the three components seismometer on the OBS A1. The Sumatra earthquake shows several clear arrivals of body and surface waves on all four components. Teleseismic data will be valuable to make a lithosphere model for the Ionian sea by means of Receiver Function [Ammon, 1991] or FTAN analysis [Dziewonski et al. 1969].

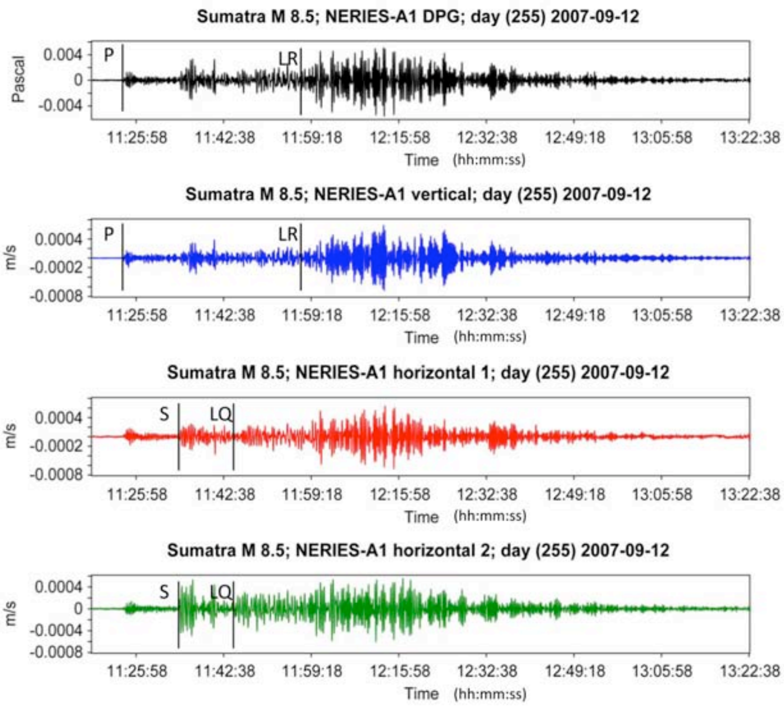


Figure 11 Sumatra teleseismic event (M = 8.5) of the 12th of September 2007 recorded by the DPG and the three components seismometer on the OBS A1, unfiltered.

Fig. 12 shows local and regional earthquakes recorded by OBS A1 and A3, as located by INGV and Greek seismic networks. Most of the earthquakes are located off Greece and Italy, being related to the Ionian subduction beneath the Aegean and the Calabrian arcs.

Fig. 12b shows a four channel recording (OBS A1) of a Greek earthquake of M = 4.8. After P and S phases arrivals, a third phase is evident: this seismic wave, trapped in the channel known as SOFAR (SOund Fixing And Ranging channel), named T-wave, travels at very low phase velocity (about 1.5 km/s) and can be used to constrain the earthquake location, together with P and S waves.

