Project N. 037110

NEAREST

Integrated observations from NEAR shore sources of Tsunamis: Towards an early warning system

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PP	Restricted to other programme participants (Including Commission Services)	
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NEAREST (INTEGRATED OBSERVATIONS FROM NEAR SHORE SOURCES OF TSUNAMIS: TOWARDS AN EARLY WARNING SYSTEM)

GEOSTAR 2009 CRUISE REPORT

26th October – 13th November 2009

(Deliverable 15c – Responsible partner INGV)

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(*) on boad r/v Sarmiento de Gamboa

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Cover: NEAREST Team on board r/v Sarmiento de Gamboa

Table of contest

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Institutions Acronyms

INGV	Istituto Nazionale di Geofisica e Vulcanologia, Italy
TUB	Technische Universität Berlin, Germany
UTM-CSIC	Consejo Superior de Investigaciones Cientificas- Unitat de Tecnologia Marina, Spain
IM	Instituto de Meteorologia, Portugal
CNR-ISMAR	ConsiglioNazionale delle Ricerche, Istituto di Scienze Marine, Italy
AWI	Alfred Wegener Institute fur Polar-und Meeresforschung, Germany

1. Introduction

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 through the near real-time detection of signals by a multiparameter seafloor observatory GEOSTAR like. To address the task of the WP4 "Tsunami signal detection" in August 2007 the GEOSTAR observatory and a communication buoy was first deployed with the help of the r/v Urania. The GEOSTAR observatory was recovered after one year in august 2008, but due to the accident occurred to the communication buoy in November 2007 the system wasn't able to demonstrate the feasibility of a quite real time communication from the bottom station charged to detect tsunamis and the shore station. After the recovery of the system, both the buoy and the acoustic communication system were improved in order to efficiently demonstrate possibility to quite real time communication between a seafloor abyssal station and the station on land.

The new deployment cruise took place with the r/v Sarmiento de Gamboa owned by UTM/CSIC from the port of Vigo (Spain) from where the vessel sailed on 4th November and where came back on 13 th November.

Figure 1 The r/v Sarmiento de Gamboa

2. Objectives

The GEOSTAR system is a single-frame autonomous seafloor observatory able to collect multiparameter data with a unique time reference for long-term investigations. In the framework of EU NEAREST project the station was configured to act also as tsunami detector being in charge to detect and deliver messages in case of a local seismic event or an anomalous tsunami wave.
The communication scheme (Figure 2) will supply a bidirectional link between the bottom station and a shore station in order to receive periodic messages from the abyssal station and the buoy, receive the notification of events detected by the bottom station, and allow reconfiguration of the system during the mission. The communication between GEOSTAR and the buoy is guaranteed by a couple of acoustic modems (Sercel manufactured) installed on the abyssal station and on the buoy. The buoy uses Globalstar satellite link to forward the messages from GEOSTAR to the station on land and to receive command from the shore station in Italy.

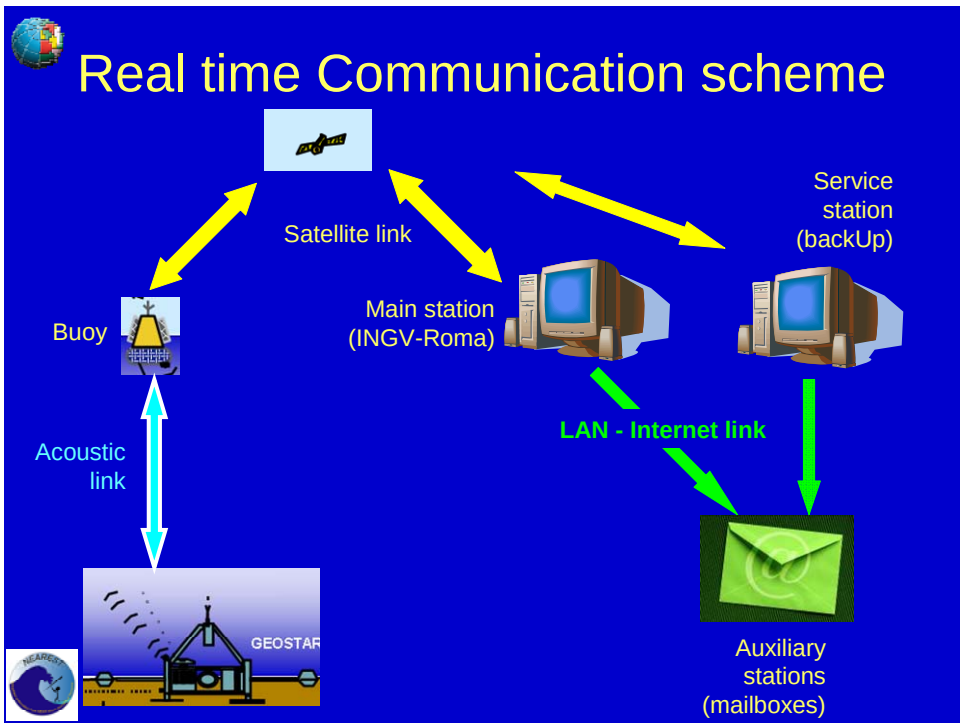

Figure 2 The communication system

3. Daily log

The report cover the cruise operation and both mob and demob operations. After being shipped from Italy, during the week before the actual cruise departure, the GEOSTAR station and the buoy, were both assembled in the CSIC warehouse near Vigo (from 26th to 29th October); then the station and the buoy with all the mooring line, were shipped by truck to Vigo on board of the r/v Sarmiento de Gamboa where the final assemble and functionality test were performed (30th October 2sd November) before the cruise start (3th - 12th November).

3.1. Monday 26th October

GEOSTAR team arrive in Vigo (Bruni, Embriaco, Monna. Viezzoli was already in Vigo to receive the first part of the material)

3.2. Tuesday 27 th October

Beginning of the assembling of GEOSTAR bottom station: DACS, station battery vessel, gravimeter, seismometer. During the assembling of the Paroscientific pressure sensor, the plastic support to be used to clamp the device to the station broke down (see Figure 4). To overcome the problem a new clamp was manufactured by the help of UTM-CSIC staff using a local mechanical workshop.

Figure 3 The beginning of the GEOSTAR assembling: the bare frame (left) and with the DACS, the battery vessel and assembled (right) .

Because also the AWI managed Hydrophone was to be assembled with a similar clamp, we proceed to assembler and fix it to the station, to verify the clamp robustness.

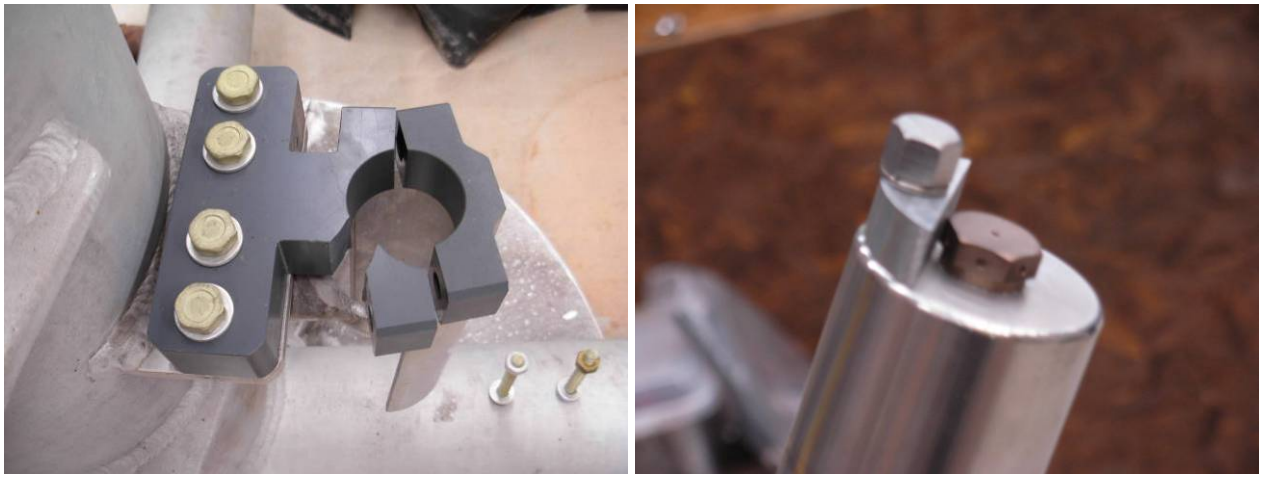

Figure 4 The pressure sensor plastic clamp broken during the assembling (left) and the anticorrosive anode touching the anti-fouling port (right)

At a visual inspection the anode of the Paroscientific pressure sensor seems in contact with the antifouling port; for Tecnomare technician (Bruni and Cenedese) this fact cannot be a source of potential corrosion damage.

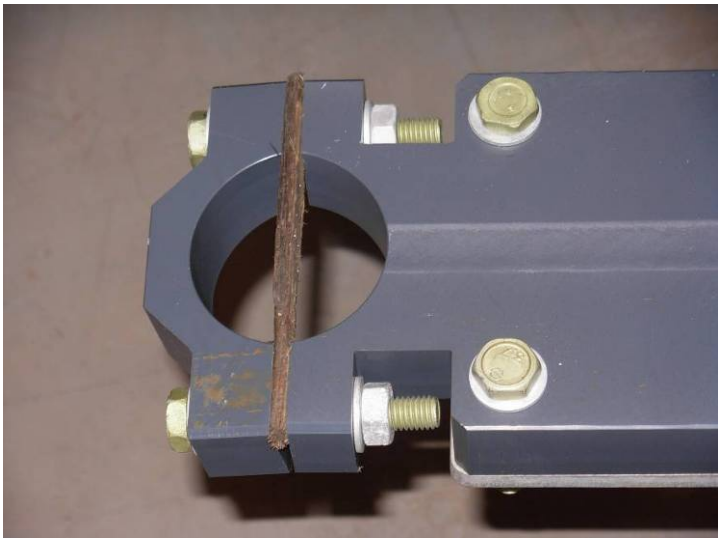

Figure 5 The clamp for the AWI Hydrophone

Other devices assembled: CTD, hydrophone OAS, echo sounder, transmissometer, acoustic modem. The assembling of the buoy starts with the mounting of the solar panel and the Floatex electronics.

Figure 6 The seismometer (left) the gravity meter (center) and the OAS hydrophone(right) during assembling operations

3.3. Wednesday 28th October

Visit to the UTM mechanic workshop in order to setup the new clamp to fix the pressure sensor to the station. The plastic bearing staff will be completely solid.
The station assembling continue with the AWI hydrophone (Wolfrang Geisler), the seismometer (assembled with the release mechanism and setup inside the seismometer vessel), installation of the battery of the acoustic modem.
The buoy electronics and all devices were assembled (meteo station, antennas, the light flashing for sea navigation warnings, everything excluding the Argos beacon that will be assembled on board just after its activation). Beginning of the assembling of the floating abyssal buoy for the mooring line (Viezzoli, Lagalante).

3.4. Thursday 29th October

Setup of the upper part of the GEOSTAR frame.
Preparation for the transportation of all devices and material on board of the ship for the day after.
A new release of the acquisition software for the transmissometer device is upload on the DACS of GEOSTAR in order to test its functionality. The new release was developed to fix a minor acquisition bug which prevent the correct storage of some samples during normal operation. A first test showed that the bug is not completely fixed.

3.5. Friday 30th October

In the morning GEOSTAR and the buoy were moved to Vigo on board of the r/v Sarmiento de Gamboa.
Pressure sensor assembling: Tecnomare (Gasparoni) suggested to isolate the anode of the pressure sensor from the anti fouling port by removing part of the zinc material (Figure 7). The new clamp for the pressure sensor is ready and the device is installed on the GEOSTAR frame, the new solution appear more stable (Figure 7)
In the afternoon the Modus vehicle and all the TFH material arrived in the port and are upload on board of the ship.

