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NEAREST

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D.18 Integration of multiparameter data from the deep-sea platform

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CO	Confidential, only for members of the Consortium (Including Commission Services)	**CO**

WP5 - Data integration/ Integrated tsunami detection network

D.18 Integration of multiparameter data from the deep-sea platform

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1. Introduction and objectives.

For a Tsunami Warning System to be effective for the whole coastal areas at risk, it must provide alert messages before the tsunami waves arrive to the shore. The only way to provide this information is to detect the tsunami waves in Deep Ocean and send this information in real time to the processing centre for further analysis. In the NEAREST project the deep-sea multi-parameter platform GEOSTAR was deployed and tested to perform this task, detect the tsunami waves and transmit the information in real time. In this document we will be concerned only by the integration of the GEOSTAR information into the data collector and processing centre operating at the Instituto de Meteorologia (IM-Portugal), where the prototype for the Portuguese Tsunami Warning Centre is being developed.

2. The data collector at IM-Portugal

The Instituto de Meteorologia is the Portuguese institution that is responsible for the National seismic network. IM operates 24/7 and delivers to the Civil Protection authorities and general public information on every earthquake that occurs in the surrounding area of Portugal Mainland, including the Gulf of Cadiz, in less than 5 minutes after the onset of the event. This is possible thanks to the real-time data collector that is operating at IM, based on the SeedLink and SeisComP technology. A simplified diagram of the dataflow for seismic data is shown in figure 1.

TREMOR is the core of the system, running SeisComP 2.5 to collect real time seismic data provided by different sources and using multiple connection links, VSAT, Internet, ADSL. The TREMOR server is inside the IM firewall for security but data can be shared to other institutes trough the imslserver.

As regards the information on sea level that is provided by coastal tide-gauges in the NE Atlantic, it is currently available trough public Internet services and web pages. These connections are not reliable for critical warning systems and so, at IM-Portugal, it was decided to work as much as possible with the well-proven SeisComP system to collect sea level data, in addition to the seismic data. Using the SeisComP data collector at IM we can profit from all the quality control tools (QC) that have been already developed, besides the technical support by GFZ and German developers. The SeisComP approach was followed for most of the Portuguese available tide-gauges.

