Project n. 037110

NEAREST

"Integrated observations from NEAR shore sourcES of Tsunamis: towards an early warning system"

Instrument: STREP

Thematic priority: 1.1.6.3 GOCE (GlObal Change and Ecosystems)

D14: Deployment cruise of the deep-sea platform and cruise report

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Actual submission date: 12

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Organisation name of lead contractor for this deliverable: INGV

Project Co founded By the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a gruop specified by the Consortium (including Commission Services	
CO	Confidential, only for members of the Consortium (including Commission Services)	

1. INTRODUCTION: NEAREST PROJECT

NEAREST is an EU-funded project (GOCE, contract **n. 037110)** which is mainly addressed to the identification and characterisation of large potential tsunami sources located near shore in the Gulf of Cadiz (fig. 1) through the near real-time detection of signals by a multiparameter seafloor observatory GEOSTAR like.

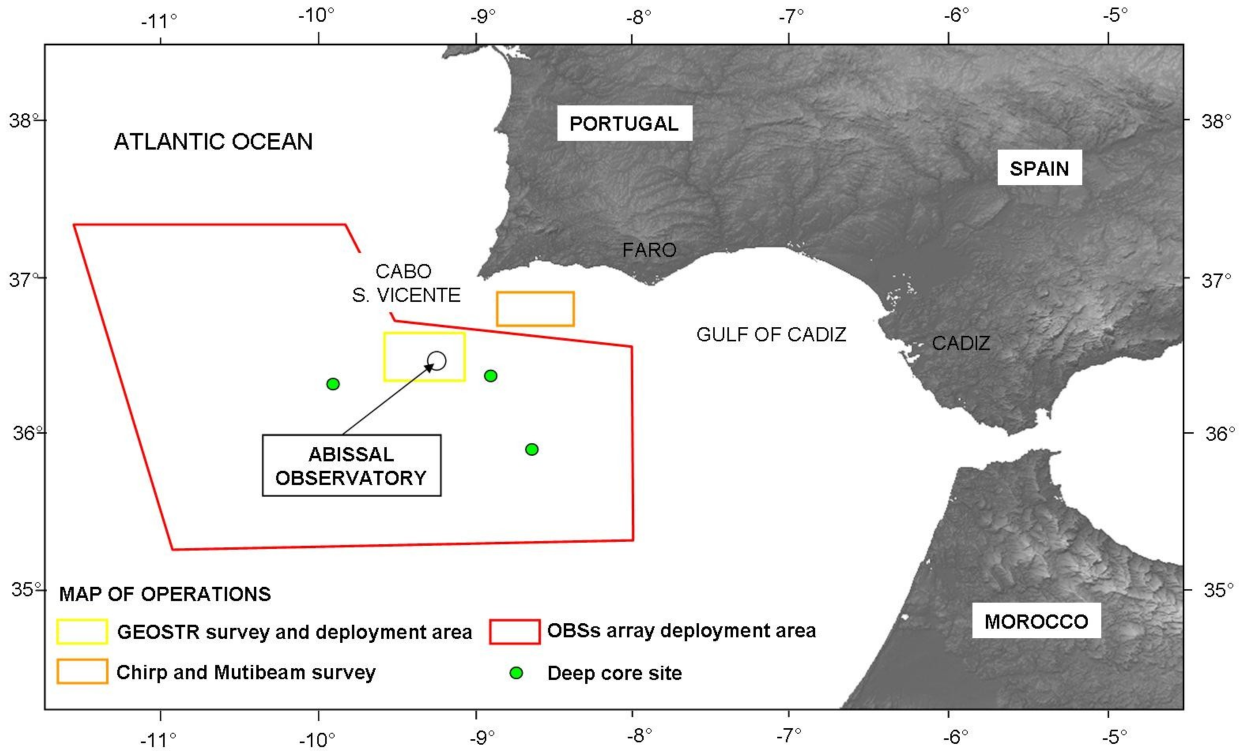

Fig. 1 - Working area

In this area, highly populated and prone to devastating earthquakes and tsunamis (e.g., 1755 Lisbon earthquake), a very good geological/geophysical knowledge has already been acquired in the last decade so it represent an excellent place in which test the near real-time detection of seismic signals.

The methodological approach will be based on the cross-checking of multiparameter time series, acquired on the seafloor by a long-term deep-sea station, equipped with real-time communication to an onshore main station, and by broad band Ocean Bottom Seismometers. All these data series also will be integrated with those coming from land seismic and tide gauge stations, actually active, to be used in a feasibility study for an Early Warning Systems (EWS) prototype in this peculiar area. The EWS will be based on reliable procedures to pass the needed parameters and information to the decision-makers (e.g., local civil protection authorities).

NEAREST, moreover, will search for sedimentological evidence tsunamis records to improve the knowledge on the recurrence time for extreme events and will try to measure the key parameters for the comprehension of the tsunami generation mechanisms.

Another aspect investigated by the project is the improvement of integrated numerical models for the building of more accurate scenarios of tsunami impact and the production of accurate inundation maps in selected areas of the Algarve (SW Portugal), highly hit by the 1755 tsunamis.

To realize all these aims a first NEAREST cruise was planned in august 2007 in order to deploy the abyssal multipurpose observatory and the array of ocean bottom seismometers (OBS).

1.1. GEOLOGICAL SETTING

The SW Iberian Margin is located at the eastern end of the Azores-Gibraltar-Fracture zone, wich is the Eurasia-Africa plate boundary in agreement with the plate-kinematic reconstructions (Olivet et al. 1996; Srivastava et al., 1990).

The area could be divided in two main morphotectonic domains (Tortella et al., 1997): the first between the Gorringe Bank and Cabo Sao Vicente to the west, and the Gulf of Cadiz, between the Cabo Sao Vicente and the Strait of Gibraltar to the east (fig.2).

The first area is characterized by a complex and irregular topography, dominated by large seamounts, deep abyssal plains, and massive rises (e.g. Bergeron and Bonnin, 1991; Gràcia et al., 2003a, Terrinha et al., 2003; Zitellini et al., 2004) such as the Gorringe Bank. The second area is characterized by a smoother topography and by a prominent NE-SW trending positive free-air gravity anomaly (Dañobeitia et al., 1999; Gràcia et al., 2003b).