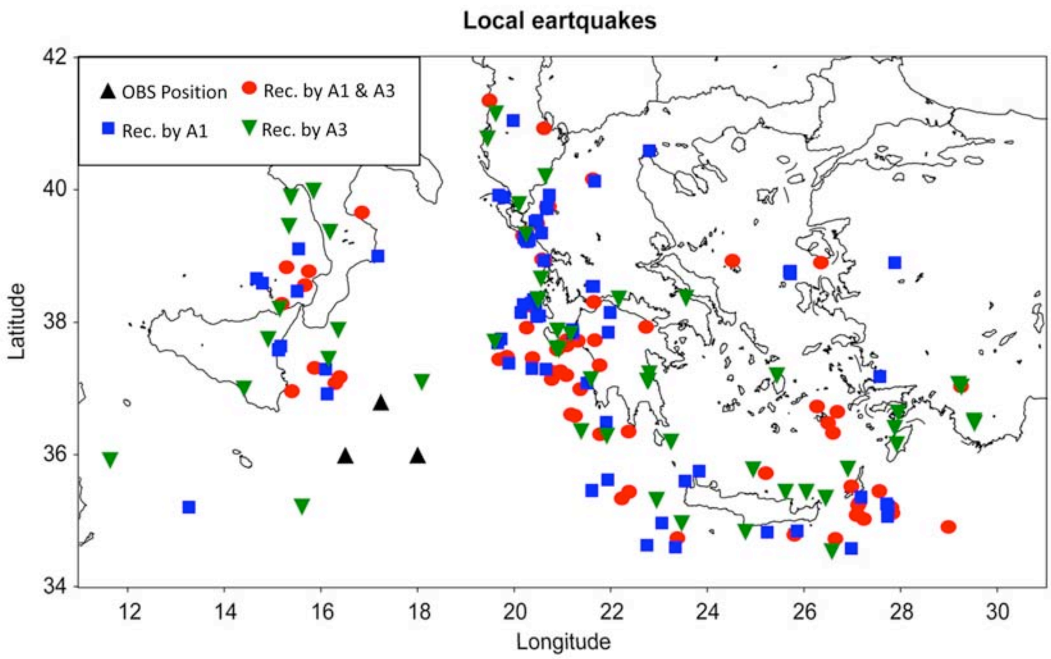
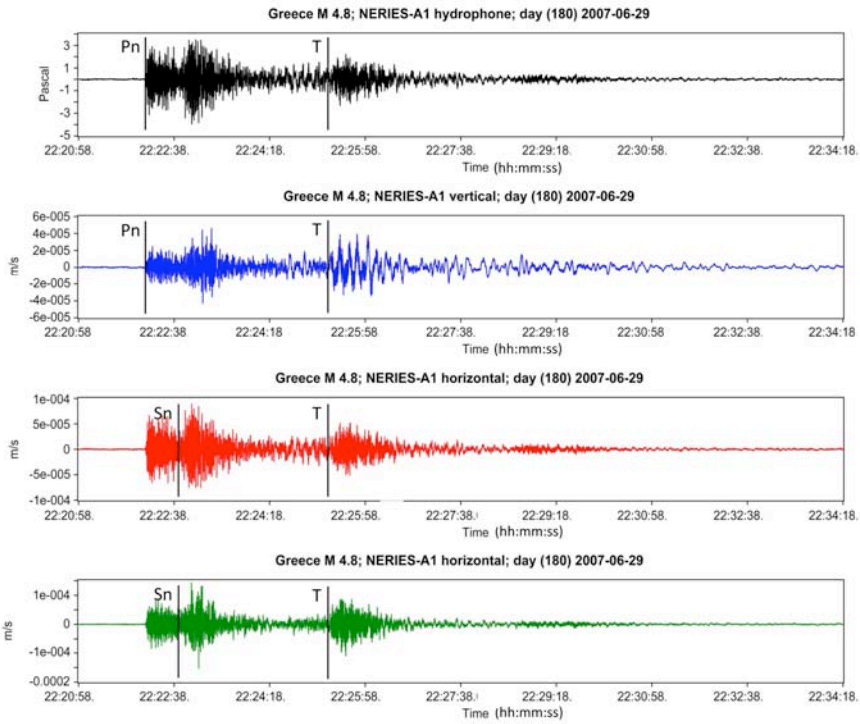
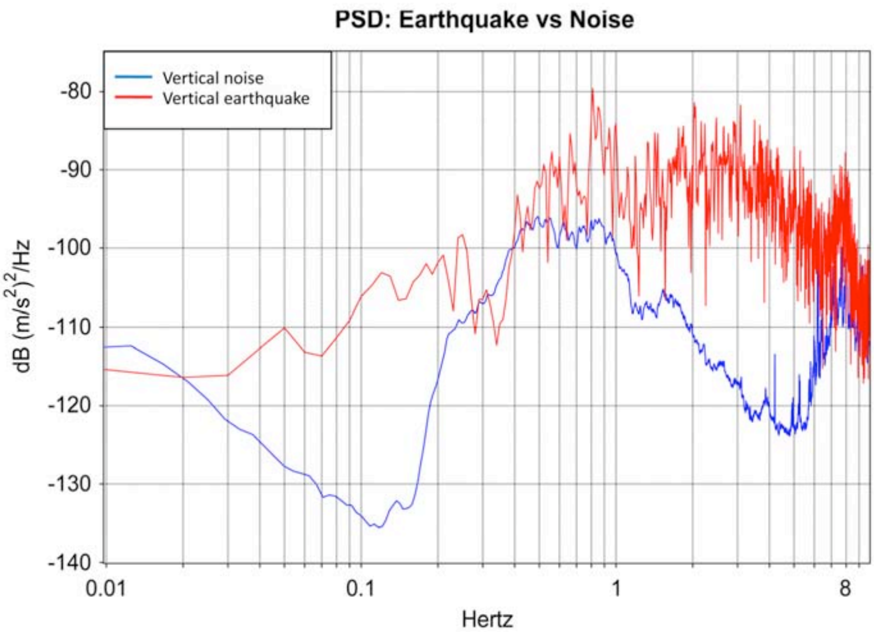


Figure 12 Local and regional earthquakes recorded by OBS A1 and A3.