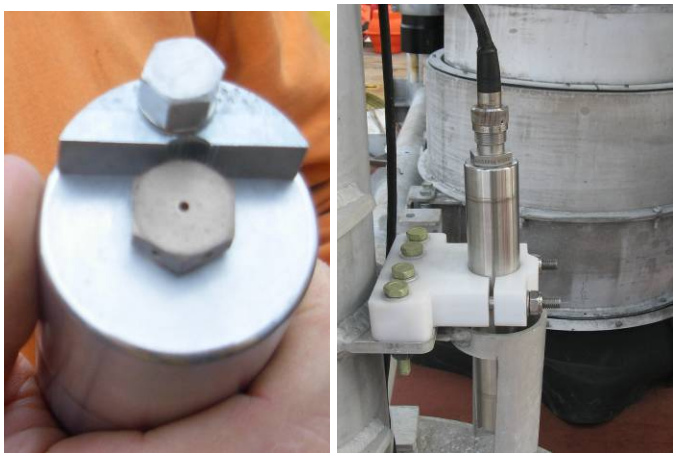

Figure 7 The Paroscientific absolute pressure sensor: the zinc anode and the anti fouling port (left) and the new plastic bearing (right)

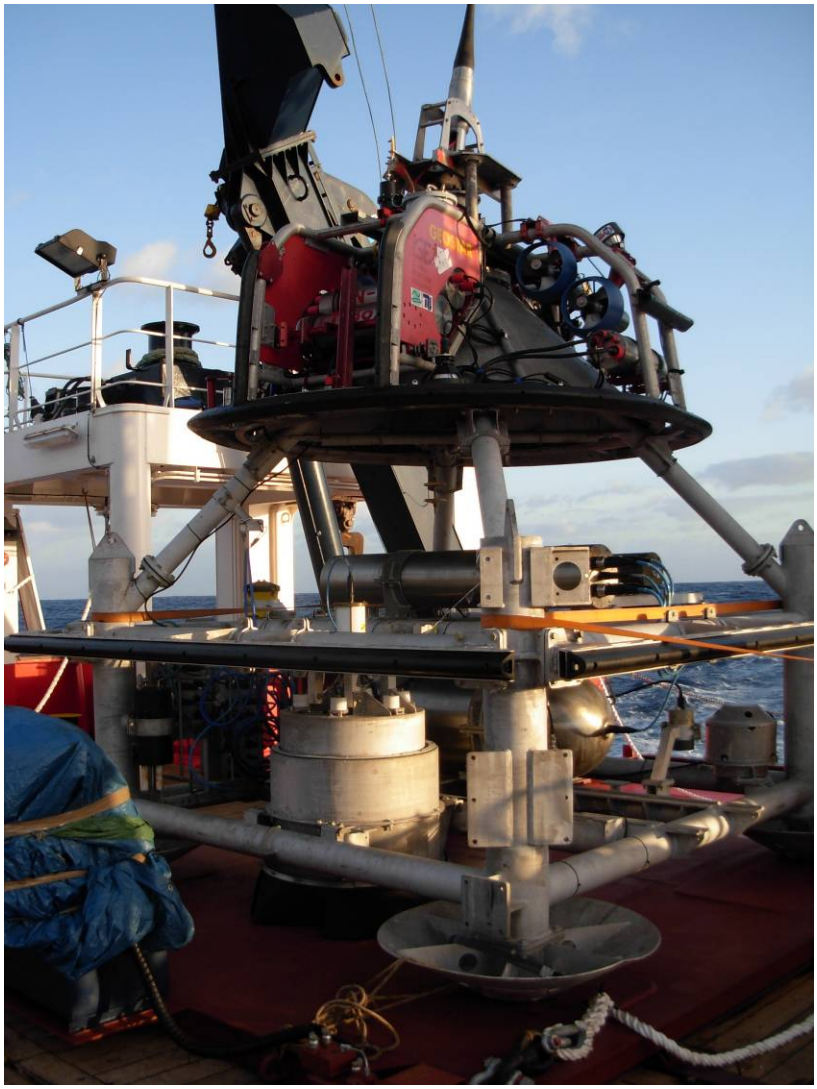

Figure 8 GEOSTAR on the deck with MODUS

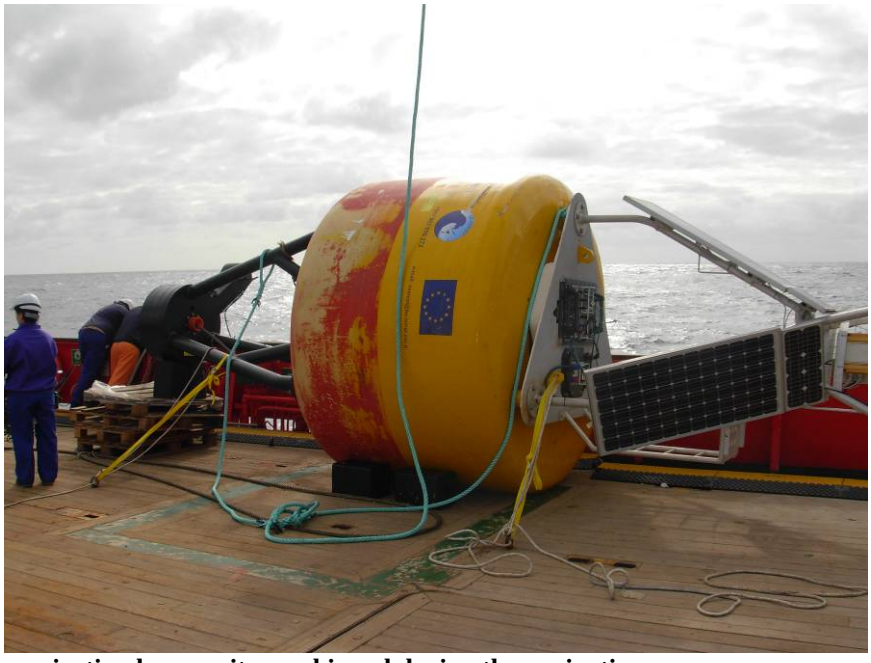

Figure 9 The communication buoy as it was shipped during the navigation

3.6. Saturday 31th October

The buoy is completely assembled: the solar panel are connected to the battery. Test of the buoy status: the buoy is working in mission mode from now on.

GEOSTAR is moved on the deck of the vessel:

- test of the seismometer release mechanism (it is verified that after the software command "release seismometer" a tension of 5VDC is present on the corresponding pin of the release cable.
- The acoustic modem are tested by Sercel.
- Test of the satellite modem: max signal=4 at 16:15; connection established between the spare satellite modem on board and the satellite modem of the buoy; the connection is not stable, probably due to partial satellite coverage and not optimal satellite antenna positioning on the buoy (which is stored on board in a horizontal position).
- The buoy automatic messages are received by the shore station (Marghera, Tecnomare) and the expected e-mail messages are distributed as scheduled (buoy data and status messages; status messages received at 17:10, with missing header: the HMI software on the shore station is to be updated)
- GEOSTAR station is switched on (using power via test cable) and a new software release of the DAU board is upload (current meter management upgrade).

GEOSTAR is put in "mission" mode: the currentmeter is located in a box full of water; the acoustic transducer of GEOSTAR and the buoy are located next to each other in order to test acoustic communication in the air. Seismometer STA/LTA configuration: STA=1s LTA=30 s trigger=1.1. The seismometer is hit in order to simulate a seismic event, but none of the event are generated as expected. After multiples attempts the decision is to manually (via software command) put GEOSTAR in event mode in order to test the event messages communications. During the forced event the acoustic messages are correctly generated at the scheduled time interval (one at the beginning, and one each 10 minutes). Some of the messages are received by the shore station and the notification e-mails were received and checked on board. Questions arise if the seismometer was damaged during the shipping from Italy.
The ship change its position in the port.
During the night GEOSTAR is left working in mission mode, with the proposed configuration (TDA) for the mission on the sea.
In the evening all INGV people arrived in Vigo.

3.7. Sunday 1st November

After the night test of GEOSTAR and the buoy the mission is stopped and DACS electronics is extracted from its vessel in order to download all the data acquired during the night, in particular to check the seismometer status. The station is found in pressure event mode (check done with the test cable). During the night the periodic messages from GEOSTAR were received by the shore station and two pressure events were generated.
At 10.00 UTC DACS electronics is opened and bring into the lab in order to download data stored on the flash cards. Due to bad weather conditions (it is raining) the DACS vessel is covered by a plastic tarpaulin and it is impossible to put back the electronic inside the vessel.
The analysis of the seismometer and GEOSTAR data reveal that the Guralp digitizer was continuously triggering events due to the slow moving of the vessel in the port. The SDU board cannot manage this effect and thus the system always remain in Mission mode. The seismometer data quality check seems confirming that no damage is present on the system , the recorded signal

correctly reproduces the oscillatory motion of the ship. In order to test the seismometer in a better environmental situation it is necessary to put GEOSTAR on shore.
Tecnomare reports that the new release of the DAU software solved the previous problem of wrong data in the hourly data file of the current meter.
The software of the buoy is upgraded: the new release include the management of the "catalog event" messages, not previously installed.
After the rain stop, the DACS is installed back on GEOSTAR and the station is moved on the docks on shore (17:00, UTC) and the test to verify seismometer status is started.
During the test two seismic event were generated (17:33 UTC and 17:51 UTC); the system correctly reveals the seismic event, the acoustic messages are correctly generated; even if the buoy is not located in a good position to test acoustics system (GEOSTAR is on the dock, the buoy on the ship deck) some of them are correctly received and forwarded to shore station. Also the e-mail with the notification of events are generated; thus all the communication chain is tested and is working as planned.
In the late afternoon a meeting with the Captain took place. Departure schedule is discussed: Wednesday morning could be a good day (following the weather forecast) for deployment operation: the trip time to the deployment site is 36 hours, thus it is decided to anticipate the departure to the Monday evening. Spanish cruise responsible (Rafael Bartolome) is advised to call all people on board for Monday afternoon.
At 19.05 UTC GEOSTAR is moved back on the ship deck.
The work for buoy mooring installation proceeds on the ship deck.
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Figure 10 Fireworks during the GEOSTAR mission on the docks in Vigo to test the seismometer status

3.8. Monday, 2nd November

At 7:10 UTC Sercel tests the buoy and GEOSTAR acoustic transducer in a water filled box in order to test acoustics with the transducer submerged in water (Figure 11): the result is positive, everything is working as expected.

Figure 11 Acoustic transducer wet test

The ship change its position in the port (9.00 UTC).
The winch is installed on board (10.00 UTC).
At 10:00 UTC the satellite connection from the modem on board and the buoy is tested: no answer, probably due to satellite bad coverage and roaming problem. The following satellite connection test with the buoy will be managed directly by shore station in Italy (Marghera, Tecnomare).
The weather forecast for Wednesday becomes worse, thus there isn't any advantage to quickly leave in the evening. The work for the platform installation last for long time, thus the departure is scheduled for the day after in the afternoon.
All scientific cruise peoples (Italian, German, France, Spanish, Portuguese) are on board.
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Figure 12 The acoustic transducer installed on GEOSTAR: original position (left), new position (right)

The battery pack of the buoy mooring line acoustic release is substituted with a new one. The release mechanism is successfully tested with open - close commands.

Sercel advises that the acoustic transducer may experience difficulties in communication due to the GEOSTAR frame shading, because of the way it is installed on the station. The agreed solution is to move upward the transducer location by 5 cm in order to make the transducer ceramics in a sufficient high position in order to have a larger angular efficiency.

Rubidium Clock synchronization. The GPS antenna is used to synchronize the Rubidium clock of GEOSTAR. At 20:54 UTC the clock is synchronized with GPS time (date/time read to check the procedure: 2 Nov 09 20.54.54.). The next calibration is set to 3 November 2009 22:30 UTC assuring that the clock is installed and GEOSTAR powered with its own battery when the next calibration took place. The date, time, resynchronization schedule time were verified again at the end of operation. The clock is mounted back on the GEOSTAR DACS (22:00 UTC).
After the clock synchronization, GEOSTAR is powered with its own battery; connection by the test cable to check GEOSTAR status:

- battery voltage 28.64V
- vessel temperature 16.95°
- battery vessel pressure: 565 mbar
- clock status ok

The command “GO MISSION” is sent to GEOSTAR (22:51 UTC) to make a complete night test with battery.

Figure 13 Setting up MODUS at perfect weather condition

The MODUS crew starts preparing the deployment tool. Sensitive components are always dismounted for transportation and thus have to be remounted for the upcoming mission: thrusters, lamps, cameras, sensors and electric cables must be installed carefully to avoid damage during the operation. High-power energy supply from the vessel and the F/O telemetry connection through the winch has to be applied. This was the first mission after the winch-cable has been renewed and fortunately the initial system check performs successfully.