During the Triassic-Jurassic break-up of Pangea, the eastward drifting of Africa respect to Iberia led to the formation of a rift basins between the new continental margins; this divergent stage ended in early Late Cretaceous. Subsequent northwards migration of Africa with respect to Eurasia led to subduction of western Tethis toward East (Late Cretaceous-Paleogene) and final continental collision with the formation of the Betics-Rif mountains belts and the Gibraltar Arc (Miocene). The

Gibraltar Arc emplacement produced a number of allochthonous units identified from the Gulf of Cadiz to the Horseshoe Abyssal Plain (Bonnin et al., 1975; Torelli et al., 1994; Flinch et al., 1996; Maldonado et al., 1999; Gràcia et al., 2003b; Medialdea et al., 2004).

From Tertiary up to now the main compression direction has rotated anticlockwise, currently the latest GPS kinematic models (Nocquet et al., 2004), show a WNW-ESE main direction of the relative movements between the African and Iberian plates.

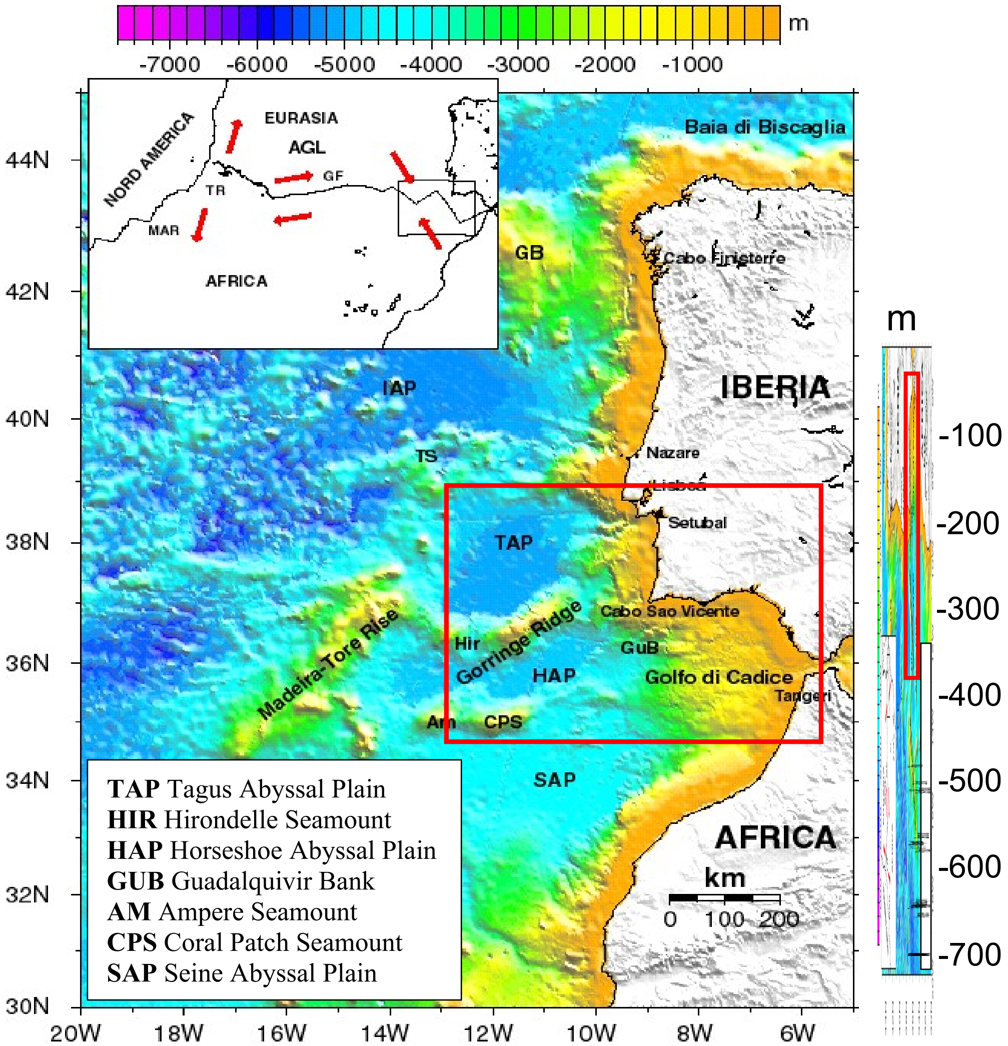

Fig. 2 – SW Iberian margin

Plate convergence of 4 mm/yr (Argus et al., 1989; Nocquet et al., 2004) is accommodated, in this area, over a wide and diffuse deformation zone (Sartori et al., 1994; Hayward et al., 1999) characterized by significant and widespread seismic activity (e.g., Grimison and Chen, 1986). This tectonically active deformation zone was been source of the largest earthquakes that affected the East Atlantic cost since historical times (i.e. 1531, 1722, 1755, 1969) (Fukao, 1973, Martins and Mendes-Victor, 1990). The 1st of November 1755 occurred the most catastrofic of this event, the Lisbon Earthquake, this event was followed by a tsunami that struck the city and impact all the West Europe and Nord African cost. A moment magnitude >8.5 (MW) has been estimated for the Lisbon Earthquake (Martins and Mendes-Victor, 1990; Abe, 1989). The location of the tectonic structure that caused the earthquake end the tsunami has been debated during the last decades (e.g., Udías et al., 1976). After 15 years of geophysical investigation (Rifano-1992, Eu_Bigsets-1998, Parsifal-2000, Hits-2001, Voltaire-2002, Sismar-2003, ESF_Swim-2003) a series of regional tectonic active structures was described and showed to be the possible tsunamigenic tectonic sources, the Marquise de Pombal fault, the Horseshoe fault and the Portimao fault (e.g. Zitellini et al., 2001; Gràcia et al., 2003; Terrinha et al., 2003). This structures converge in a relatively small area located 100 miles offshore Cabo Sao Vicente, the SW culmination of Iberian peninsula that was choosen for the deployment of the seafloor observatory.

1.2. STATE OF THE ART FOR TSUNAMI DETECTION

The reason for developing a real-time, deep ocean tsunami measurement system was to foreseen the impact of tsunamis on coastal areas in time to save lives and protect property.

The first approach to Tsunami waves monitoring was a combination of tide gauges and seismometers. After that, in order to provide a much earlier warning of an approaching tsunami, NOAA (National Oceanic and Atmospheric Administration), developed the research project for Deep-ocean Assessment and Reporting of Tsunami (DART), using buoys in deep sea, acoustically linked to sea-floor pressure gauges. In turn, the buoys would relay the sensor data to a central land site by satellite radio links.

