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)

D17: integration of tide gauge data

Due date of deliverable: August 2009
Actual submission date: August 2009

Start date of the project: 01/10/2006 Duration: 36 + 6 months

Organisation name of the lead contractor for this deliverable: UGR

Revision: Final

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

WP5 - Data integration/ Integrated tsunami detection network

D.17 Integration of tide gauge data

Task 5.1 Leader: UGR

Task 5.1 Responsible: José Morales

Authorship:

This report has been compiled by Luis Matias with the contributions from the main partners involved in the management of the national and regional geophysical monitoring networks operating in the region of the SW Iberia and surroundings: Meteorological Institute at Lisbon (IM) as responsible of the national seismic network of Portugal, The National Geophysical Institute of Morocco of the Centre National pour la Recherche Scientifique (CNRST) as responsible of the national seismic network of Morocco and The Instituto Andaluz de Geofisíca of Granada University (UGR) as responsible of the broad band seismic network of southern Spain. Abdelouahad Birouk from CNRST completed the report with their contributions to the sea level monitoring by tide gauges.

Table of contents

1. Introduction and objectives

The operation of a Tsunami Warning Centre (TWC) differs from currently operating Seismic Network Centres operating in the Gulf of Cadiz area in the fact that the occurrence of a tsunami triggered by a large earthquake has to be confirmed by observations of sea-level data. In fact, it is well known that a warning message based exclusively on seismic information, available after a few minutes of the earthquake onset, has a very large uncertainty. The message thresholds are defined in a conservative way so that all known historical tsunamis or modelled tsunamis can be accounted for.

The approach taken in the NEAREST project to build the capacity required for the proper operation of a National or Regional TWC on sea level monitoring was to use the already installed facilities, manpower and know-how, developed for seismic monitoring, and extend their operation to sea level observations. The two main agencies and NEAREST partners that took over this job were the CNRST for Morocco and the IM for Portugal.

This deliverable reports on the contribution of the NEAREST project to improve and integrate the sea level observations within the current operational seismic networks of Portugal, Spain and Morocco, in order to prepare the three main responsible agencies to run a fully operational Tsunami Warning Centre in the near future.

2. The situation of sea-level observations around the G. of Cadiz

Real time sea level data are a basic component of the tsunami warning systems, and they are used first of all as a validation tool, that is to confirm that a major tsunami was generated by an earthquake or, on the contrary, to cancel alert messages in case of no tsunami observations. Traditionally, such observations are carried out through tide gauges typically placed in harbours, and through pressure gauges on the sea floor deployed offshore far from the coast. The Gulf of Cadiz is integrated in the NEAM region and the Working Group 3 under the ICG/NEAMTWS has addressed sea level monitoring. In this broad area, the NEAM region, tide-gauge stations are operated by a number of national agencies and of research institutions that usually process their own data. Data transmission and exchange in real-time with the characteristics required by the TWS are rarely met. At the several ICG/NEAMTWS meetings the slow development of the sea level monitoring system to comply with tsunami detection requirements has been recognized as one of the weakest components of the NEAMTWS, particularly when compared with the strong development of seismic networks.

Many of the existing coastal tide gauges in the NEAM region are part of global or regional networks such as GLOSS, MedGLOSS, ESEAS or ODINAFRICA, multi-user/multi-purpose sea level observing networks that serve both research and operational purposes (i.e. monitoring long-term sea level change, storm surge and port operations). To complement this core network, denser networks are required in the areas of the NEAM region that are close to the tsunamigenic zones and may be hit by dangerous waves soon after the earthquake occurrence. Network densification is a task to be designed in the first phase and accomplished in the second phase of the TWS implementation, as recommended by the NEAMTWS Implementation Plan. Based on the current and known operating stations, it was possible to design the backbone of the sea level monitoring system for the NEAM region, shown in figure 2.1

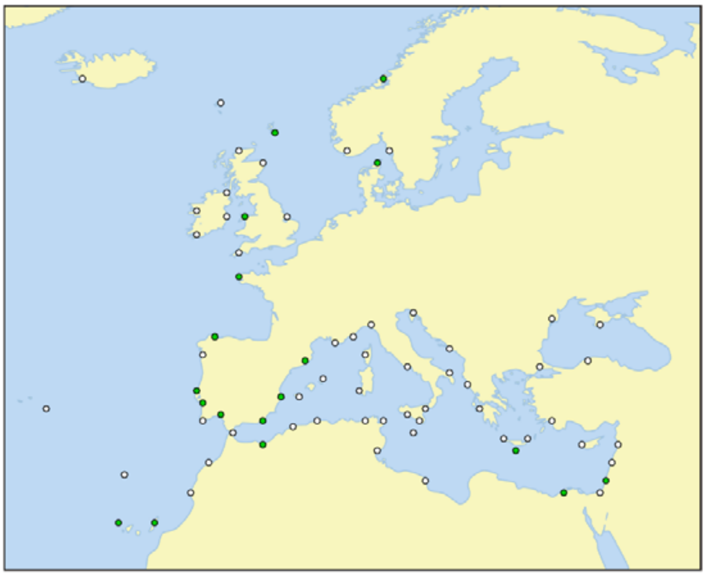


Figure 2.1 - Final regional network of coastal sea level stations to be part of the system agreed upon during the ICG/NEAMTWS IV meeting in Lisbon (November 2007) and actual status (October 2008). Green dots correspond to the ones that are already available to become part of the system. From the NEAMTWS Implementation Plan.

Many of the indicated stations provide data online at the IOC Sea Level Station Monitoring Facility website (http://www.ioc-sealevelmonitoring.org/), as can be seen on figure 2.2. This website is one of the major sources for sea level data on the Gulf of Cadiz. However it cannot be used for operational purposes due mainly to three reasons: (i) the considerable delay (latency) of the data, rarely less than 5 minutes; (ii) the unreliability of the public Internet service; (iii) the service provided is not on an operational basis and there is no guarantee that data is available 24/7.

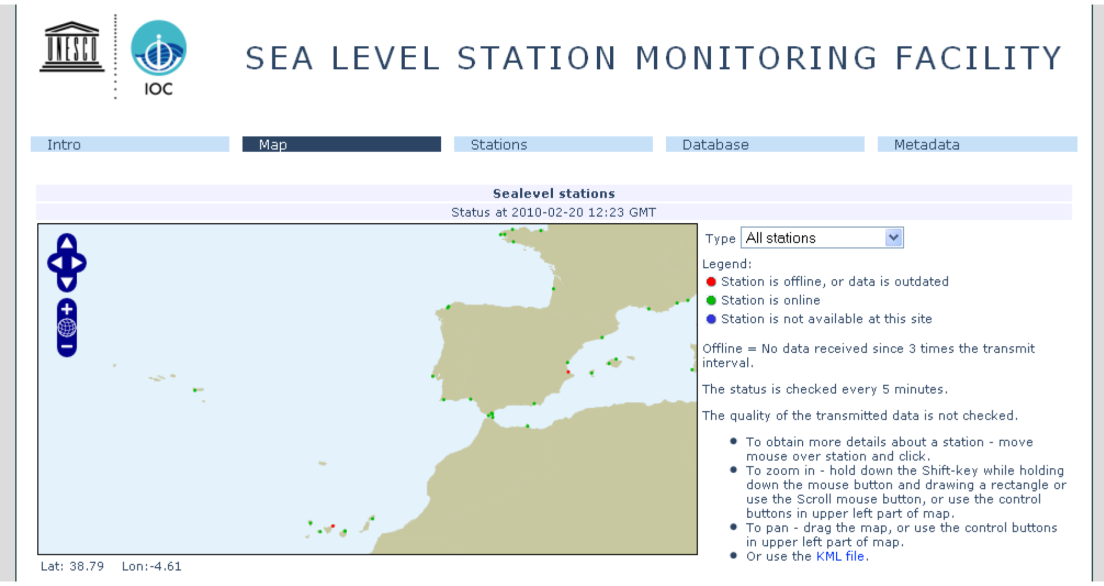


Figure 2.2 – Tide gauge stations available at the IOC website.

So far there is not a single deep-ocean sea level station operating in real or near-real time in the Gulf of Cadiz. The next paragraphs summarize the situation on each country that surrounds the Gulf of Cadiz, regarding only coastal tide gauge systems.