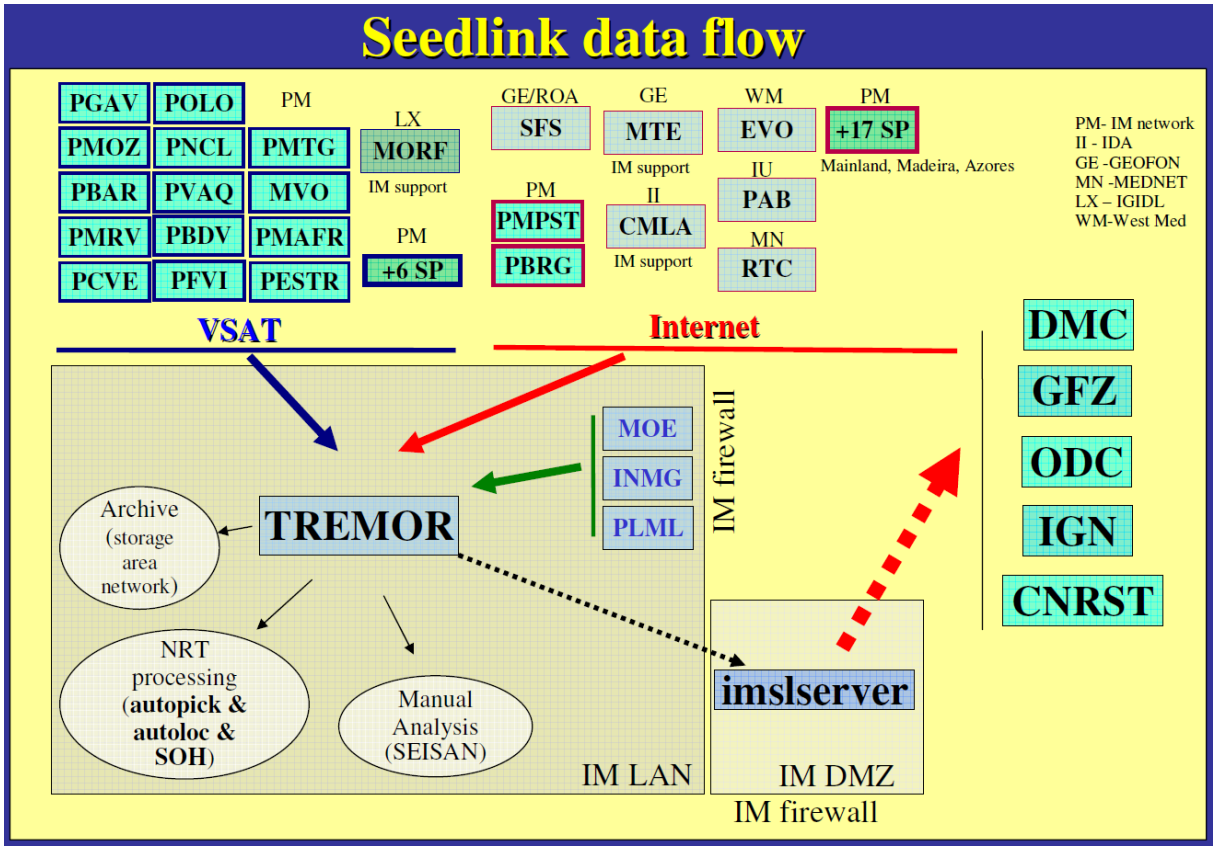

Figure 1 – The seismic data collector at IM-Portugal.

Thanks to the negotiations and agreements reached with the sea level data providers IGP and IH, the data is provided at pre-defined tcp-ip ports that can be remotely accessed. The messages available at these ports comprise a time-stamp and data for the sea level and other environmental variables, like temperature or atmospheric pressure. In order to integrate this data into the SeisComP data collector at IM, one plug-in application was developed (Mare2Liss; see figure 2) that continuously monitors the IP ports and translates all information available into the format mini-seed, that SeisComP can read. This is the standard way that SeisComP acquires real-time data, continuously listening to a pre-defined set of data ports.

Currently a total of 8 channels from 4 tide-gauge stations are continuously collected at IM and integrated with SeisComP using the Mare2Liss plug-in. The list of these channels is given in the table below. On figure 3 it is possible to see the real-time display of data from these four of the tide-gauges that are available at IM data centre.

Site	Code	Owner	Channel	Sensor	Lat. N	Lon. E	Sampling (s)	Average delay
Cascais	IGCAS	IGC	VTZ	Pressure	38.6917	-9.4167	2.5	< 1 min
Lagos	IGLAG	IGC	VTZ	Pressure	37.0967	-8.6650	2.5	< 1 min
Sesimbra	IHSES	IH	UDH	Radar	38.4367	-9.1117	7.5	< 1 min
Sesimbra	IHSES	IH	UDI	Atmospheric P.	38.4367	-9.1117	7.5	< 1 min
Sesimbra	IHSES	IH	UTZ	Pressure	38.4367	-9.1117	7.5	< 1 min
Sines	IHSIN	IH	UDH	Radar	37.9467	-8.8867	7.5	< 1 min
Sines	IHSIN	IH	UDI	Atmospheric P.	37.9467	-8.8867	7.5	< 1 min
Sines	IHSIN	IH	UTZ	Pressure	37.9467	-8.8867	7.5	< 1 min

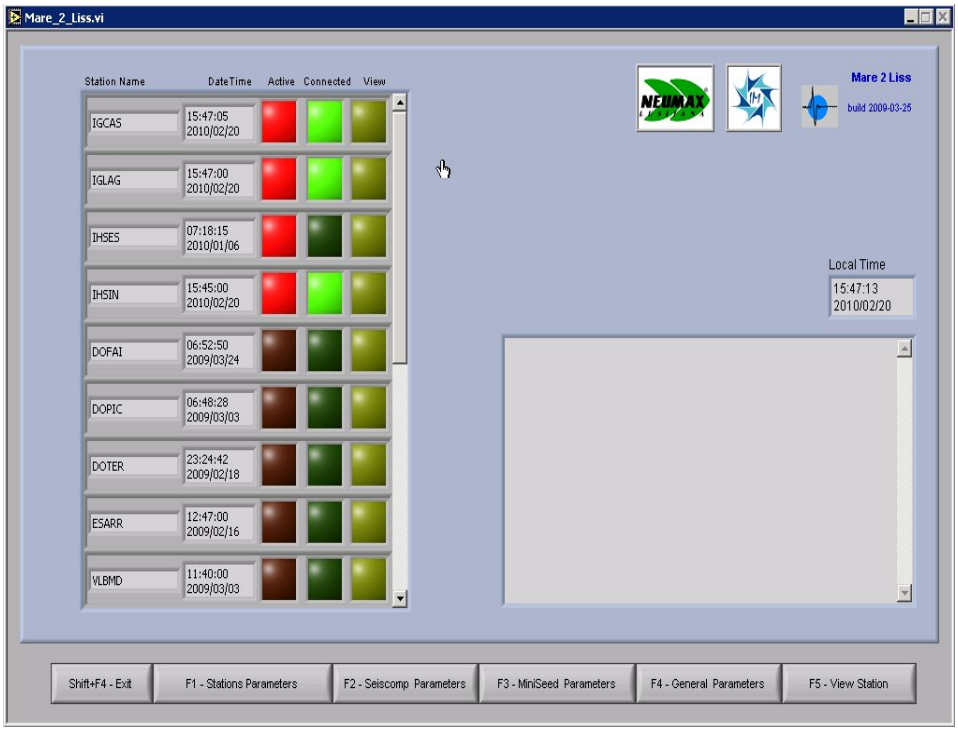

Figure 2 -Mare2Liss main screen. The IH and IGP stations are the first four. The remaining five stations are not being received yet.