The first-generation DART was based on an automatic detection and reporting algorithm triggered by a threshold wave-height value. The DART II design incorporated two-way communications that enables tsunami data transmission on demand, independent of the automatic algorithm.

Each DART gage was designed to detect and report tsunamis on its own, without instructions from land. The tsunami detection algorithm developed in the gage's software works by firstly estimating the amplitudes of the pressure fluctuations within the tsunami frequency band and then testing these amplitudes against a threshold value. The amplitudes are computed by subtracting predicted pressures from the observations, in which the predictions closely match the tides and lower frequency fluctuations. The predictions are updated every 15 seconds, which is the sampling interval of the DART gages. The detection threshold was defined using statistical analysis on background oceanic noise. Based on past observations, a reasonable threshold for the North Pacific was fixed to 3 cm. When the amplitude exceeds the threshold, the gage goes into a rapid reporting mode to provide detailed information about the tsunami.

1.3 TSUNAMI MODELLING

The life of Tsunami can usually be divided in three phases: generation (source), propagation and inundation.

Using different models to generate the initial displacemment of the seafloor and long waves or shallow water models to decribe tsunami propagation and to calculate the inundation, tsunami modelling has proved to be an important tool to evaluate the impact of tsunami waves in coasts and to assess the candidate sources for historical tsunamis in the possible tsunamigenic zones along the studies area.

However several authors investigated the tsunami sources in the SW of Iberia and Gulf of Cadiz, Fukao (1973), Johnston (1996), Baptista (1998,2003), Zitellini (1999) and Gutscher(2003), in the purpose to explain observable data for historical tsunamis (the great Lisbon earthquake and tsunami of 1755 with estimate magnitude 8.5-9), or to confirm instrumental records for recent tsunamis (the 1969 Horseshoe fault (HSF) earthquake MW 7.9).

The present study led in this area consists to use tsunami modelling to determine the impact of waves in the different coasts and, afterward, evaluate tsunami risk and vulnerability. Modelling was performed with COMCOT code, from Cornell University (Liu et al., 1994). The simulation domain covers the eastern part of the Atlantic Ocean offshore Morocco and the Gulf of Cadiz, from the most prone tsunami generation area. Three nested grid layers of different resolution (0.008º, 0.002º and 0.0005º) are incorporated to obtain a good description of bathymetric and topographic effects near shore. Results of the numerical simulations are discussed in terms of wave heights, flow depth and maximum velocity.

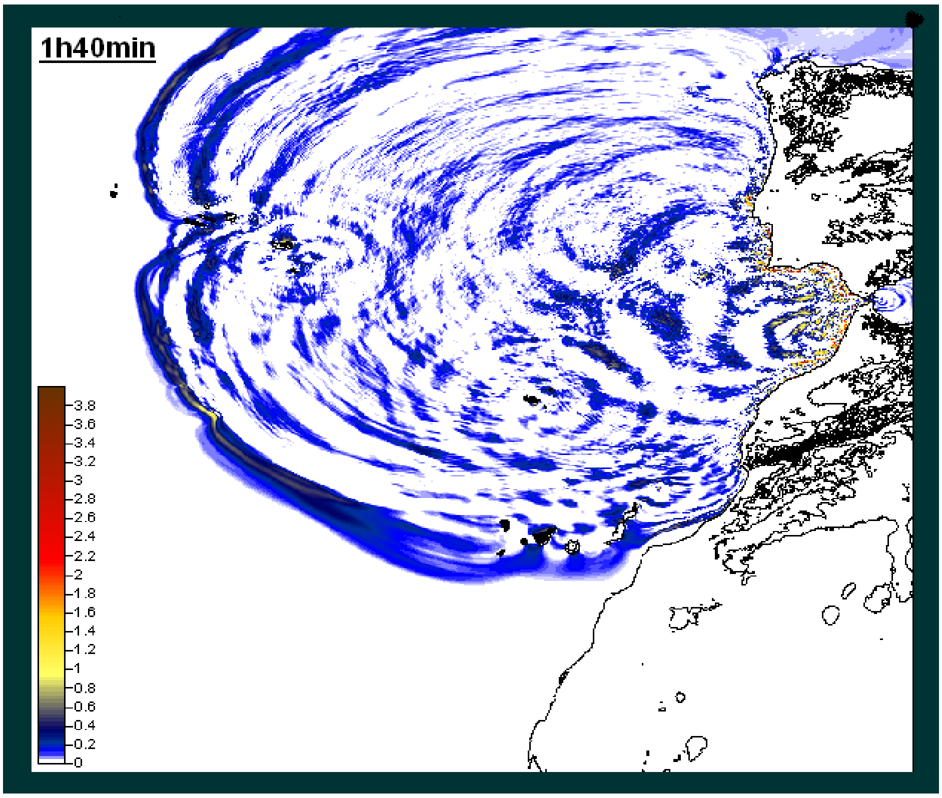

Fig:3 - Modelling of tsunami propagation for the 1755 tsunami for the source proposed by Zitellini et al. (1999) and Baptista et al. (2003)

2. NEAREST 2007 FIRST LEG: GEOSTAR AND BUOY DEPLOYMENT

The main goal of the first leg was the deployment of the seafloor multiparametric station, GEOSTAR like, linked to land receiving stations by an acoustic communication system assembled on a buoy. The seafloor station, equipped with a seismometer and oceanographic sensors, will record seismicity and oceanographic data for one year. After detailed tectonic and morphological studies and during the first meeting of the NEAREST team (Lisbon, may 2007) was identified the GEOSTAR deployment area (9°29.00'W, 36°18.00'N, 9°28.00'W, 36°24.00'N, see Fig 10 and 11). To detect possible presences of geomorphological instabilities that could compromise the site safety, a subbottom (CHIRP) survey was performed before the deployment (Fig.13 and 14). Moreover two CTD measures were collected before the deployment in order to determine the main oceanographic characteristics of the Geostar area and to calibrate the multibeam with an appropriate sound velocity function (Fig 29 and 30 ,chapter 3).

2.1 TECHNICAL DESCRIPTION OF THE GEOPHYSICAL SEAFLOOR OBSERVATORY AND INSTRUMENTS

The Geostar system is a single-frame autonomous seafloor observatory able to collect multiparameter data with a unique time reference for long-term investigations.