(a)



(b)

Figure 13 (a) Four channels recording of an earthquake located in Greece (M = 4.8), signals band-pass filtered between 2 and 12 Hz; (b) The earthquake vertical component spectrum compared with the background noise.

The OBS's also recorded more than 100 local events not reported by any land seismic network. *Fig 14* shows the waveforms of one of these unreported local events recorded on the 23rd July 2007 by OBS A1.

We tried to determine the epicenter distance by P and S arrival times assuming the crustal model proposed by Finetti et al. (2005). T-waves arrival time was used as independent and additional information to constrain the epicentral distance estimation. For local seismic event of *Fig. 14* we estimate a epicentral distance of about 150 km.

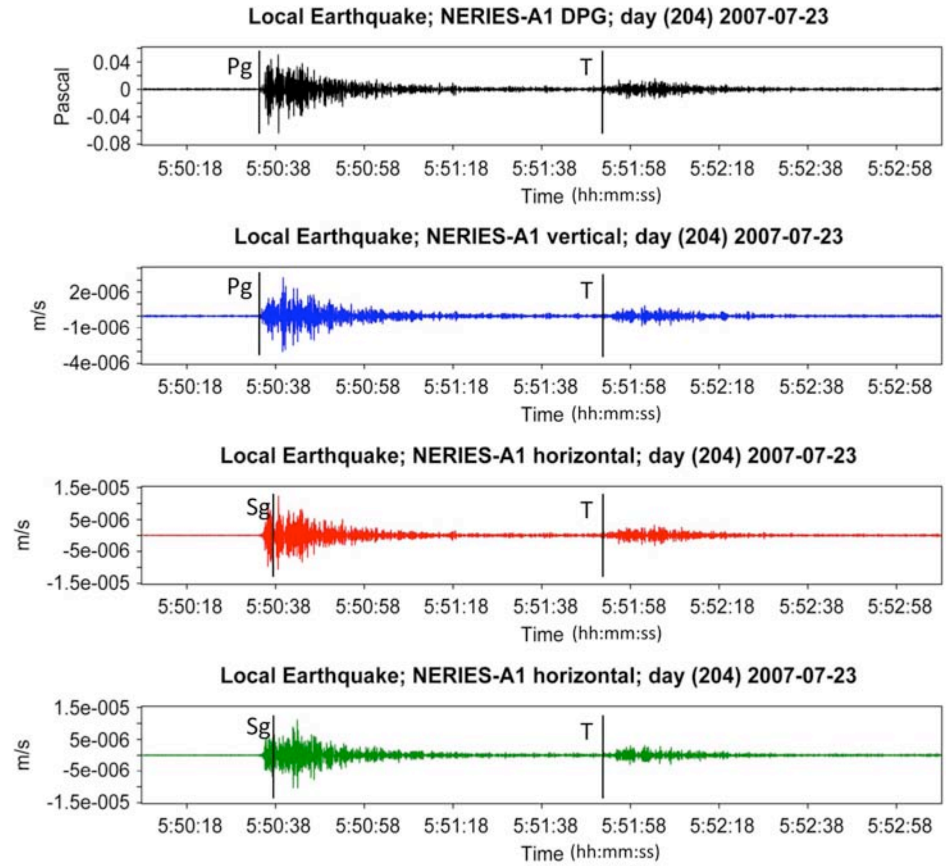


Figure 14 Local event not reported by seismic networks bulletins, signals band-pass filtered between 2 and 10 Hz.

5. Conclusions

After the prototype test on the top of the Marsili submarine Volcano [D'Anna et al. 2007], this was for us the first longtime experiment: even if the NERIES project planned the deployment of only one OBS, we decided to deploy three OBS's for redundancy and to have more information about the behaviour of the instruments in high-depth and longtime experiment.

We're satisfied by the easy recovery of the three OBS's and we are working on the leveling problem of the seismic sensor by building a new active gimbals system.