2.1 The situation in Portugal

In Portugal there are several agencies that collect sea level data from coastal tide gauges. The main agency is the Hydrographical Institute (IH) that uses sea level data to assist navigation and harbour operations with predicted tidal information. Information on predicted tides can be found at the Institutes website http://www.hidrografico.pt/previsao-mares.php (see also figure 2.1.1).

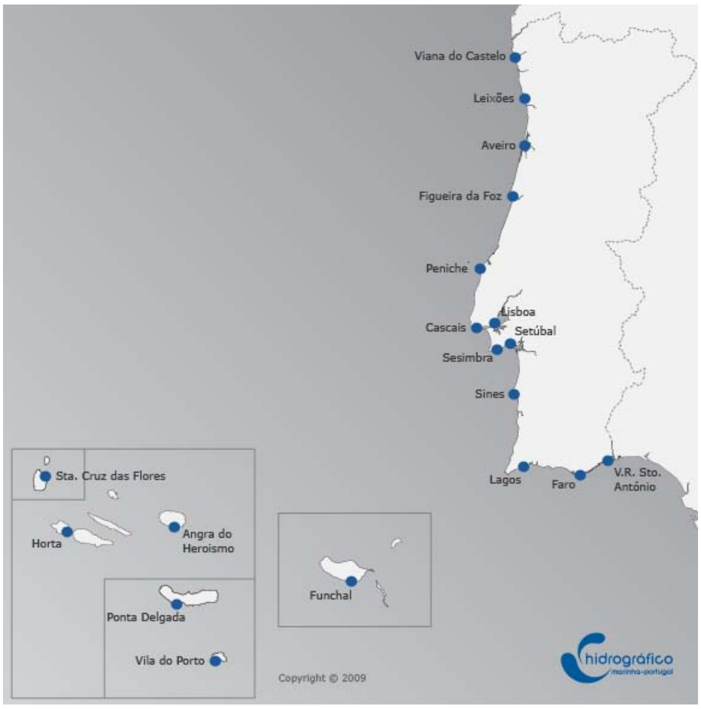


Figure 2.1.1 – Tidal information provided by IH.

The list of coastal tide gauges currently operated by IH (sometimes associated with other institutions) is shown in the following table.

Location	Sensor	Sampling	Institution	Status	Observations
Leixões	Radar	1 min	IH	INOP	Under installation
Peniche	Radar	1 min	IH	INOP	Under installation
Sesimbra	Radar/Pressure	1 min	IH	Operational	
Sines	Radar/Pressure	1 min	IH	Operational	
Caniçal, Madeira	Acoustic	1 min	IH/APRAM	Operational	
Ponta Delgada, Azores	Radar/Pressure	1 min	IH/GLOSS	Operational	

The other national agency that operates coastal tide gauges is the Instituto Geográfico Português (IGP) with the purpose of defining the datum level for cartographic purposes. IGP operates the two oldest coastal tide gauges in Portugal, the Cascais station (since 1882) and the Lagos station (since 1902). More information on the IGP activity can be found at their website, http://www.igeo.pt/produtos/Geodesia/maregrafos.htm

The main characteristics of these two sensors are presented in the table below.

Location	Sensor	Sampling	Institution	Status
Cascais	Pressure/Acoustic	6 min	IGP	Operational
Lagos	Pressure/Acoustic	6 min	IGP	Operational

Data from these two sensors is provided via ftp (ftp://www.igeo.pt/Cascais/maregrafo and ftp://www.igeo.pt/Lagos/maregrafo) as well as at the SLEAC and IOC websites (http://www.sleac.org, http://www.vliz.be/gauges/station.php?code=casc and http://www.vliz.be/gauges/station.php?code=lagos).

Recently, the Departamento de Oceanografia e Pescas (DOP-UAc) from the Azores University, installed 4 new coastal tide gauges in the Azores archipelago, Faial, Pico, Terceira and Santa Maria.

Location	Sensor	Sampling	Institution	Status
Faial	Radar	~4 min	DOP-UAc	Operational
Pico	Radar	~4 min	DOP-UAc	Operational
Terceira	Radar	~4 min	DOP-UAc	Operational
Santa Maria	Radar	~4 min	DOP-UAc	Operational

The main objective of these sensors is to provide information relevant for biological studies in the Azores archipelago and so the sampling rate adopted is not very precise. The values indicated are averages. Information on the tide gauges can be found at the DOP website, http://oceano.horta.uac.pt/azodc/tidegauge.php where data can be recovered also.

In addition to these “public domain” instruments, there are several tide-gauges operated by the Harbour authorities for exclusive use to help navigation and Harbour operations.

2.2 The situation in Spain

The main operator of coastal tide gauges in Spain is Puertos del Estado (PE-ES, the Spanish Harbours Authority). Information on the current status of the observation network can be found at http://www.puertos.es/en/oceanografia_y_meteorologia/redes_de_medida/index.html (see also figure 2.2.1).

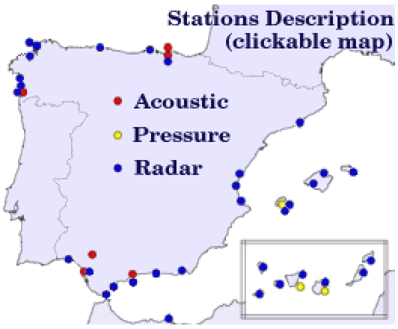


Figure 2.2.1 – Coastal tide gauges operated by Puertos del Estado in Spain.

Despite the fact that this network is mainly dedicated to tidal forecast, to help the navigation and harbour operations, there has been a continuous improvement on the sensors and acquisition systems, making many of them adequate to integrate a Tsunami Warning System. Data from all the stations is also available online at the same Internet address. As we can see from figure 2.2.1 there are several coastal tide-gauges that could be interesting to incorporate in any Tsunami Warning System to monitor the North-East Atlantic area.

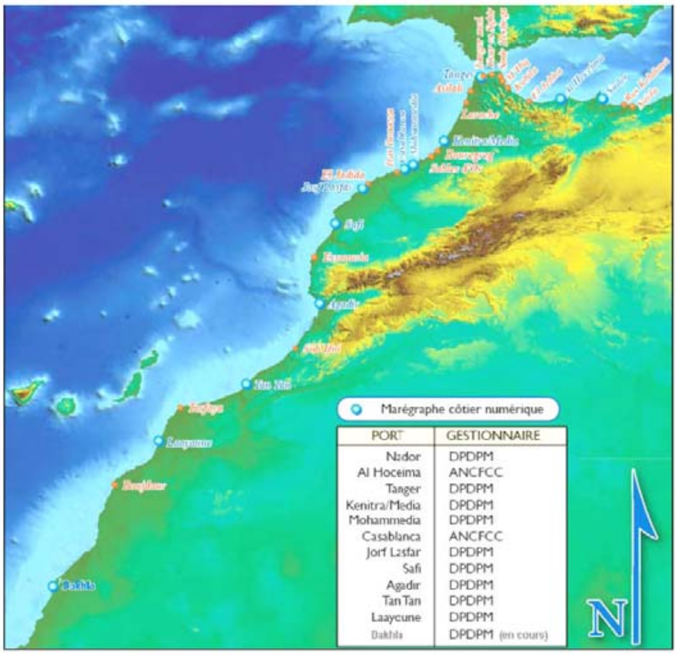
The second major owner of costal tide-gauges in Spain is the Instituto Español de Oceanografía (IEO-ES, http://www.ieo.es/inicial.htm). They operate a number of stations (http://indamar.ieo.es/) and the data can be found online. However, only a few of the stations are providing a minimum of 1 sample per minute, which is considered adequate for tsunami watch.

2.3 The situation in Morocco

Currently two institutions in Morocco operate tides gauges for their specific use: The Directorate of Ports and Maritime Public Domain under the Ministry of Public Works (DPDPM) and the National Agency of Land Conservation Land Registry and Mapping (ANCFCC) under Ministry of Agriculture.

The DPDPM is operating a new network of ten digital tide gauges installed from 2003. They are installed (fig.2.3.1) on the Atlantic coast in the Cities of Tangier, Kenitra, Mohamadia, Eljadida, Safi, Agadir, Tan Tan, Laayoune and Dakhla and in the Mediterranean Sea in the city of Nador. The equipment includes a data-logger Aurore 200 of the Company Martec, the Radar Vega (VEGAPULS 65 and 51), a GPS and a flash memory cartridge. Data is recorded every 10 minutes on the Flash memory and sent periodically every month to

DPDPM. The ANCFCC in turn has two acoustic tide gauges installed at Casablanca and Alhoceima.