The technology of this observatory derives by the synergy among research institutes and industries starting from 1995 to develop seafloor systems able to operate from shallow water up to deep sea.

During these years, a fleet of observatories has been built up with the economical support of European Commission (i.e. GEOSTAR; GEOSTAR-2; SN-1;ORION-GEOSTAR-3; ASSEM etc.), bringing more and more improvements at the main technology of benthic observatories. These systems satisfy the main conditions of seafloor observatories: multidisciplinary, long-term monitoring, unique time reference, autonomy, and development of (near) real-time communication system for warning of local events.

The last generation of Geostar seafloor observatory, planned in the framework of NEAREST project, is equipped with:

- geophysical and oceanographic sensor package

- central acquisition, control unit (central clock)
- data processing unit
- local memory storage
- acoustic communication system

All of these characteristics are indispensable to be able to acquire scientific multiparametric data, to detect real-time events (seismic and water pressure) and to communicate possible warning messages.

The observatory is constituted by three main sub-systems:

1. Bottom station constituting the monitoring system (fig.4)
2. MODUS vehicle that allows deployment and recovery procedures (fig.5)
3. Buoy system representing the communication system (fig.6)

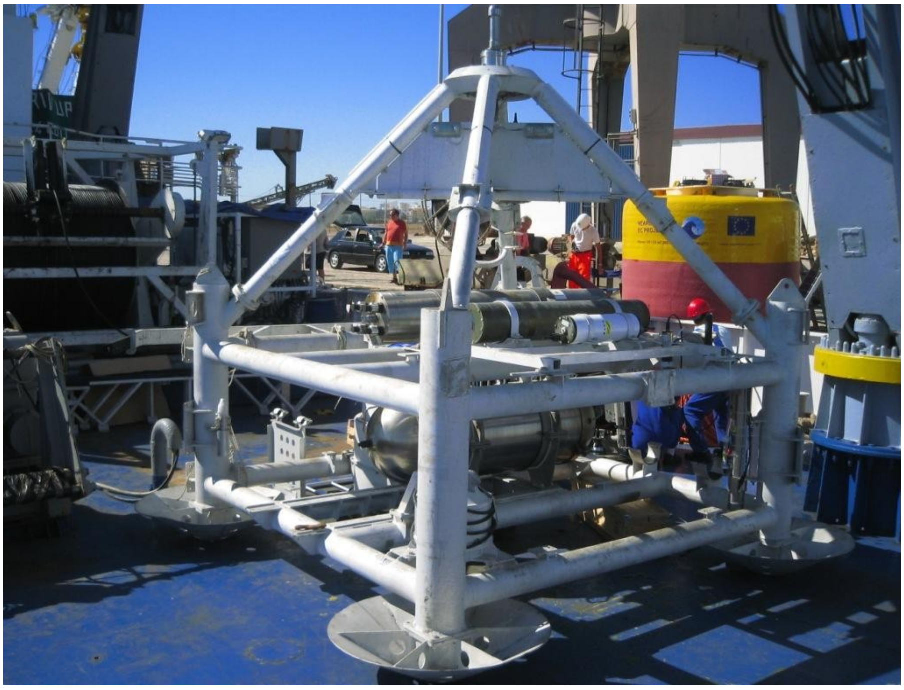

Fig. 4 - GEOSTAR bottom station

The Bottom station consists in a marine aluminum frame hosting instrumental sensor packages (see table 1), compass controlling heading, pitch and roll of the observatory during the deployment, lithium batteries for power supply, echosounder to determine the distance between Geostar and bottom surface during the deployment, electronic for data acquisition, hard disks for data storage, underwater part of acoustic communication system.

The acquisition data is entirely controlled by a central unit (DACS: Data Acquisition and Control System) that prepares and updates the hourly data messages, performs the TDA algorithm and transmit data messages on request; also it is able to send in real-time warning messages of detected events towards the surface communication system (buoy).

DACS manages a wide set of data having quite different sampling rate (from 100 Hz to 1 sample/15 sec), tagging each datum according to a unique time reference set by a central high-precision clock.

Sensor	**Sampling rate**	**Acquisition**
3-comp. broad band Seismometer	100 Hz	Continuous
3-comp. Accelerometer	100 Hz	Continuous
Hydrophone	100 Hz	Continuous
Pressure sensor	1 smp/15 sec	Continuous
Gravity meter	1Hz	Continuous
CTD & Transmissometer	1 smp/min	Continuous
ADCP	1 smp/ hour	Continuous
3 comp. Currentmeter	5 Hz	Continuous

Table1: GEOSTAR main sensors

Fig 5 – The Modus Module

MODUS is an underwater vehicle dedicated to deploy and recover the bottom station. It is equipped with a latch/release device, thrusters, video cameras, compass, sonar and altimeter mounted on the frame to visual control during the observatory diving and assisting the docking procedure (see MODUS characteristics in Table 2).

Modus is remotely controlled from the ship through a telemetry system (umbilical cable) that provides the primary communication link with the station during the deployment phase.

Sensors	**Material**		**Dimension & Weight**	
Horizontal thruster	Frame	Aluminum	Total length-L	2878 (cm)
Vertical thruster	Docking Device	Stainless steel	Total width-W	2348 (cm)
Heading accuracy (degree)	Pressure Vessel	Titanium	Total height –H	1700 (cm)
Tilt accuracy (degree)			Weight in air	ca. 10 (kN)
360º sonar range (m)			Weight in water	ca. 7 (kN)
Video Cameras (+ lights)				