Figure 3 - Display of tide-gauge signals (Sines, Cascais, Lagos and Ponta Delgada)

There is another Portuguese tide-gauge station, at Ponta Delgada, that is operated by the Portuguese Hydrographic Institute (IH) and integrated in the GLOSS network. The data from this station is delivered trough the GTS communications system operated by the WMO. IM as the Portuguese Meteorological Agency has the ability to receive and feed messages from and to the GTS. At IM the messages related to tide-gauge stations are filtered out and copied to a local directory. To retrieve these messages and feed them to the SeisComP data collector a special application was developed at IM (gts-getput). This application periodically checks the GTS directory and reads all new files that appear. The messages originated by the Ponta Delgada tide-gauge are interpreted and converted to mini-seed format. The mini-seed files are then copied to another directory where SeiscomP picks them up and integrates into the data collection streams. This procedure introduces an additional time delay that is estimated to be less than 1 minute. The GTS messages are provided by Ponta Delgada every 5 minutes and made almost instantly available at IM. Each message comprises 10 samples at 1-minute interval, meaning that there is a 5-minute overlap between consecutive messages. This redundancy is useful since sometimes one message fails and the next message provides the missing data. The properties of the data streams received by GTS at IM are summarized below.

Site	Code	Owner	Channel	Sensor	Lat. N	Lon. E	Sampling (s)	Access	Average delay
Ponta Delgada	IHPDA	IH	UDH	Radar	37.7350	-25.6717	60	GTS	3 min
Ponta Delgada	IHPDA	IH	UTZ	Pressure	37.7350	-25.6717	60	GTS	3 min

The communication by GTS has the great advantage of reliability but the data latency may be a little too high for the evaluation of the tsunami impact of local or regional originated events. It is however one of the recommended communications links for the Global Tsunami Warning System.

The scheme for tide-gauge data collection operating at IM-Portugal is shown in figure 4.

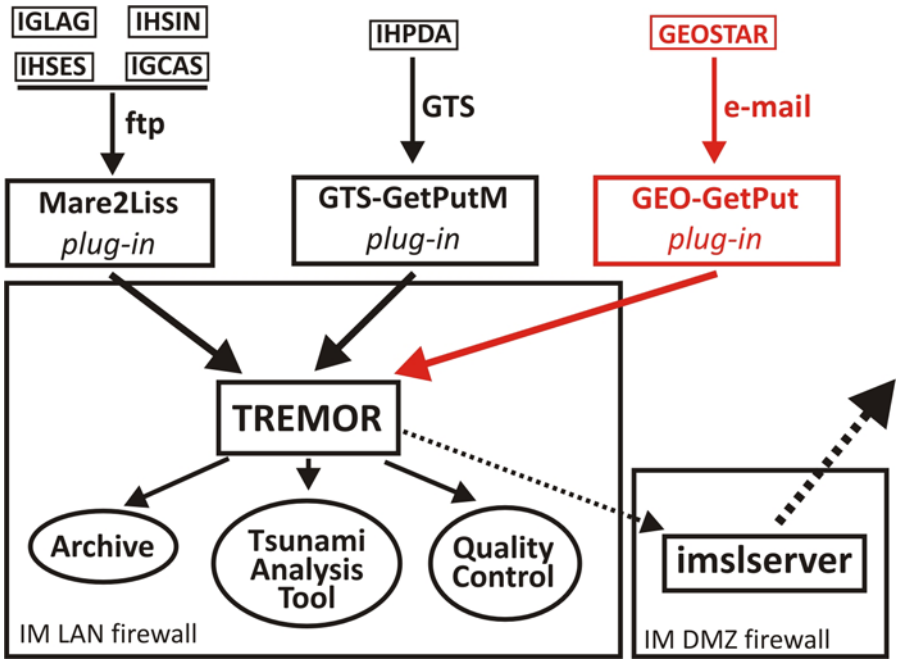

Figure 4 – Schematic diagram showing the tide-gauge data collection at IM-Portugal. On red we show the additional links developed to integrate the sea-level data measured at the multi-parameter platform GEOSTAR.

Profiting from this framework we developed one additional link (in red in figure 4) to collect the sea level data measured at the multi-parameter platform GEOSTAR. The details will be presented in one of the next sections.