DPDPM: 10 Tide gauges:

-VEGAPULS 65 Radar Sensor
- AURORE 200 datalogger. Martec/Serpe-IESM
- Data is recorded every 10 minutes but presently only a Flash memory is used
- Data sent as an attachment to an email on a monthly or 3 monthly period from all ports

ANCFCC: 2 Tide gauges

- Mors HT200 Acoustic
- No information availaible on data storage and transmission

Figure 2.3.1 – Moroccan tide gauge network

3. The contribution of NEAREST to improve the sea-level observations

3.1 The situation in Portugal and Spain

In this paragraph we will present the contribution of NEAREST to the sea level observation infrastructure and will leave the question of real-time integration to section 4 of this report.

Looking into the backbone of sea level monitoring desired for the NEAM region (figure 2.1) we immediately identified as priority sites for tide gauge connection the Lagos and Cascais stations, operated by IGP. As mentioned before, IPGP interest on sea level is mainly for cartographic purposes so that the requirements needed by a TWS, real-time and high sampling rate, were not a priority. Thanks to NEAREST, we approached the IGP responsible and an agreement was signed between IGP and the NEAREST partner FFCUL so that FFCUL could support the technical upgrade of both Cascais and Lagos tide-gauges. The technical solution currently installed, implying the replacement of the data-logger, provides one sample every 2.5 seconds.

As regards the Hydrographical Institute, there was no need for direct support since the upgrading of the IH tide-gauges was already planned, according to GLOSS recommendations on tsunami observations. The cooperation between IH, IM (the Portuguese Tsunami Focal Point) and the research institute IDL were facilitated by NEAREST activities that supported the participation of the researchers at the ICG/NEAMTWS meetings. At the national level, the coordination of sea level observations aimed to the establishment of the Portuguese Tsunami Watch Centre has been performed by the GT-IMAT, the Portuguese Working Group established by the National IOC representative. Several meetings and visits to sites were organized between the interested partners during these last 3 years.

Considering the importance of sea level observations in the Azores archipelago, to monitor trans-oceanic tsunamis and local generated events, the NEAREST project supported the activities of DOP-UAc in order to facilitate the funding of the continuous operation of the network. However, the technical solution installed in the DOP-UAc stations does not allow the construction of a regularly sampled time series. To overcome this difficulty, NEAREST supported the negotiations with a local service company, Amberjack Solutions, to purchase a dedicated system to be installed during 2010 on the same vault as the existing DOP-UAc sensor. This system will comprise a sensor pressure and a completely autonomous data-logger and communication system, based on a local Seiscomp PC. This is the same system that is installed for data collection in most of the seismic stations operated by IM. The major funding of this upgrade will be supported by IM.

3.2 The situation in Morocco

On the NEAREST project, the Tsunami Early Warning System (EWS) Prototype is designed on the basis of land recorded seismic data, deep ocean water height and near-shore tide-gauge data. Seeing that at the present time, there is a deficiency in coverage by real time tide gauges of the southern part of Moroccan-Iberian region, the localization in morocco of a new real time tide gauge will satisfy the need and will improve greatly the efficiency of the Tsunami early warning System prototype. For this reason, CNRST decided to contribute to the development of TEWS in addition to WP5 seismic activities, by the acquisition and installation of a digital tide gauge system allowing near real time data transmission of Sea level to Rabat data collector and assuring near real time data sharing with others data collectors.

After studying different offers on the market, the CNRST has opted for equipment and the solution given by OTT manufacturer. An order is placed on June 2008 for the purchase of a digital gauge and software necessary for its operation, off-line data processing and archiving. Due to unavailability of stock at the supplier, the equipment was unfortunately not delivered before December 2008.

The acquisition consists of the following modules and software:

1. A radar sensor Type Kalesto from OTT manufacturer with 100 m of cable;
2. A data Logger LoggoSens2 type from OTT with an 2 analogical inputs expansion board;
3. A network adapter eDbox-200 of eDevice;
4. An AC power control unit 200 W with battery backup 12v/25Ah;
5. A stainless steel cabinet for modules mounting;
6. OTT LoggoSens: loggoSens2 data logger operating program;
7. OTT Hydras 3 Receiver: real time data collecting Software;
8. OTT Hydras 3: configuration, data collecting and off-line data processing and archiving Software.

The CNRST has also proceeded to the exploration of a number of potential ports able to accommodate the installation of tide gauge. So, were successively visited the ports of Sid El Aidi, Mohamadia and Casablanca respectively 15, 70 and 90 KM from Rabat. For this first installation, 3 ports were chosen in the northern part of Morocco to be as near as possible to tsunamigenic areas, in order to ensure fast detection, but also near Rabat for implementation, monitoring and maintenance purposes.

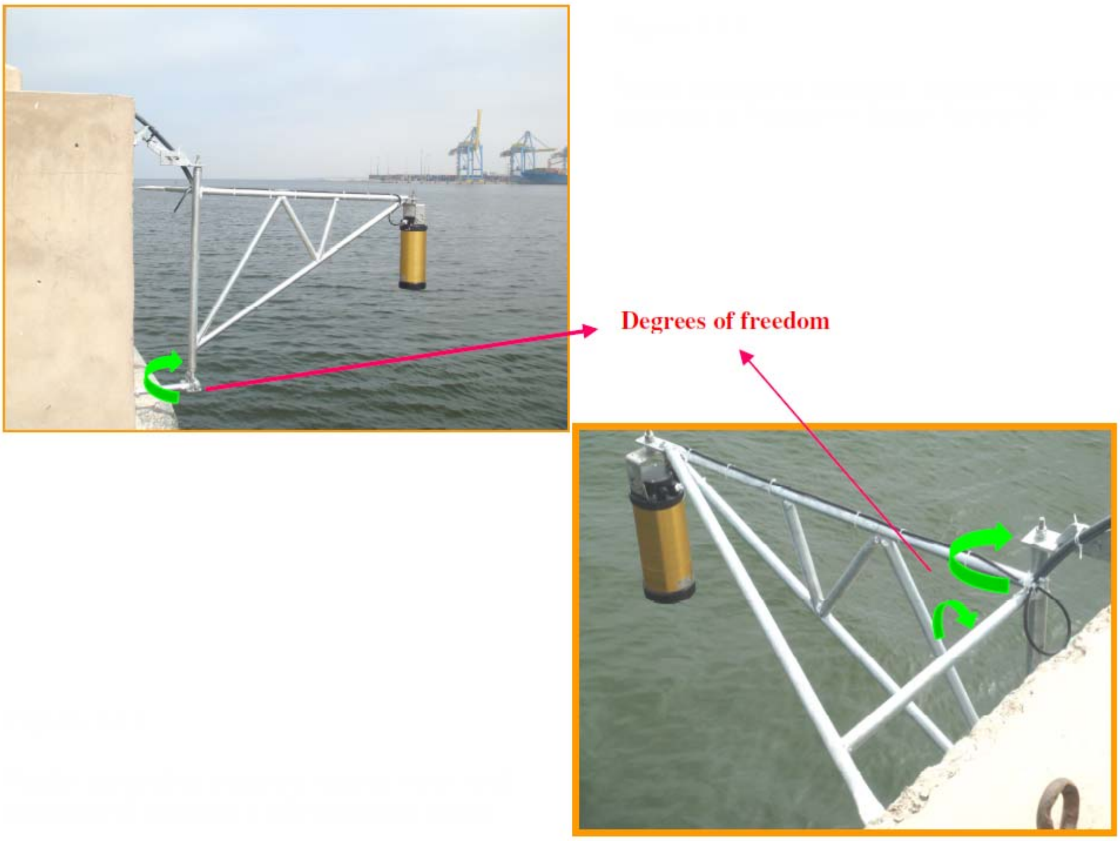
However, it is noted that the CNRST will implement in a second phase two more real time digital tide gauge one in the extreme part of Morocco probably in Tangier port and the other in southern part. Theses implementations will be either new acquisition or upgrade of existing tide gauge for real time data transmission.

To carry out these various actions, CNRST should cooperate closely with the departments responsible for ports building and operation that are respectively the Directorate of Ports and Maritime Public Domain (DPDPM) and Harbours National Agency of the Ministry of Public Works.