Table 2: Modus main characteristics

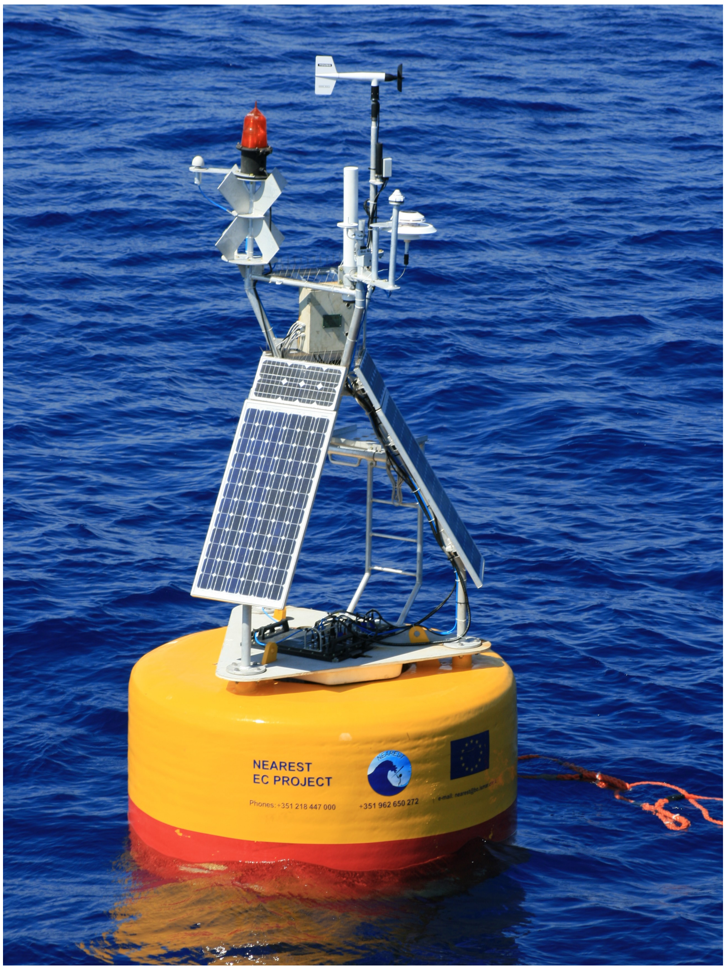

Fig. 6 – The Buoy

The buoy is a surface system that works as relay between the hydro-acoustic communication system (toward the bottom station) and the satellite system (towards the shore station) assuring a (near) real-time transmission of the messages acquired. It hosts:

- An acoustic communication system able to transmit message request (status sensors, status message, etc.) at the bottom station by a land operator and also to receive periodic message (each 6 hours) of pressure and status sensors and warning message related to possible events (trigger time and pressure data).
- A satellite system as support of communication system between benthic observatory and shore station. It is able to send the received bottom station messages via GLOBALSTAR satellites. Further, a storage system inside the buoy allows to save the received messages when the satellite cover is not available and to send them subsequently.

- A meteo station equipped also with auxiliary sensors as temperature, humidity, anemometer, etc. (see Table 3) acquires and store meteorological information.
- A GPS positioning system managed from the buoy as well as an autonomous positioning system (ARGOS Beacon) working with a different satellite constellation.
- Six Photovoltaic Panels
- A acoustic transducer (ATS) communicating with the bottom observatory

Sensors	**Measured Parameter**	**Sampling Rate**
Meteo Station	Barometric pressure (mbar)	2 smp/sec
	Wind velocity (m/sec)	2 smp/sec
	Measured wind direction (deg)	2 smp/sec
	True wind direction (deg)	2 smp/sec
	Heading (deg)	2 smp/sec
	Air Temperature (° C)	2 smp/sec
	Air Humidity (%)	2 smp/sec
Tiltmeter	Tilt x	1 smp/sec
	Tilt y	1 smp/sec
	Heading (deg)	1 smp/sec
GPS	Longitude (deg)	1 smp/sec
	Latitude (deg)	1 smp/sec
	Drift (m)	Derived by lat and long values

Table 3: Scientific payload of the buoy

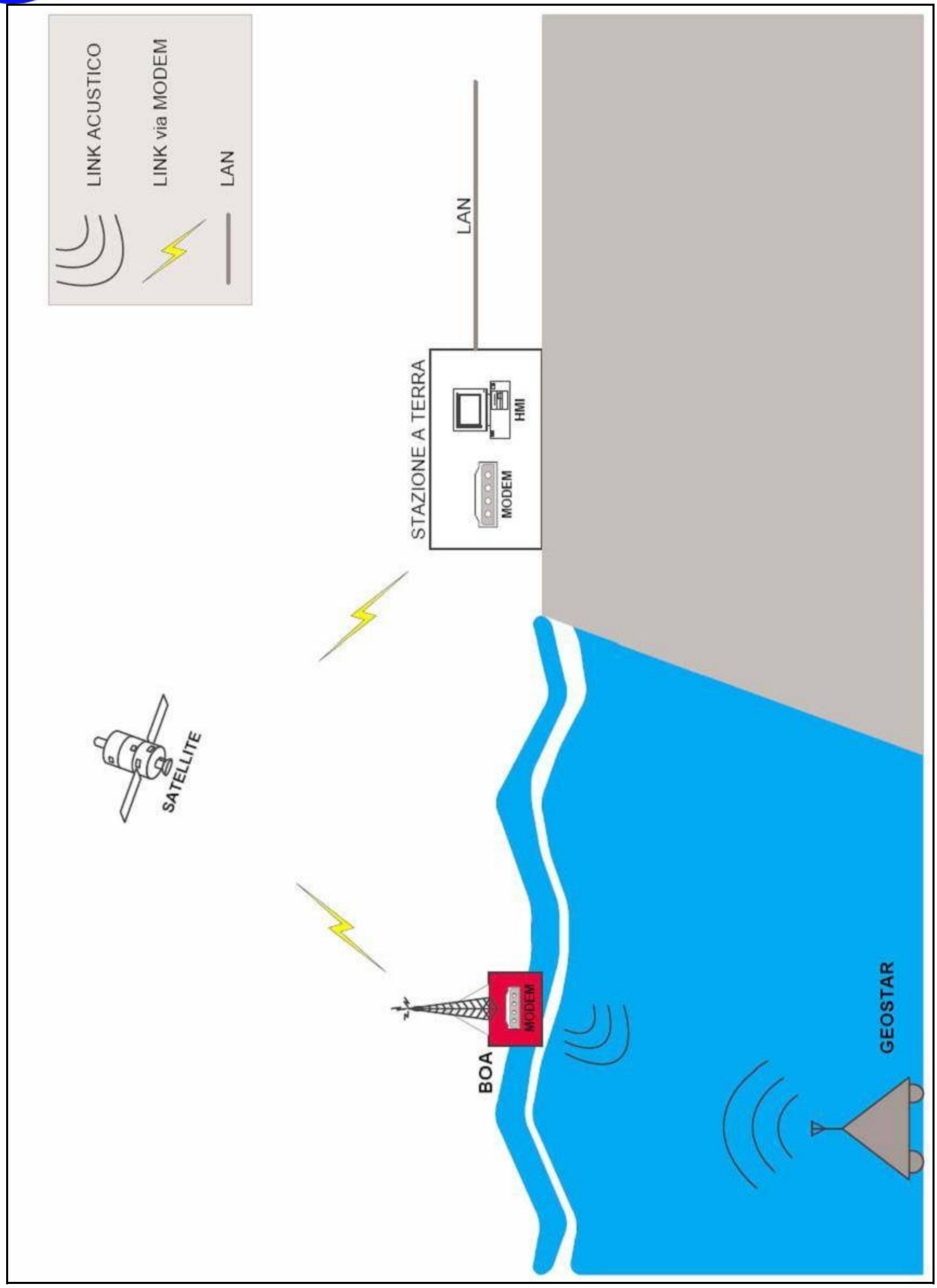

Fig. 7 - Communication systems scheme.