3. The GEOSTAR messages

GEOSTAR is a multi-purpose, multi-parameter data collector platform that operates in deep-sea. For the particular interest in testing its integration in the prototype of a Tsunami Warning System, we will be only concerned with the GEOSTAR ability to collect sea-level information, by an Absolute Pressure Gauge (APG) and the communication of this information in near real-time to the data collector at IM-Portugal.

The messages received at IM-Portugal are broadcast by a Central Station operated by INGV with the technical assistance of Tecnomare-ENI-SpA (hereafter referred as TEC, subcontractor), using Internet services (e-mail). Before that, the information generated by GEOSTAR reaches the Control Station via a complex communication path (figure 5): (i) GEOSTAR communicates with the moored surface buoy via an acoustic link; (ii) the surface buoy uses a redundant GLOBALSTAR telephone link to deliver the messages to the Control Station located in Italy (Marghera, Venice). The details of these pathways will not be presented here.

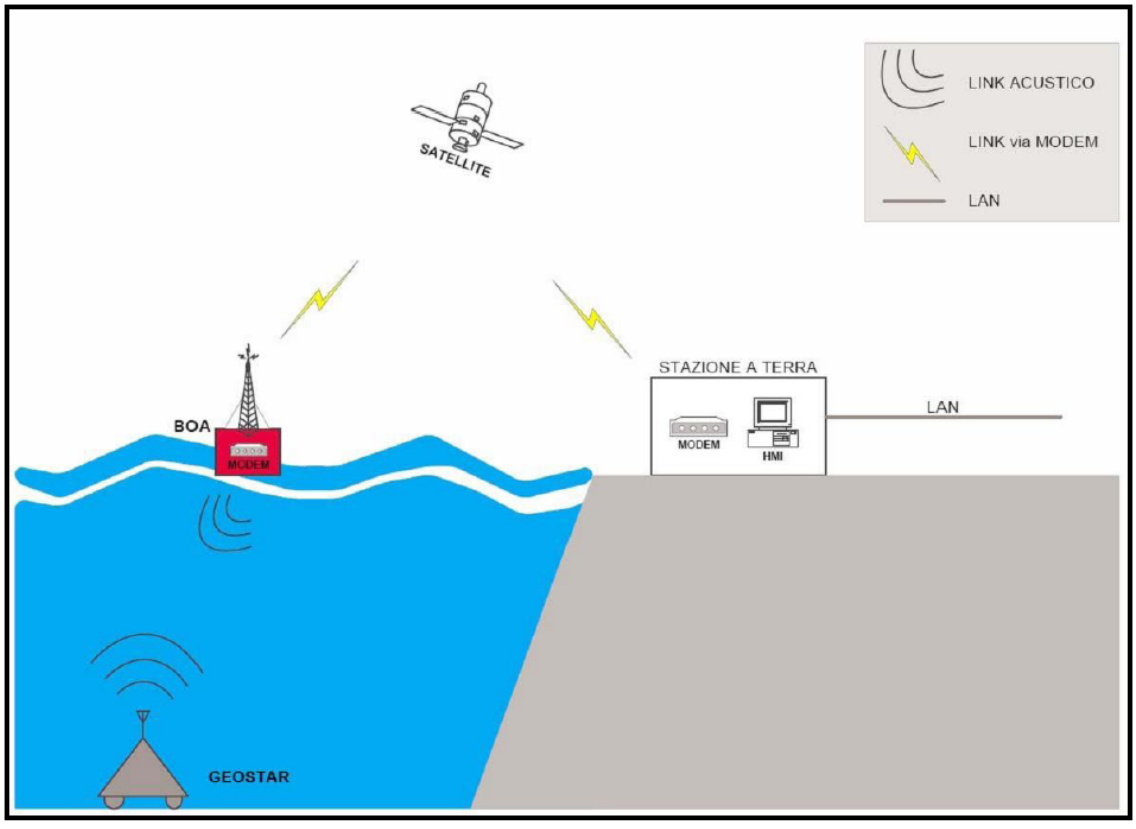

Figure 5 – The GEOSTAR deep-sea platform communication links to the land control station.

In “Normal Mode” (Mission Mode) GEOSTAR sends a status message and a data message every 6 hours. These messages are complemented by two additional messages from the buoy, one status and another data message. The “data” and “status” messages from GEOSTAR are sent to the surface buoy at minute 18 and 24 after the hour. All messages collected at the buoy are scheduled to be sent at minute 41 of the hour. In the following we will be interested only on the data messages from GEOSTAR that include information on sea level.

In “Mission Mode” every periodic message contains 6 values of absolute pressure, one value per hour. In “Event Mode” GEOSTAR generates also event messages that are sent at the rate of one every 10 minutes starting from the event detection. The event messages contain the sea-level data stored at one sample every 15 seconds. During the activity period of the NEAREST project we were only able to test the integration of GEOSTAR data messages in “Mission Mode”.