So CNRST came into contacts with many officials of these departments notably the Hydrography, Bathymetry and oceanography Department of DPDPM made on 3 November 2008, which resulted after several correspondences with the signing of a cooperation agreement in July 2009. This framework agreement has set goals for collaboration between the two institutions for the upgrading of existing tide gauges belonging to DPDPM and for all future actions of cooperation on tsunami hazard assessment and risk reduction as well as tide gauges data exchange. At the same time, contacts have helped to organize the 20/01/2009 a joint visit of the Port of Casablanca resulting in a common decision in the opportunity of installing the gauge in this infrastructure, given its importance, the geographical location for tsunami detection and given that the former gauge, isn't no longer operational since certain time.

The installation of the gauge has been carried out from 14 to 16 August 2009 witch has involved the following actions:

1 - Radar Support Installation and Sensor Mounting: support installation was made on the wall of a shelter located near the harbour master's office (VTS) .The support that has been manufactured in the assembly shop of the CNRST has been designed so that it has 3 degrees of freedom see Figures 3.2.1 and 3.2.2. This makes possible its horizontal adjusting at any time just by a set of screws, and also permit rotating the sensor horizontally and make it accessible for any sensor maintenance or/and cable and connection controls before putting it back in its place. For setting the horizontality of Kalesto sensor, we fixed with elastics two bubble levels on the radar that has been withdrawn with a thread after setting.



Figures 3.2.1 and 3.2.2 – Radar mounting support: lateral view and degrees of freedom. Topo - (back and forth; Bottom - left right and pivot.

<u>2 - the installation of the cabinet comprising the various modules of the digital gauge:</u> the cabinet has been installed on the wall of an empty room located at VTS (harbour master's office) not too far from the sensor (thirty meters). The cabinet contains the following modules see Figure 3.2.3:

- An OTT Data-logger, type LogoSens:
  - with 8 freely configurable input channels expandable to 16 Channels: voltage, current, PT100, NTC, conductivity, impulse (SDI-12 and RS-485), frequency, SPI;
  - 4 output channels: voltage, power, relay.
  - 4 MB of total memory with 917 KB available for measurements storage
  - Interfaces: 2 RS-232, Infrared IrDA, RS485, SDI-12;
  - Sampling: 5s-24h;
  - Transmission: dial-up line, GSM, GPRS, ADSL and satellite
  - Clock: RTC ± 1 min/month at 25°C

The configuration of the data-logger is done with the operating LogoSens program. This allows configuring different logical channels, sample rate, channel processing and storage, mode and frequency of transmission, alarms, etc.

Figure 3.2.3 –Rack containing digital tide gauge modules

Figure 3.2.4 - Tide gauge configuration, PC data transfer running LogoSens operating program.

- A network adapter eDbox-200 of eDevice. The box interface the serial port of the data-logger to TCP/IP connexion. It's able to send/receive emails, get/put files via FTP and open TCP sockets over the Internet when connected to an Ethernet network. Support ARP, TCP, DHCP, SMTP, FTP and HTTP. The eDbox-200 is driven using AT# command Set.
- An AC power control unit 200 W with battery backup 12v/25Ah

Figure 3.2.5 - Tide staff used for tide gauge calibrating and benchmark.

<u>3 - Fixing cables</u>: the cable between the radar and the cabinet, and the cable between the cabinet and the local Ethernet network connecting the network adapter and switch, since the room had no Ethernet jack.

<u>4 - the tide gauge calibration</u>: for calibration we used a tide staff witch's placed not far from the location of tide gauge installation. This tide staff was installed a few years ago see Figure 1.2.5. The zero of the tide staff is referenced to a principal benchmark located few meters away. The referencing includes also in the vicinity two secondary benchmarks. The zero of the new installed tide gauge was calibrated and aligned with the zero of the tide staff. The calibration was done by a sunny day and by analyzing the errors of reading between gauge and tide staff. This was done for thirty measurements over several hours to reduce the

effect of ‘clapot’ on the accuracy of reading the tide staff. This later will be also used for periodical control and calibration

5 - Setting the gauge: the gauge has been configured with the software Logosens operating program, including the sampling rate witch was temporarily set to one sample every 3 min. Once data transmission is operational, this rate will be increased to 1 sample every 2 min. We did this to save the internal memory and avoid possible filling of the buffer.

We also configured the system for data transmission by TCP / IP as we had opted initially for a connection between the gauge and the data server at CNRST through local networks and the Internet (see figure 3.2.6 and possibilities envisaged for data transmission in paragraph 4.2).

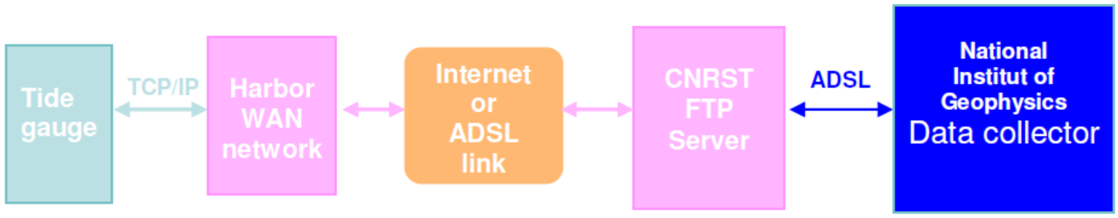


Figure 3.2.6

The transmission use FTP protocol and should work with cyclic sending data every 3 min to CNRST FTP server located in Rabat. Then, OTT Hydras 3 Receiver Software will transfer data in real time from CNRST FTP Server to a workstation located at CNRST data collector located at the National Institute of Geophysics (ING-CNRST).

The real time data from tide gauge will be made available at the FTP server ING-CNRST data collector for the benefit of the port, the DPDPM and NEAREST data collector in charge of tsunami warning.

Hydras 3 software was also used on site during installation for collecting, displaying, analyzing and storing data on a database. This same software will be used regularly at ING-CNRST data collector for tidal quality data checking, analysis data processing and their storage in a database. The software has many features including the following:

- Data collection
- Data presentation in numerical or graphical format, multi-curve graph, generating curve min-max, choice of scales
- Data correction
- Generating polynomials or splines to complete periods

- Creating Tables (provisional, permanent...)
- Managing databases
- Statistical functions (analysis of correlations, calculation of standard deviation, dispersion curve...)
- Calculation of isometric curves
- Data export in various formats

4. Real-time connection of sea-level sensors to the National Tsunami Watch Centres

4.1 The solution developed in Portugal

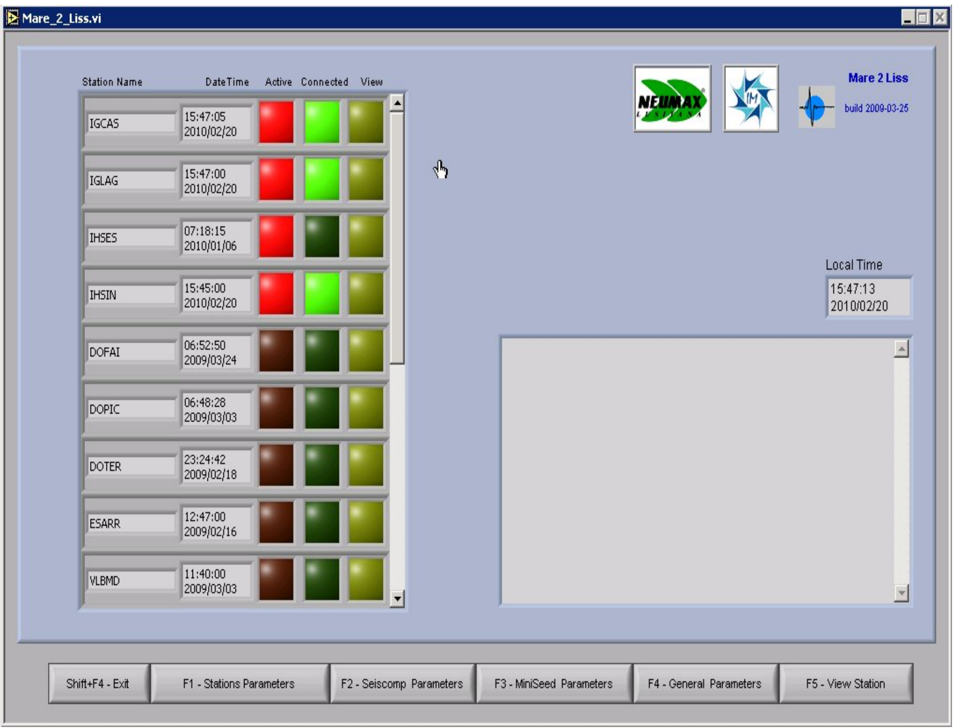
In a region, like the North-East Atlantic and Mediterranean Sea, where destructive tsunamis are generated very close to the shore, the timely observation of sea level data to confirm or cancel a warning is essential.