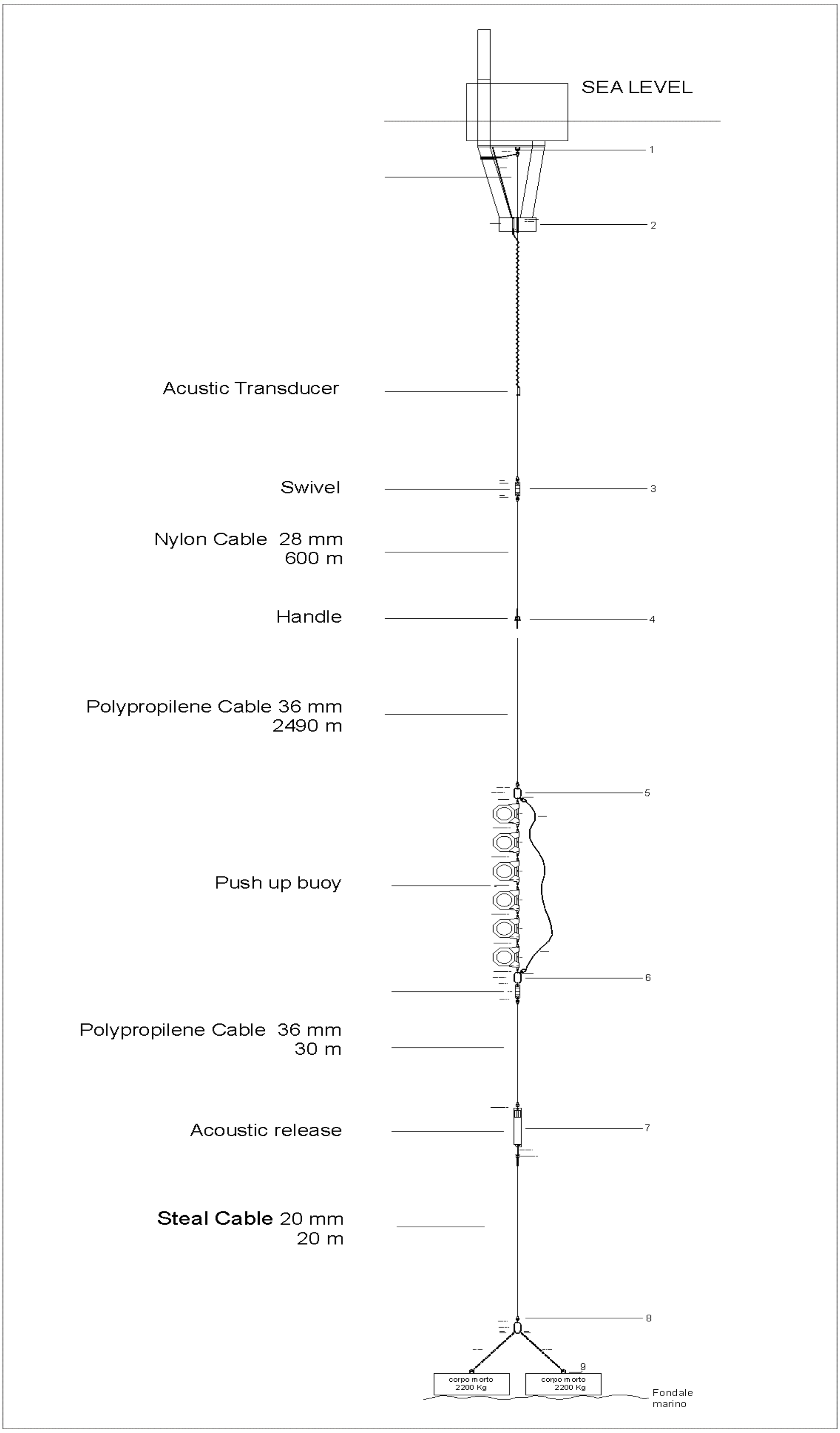

Fig 8 – Buoy anchorage system

2.2 GEOSTAR DEPLOYMENT

The buoy and abyssal station deployments were performed during 25th of august (as described in the daily report). Before deployment a detailed chirp dataset was acquired in order to definitively identify a place free from instability phenomena, but, the presence of military submarine drill closest to the area and the forbiddance to cross the 9°30’ W of longitude by the Portuguese authority, have forced the shift toward east of the instrument position (Fig. 9 and 10).

The buoy anchorage system was deployed at 3217mt depth with the following official coordinates: 36°22.058’ of latitude North 9°28.812’ longitude West.

The GEOSTAR station was deployed at 3207 mt depth with the following official coordinates: 36°21.875’ of latitude North 9°28.885’ longitude West.