We show in figure 6 one example of a GEOSTAR data message received at IM-Portugal. INGV, with the assistance of TEC, broadcasts the message as soon as it is received and after some automatic pre-processing is done.

Subject: NEAREST GEOS DATA FILE of 30/11/09 ore 12:00:00
From: "flavio.furlan@tecnomare.it" <flavio.furlan@tecnomare.it>
Date: Mon, 30 Nov 2009 14:41:01 +0000
To: "nearest.prj@gmail.com" <nearest.prj@gmail.com>, "giuditta.marinaro@ingv.it" <giuditta.marinaro@ingv.it>, "paolofa@ingv.it" <paolofa@ingv.it>, "beranzoli@ingv.it" <beranzoli@ingv.it>, "luca.pignagnoli@bo.ismar.cnr.it" <luca.pignagnoli@bo.ismar.cnr.it>, "chierici@ira.inaf.it" <chierici@ira.inaf.it>, "gasp.f@libero.it" <gasp.f@libero.it>, "sarsa@libero.it" <sarsa@libero.it>, "flavio.furlan@tecnomare.it" <flavio.furlan@tecnomare.it>, "fabio.zanon@tecnomare.it" <fabio.zanon@tecnomare.it>, "federico.bruni@tecnomare.it" <federico.bruni@tecnomare.it>, "francesco.gasparoni@tecnomare.it" <francesco.gasparoni@tecnomare.it>

FILE RECEIVED ON 30/11/09 AT 15:41:15
CONVERSION DONE

09113012_dat.txt	**Content-Description:**	09113012_dat.txt
	Content-Type:	application/octet-stream
	Content-Encoding:	base64

Figure 6 – Example of one GEOSTAR data message received at IM-Portugal.

In this example the periodic message was prepared by the GEOSTAR platform the 30/11/2009-12:00:00 (UTC) and it was received by the Central Station the same day at 15:41:15 (CET). The message was received at IM-Portugal the same minute, at 14:41:00 (UTC). We cannot confirm the message times up to second since we do not know of the procedures put in place to synchronize the clocks, if any.

The subject of the GEOSTAR data messages is always "NEAREST GEOS DATA FILE of DD/MM/YY ore HH:MM:SS". The data content of the message is provided in the attached file, in this case, "09113012_dat.txt". The name of the data files has always the form "YYMMDDHH_dat.txt" indicating the scheduled time of the message prepared by GEOSTAR.

The first data message delivered by GEOSTAR was dated the 16/11/2009-00h. There was then a period when INGV collected all the messages at the Central Station and made some communication and operational tests. These messages (data file only) were later delivered to the NEAREST WP-5 partners the 24th November. After that day the IM-Portugal e-mail addresses were included in the distribution and began receiving the automatic messages broadcast by INGV.

From 27/11 to 29/11 this automatic distribution was interrupted due to some technical problems and the missing messages were distributed the 30th. The automatic message delivery was resumed then. IM-Portugal received the last GEOSTAR data message dated the 02/12/2009-18h (GEOSTAR preparation time). After that, IM-Portugal continued to receive Buoy messages till the 24th December, when a major accident disrupted all communications from the buoy. A fact that was later confirmed by visual inspection from an airplane and a Portuguese Navy Ship.

A total of 6 GEOSTAR data messages were received by IM-Portugal automatically distributed. The list of these messages is presented in the next table.

Table 3 – List of automatic messages received by IM-Portugal delivered by INGV/TEC

GEOSTAR		INGV/TEC				IM-Portugal				
Date	**hh**	**Date**	**hh**	**mm**	**Delay**	**Date**	**hh**	**mm**	**Delay**	**Data File**
27/11/2009	12	27/11/2009	13	41	60	27/11/2009	13	41	60	09112712_dat.txt
30/11/2009	12	30/11/2009	14	41	120	30/11/2009	14	41	120	09113012_dat.txt
30/11/2009	18	30/11/2009	18	41	0	30/11/2009	18	41	0	09113018_dat.txt
02/12/2009	0	02/12/2009	3	41	180	02/12/2009	5	41	300	09120212_dat.txt
02/12/2009	12	02/12/2009	13	41	60	02/12/2009	15	41	180	09120212_dat.txt
02/12/2009	18	02/12/2009	21	41	180	02/12/2009	23	41	300	08120218_dat.txt

Delay time in minutes, measured from the buoy broadcast scheduled time (see text for details)

Considering the activity period of GEOSTAR deep-sea platform as a message provider to the prototype of Tsunami Warning System under development at IM-Portugal, between the 16th November and the 2nd December 2009, a total of 68 messages should have been received by the Central station and delivered to IM-Portugal (see Table 4). Of these, 36 messages were well received (Table 4), giving a success ratio of 53%. The most continuous sequence of messages (10), encompassing

2.5 days, was received for the period between 27/11/2009-06h and 29/11/2009-12h. This is the sequence of messages that will be used to test the integration of the GEOSTAR data into the IM-Portugal data collector, to be described in the next paragraph.