Figure 14 Commissioning of moving platform to support the deck operation

Meanwhile the installation of a special moving platform by UTM/CSIC was completed. The idea behind, is to manage the displacement of the GEOSTAR/MODUS *stack* while changing inclination of the A-frame for the deployment. This was necessary, due to insufficient height of the A-frame.

3.9. Tuesday, 3th November

Operation performed in order to complete the MODUS and GEOSTAR preparation to deployment:

- 7.44 UTC: sent command "GO IDLE" to GEOSTAR
- 8.15 UTC: start the operation to create the vacuum in the DACS vessel: - 0.36 bar
- 10.00 UTC: snatch block definitely installed on board.
- 10.48 UTC: Modus locked to GEOSTAR
- 11.30 UTC: Test of Modus release: successful
- 13.40 UTC: DACS vacuum test: -0.36 bar: successful.
- 15.35 UTC: Connection of the winch telemetry.

At 14.30 UTC: meeting on board for safety procedures take place.
At 16.00 UTC: The r/v Sarmiento de Gamoboa sail from Vigo port to the wet test site.
Reached the test place in the VIGO arbour the operation begins at 19.30 UTC: and last for one hours with successful results. Sea condition 1 meter wave, 21 knots wind, depth around 40m.
At 20:30 UTC beginning of navigation toward the deployment area

Figure 15 Test of deployment procedure in the harbour of Vigo

The entire deck operation including *docking, displacement, dumping* and *recovery* was tested in Vigo before leaving the harbour. This is to instruct the crew and all participants for the upcoming task at sea. It was apparent that the dimensions of the A-frame were just about enough to fulfil the operation and that it will be quite delicate at rough sea states.

3.10. Wednesday, 4th November

Navigation towards the deployment site.

3.11. Thursday, 5th November

Early in the morning the vessel arrives in the operation area to check is the sea condition allow the deploy of the buoy.

- 6:30 UTC CTD cast in the site: 36° 29' 2.76"N - 9°30'21.9" (depth 3315 m) at the beginning of a Spanish survey line)
- In order to evaluate the maximum distance between GEOSTAR and the Buoy, an elaboration is performed: the mooring line will be around 3200 m, considering a 12% of max elongation the maximum mooring line will be 3565m; with the depth of 3200m the max dislocation of the buoy from the dead weight vertical position will be less than 1570 m.
- 10:00 UTC technical meeting; updated situation for the buoy deployment operation: in the afternoon the Argos beacon will be installed and activated; the acoustic transducer of the buoy will be definitively installed on the buoy frame and the acoustic modem configured in order to operate in the sea water. MODUS: one of the plastic fender of GEOSTAR used to pull apart the station from MODUS was lost: it is necessary to replace it for the recovery operation; in the afternoon it would be possible move GEOSTAR, and replace the fender. Tecnomare (Bruni) asks for a check of the telemetry system and a verification of CR calibration (done on November, 3). Sercel ask for the removal of the MODUS altimeter and sonar in order to reduce acoustic noise. The decision is to use the usual configuration with sonar and altimeter working which can be useful in case of trouble. TFH suggest to make a simulated "warm up test" in the evening in order to verify all the procedure to be done during the deployment.
- 11.30 – 11.45 check of the MODUS release.
- 15.00-15.30 setup of the "flags" used to show the seismometer release after the touch down.
- 15:00: the wheatear forecasts for tomorrow are bad: in order to complete the setup operation on board the decision is to go near the Portuguese cost to be in quite condition for work.
- 16:00 Sercel technician setup the buoy and GEOSTAR acoustic modem in order to operate in the sea (max power) .
- 17:00 meeting with Captain, Embriaco and Viezzoli: the mooring operation are explained. Taken the decision to go to Algarve, in order to safety operate on the mooring and buoy

death weight. It is planned to reach a safety position at 8 in the morning of 6th Nov. Then work in the area on deck, try to move the buoy, move MODUS (unplug and plug again) . plug the cable between modus and GEOSTAR. Buoy deployment operation: communication between navigation lab (Embriaco) and deck (Viezzoli) are needed; Embriaco will give count down and information on the vessel position on the line; the Captain will listen to the communication.

- 21:00 Meeting (Embriaco, Viezzoli, Bartolome and the Captain) regarding the updated weather forecast: an available window of 24h starting from tomorrow at noon seems available for buoy operation. Thus the decision is to remain in the area. We will try to start operation in the morning as soon as the sea condition allow to move the weight on board with safety.

3.12. Friday, 6th November

- 12:00 UTC Argos beacon activated, the buoy will be deployed starting at 14:30 UTC
- 12:30 UTC the Buoy is operative and working
- 14:00 UTC start of buoy deployment operations
- 15:55 UTC deployment of the dead weigh
- 19:15 UTC buoy dead weight localization found with the help of graphical tool of navigation system Position found with an uncertainty of 258 X 128 m around a point which is not on the shipping line.
- 22:45 UTC New Buoy position determination: after a deeper analysis of acoustic release data, a more reliable buoy position is found. It is on the line ship travel made during buoy deployment, uncertainty on dead weight position is estimated on 15 meters.

Buoy Dead Weigh position (WGS 84):

Lat	36.351385	36° 21.0831’ N	36° 21’ 4.99’’ N
Long	- 9.518264	9° 31.0958’ W	9° 31’ 5.75 ’’ W

Estimated uncertainty on DW position: 15 meters
Estimated depth (from bathymetric data): 3187 m
End buoy deployment (DW deployment) 16:00 UTC 6th November 2009

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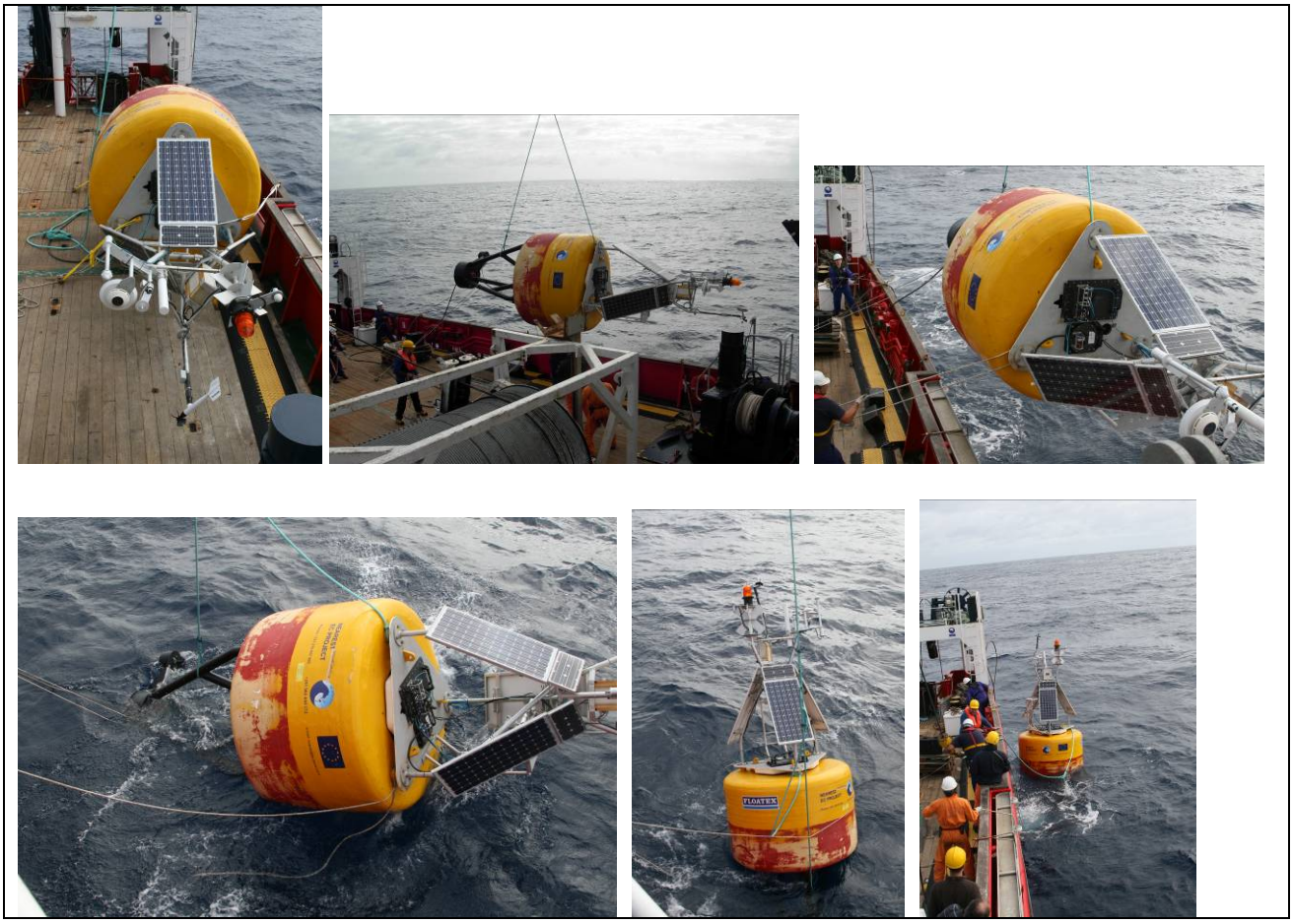

Figure 16 The operation for the buoy deployment

3.13. Saturday, 7th November

Navigation.

- 8:00 Meeting with Captain, Viezzoli, Embriaco: bad sea conditions, Viezoli says it is not safe to operate with this wave height (3 m). The rear of the vessel oscillates too much . The weather forecast show a worse condition up to few hours, with waves increasing up to 5 meters in the afternoon. Lagalante says he never worked in such a bad sea condition. Tecnomare remembers that the pull of the winch cable should not exceed break value, and that in a previous cruise a critical value was reached during the deployment even if the sea condition were better.
- 8:11 Buoy tracking with radar: Buoy Position at 7:11 UTC reported by the captain using radar system: 36° 21,449' N , 9° 31.213' W
- 9:00 phone call with Italy INGV headquarter (P.Favali, L.Beranzoli) in order to explain the situation: due to the bad weather forecast for the following days , probably it will be possible to work only on Tuesday 10 thus a delay in returning to port in Vigo (already scheduled for November, 11th at midnight) is needed. Favali and Beranzoli will contact UTM to ask for a to give instruction to the Captain to postpone the departure from the operation area
- From 9:00 navigation making Spanish team lines
- 15:00 Phone call with Italy INGV headquarter (L.Beranzoli): it is explained that the Captain should be informed of the need of delaying the coming back for 24-36 hours in order to finish GEOSTAR deployment operation.

- 21:00 meeting with the Captain: he will inform Portuguese navy about the feature of the buoy position, size, picture and light emitting properties
- 23:00 sea forecast: up to 4.5 meters in the area during all Sunday, the sea wave height will start lowering from Monday.

3.14. Sunday, 8th November

Navigation (bad sea conditions).

- 10:00 Sea forecast: confirmed a better sea conditions starting from Monday afternoon-evening and Tuesday morning (forecast run MM 7 Nov 12 UTC). It corroborates the previous 12 hour forecast
- 11:30 and 15:00 phone call with Italy INGV headquarter (Favali) in order to discuss the updated deployment procedures.

3.15. Monday, 9th November

Navigation, bad sea conditions.

- Sea forecast confirms previous evaluation, sea level lowering starting from tomorrow morning
- 10:00 The Captain says he is allowed to stay in the operational area until Tuesday evening at 8pm; then the ship must come back to Vigo (36 h trip), if no other new order comes from shore (UTM/CSIC)
- 14:30 GEOSTAR team meeting
- 17:00 Meeting with the Captain: Decision to reach the target point at 8:00 am of the following day. An acoustic test between the surface transducer and buoy transducer will be performed together with some acoustic localizations to confirm the dead weight mooring localization
- 18:00 Luis Mattias Seminar on the NEAREST project
- 19:00 phone call with Italy INGV headquarter (Favali): definition of the update version of deployment procedures.