We have seen in the previous paragraphs that in the NE Atlantic there are a number of existing and operating coastal tide-gauge stations but the access to data is trough public Internet links, with very large time delays (more than 10 minutes). To circumvent this difficulty it was decided in Portugal to work as much as possible with the well-proven Seiscomp system to collect sea level data, as well as seismic data. Using the Seiscomp data collector IM profited from all the quality control tools (QC) that have been already developed, besides the technical support by GFZ and German developers. The Seiscomp approach could be followed for most of the Portuguese available tide-gauges but not for the stations operated by other countries, where another approach was designed.

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 we needed the development of one plug-in application (Mare2Liss; see figure 4.1.1) that continuously monitored the ip ports and translated all information available into another format, miniseed, that Seiscomp could read. The Mare2Liss also acts as Liss miniseed server (Slad et al., 1998) making, this way, data stream available at an output port for Seiscomp. This is the standard way that Seiscomp acquires real-time data, continuously listening to a pre-defined set of data ports. The development of this plug-in was made by a contract to external assistance, supported by NEAREST.

Currently a total of 8 channels from 4 tide-gauge stations are continuously collected at IM and integrated with Seiscomp. The list of these channels is given below.

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



Figur214.1.1 Mare2Liss main screen. The IH and IGP stations are the first four. The remaining five are not beeing received due to reasons explained in the text (DOP and OSTENDE stations)

At the IM Seiscomp data collector another problem had to be solved. In fact the ftip address where data is available from Sines and Sesimbra stations is defined dynamically, meaning that every now and then, with some days interval, the ftp address changes. The information of the change is send by e-mail to IM that has to process that information and update the plug-in with a minimum of time delay.

We must also stress that the current communication link established to collect these tide gauges is not ideal for an operational TWS. It is desirable that in the future a more resilient and reliable link may be established, like satellite VSAT, as it is recommended by International Agencies and as it is already used for many seismic stations received by IM.

As regards the Ponta Delgada tide-gauge, operated by IH and integrated in the GLOSS network, the data is provided trough the GTS 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, identified by the code 354271CC, 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.

On figure 4.1.2 its possible to see the real-time display of data from four of the tide-gauges that are available at IM data center.

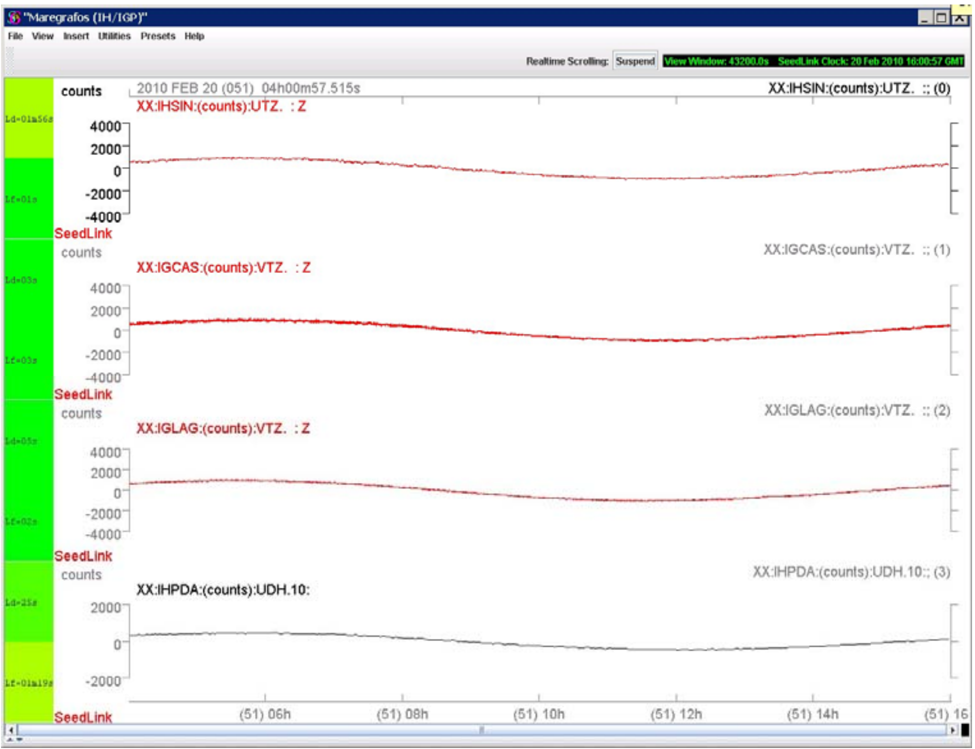


Figure4.1.2: Display of tide-gauge signals (Sines, Cascais, Lagos and Ponta Delgada)

To be able to act as a Regional Tsunami Warning Centre for the North-East Atlantic, any candidate has to collect sea level data from other coastal countries like Spain, Morocco, France, the UK, and Ireland and also from the Caribbean and Eastern United States. As we have seen, many of these stations provide data over the public Internet at dedicated web pages. Using appropriate applications, the web pages can be queried and new data can be collected. This is the approach that was tested at IM using the Tsunami Analysis Tool developed by Alessandro Annunziato and colleagues from the Joint Research Centre in Ispra, Italy.

TAT is used at IM for Tsunami analysis and integrates seismic parametric data and tide-gauge data provided by the Seiscomp server. The sea level data is used to evaluate if a tsunami was indeed generated after a large earthquake. Using the plug-ins developed for TAT any station from the GLOSS network, from Puertos del Estado in Spain or from DOP-UAc in the Azores can be read, independently from the Seiscomp. However this solution proved to be too time-consuming for practical purposes. For instance, the recovery of each station from Puertos del Estado takes near 1 minute. We were also able to verify that the delays in data availability were too high for the application to tsunamis generated close to the shore. As we mentioned before, Internet communication links should be avoided on an operational TWS due to: lack of reliability, no 24/7 service warranted, large data latencies.

The current status of the sea level data collection at IM is illustrated on figure 4.1.3 The 17th December 2009 a magnitude 6.0 (ML) occurred on the Gulf of Cadiz. The earthquake was felt in Portugal and also Southern Spain and Morocco. Figure 4.1.4 illustrates the recordings from the 4 costal tide-gauges a few hours before and after the earthquake. The focal depth of this event was larger than 40 km and this is the most probable reason that no significant effect is seen on the records.

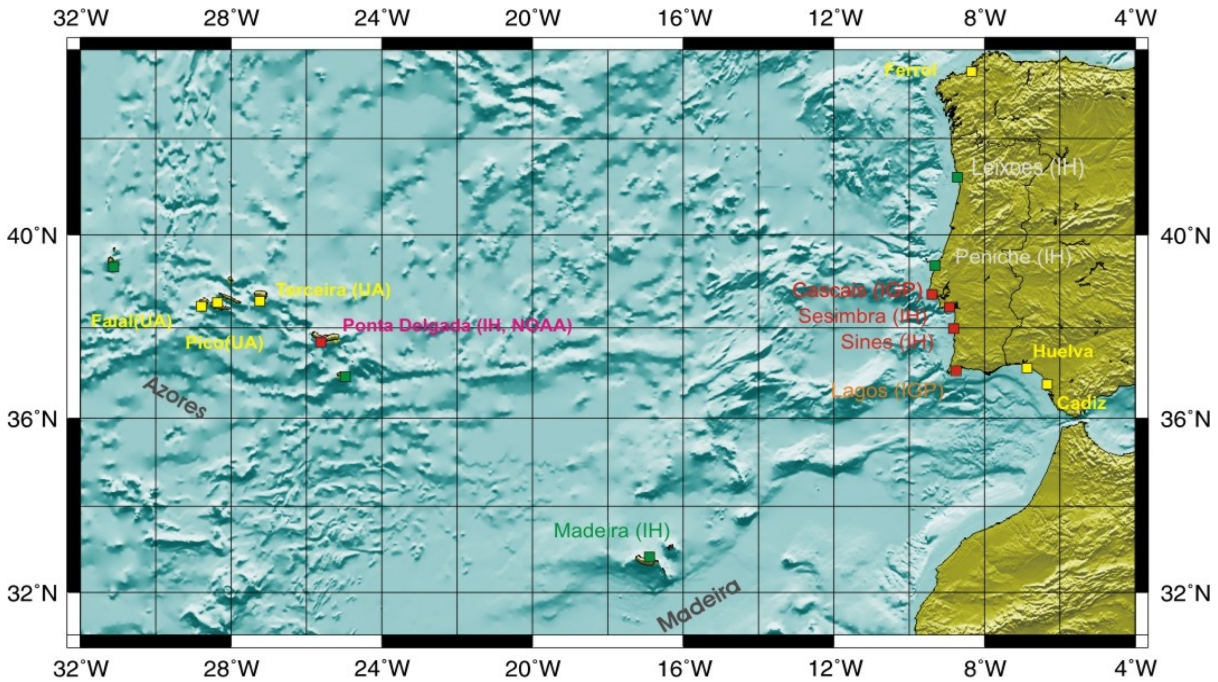


Figure 4.1.3 – Current status of the coastal tide gauge collection at IM. Red squares, real-time connection via Seiscomp. Yellow squares, near real-time connection trough Internet and TAT. Green squares, expansion of the network planned for 2010.

