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)

D16: integration of seismicity data

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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.16 Integration of seismicity data

Task 5.1 Leader: UGR

Task 5.1 Responsible: José Morales

Authorship:

This report has been compiled by José Morales with the contributions from the main partners involved in the management of the national and regional seismic 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. Fernando Carrilho from the IM and Abdelouahad Birouk from CNRST they completed the report with their contributions related with their seismic networks.

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1.- Introduction and objectives.

In the last decade the number of on scale high-quality broad band seismic stations deployed in the Iberia Peninsula and Morocco increased significantly. The lack of broad band seismic stations in the 90's has changed in the present to a new framework where the different agencies contribute to have a high density spatial distribution of seismic stations. The improvement in the distribution, space covering and quality of the seismic stations deployed allows to work with a high number of data that improve in a quantitative way the epicentral locations of the seismic activity of the different seismogenetic regions. The main objective of the different institutions that operate in the region: national or at regional level, is the monitoring of the seismic activity that takes place in the Euroasian-African (Nubia) plate boundary (Gulf of Cadiz-South of the Iberian Peninsula - North of Africa), where the high seismic rate is due to an oblique convergence (around 4-5 mm/year) between the above mentioned litospheric plates. As response to this oblique convergence together upper mantle processes related to the Gibraltar arc generation, a partitioning in the seismic strain take place in the region facilitating different seismic styles that goes from a dominant reverse faulting component in the Algeria coast and in the SW Iberia earthquakes, strike-slip faulting in the *Trans Alboran shear zone* or extension in the Alborán sea (Stich et al 2006).

This brittle seismic strain release mainly microseismic and low seismic activity ($Mw < 5.5$), with moderate earthquakes ($Mw \approx 6.5$) spaced in the time (i.e $Mw=6.3$, Alhoceima 2004 earthquake). This seismic rate path is mainly restricted to the south Spain-Alborán-north of Morocco region with an spatial width that may reach several hundreds kilometres. In other hand, large earthquakes ($Mw \approx 7$) also occur in the SW Iberia and Algeria coast, which can generate tsunamis that affect to the surrounding coasts. For instance the Mw 6.9 May 21, 2003 Algeria earthquake generated a tsunami after the earthquake along the coast of northern Algeria. It was reported significant damages in the ports along the southern coasts of the Balearic Islands north of the epicentral region. Early reports describe waves of 1 to 3 m in amplitude which damaged many hundreds of vessels in the various harbours. Waves from the earthquake region are computed to arrive at the ports in the islands approximately 40 to 60 minutes after generation.

Special case, fundamentally of the Gulf of Cadiz, to generate earthquakes of magnitude Mw> 7 are well documented in the historic seismic catalogue and also in instrumental period. The earthquake of November of 1755, of Mw > 8, was a dramatic example of the potentiality of the region to generate big earthquakes and tsunamis that attack the costs of the SW of Iberia and North of Africa in less than a half of hour approximately.

Before the *Nearest* project, the seismic monitoring facilities around the Gulf of Cadiz comprehend autonomous systems operating on each of the concerned countries: Portugal, Spain and Morocco, without interconnection.

Now the new broad band equipments and other types of seismic stations deployed in the region (Iberian Peninsula and north of Morocco), together the new communication technologies allows approaching in the integration of seismic data belonging to different networks managed by different agencies, configuring a *Virtual Seismic Network in Real Time*. The data collection of seismic data in real time allows having parametric data of seismic source and location of the seismic activity only few minutes after the origin time of the earthquake.

In this deliverable we want to show the advances obtained by the three partners (IM, CNRST and UGR) that manage seismic networks in their regions with the objective of:

1. Upgrade and update the seismic instrumentation both in hard and software.
2. To look for technological initiatives that allows the seismic monitoring in real time compatible with their respective networks, with low-consume equipments and with different data transmission.
3. The share of raw seismic data in real time among the partners as well as with other national or regional organisms operating in the region with seismic networks.

The achievement of the main objectives will allow to the different seismological agencies to give fast information of the parameters of the seismic activity. The coordination among these agencies and others that operate in the region it will be fundamental to achieve the final goal to fix of a focal point dedicated to the surveillance and quick answer of the seismic activity in the tsunamigenic region of the Gulf of Cádiz.

2.- Situation of each seismic node previous to *Nearest* :

An interesting way to value and to evaluate the changes carried out by the different partners involved in this workpackage is to observe the evolution that have taken place in the different seismic networks during the developed during the *Nearest* project to get the objectives marked in the different tasks.

2.1.- IM seismic network before "Nearest"

2.1.1. The Short-Period network

Instituto de Meteorologia (I.M.), from Portugal, was running a network of 14 enhanced short period stations (SP), consisting on sensors with flat velocity response in the band 0.2-50Hz and equipped with acquisition systems with 16bits of dynamic. In the southern part of Portugal there were 3 of those stations operating (figure 1), and the remaining 11 were installed in Mainland and Madeira archipelago. Five of those stations were transmitting data through a VSAT link into de I.M. headquarters, and the remaining 9 stations are accessed via dial-up processes over public telephone lines (analogue and IDSN). The VSAT stations were called each minute, and the remaining ones each 15 minutes. If an event was detected then the on duty operator triggers data retrieve from the other stations.

2.1.2. The Broadband network

There was only one BB stations operated by I.M. At Manteigas, on I.M. facilities, there was a GEOFON broadband station (STS-2 sensor, Quanterra digitiser and SeiscomP datalogger), with data being sent on a dial-up process over a IDSN line to I.M. headquarters (each 15 minutes) and then to Potsdam (GEOFON Data Center) by Internet.