3.16. Tuesday, 10th November (GEOSTAR deployment)

- 8:40 the vessel is in the target site for GEOSTAR deployment
- 9:00 Meeting with captain: we go to point beacon5 (200m north of DW) in order to perfom an acoustic range measurement
- 9:30 Moving toward the buoy up to 150 meter
- 10:00 Beacon 6 new range measure. Sercel acoustic test between surface unit and buoy transducer, in order to measure noise level on both surface transducer and buoy transducer. Distance 150 m, buoy in front of the surface transducer. Sercel says the modem of the buoy correctly answer the interrogation (we can hear the answer).
- 10:20 Phone call with Italy INGV headquarter (Favali): probably more ship time is needed; a new phone call within one hour is necessary to define the 24 hours to be asked to ship owner
- 10:40 Start moving around the buoy, in order to make a movie showing buoy movements. The sea conditions are improving (thus following the weather forecast), but it is not completely safe to operate.
- 11:15 Try to call Italy In order to ask for 24 hours more of ship time

- 11:40 the 24 hours more of ship time are allowed as reported by Italy INGV headquarter (Marinaro)
- 17:00 GEOSTAR deployment operation begins: sea wave 2m, wind speed 15 knots.
- 19:40 GEOSTAR touch down
- 21:30 beginning of acoustic interrogation from surface unit and GEOSTAR acoustic modem
- 24:30 end of tentative of acoustic communication: the bottom station never answered any interrogation. The ship move toward Vigo.

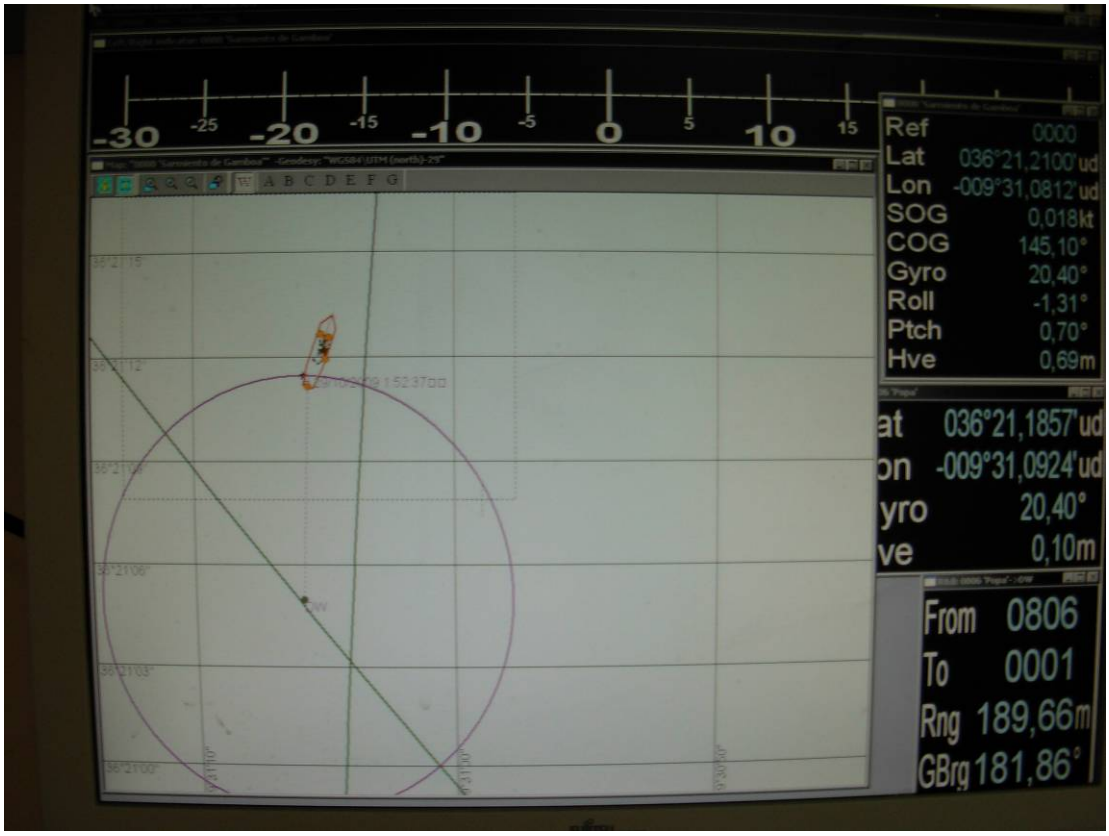

Figure 17 The navigation system locating the vessel during the GEOSTAR deployment procedures. The magenta circle represents the 200 m safety area from the dead weigh position

In spite of acceptable sea conditions, many slack-events happened during the deployment, particularly when the winch was stopped. The resulting effects were visible in the acceleration charts of the control screen, derived from realtime data of a Tritech Gyro which is mounted on MODUS. After one hour of diving, two lamps failed at a depth of 1750m, due to mechanical stress induced by slack events. Apart from that, the system performance was satisfying during the deployment and the telemetry link worked fine without any interruption (new umbilical!). Some meters before the seabed, the desired orientation of GEOSTAR must be *froozen* by MODUS. Unfortunately the thruster control failed close to the touch-down, but as actual heading was within valid range, it was possible to dispose the station without further adjustments.
In the workshop of TUB, the problem was identified as a failure of an I/O-control module inside the electronic boxes, which provides the thruster control-voltage: the DC/DC circuit *hang up* above critical temperatures.

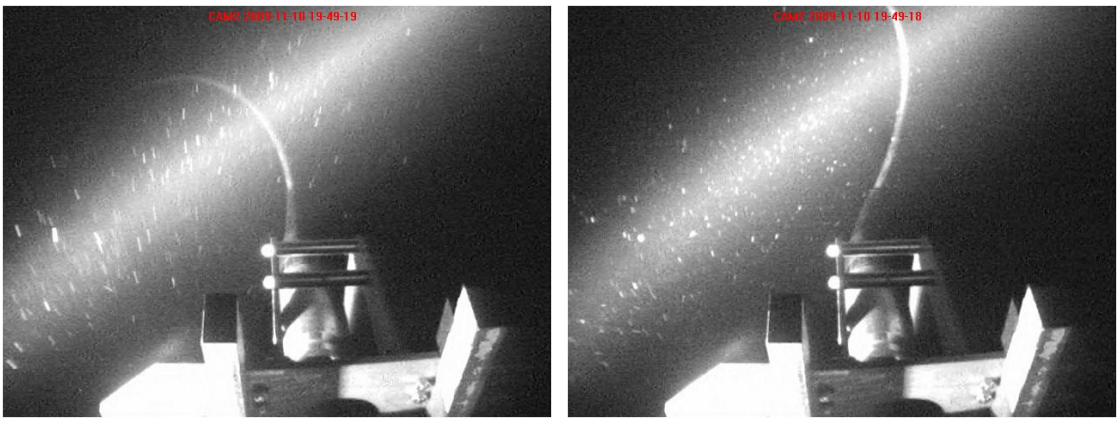

Figure 18 Intense cable-slack events during deployment

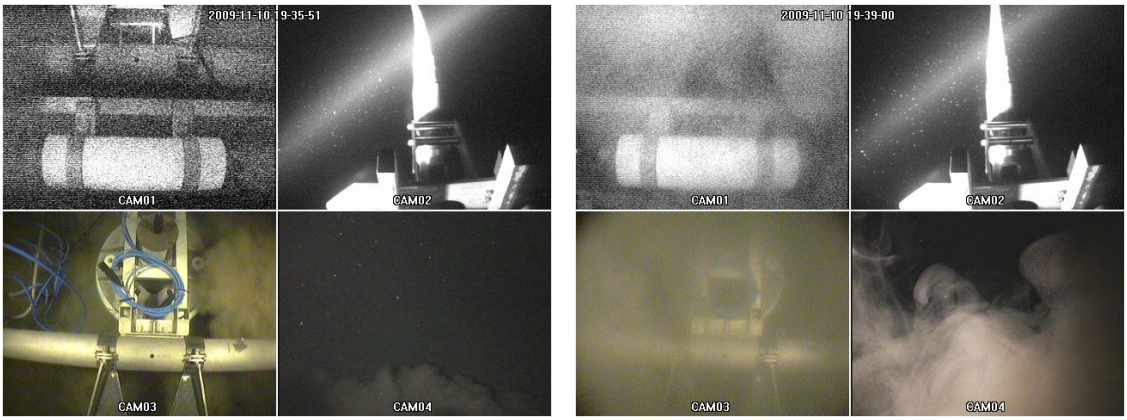

Figure 19.Touch-down of GEOSTAR

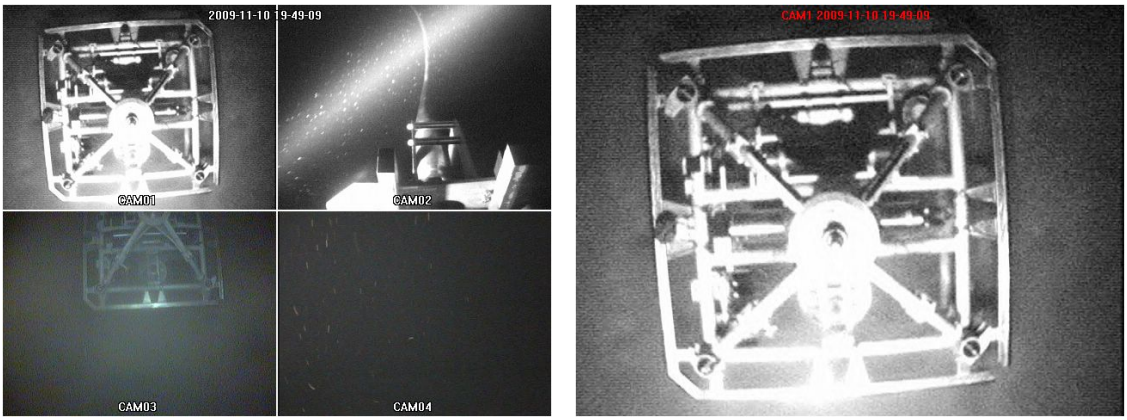

Figure 20 GEOSTAR at seabed after releasing MODUS

3.17. Wednesday, 11th November

Navigation towards Vigo

3.18. Thursday, 12th November

The r/v Sarmiento de Gamboa arrives in Vigo port, beginning of demob operation.

3.19. Friday, 13th November

NEAREST team departure. Demob operation last for the weekend (MODUS vehicle demob managed by Viezzoli and Lagalante).

4. Wet Test

Just after the sail from VIGO port a test of GEOSTAR deployment operation is performed in order to check on deck operation and again test the acoustic communications.
At 17:15 on the test site the operation starts: connection between MODUS and GEOSTAR, telemetry test passed.
Deployment test start at 19:46 UTC.
At19.52 UTC: GEOSTAR is at 11 m from the sea bottom.; total depth around 40 m: start of test connection from the vessel using the modus telemetry.

Data reading:

- Gravitymeter: 887562.26 ng
- T 17.8 °C
- CTD pressure: 28.15 dbar, CTD temp: 16.598 °C
- Paroscientific Pressure sensor: 3636.520 mbar
- Gravitymeter 8904683.49 ng
- Sensor Status 28.26V – 185mA

At 20.10 acoustic communication test using the surface acoustic unit deployed around 20 m from the vessel. Sercel reconfigures the bottom station transducer in order to set it to max power and with the operative configuration to work on the sea floor. DACS status request with the acoustic: positive results. Sensor status request with a time out error. Timeout set to 180 s. Sensor status request with a positive answer. From the acoustic test performed by Sercel: the average distance between surface transducer and the bottom transducer was 34m measured by the acoustic modem system, SNR (Signal to Noise Ratio) 40 dB on the surface unit, 49 dB on the bottom station unit, absence of strong echoes in acoustic data transmission and no error in transmission tests: the acoustic transmission is considered good and the test is considered successfully passed.
At 20.27 end of acoustic test, recovery of the bottom station.
21.50 UTC: navigation to the deployment site.