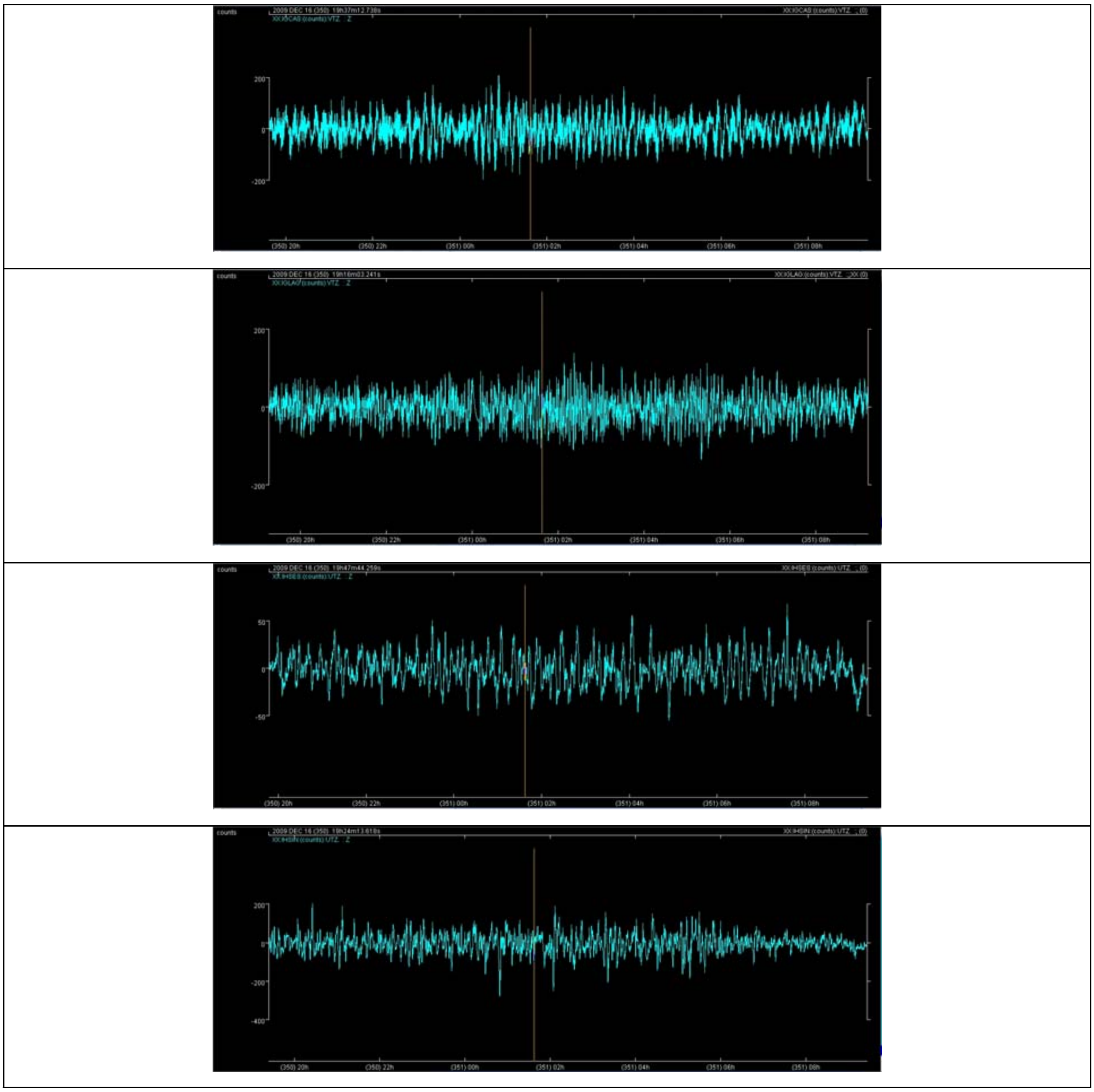


Figure 4.1.4 – Tide-gauge recordings from the Cascais, Lagos, Sines and Sesimbra stations the day a magnitude 6.0 earthquake occurred in the Gulf of Cadiz, the 17th December 2009 (origin time marked by yellow line).

4.2 The solution planned for Morocco

Initially two solutions have been proposed for sending data in real time to ING-CNRST data collector. Both options were envisaged but just for the medium term until the installation of other gauges in the future real time tide gauge network.

The first solution (1) consist of sending real time data from tide gauge to ING-CNRST data collector via the WAN of Casablanca port, Internet and finally the CNRST WAN see Figure 4.2.1. a. This solution (1) is made possible with the help of he LAN adapter eDevice-

200 of the gauge interfacing data logger with Ethernet local Network. This solution is interesting in term of cost and ease of implementation. However it has two points of weakness. The first one is the requirement to pass through the WAN's of Casablanca port and the CNRST. Any interruption of service of segments involved in the connection of these two networks will affect data continuity. The second weakness lies in the segment of the Internet connection that remains in spite of a weak link that may experience a service interruption more or less long, or at least congestion in the data flow. These limitations mean that even though this solution is attractive can't be retained for long-term use in a tsunami warning system.