During the campaign the OBS's array recorded more than 400 events: about 90 are teleseismic events, more than 200 are regional events also recorded by the seismic networks onshore, while more than 100 events were not recorded by any seismic networks on land.

6. Bibliography

Ammon C.J., (1991). *The isolation of receiver effects from teleseismic P waveforms*. Bull. Seism. Soc. Am., 6, 2504-2510.

Catalano R., Doglioni C., Merlini S. Sulli A., (2002). *The Ionian crust and the calabrian accretionary wedge*. AAPG Hedberg Conference.

Bernabini M., Manetti P., 2003. *CROP Project: goals and organization*. Mem. Descr. Carta Geol. d'It., LXII, 9-14.

Cassinis R., Scarascia S., Lozej A., 2005. *Rewiew of seismic Wide-Angle Reflection-Refraction (WARR) result in the Italian region (1956-1987)*, CROP Project, Finetti, I.R. (Editor), 31-55.

D'Anna G., Mangano G., Amato A, D'Alessandro A., Selvaggi G., (2008). *INGV Broad Band Ocean Bottom Seismometers deployed in the Ionian Sea*. Geophysical Research Abstracts. Vienna, Austria, 13-18 April 2008, vol. 10°, ISBN/ISSN: 1029-7006

D'Alessandro A., D'Anna G., Luzio D., Mangano G., (2008). *Polarization and high resolution parametric spectral analysis applied to the seismic signals recorded on the Marsili submarine volcano*. Geophysical Research Abstracts. Vienna, Austria, 13-18 April 2008, vol. 10°, ISBN/ISSN: 1029-7006

D'Anna G., Mangano G., D'Alessandro A., Amato A., (2007). *The new INGV broadband OBS/H: test results on submarine volcano Marsili and future developments*. Geophysical Research Abstracts. Vienna, Austria, 15 – 20 April 2007, vol. 9°, ISBN/ISSN: 1029-7006.

Favali P., Smriglio G., Beranzoli L., Braun T., Calcara M., D'Anna G., De Santis A., Di Mauro D., Etiope G., Frugoni F., Iafolla V., Monna S., Montuori C., Nozzoli S., Palangio P., Romeo G., (2002) - *Towards a quasi-permanent deep sea observatory: the GEOSTAR European experiment.* Science-Technology Synergy for Research in the Marine Environments:Challenges for the XXI Century *(L.Beranzoli, P Favali and G. Smriglio, editors*); in:Developments in Marine Technology Series, 12, 111-120. Elsevier, Amsterdam.

Finetti I.R., 1982. *Structure, stratigraphy and evolution of Central Mediterranean*. Boll. Geof. Teor. Appl., 24, 247-426.

Finetti I.R., Del Ben A., *Crustal tectono-stratigraphy of the Ionian Sea from new integrated CROP seismic data. CROP Project*, Finetti, I.R. (Editor), 447-470.

Finetti I.R., Del Ben A., Forlin E. Prizzon, A., 2005. *Review of the main results of the pioneering MS seismic exploration programme in the deep water of the Mediterranean Sea (OGS, 1969-1980)*. CROP Project, Finetti, I.R. (Editor), 1-30.

Dziewonski A., Blocj S., Landisman M., (1969). *A tecnique for the analysis of transient seismic signals.* Bull. Seism. Soc. Am., 59, 427-444.

Peterson J., (1993). *Observation and modeling of background seismic noise.* U.S. Geol. Surv. Open-File rept., Albuquerque, 93-322.

Scrocca D., Doglioni C., Innocenti F., Manetti P., Mazzotti A., Bertelli L. Burbi L., D'Offizi S. (Editors) (2003). *CROP Atlas: seismic reflection profiles of the Italian crust*. Mem. Descr. Carta Geol. It., 62, pp. 194.

Sgroi T., Beranzoli L., Di Grazia G., Ursino A., Favali P., 2007. *New observation of local seismicity by SN-1 seafloor observatory in the Ionian Sea, off-shore Eastern Sicily (Italy)*. Geophys. J. Int., 169, 490-501.

Tinti S., Maramai A., Graziani L., 2004. *The new catalogue of Italian Tsunamis*, Nat. Hazards, 33, 439–465.

Wasseman, J., (2002). *New Manual of Seismological Observatory Pactice.* Editor: Peter Normann.

Webb S.C., (1998). *Broadband seismology and noise under the ocean*. Reviews of Geophysics, 36, 1: 105-142.