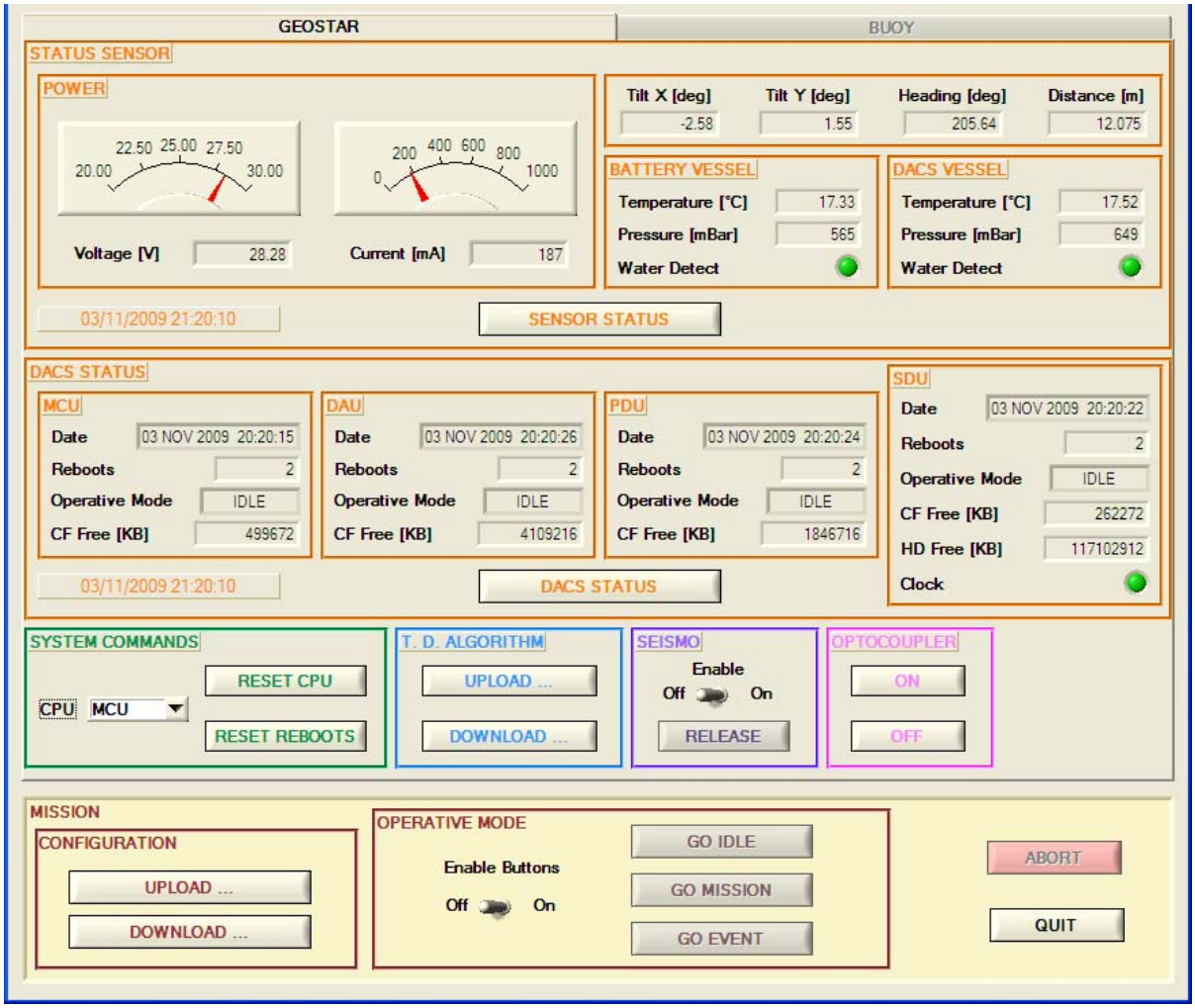

Figure 21 WET test: GEOSTAR status and sensor status request results, obtained with the acoustic link

5. CTD data

In the morning of the November, 5th at 6:30 UTC a CTD cast in the site: 36° 29’ 2.76”N -

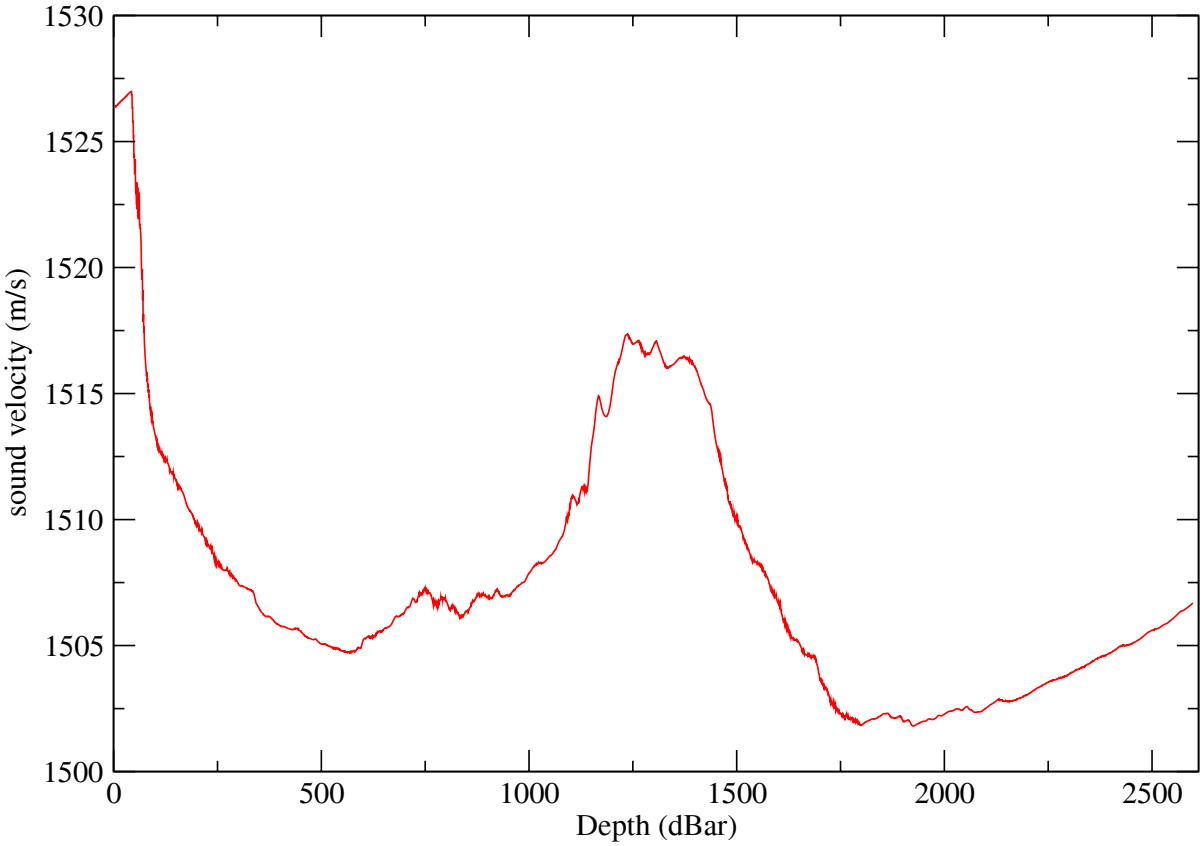

Figure 23 Sound velocity profile from CTD cast in the deployment area

6. Buoy Deployment and dead weight localization

After the buoy deployment four location were determined in order to perform an acoustic distance measurements with the acoustic unit console of the acoustic release system. The estimated depth of the death weight is 3187 m. In Tab. 1. the position in the projected UTM 50/ 29N zone metric position and the range measures are shown.

Point Name	X (East)	Y(North)	d (m)	d_{2d} (m)
Beacon1	454054	4023815	3301.5 ± 1	862
Beacon2	452676	4023982	3404.0 ± 1	1196
Beacon3	452793	4021676	3481.5 ± 2	1401
Beacon4	455350	4021538	3916.5 ± 1	2276

Tab. 1 Position and acoustic distance measures and the reduced distance in the 2D plane

For each location five – six acoustic measurement were taken, the typical incertitude was 1 or 2 meters. The reduced 2D distance d_{2d} is obtained from the measured distance (d) considering the estimated depth $h = 3187$ m: $d_{2d} = \sqrt{d^2 - h^2}$.

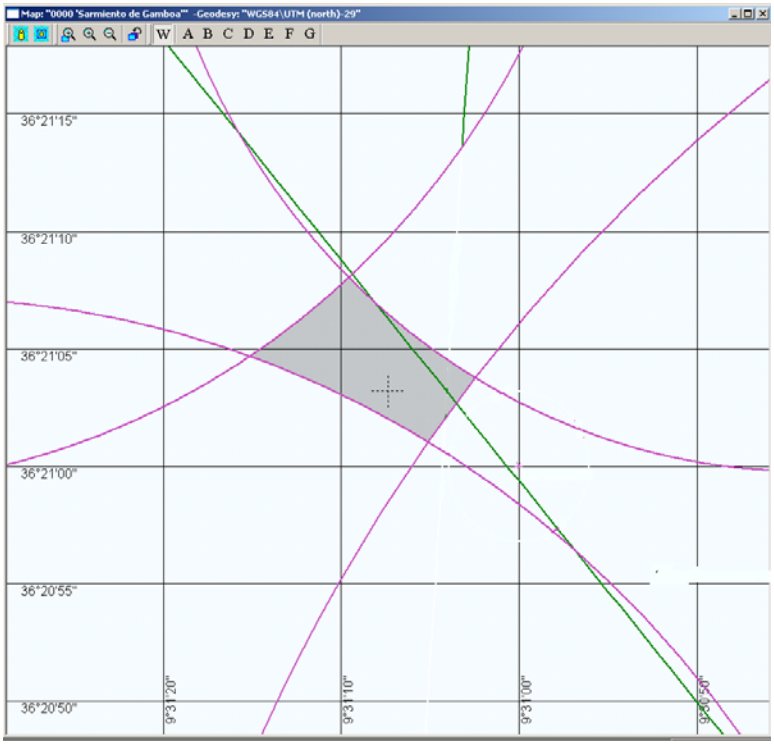

Figure 24 Preliminary graphical buoy DW localization. The magenta arcs of circle are centred in each of the four WPs of Tab. 1 , their intersection gives the DW localization. The shaded region extend aprox. 250 times 120 meters is the candidate localization area after preliminary evaluation; the diagonal green line is the trip of the vessel during the deployment buoy operation (screen capture from the navigation system);

Despite the accuracy in acoustic pinger localization thanks to GPS position of the measurement point supplied by the vessel navigation system and to the repeatability in acoustic range measurements, this preliminary localization with an uncertainty localization of hundreds of meters is not satisfactory enough. The measures supplied by the acoustic release surface module is a time measurement converted in meters using a given sound velocity, but as we can see from the result of

CTD cast (Figure 23) the sound velocity vary up to 1% in all the depth. Thus a more flexible procedure was setup in order to fit the measured data range taking the sound velocity as a free parameter. Operatively the fitting procedure uses a scale factor for the measured range values given in Tab. 1 as the fitting parameter and a software code *ad hoc* developed to find the DW localization using trigonometric triangulation (circles intersection); the target function to minimize is the uncertainty in DW localization. A satisfactory solution was obtained using a scale factor of +1.1% for range measurements, which correspond to the same 1.1% increase in the effective sound velocity used in the range determination from acoustic release time response with respect to the one (unknown) configured on the console device setup.
.

Point Name	X (East)	Y(North)	d^* (m)	$d_{2d}{}^*$ (m)
Beacon1	454054	4023815	3337.8	991
Beacon2	452676	4023982	3441.4	1299
Beacon3	452793	4021676	3519.8	1494
Beacon4	455350	4021538	3959.6	2350

Tab. 2 Scaled range measured and 2d values with a 1.1% scaling factor used in the definitive localization procedure.

With the range 1.1% scaling a consistent solution was found in an area of 14X14 meter (defined as the maximum range were all the intersections between the circles used in the trigonometric triangulation are found). The estimated DW position from software triangulation is:
453501 m East and 4022985 m North in the ED 50/UTM zone 29N metric projection coordinates system.

NEAREST BUOY DW POSITION (WGS 84)			
Lat	36.351385	36° 21.0831’ N	36° 21’ 4.99’’ N
Long	- 9.518264	9° 31.0958’ W	9° 31’ 5.75 ’’ W

Estimated uncertainty on DW position: ± 15 meters
Estimated depth (from bathymetric data): 3187 m

The estimated position lie on the trip line followed by the vessel during buoy operation deployment: a constrain which must be satisfied, but not a-priori imposed in the triangulation procedure.