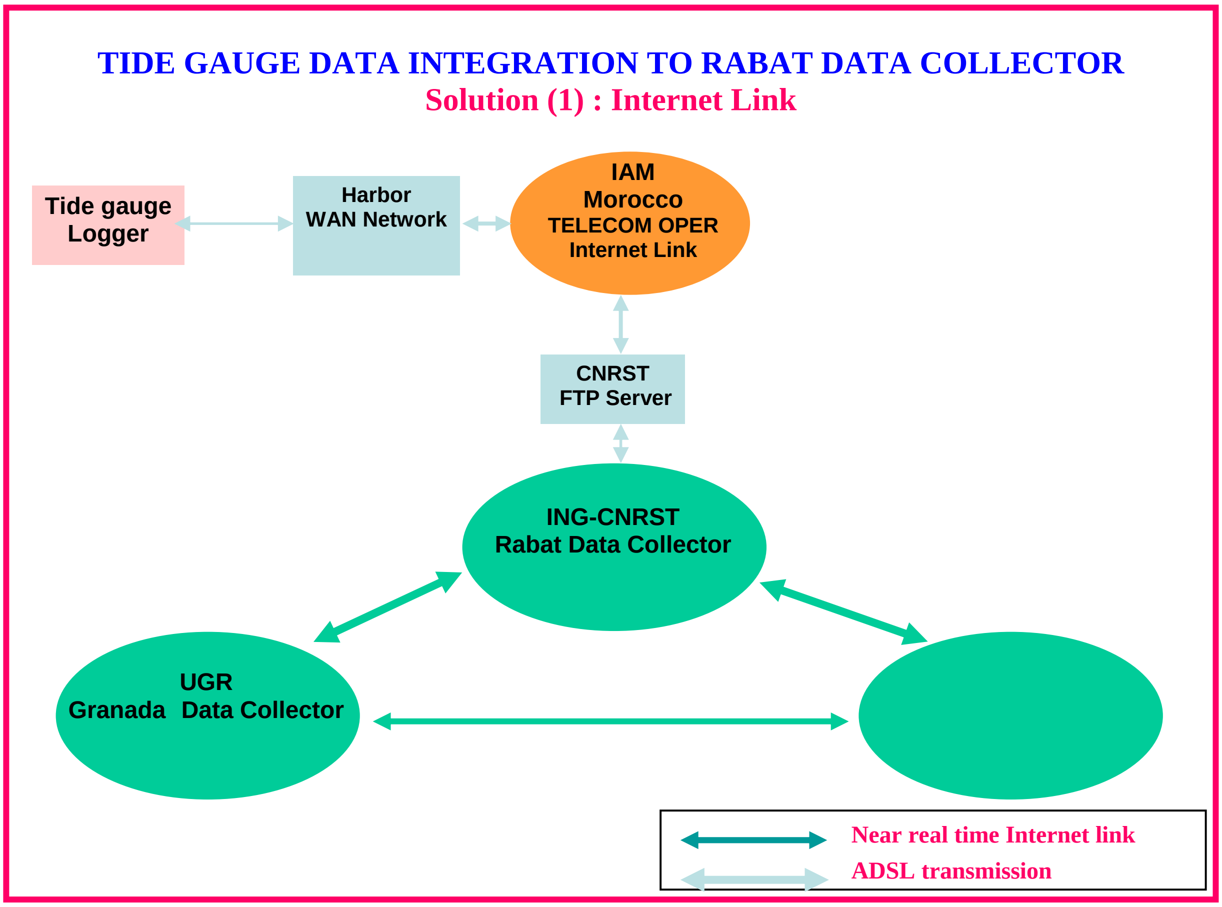


Fig. 4.2.1.a - Tide gauge data integration to Rabat data collector - Internet & WAN configuration (solution (1)).

The second possible solution (2) (Figure 4.2.1.b) plans on using a direct ADSL link between the ING-CNRST data collector and tide gauge. Such link that does not involve local networks can experience problem only if ADSL is subject to the operator service interruption.

However ADSL lines are not so reliable and interruption more or less long are possible. Also this solution requires a subscription to an ADSL line, to which one must add possibly the high costs of installing a new telephone line if a pair of phone line is no more available at the VTS, witch is located several hundred meters from the port entrance. For all this reasons we opted first for the solution (1) described above, through the port WAN, CNRST WAN and Internet.

In both cases, i.e. solution (1) or solution (2), real-time data from tide gauge will be made available at the FTP server of the ING-CNRST data collector for the benefit of the port, DPDPM and NEAREST data collector responsible for the tsunami warning.

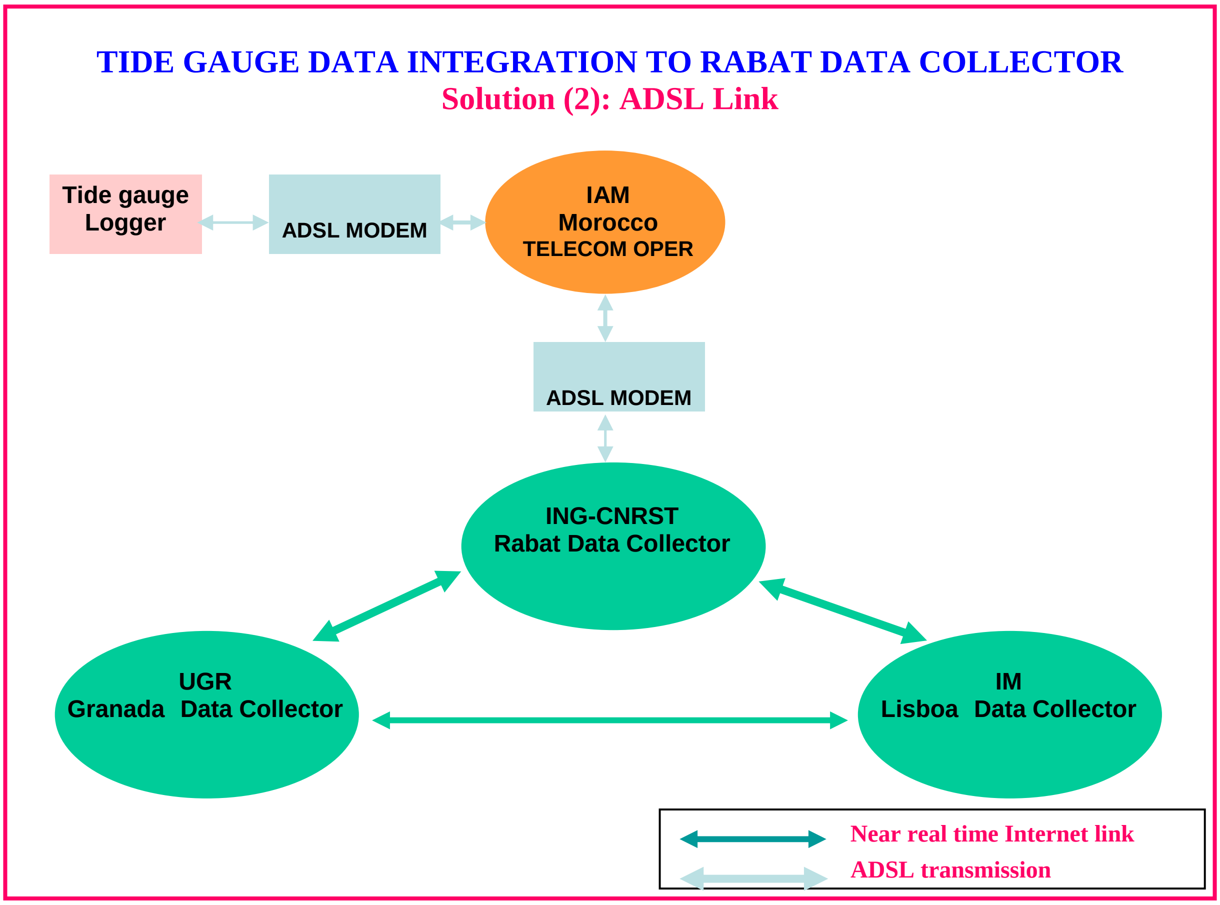


Fig. 4.2.1.b - Tide gauge data integration to Rabat data collector - ADSL configuration (solution (2)).

The configuration of the gauge was therefore made, when installing the gauge during August 2009, in accordance with solution (1). Unfortunately the installation coincided with a broad program of renewal of the complex WAN network of the Port of Casablanca, which covers several administrations and buildings in a wide area with number of routers and Fire Walls. The commissioning of the new network was scheduled in gradual and progressive manner while respecting priorities. This took almost 3 months, and the complete migration to the new network was finished by early December 2009. Thus the testing of FTP connection between gauge and CNRST FTP server could not be performed before the end of the first week of December.

Unfortunately, when tested 8 December 2009, this connection has not fully worked. We tried then to isolate the problem by testing the FTP connection between a PC instead of a tide gauge and the FTP server CNRST. The result is that the FTP session worked well under Windows. While when the test is done under DOS system the session opens well but limits certain FTP commands such as 'put', 'get' or list. This seems likely due to restrictions at the firewalls level. The team operating the new network has promised to try solving of this problem and to call if necessary the company having commissioned. During this visit we were able to retrieve data stored in the gauge of more than one hundred days. These data are presented in Figure 4.2.2.

However, fearing that this leads to further delay has led us to consider the second solution based on an ADSL line. At the time of this writing, a subscription to an ADSL line between the Casablanca port and the FTP server CNRST has been sent from ING to CNRST administration. If the administration accepts the CNRST financing of the subscription fees, but especially the cost of installing a new telephone line if a pair is not available at the VTS, the gauge connectivity to the server CNRST will be made immediately after the line installation.