Table 4 – List of all messages received and missing

GEOSTAR		IM-Portugal	GEOSTAR		IM-Portugal
Date	**hh**	**File Received**	**Date**	**hh**	**File Received**
16/11/2009	00	09111600_dat.txt	24/11/2009	12	
16/11/2009	06	09111606_dat.txt	24/11/2009	18	
16/11/2009	12	09111612_dat.txt	25/11/2009	00	
16/11/2009	18		25/11/2009	06	
17/11/2009	00	09111700_dat.txt	25/11/2009	12	
17/11/2009	06		25/11/2009	18	
17/11/2009	12	09111712_dat.txt	26/11/2009	00	
17/11/2009	18	09111718_dat.txt	26/11/2009	06	
18/11/2009	00	09111800_dat.txt	26/11/2009	12	
18/11/2009	06	09111806_dat.txt	26/11/2009	18	
18/11/2009	12		27/11/2009	00	
18/11/2009	18	09111818_dat.txt	27/11/2009	06	09112706_dat.txt
19/11/2009	00	09111900_dat.txt	27/11/2009	12	09112712_dat.txt
19/11/2009	06		27/11/2009	18	09112718_dat.txt
19/11/2009	12	09111912_dat.txt	28/11/2009	00	09112800_dat.txt
19/11/2009	18	09111918_dat.txt	28/11/2009	06	09112806_dat.txt
20/11/2009	00	09112000_dat.txt	28/11/2009	12	09112812_dat.txt
20/11/2009	06		28/11/2009	18	09112818_dat.txt
20/11/2009	12		29/11/2009	00	09112900_dat.txt
20/11/2009	18		29/11/2009	06	09112906_dat.txt
21/11/2009	00	09112100_dat.txt	29/11/2009	12	09112912_dat.txt
21/11/2009	06	09112106_dat.txt	29/11/2009	18	
21/11/2009	12		30/11/2009	00	
21/11/2009	18	09112118_dat.txt	30/11/2009	06	
22/11/2009	00	09112200_dat.txt	30/11/2009	12	09113012_dat.txt
22/11/2009	06	09112206_dat.txt	30/11/2009	18	09113018_dat.txt
22/11/2009	12		01/12/2009	00	
22/11/2009	18	09112218_dat.txt	01/12/2009	06	
23/11/2009	00		01/12/2009	12	
23/11/2009	06		01/12/2009	18	
23/11/2009	12		02/12/2009	00	09120200_dat.txt
23/11/2009	18	09112318_dat.txt	02/12/2009	06	
24/11/2009	00	09112400_dat.txt	02/12/2009	12	09120212_dat.txt
24/11/2009	06		02/12/2009	18	08120218_dat.txt

4. Integration of messages into the data collector

The integration of the GEOSTAR data messages into the IM-Portugal data collector follow the path indicated in figure 4: (i) the electronic mail message is received at one of the IM-Portugal mail boxes; (ii) an automatic procedure is in place that recognizes the subject of the message and automatically downloads the data file into one particular directory; (iii) an automatic routine, the GEO-GetPut plug-in, periodically checks the message directory and converts any new message to mini-seed format that is then fed into the SeisComP data collector.

Each data file generated by the GEOSTAR contains a multitude of information, as it is exemplified in figure 7. The file is structure in a way that allows for an easy import to Excel: a TAB character separates the fields and values.

09111600_DAT			SDU									
					OBS							
Date-Time	Flags	SciPackCt	Flags	Index	NDataTot	NSeis	NSeisEvent	NAccAS	NHydro	NEv	NErr	LastPkt_Time
15/11/2009 23.00	FULL	0xffc3	OK	5	5564	2775	0	1807	871	0	2	Sun Nov 15 23:59:59 2009

PDU													
		PRESS						IMU					
Flags	Index	Press_0 [mbar]	Press_1 [mbar]	Press_2 [mbar]	Press_3 [mbar]	Press_4 [mbar]	Press_5 [mbar]	Gyro_x [de	Gyro_y [de	Gyro_z [de	Acc_x [g]	Acc_y [g]	Acc_z [g]	Temp [°C]
OK	126	323890.84	323837.78	323773.67	323714.73	323675.01	323663.06	1.01	0.24	0.06	0.016	0.001	-0.999	0,215278

DAU																									
		GRAV						CTD					ADCP300					3DACM								
Flags	Index	Empty valu	Comm	Media G	r	Media Ter	S.dev. G	r	S.dev Tem	Flags	Temp	Conduct	Press [dbar]	Transm	Flags	Headin	Pitch	Roll	(Temp	mVe [cm/s	mVn [	mVw [c	mT [°C	mMx	mMy	mPi [	mRo [de
OK	126	0	0	10797080.		4.449	336.96		0.002	OK	2.606	32.579	322999900	66	OK	180.63	1.17	-0.51	2.42	0,05	61,83	61,88	0,15	0,00	0,07	61,84	61,79

Figure 7 – Example of one GEOSTAR data file.