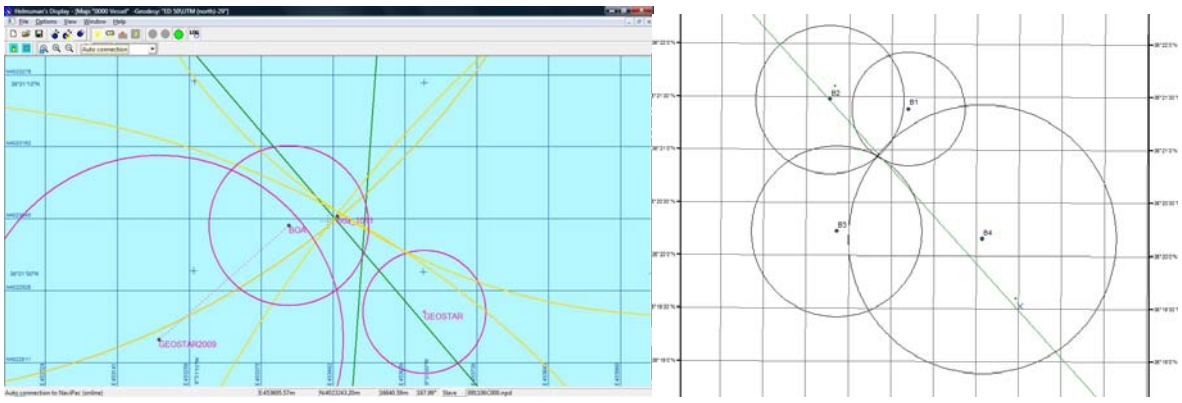

Figure 25 Geometric determination of dead weight position using 4 point of range measurements. The diagonal green line represent the route followed by the vessel during buoy deploymen; The yellow circles are centered each one in the four point of measure; B1-B5 are the points for acoustic localization, the circle intersections localizes the DW position.

7. GEOSTAR deployment

Once reached a moderate good sea condition for safety operate on board during GEOSTAR deployment (10 November, 17 UTC) and with good sea forecast for the following hours, the operation for deployment starts. The ship was located around 200 m northwards from the buoy dead weight position, with the buoy floating southwards.

As was agree during the on board technical meeting and with INGV headquarters the operative procedure for test and decision to be taken during deployment operation are shown in Tab. 3**.** The procedures foresee that during the deployment GEOSTAR status is continuously checked by way of the MODUS telemetry; four stops are also foresee in order to check the correct working of the acoustic communication system at various depths (100, 1000, 2000, 3150 m).

During the deployment the ship maintains its position thanks to the Differential Positioning system (DP).

DEPTH (m)	ACTION	COMMAND/TEST	DECISION/note
25>		Check GEOSTAR (status sensors) (TEC)	
100	STOP DEPLOYMENT	Check on MODUS status (TFH) Check on GEOSTAR status (TEC) (STATUS SENSORS) RAW DATA from all devices ATS TEST (TEC+SERCEL)	If DACS does not answer, RECOVER GEOSTAR (2 hours delay) If acoustic fails switch off ship engine, try again at 1000 m
500	Continuously test without stopping deployment	Check MODUS (TFH) STATUS SENSORS (TEC) RAW DATA da CTD – pressure Sensor	
1000	STOP DEPLOYMENT	Check MODUS(TFH) STATUS SENSORS (TEC) RAW DATA from all devices (TEC) ATS TEST (TEC + SERCEL)	Max 5 min acoustic test
1500	Continuously test without stopping deployment	Check sullo stato di MODUS(TFH) STATUS SENSORS RAW DATA da CTD– pressure Sensor	
2000	STOP DEPLOYMENT	Check MODUS(TFH) STATUS SENSORS (TEC) RAW DATA from all devices ATS TEST(TEC + SERCEL)	Max 5 min acoustic test
2500	Continuously test without stopping deployment	Check MODUS(TFH) STATUS SENSORS (TEC) RAW DATA da CTD – pressure Sensor	
3150 (-30 from the floor)	STOP DEPLOYMENT	Check MODUS(TFH) STATUS SENSORS (TEC) RAW DATA from all devices ATS TEST(TEC + SERCEL)	Max 5 min acoustic test Slow down deployment speed Continue to deploy following echo sounder data
	Continue the deployment at minimum speed	Check echo sounder data (TEC)	CLAUDIO: tell the captain to increase DP precision
	Check heading	GEOSTAR heading must be 220° MODUS heading must be 40°	To put acoustic transducer face to buoy mooring

0	TOUCH DOWN lasciare il cavo in lasco	STATUS SENSORS (TEC)	conferma TOUCH DOWN (tilt, distance from the floor 60 cm) Tilt ok if less than or equal 5° If Tilt >5° recover and shift position
	GEOSTAR on the SEAFLOOR	RAW DATA from all devices (check Paroscientific sensor) ATS TEST (TEC)	
	RELEASE sismometer	Verify release (“flag” or powder)	If no release repeat the release seismometer (numero pari di volte) In good sea condition it is possible to recover GEOSTAR
	START MISSION		
	CLOSE OPTOINSULATOR	DACS STATUS using telemetry (if there is no time, skip)	GEOSTAR should NOT response, otherwise give again CLOSE OPTOINSULATOR (repeat only ONCE)
	DISCONNECT MODUS RELEASE MODUS		

Tab. 4 **GEOSTAR deployment procedures followed in VIGO mission**

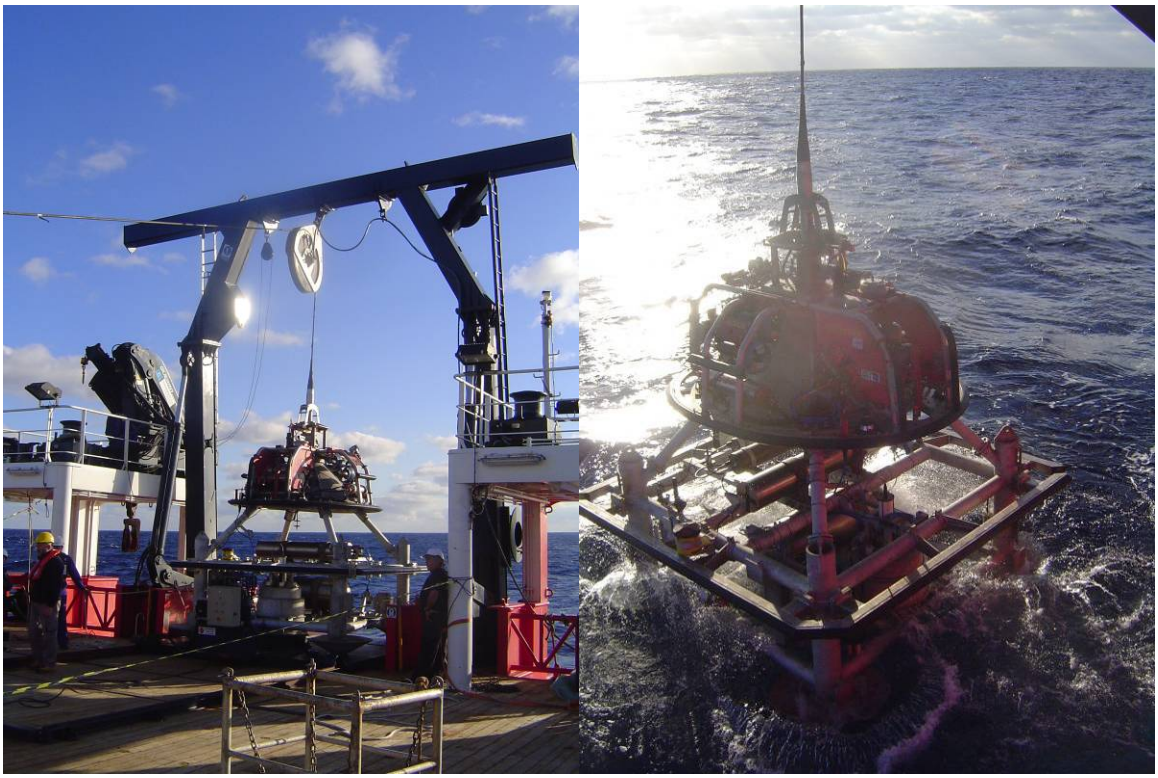

Figure 26 GEOSTAR at the beginning of the deployment operations

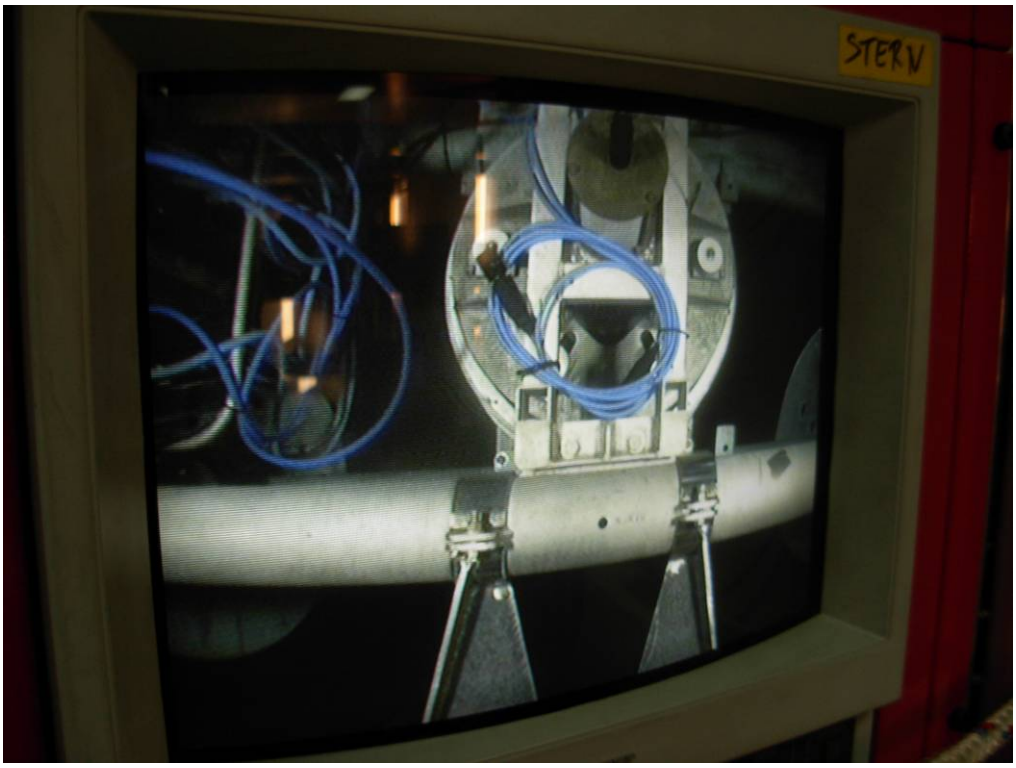

Figure 27 Picture from the MODUS camera looking at the seismometer during the deployment

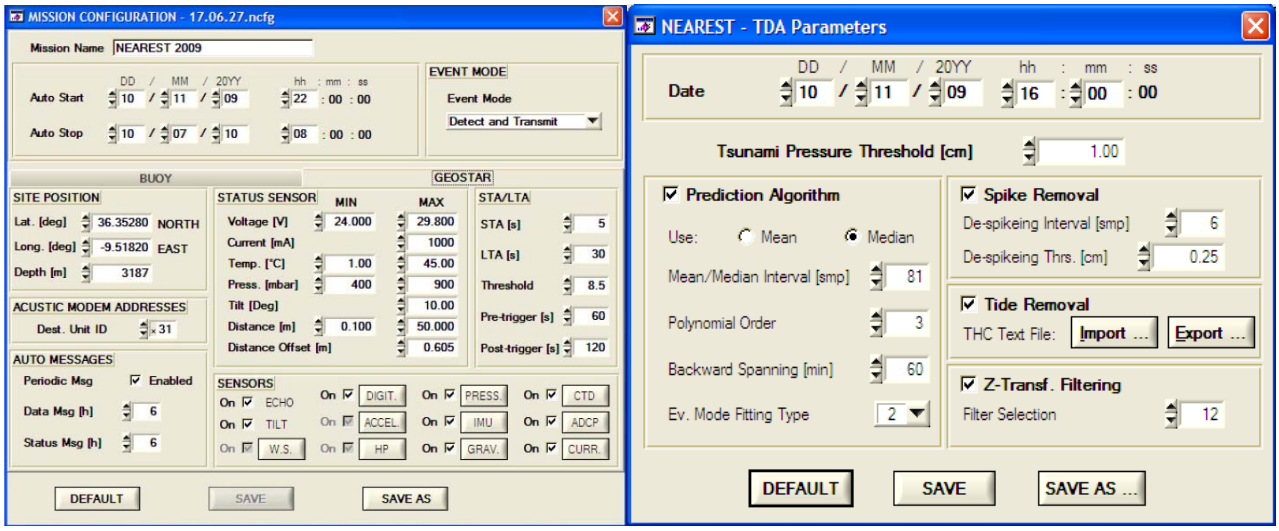

Figure 28 The mission configuration (left) and the Tsunami Detection Algorithm parameters for the GEOSTAR mission

Before the deployment the updated configuration file for mission and TDA setup were upload on the bottom station (Figure 28)
Deployment log (UTC time):

- 16:20 start deployment operation
- 16:34 GEOSTAR at 100 m depth, acoustic test (Sercel) and GEOSTAR communication (DACS status): ok (Figure 33)
- 17:09 GEOSTAR at 1000 m depth, acoustic test (Sercel) and GEOSTAR communication (DACS status): ok (Figure 34)
- 17:32 one lamp of the MODUS camera shut down
- 17:38 GEOSTAR at 2000 m depth, acoustic test (Sercel) and GEOSTAR communication (DACS status): the bottom acoustic modem answer to the command, but results are received with errors; the cause is probably a low S/N level on the surface transducer due to the ship induced noise (Figure 35).
- 17:53 GEOSTAR at 2200 m depth,
- 18:24 GEOSTAR at 3200 m depth (around 30 m from the sea floor): acoustic test (Sercel) performed, but no answer from the bottom acoustic modem received on board.
- 18:32 The thruster of MODUS stop working: it is no more possible to control the GEOSTAR heading
- 18:38 Touchdown (heading 137°, tilt less than 0.5 °). The echo sounder never worked during the last meters of the deployment. A lot of see floor deposit were raised by the touchdown
- 18:38-18:50 operation to check the bottom station working: CTD and pressure sensor data acquisition (Figure 36) , seismometer release, start of GEOSTAR mission, check of the GEOSTAR status (all the board are found in mission mode),shutdown of the optocoupler device;
- 18:50 MODUS release, start of recovery
- 20:00 MODUS recovered on board.