Fig. 9 - GEOSTAR deployment

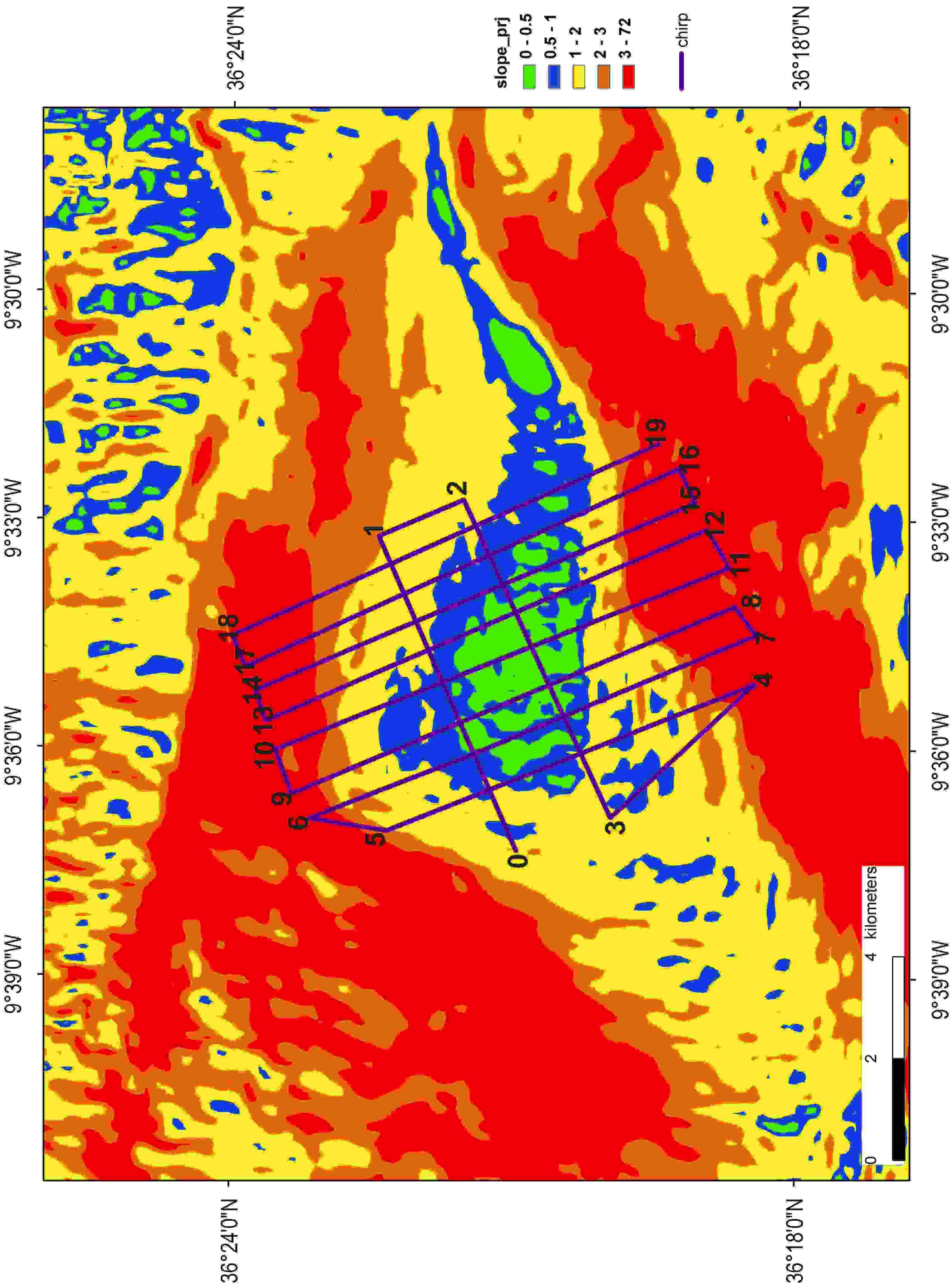

Fig. 10 - Foreseen chirp survey, based on the slope distribution map.

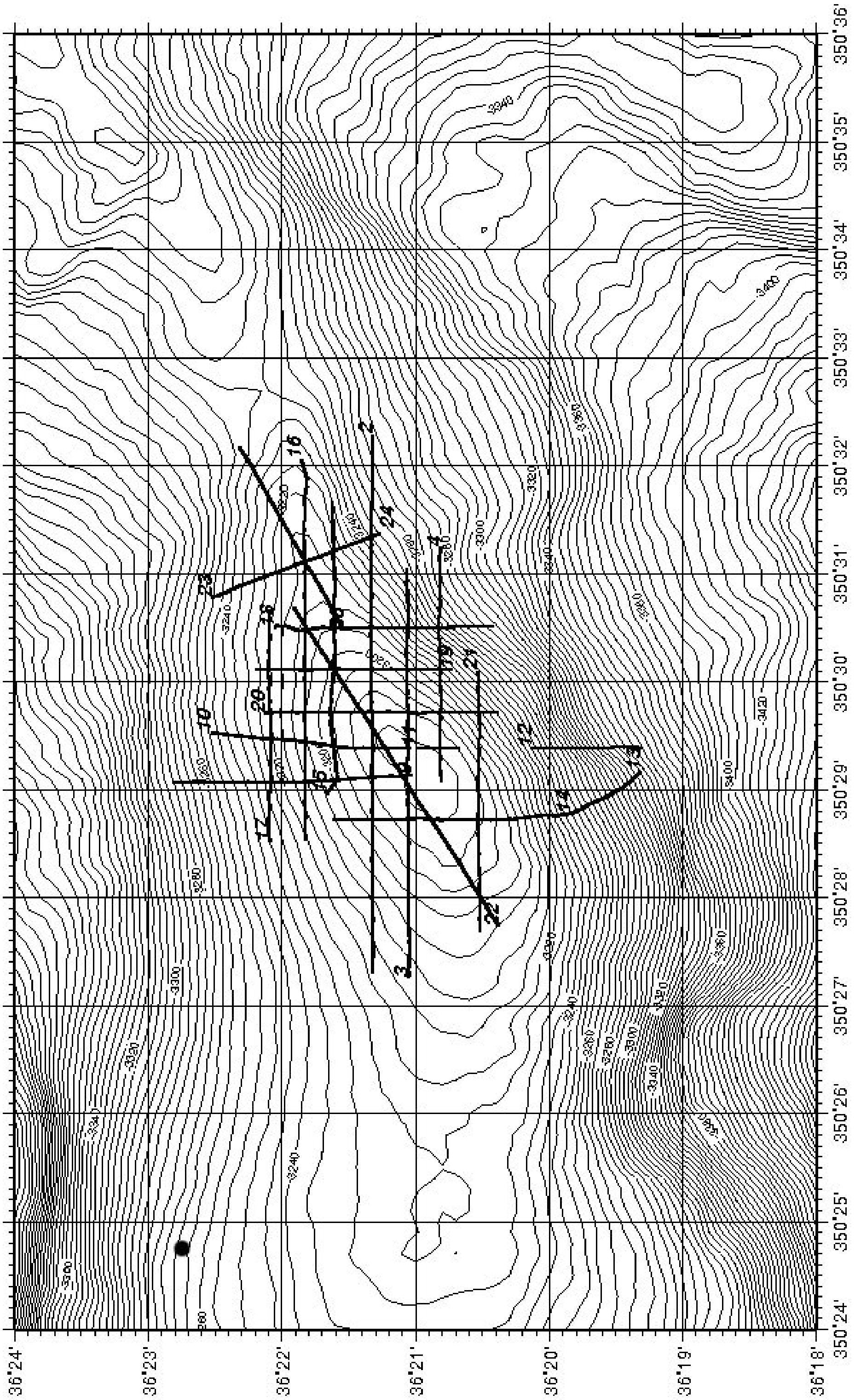

Fig 11 - Performed chirp survey on the Geostar site.