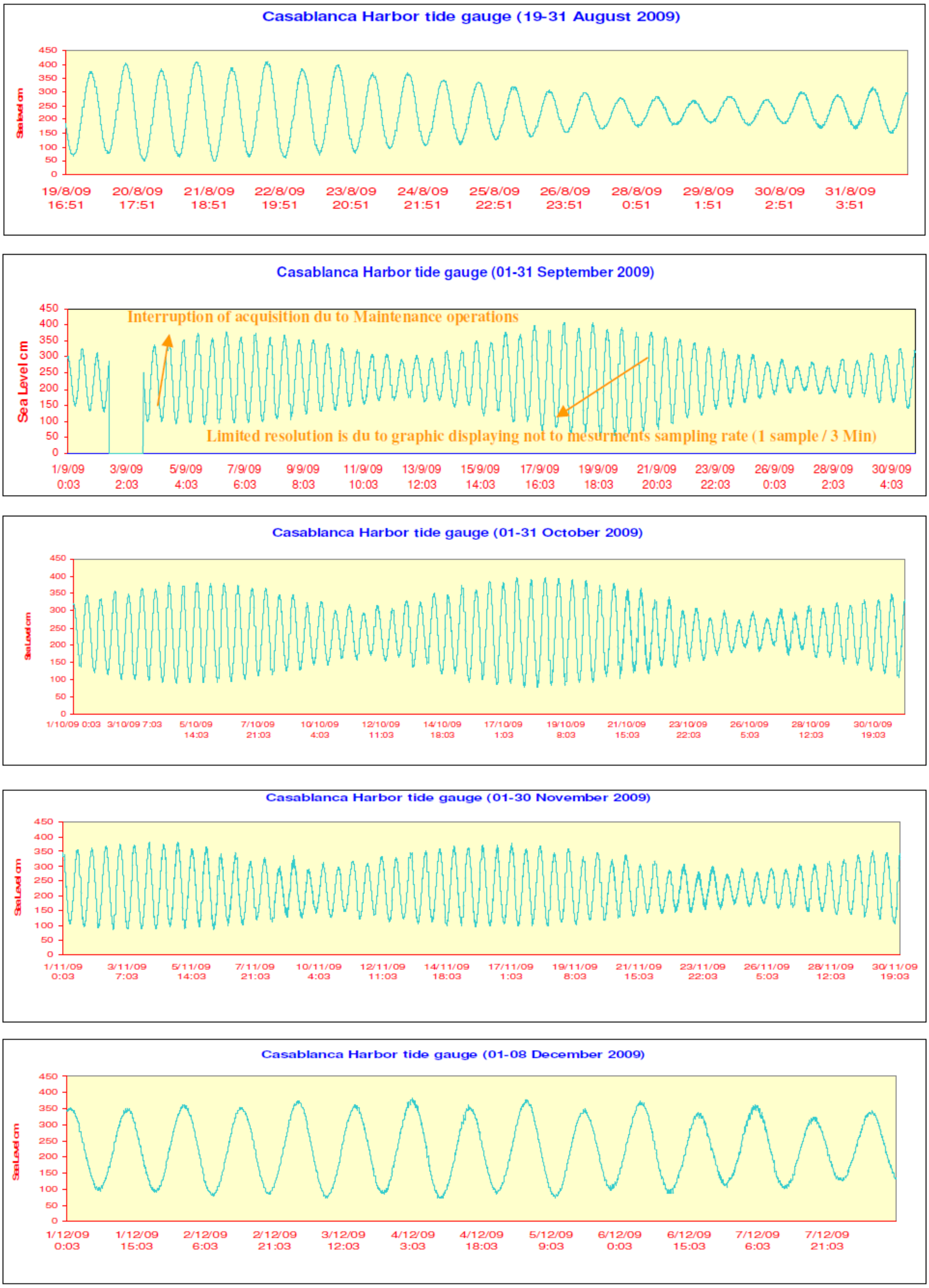


Fig. 4.2.2 – Sea level data recorded by Casablanca Port tide gauge between 18 August and 8 December 2009.

5. Future perspectives

5.1 The situation for Portugal and Spain

In 2010 we expect that the new costal tide-gauges planned by IH at Peniche, Leixões, Santa Maria and Flores, as well as the existing Madeira station, can be connected in real-time to the IM Seiscomp data collector, using the connection links provided by IH.

The Portuguese Tsunami Focal Point (IM) will continue the negotiations with Puertos del Estado to improve the current access to their costal tide-gauges in Spain mainland and the Canary Islands.

In 2010 the first dedicated tide-gauge operated by IM will start operation, thanks to an agreement with DOP-UAc that allows the use of their facilities.

In 2010 we will continue negotiations with the Pacific Tsunami Warning Center to provide a few of their costal tide-gauges data over GTS to IM. In exchange, the sea level data collected at IM will be also made available to the PTWC, depending on an agreement from the data owners, IH and IGP.

5.2 The situation for Morocco

Some of the type of configuration connectivity gauge chosen for this first phase of the gauge exploitation, the final configuration will certainly be using the VPN (Virtual Private Network) which is planned to deploy when will change or upgrade already existing gauges for real-time connectivity probably in Tangier and Agadir. The VPN solution is among the most reliable type of digital transmission. The VPN service is based on secured dedicated digital lines, more, it guaranties in case of temporary line failure an automatic switching on redundant lines avoiding service interruption. This feature is obviously ideal for a service like a tsunami early warning system.

The major drawback of this solution is by far the very high cost. This cost can be profitable and cost effective if the VPN is used for a minimum number of terminal equipments, i.e. multiple gauges in our case. This results in lowering the cost of data flow by channel. That’s why we reserved this very reliable solution for the near future once we incorporate at least two other gauges namely of Agadir and Tangier. Meanwhile, the tide gauge data will continue to be transmitted in real time data collector by CNRST solution 1 (WANs and Internet) or solution 2 (ADSL).

Working already in the perspective of enlarging to others gauges, ING began with the help of DPDPM to lock for possibilities of upgrading the gauge of Tangier port for real time data transmission. So a CNRST- DPDPM common visit to Tangier Port was organised during last October 2009 see figure 5.2.1

Once the real time gauge network is fully operational in Morocco, and if the real time data sharing will continue in the region (outside the NEAREST project or as part of its extension), ING-CNRST plans exploiting and developing results produced in NEAREST framework, namely the algorithms and procedures for early detection of tsunamis in the region. One of the present objectives of ING-CNRST is to make the tsunami warning system an integral part of the system deployed by ING-CNRST for earthquake monitoring and warning. This will address a need increasingly voiced by the Moroccan authorities in terms of tsunami warning. These same authorities are also increasingly seeking more of tsunami hazard assessment on the Moroccan coast in general, in order to be taken into account in policies for management of natural hazards.

Fig 5.2.1 ING-CNRST and DPDPM common visit to Tangier Port to look for possibilities of upgrading the gauge for real time data transmission

6. Recommendations

IM:

The major problems facing the sea level data collection at IM from tide-gauges are the following:

(i) Unreliability of most of the communication links

(ii) Non-sustainability of the system due to lack of long-term commitments

(iii) Lack of deep-ocean observations, essential to provide early warning to the closest costal areas.

It is recommended that the future Tsunami Warning System must rely on dedicated satellite connections. This requires some level of funding that is not planned in the near future. The long-term sustainability of the sea-level monitoring network has to be ensured by National Agencies, but it is not predicted to occur in the near future. The same level of support is required to establish a network of deep-ocean observatories. Currently there are no serious technical difficulties to the development of the National or Regional Tsunami Warning Centres. The only item missing is political and funding support.

CNRST:

Given the importance of assessment and reduction of tsunami risk in the Ibero-Maghreb region, it would be regrettable not keeping the efforts that have been already made by the various partners in the framework of NEAREST project, mostly work aiming to develop a prototype of an tsunami early warning system. It is highly desirable on this subject to work towards a broadening of the necessary infrastructure for such systems, it is seismic, tide gauge, or even a permanent multiparameter ocean-observing system, and continue the development of algorithms and procedures for fast detection of tsunamis in the region.

It is interesting to note, that unlike earthquake alert, tsunami warning leaves a margin of time to act and reduce the impact on human lives. However, this warning based primarily on seismic early detection, needs to be fairly accurate, reliable and efficient, validated by high seas observations and measurements of coastal tide gauges installed at a regional scale.

This need for deployment, on a large geographical scale, both seismic networks as well as marine and coastal observations, gives the tsunami warning a regional character that requires collaboration between different countries facing the same risk. This regional collaboration is necessary as the costs for setting up such warning system can be high enough to be supported by a single institution, mainly the acquisition, deployment and operation of a permanent observatory on the high seas.

The National Institute of Geophysics under CNRST, for its part, has decided to work in this perspective, trying to provide adequate means, and stands ready to continue regional collaboration that can address these concerns.

7. References

eDevice technology eDbox-200 user Manuel.

eDevice technology eDsoft_commands Manuel.

eDevice technology eDsoft_parameters Manuel.

OTT LogoSens data logger use Manuel.

OTT LogoSens operating program Manuel.

OTT Hydras 3 Receiver documentation.

OTT Hydras 3 software Manuel.

Slad, G.W., R.L. Woodward and C.R. Hutt, 1998. Live Internet Seismic Server: Open Distribution of Near-Real-Time Data via the Internet, abstract. EOS, **79**, no. 45.

Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas, NEAMTWS, Implementation Plan, Version 3.4. Intergovernmental Oceanographic Commission, Technical Series 73, 2009.