The official GEOSTAR deployment site and time is:
Touch down on 10th November at 18:38 UTC
GEOSTAR2009 (WGS 84)

Lat	36,352917 °	36° 21.175’ N	36° 21’ 10.50‘‘ N
Long	-9,518245 °	9° 31.0947’ W	9° 31’ 5.68‘‘ W

Distance from dead weight (DW) to GEOSTAR2009: 170 m, direction North (0.6° from North).
Depth from pressure measurements (CTD and Paroscientific depth sensor): 3226 m

Starting from 20:20 a series of acoustic test were performed in order to verify the working of the acoustic communication modem on board of the bottom station. In order to lower the surface acoustic noise induced by the ship on the surface acoustic transducer. The ship is moved northwards against the current and let drifting with the engine switched off making a series of transit in the area of the vertical of the GEOSTAR station. The test last until midnight but no answer were received from the bottom station acoustic modem.

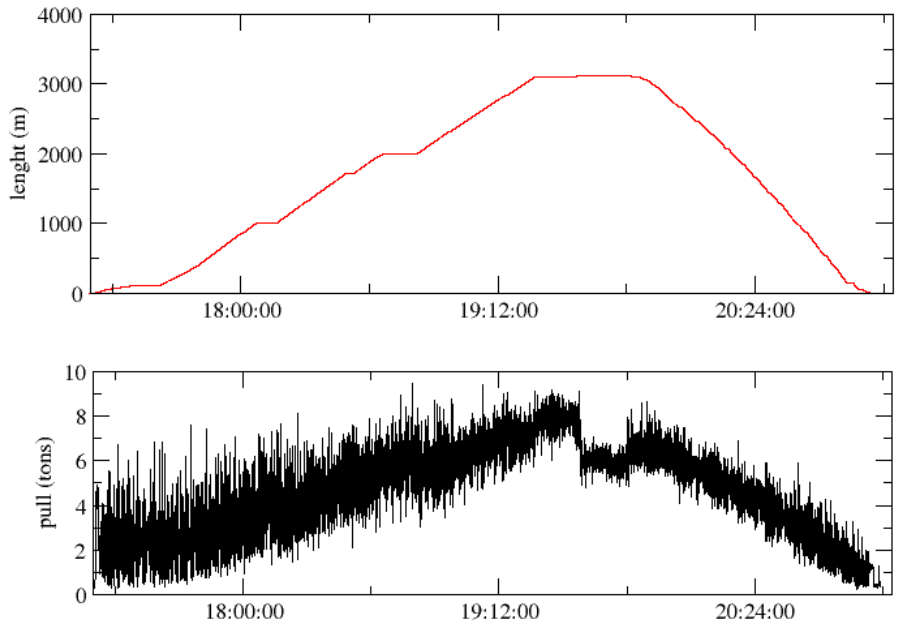

Figure 29 The winch payout (red line) and pull (black line) during the deployment of GEOSTAR

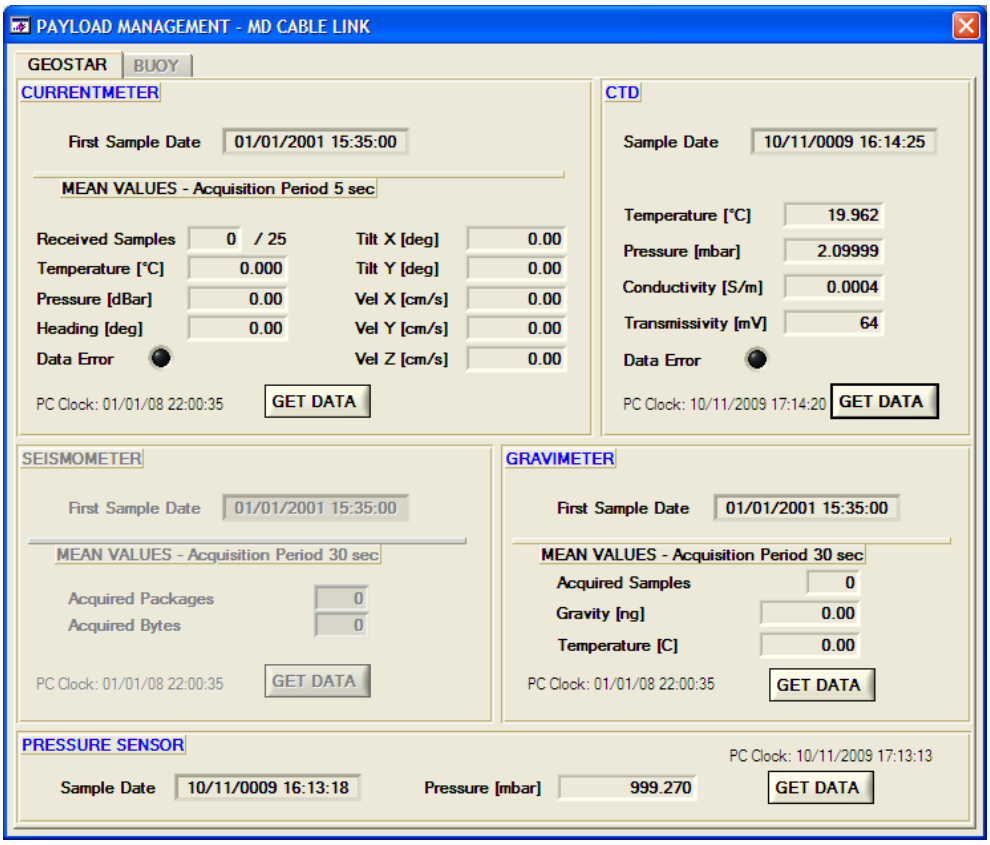

Figure 30 GEOSTAR interrogation (CTD and pressure) just before the deployment (station on the ship deck)

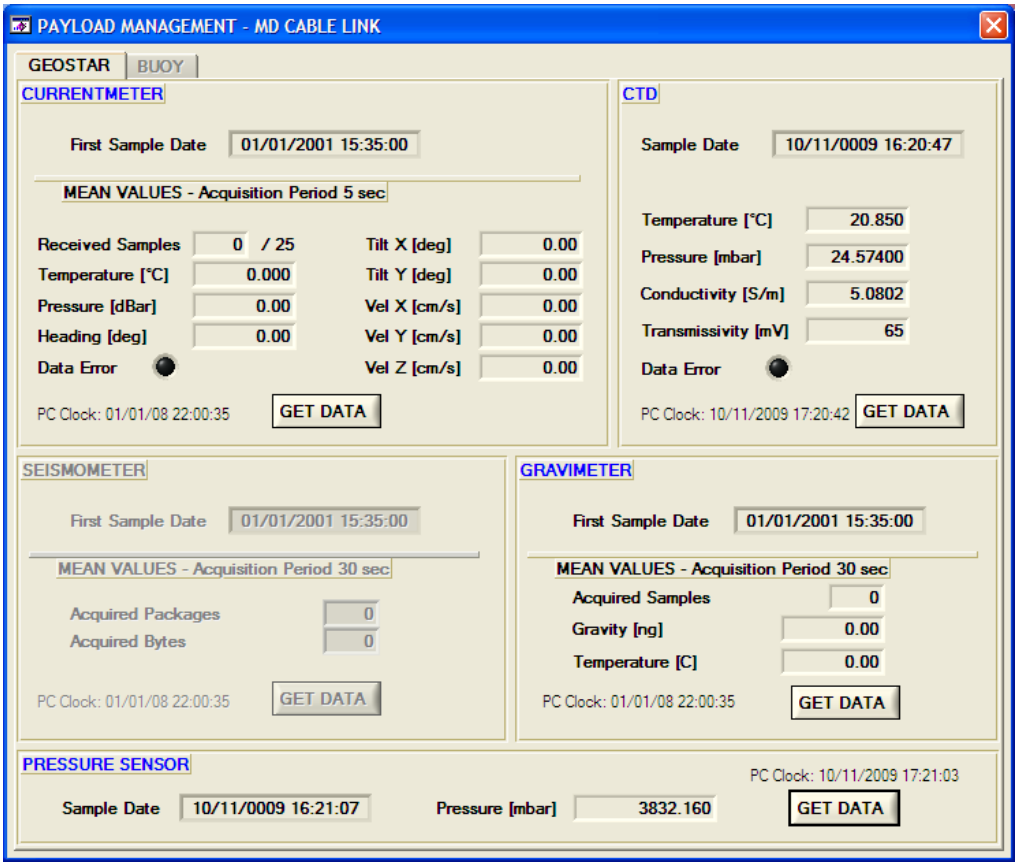

Figure 31 GEOSTAR interrogation (CTD and pressure) just after the station enter the sea water