From all the multitude of parameters in the message, only a few concern the measurement of sea-level made by the GEOSTAR Absolute Pressure Gauge. These are identified below in Table 5.

Table 5 – Message fields, description and example values concerning the sea-level measurements

Header	Description	Value
Date-Time	Date and time of message	15/11/2009 23:00
LastPkt_Time	Date and time of last sample	Sun Nov 15 23:59:59 2009
Press_0 [mbar]	Absolute pressure, at “date-time” + 1 hour	323890.84
Press_1 [mbar]	Absolute pressure, at “date-time”	323837.78
Press_2 [mbar]	Absolute pressure, at “date-time” - 1 hour	323773.67
Press_3 [mbar]	Absolute pressure, at “date-time” - 2 hour	323714.73
Press_4 [mbar]	Absolute pressure, at “date-time” - 3 hour	323675.01
Press_5 [mbar]	Absolute pressure, at “date-time” - 4 hour	323663.06

The pressure values, once for each hour, are written in reverse order, from the most recent to oldest. Each value represents the last sample measured during that hour

period at 15 s. sampling rate. For simplicity we will assume that the value was measured exactly at the hour and not 15 seconds before

To work properly, the GEO-GetPut plug-in must be initiated with a number of parameters that are described below:

Get Section	
ftp_address	Complete address of the machine where the GEOSTAR data files are received inside the IM firewall. e.g. 'gts:gts2008@180.180.18.7'
s_delay	delay in seconds between consecutive calls to the system. In “Mission mode” one call every 10 minutes is considered adequate.
local_dir	The local directory where the log files are written for debugging and quality control.
Put Section	
seeddir	Location of the directory to save the files in mini-seed format, locally.
ftp_putadd	FTP destination of files the mini-seed files. It is the place that SeisComP screens for new data files.
p_delay	delay in seconds between consecutive calls to the system while transferring the mini-seed files. On average one single file should be transferred every 4 seconds to allow SeisComP to respond.

Since we are interested, for tsunami warning purposes, on the variation of the sea-level and not on the absolute pressure at the sea-bottom, before conversion to mini-seed all samples are corrected for a constant offset of 323000.

After being processed by GEO-GetPut and collected by SeisComP, the GEOSTAR data can be accessible by all applications inside the IM-Portugal firewall. One of these applications is TAT (the Tsunami Analysis Tool) that is used for the prototype Tsunami Warning System to confirm the occurrence of a tsunami, by comparison of predicted sea-level values with observed sea-level measurements at coastal or deep-ocean tide-gauges (see figure 4).

The GEOSTAR data can be made also readily accessible to outside partners, in mini-seed format, using the imslserver (figure 4). In figures 8 and 9 we show how the data from GEOSTAR can be visualized using the SeisGram application or the SEISAN application.