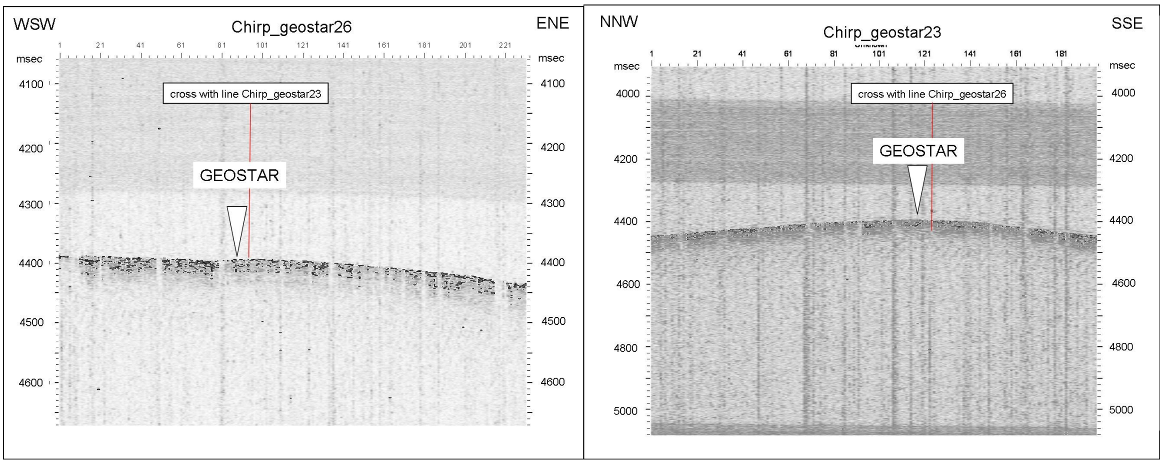

Fig 12 - Example of chirp data and Geostar location

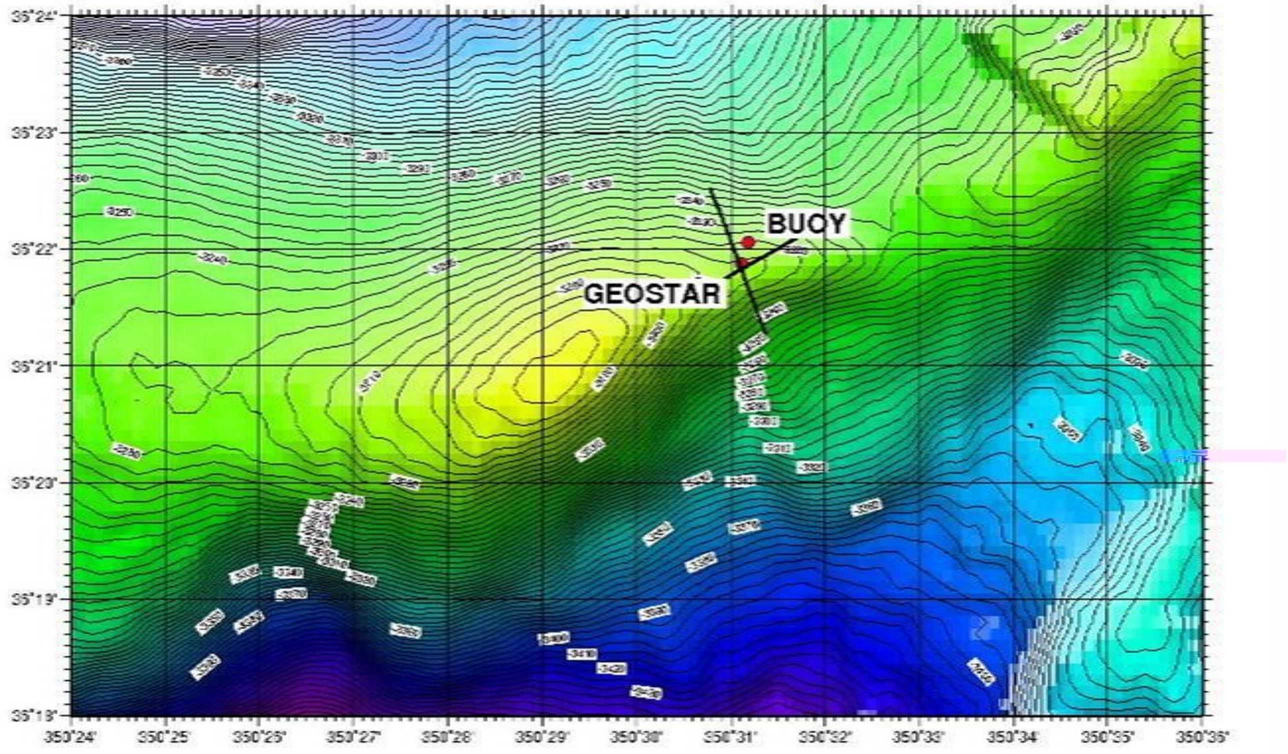

Fig 13 - Geostar and buoy site deployment

FIRST LEG: Scientific and technical personnell

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Costagliola Michele	2° Officer
Ciano Pietro	Chief Engine
Carrassi Giuseppe	1° Off. Engine
Corcione Procolo G.	Mechanic
Mastronardi Luigi	Boatswain
Martiradonna Nicola	Seaman
Sano Gian	Seaman
Zimmitti Sebastiano	Cook
Pizzonia Leonardo	Steward
De Lauro Tommaso	Y.D.Boy
Cannavò Giovanni	Galley Boy
De Simone Troncone Paolo	Y.D.Boy