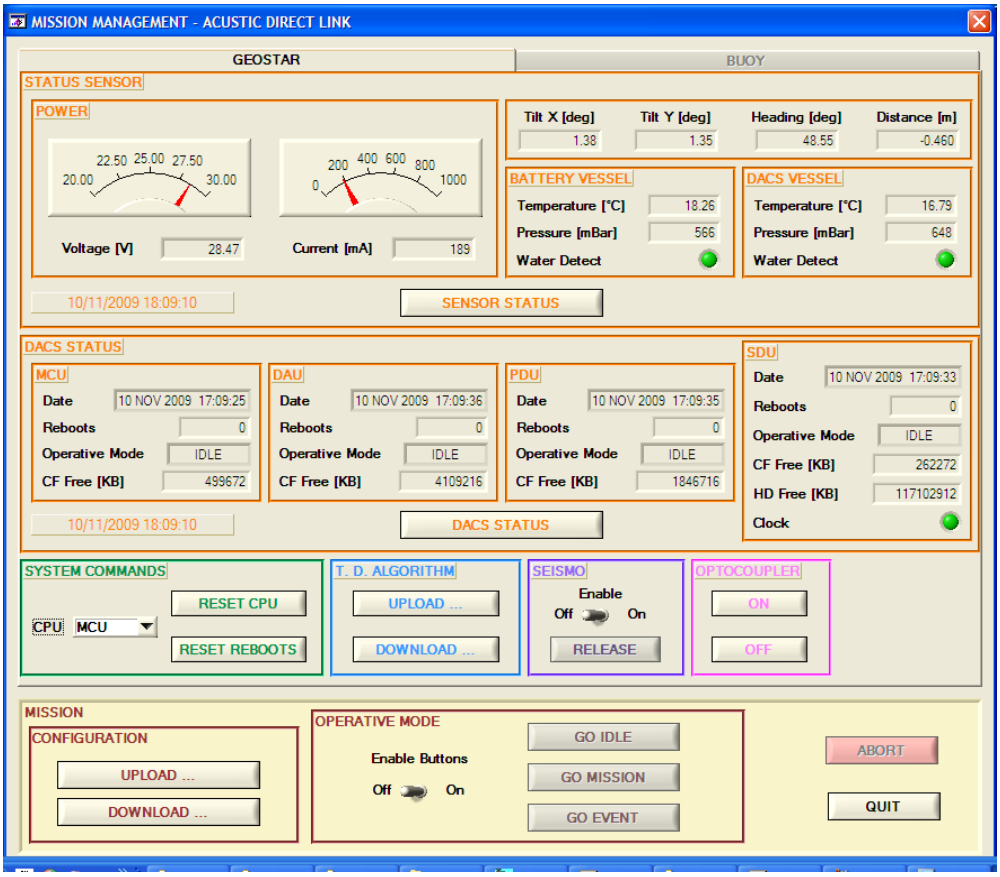

Figure 32 GEOSTAR at 1000 m

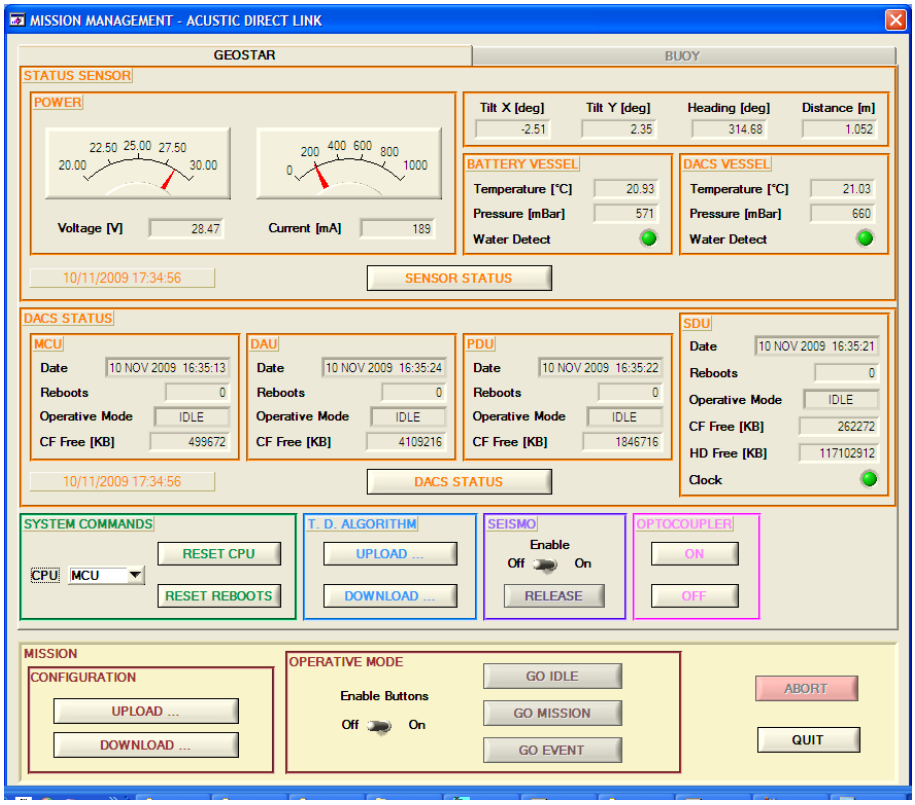

Figure 33 interrogation with acoustic link with GEOSTAR at 100 m depth

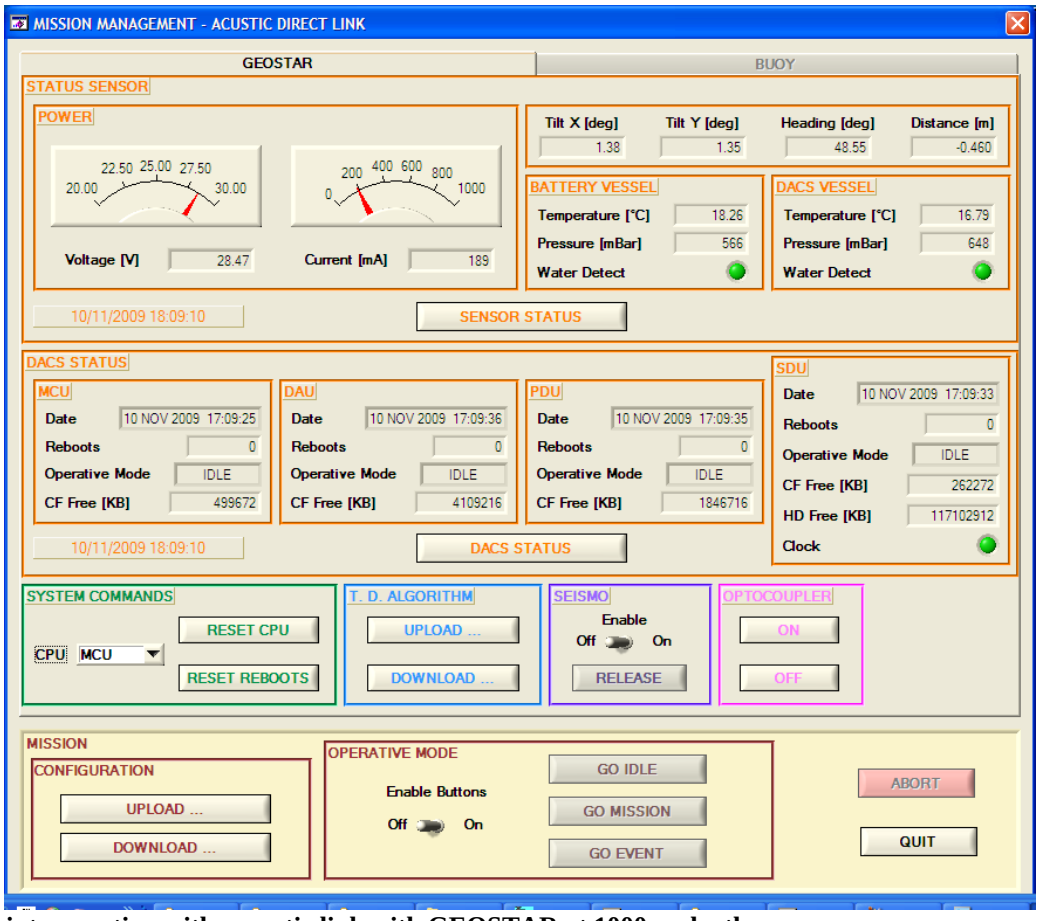

Figure 34 interrogation with acoustic link with GEOSTAR at 1000 m depth

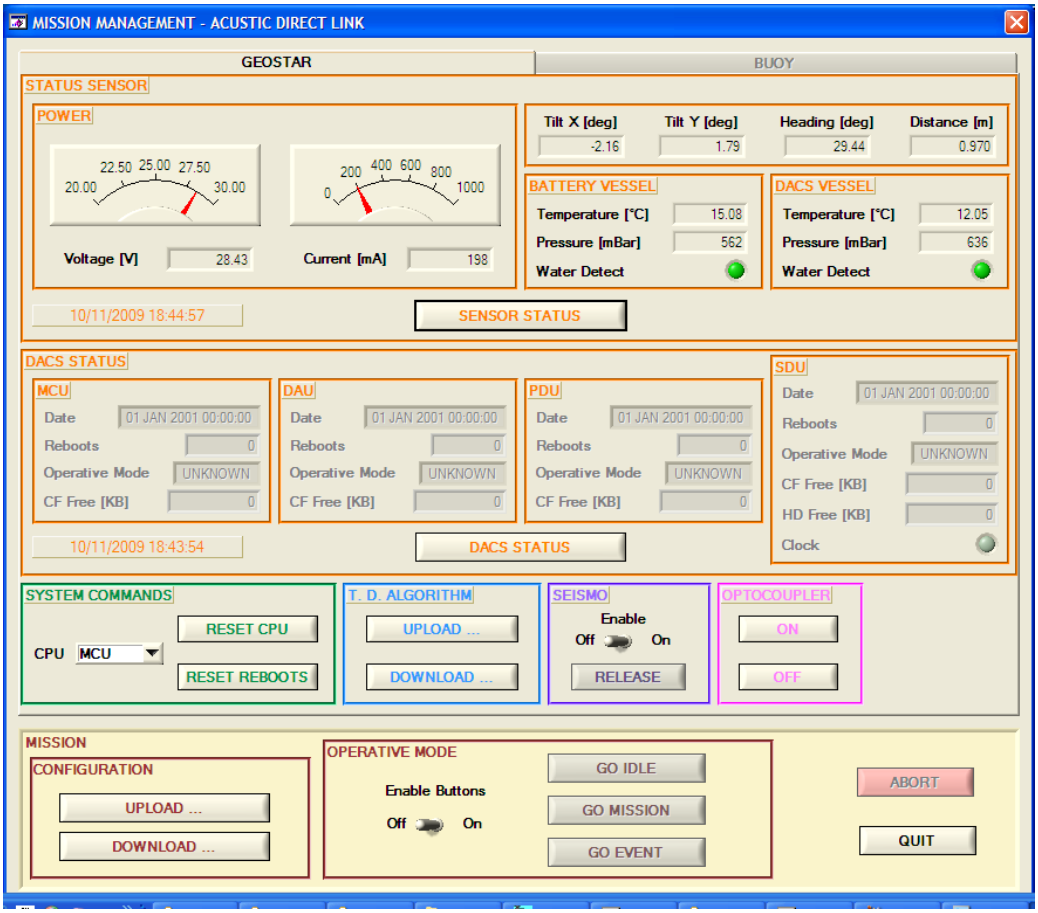

Figure 35 GEOSTAR acoustic interrogation at 2000 m depth

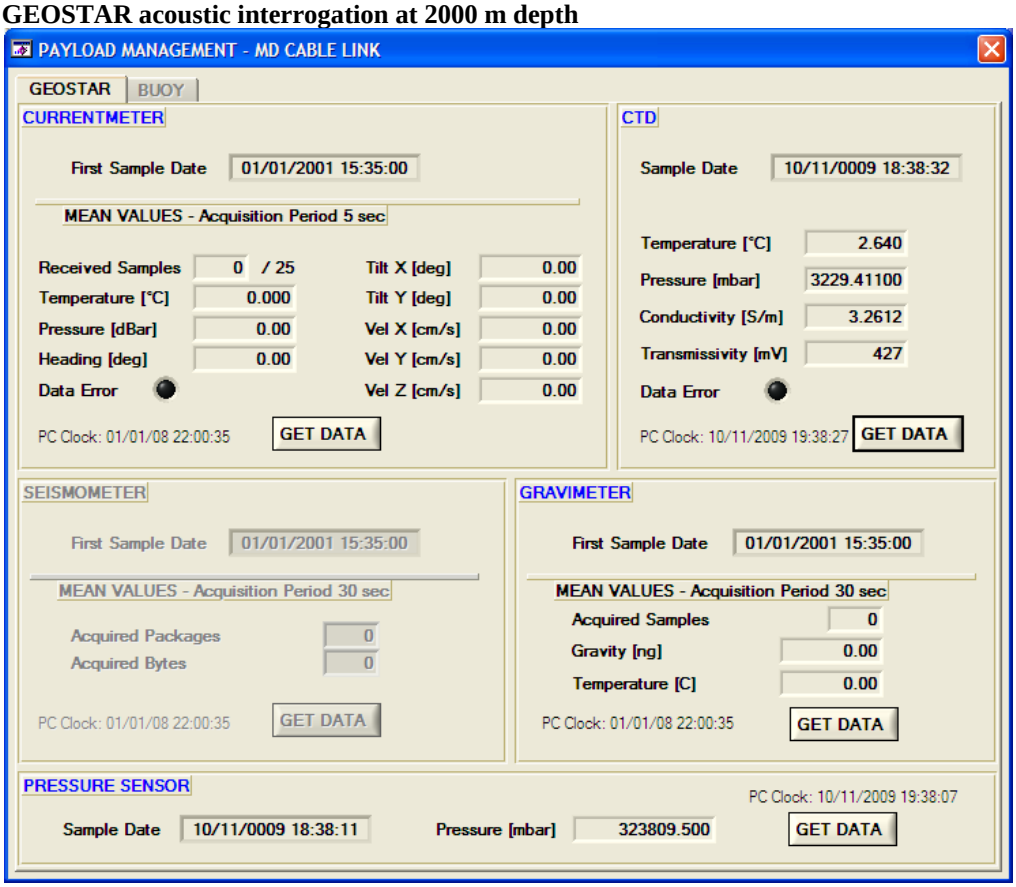

Figure 36 GEOSTAR interrogation after the touch down (pressure and CTD data)