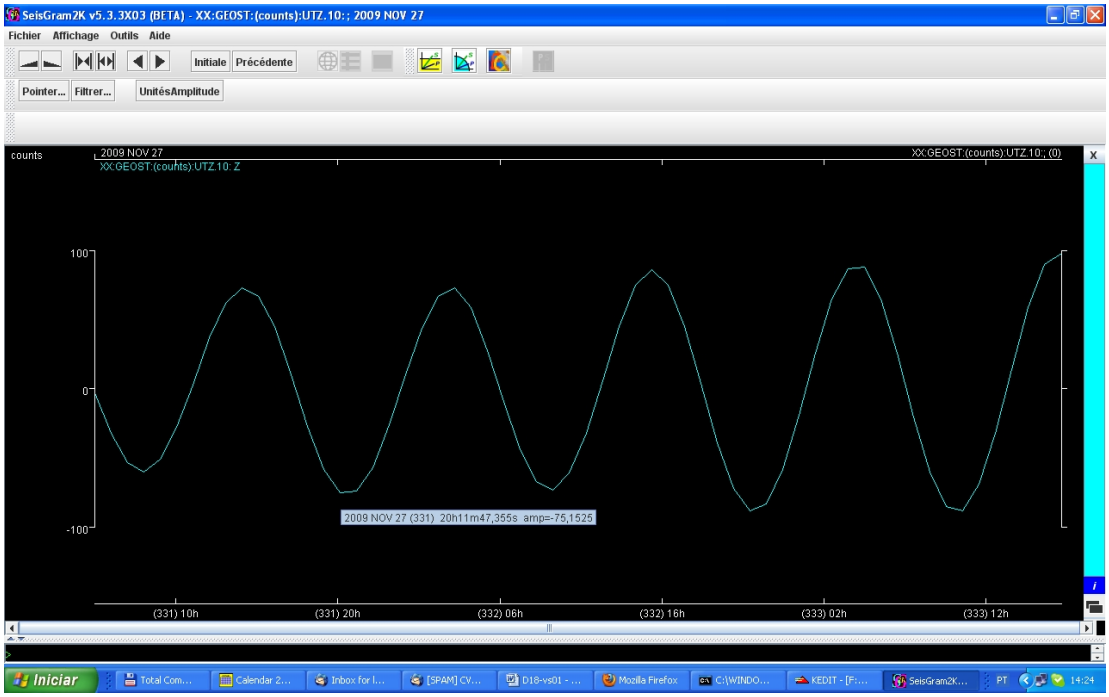

Figure 8 – Visualization of the data collected by GEOSTAR data file for the period between 27/11/2009-06h and 29/11/2009-12h, using the SeisGram application.

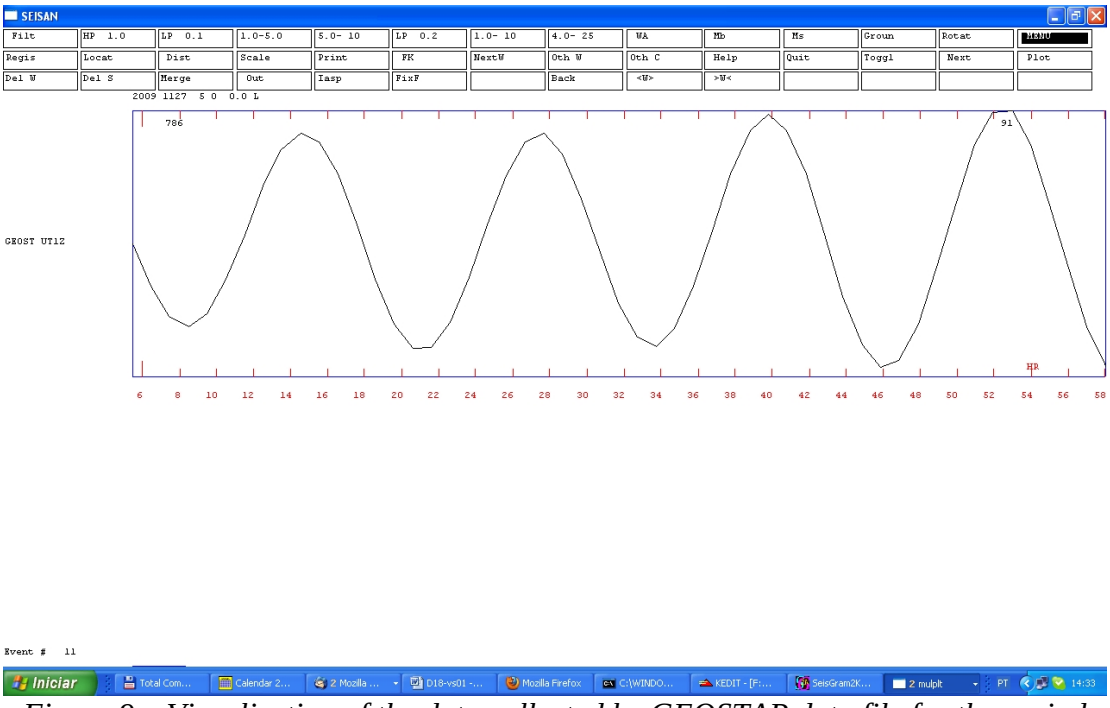

Figure 9 – Visualization of the data collected by GEOSTAR data file for the period between 27/11/2009-06h and 29/11/2009-12h, using the SEISAN application.

5. Conclusion

We have seen that the GEOSTAR deep-sea platform connected to a moored buoy is able to provide in near real time messages containing information on the sea level, which is essential for a Tsunami Warning System. In “Mission mode” these messages are broadcast by GEOSTAR every 6 hours and each message contains 6 samples of the absolute pressure measured at the sea floor, one sample per hour. During the testing period these messages arrived to the data collector at IM-Portugal, where the prototype of a Tsunami Warning System is under development, with a delay between 2 to 5 hours. Considering all the messages received at IM-Portugal, we note that only 52% of the GEOSTAR expected messages were delivered. Unfortunately, due to the collapse of the buoy communication system in December 2009, it was not possible to test the system on the “Event Mode” where more frequent messages are delivered and the sampling rate is higher.

Using the messages received from GEOSTAR it was possible to perform the integration of the sea-level information into the data collection system already in place at IM-Portugal. A specific plug-in was designed and successfully tested.