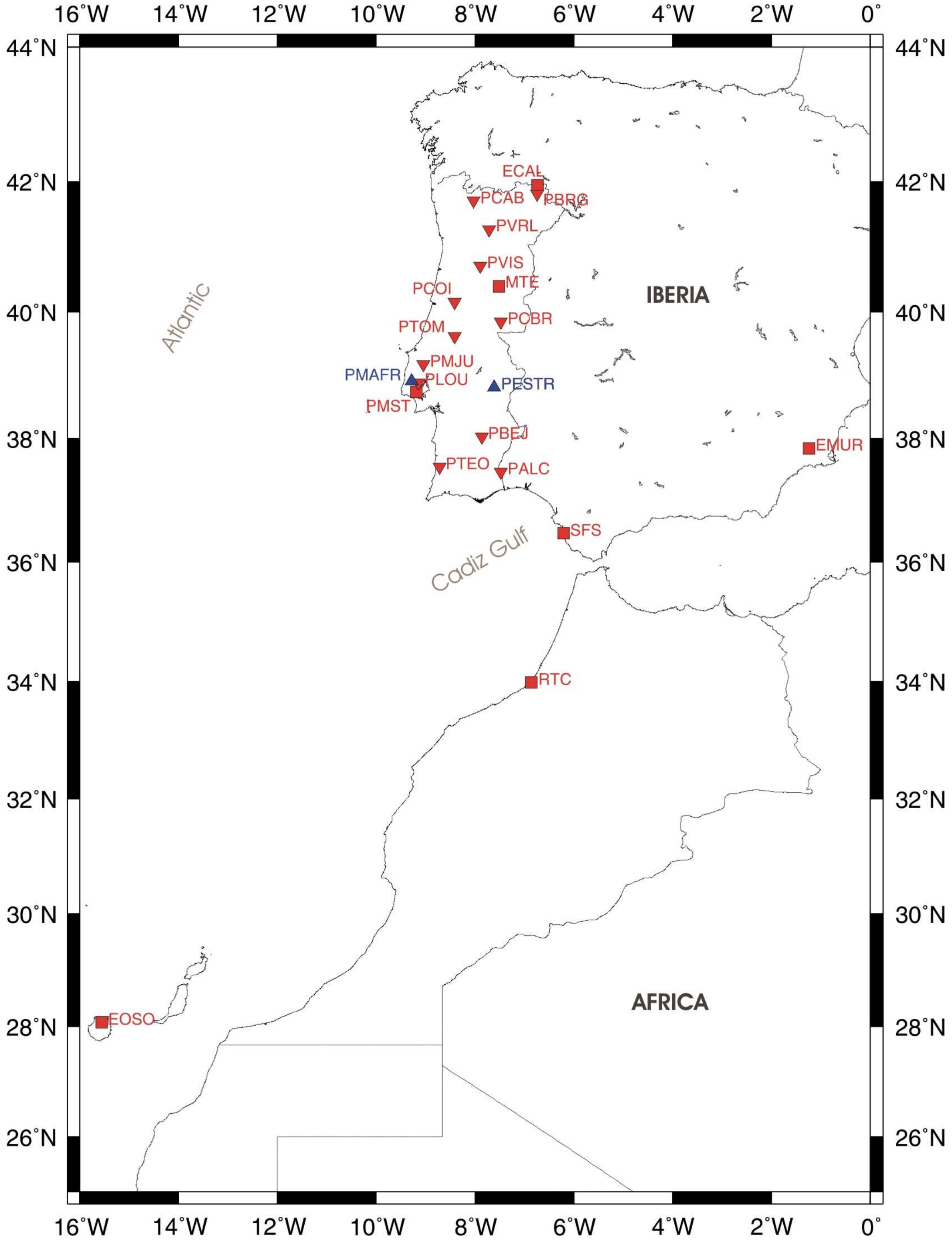


Figure 1. Seismic stations available at IM before NEAREST

By that time it was also possible to access to few other BB stations that were transmitting data to international data centers, such as ORFEUS, in near real time. In particular, there is a station operating near Lisbon (PMST) belonging to IST, a MEDNET (Mediterranean Network, from INGV, Italy) station installed at Rabat (RTC), Morocco, a ROA station at San Fernando (SFS), and three IGN stations in Canarias (EOSO), southern Spain (EMUR) and Northern Spain (ECAL). Those stations were sending data to the mentioned ORFEUS Data Centre in the environment of the VEBSN (Virtual European Broadband Seismic Network) project.

However, during the period of NEAREST and thanks to a major funding from the Portuguese Science and Technology Foundation (MODSISNAC project), contributions from a Portuguese Oil Company (GALP Energia) and IM own budget, it was possible to implement a new seismic network during the period mid 2006 to 2009 (Carrilho *et al.*,2007).

After July 2006, twenty one new broadband stations have been installed on the mainland, Azores and Madeira archipelago (figures 2 and 3), connected in real-time by VSAT to the IM headquarters, in Lisbon.

Figure 2. Seismic station of Vaqueiros (PVAQ), Algarve (Installed on an old mine). Left: Guralp 3T broadband seismometer and Guralp 5T accelerometer; Earth Data 24 bits PS2400 digitizer, modem and Pc interface where the data are locally stored in at 30 Gbytes hard disk. Right: Seiscomp PC (storage disk for 60 days of autonomy), VSAT modem unit, batteries (communications autonomy for 4 days; data acquisition autonomy of 10 days), charging control unit).

All of the new stations are equipped with broadband sensors (Guralp 3T , Guralp 3ESP Compact and STS-2), strong-motion sensors (Guralp 5T and Kinemetrics Episensor), 24 bit digitisers (20 Guralp DM24 and 1 Quanterra Q330) and Alpha2000 PC's (Linux) for local data storage and communication managment.

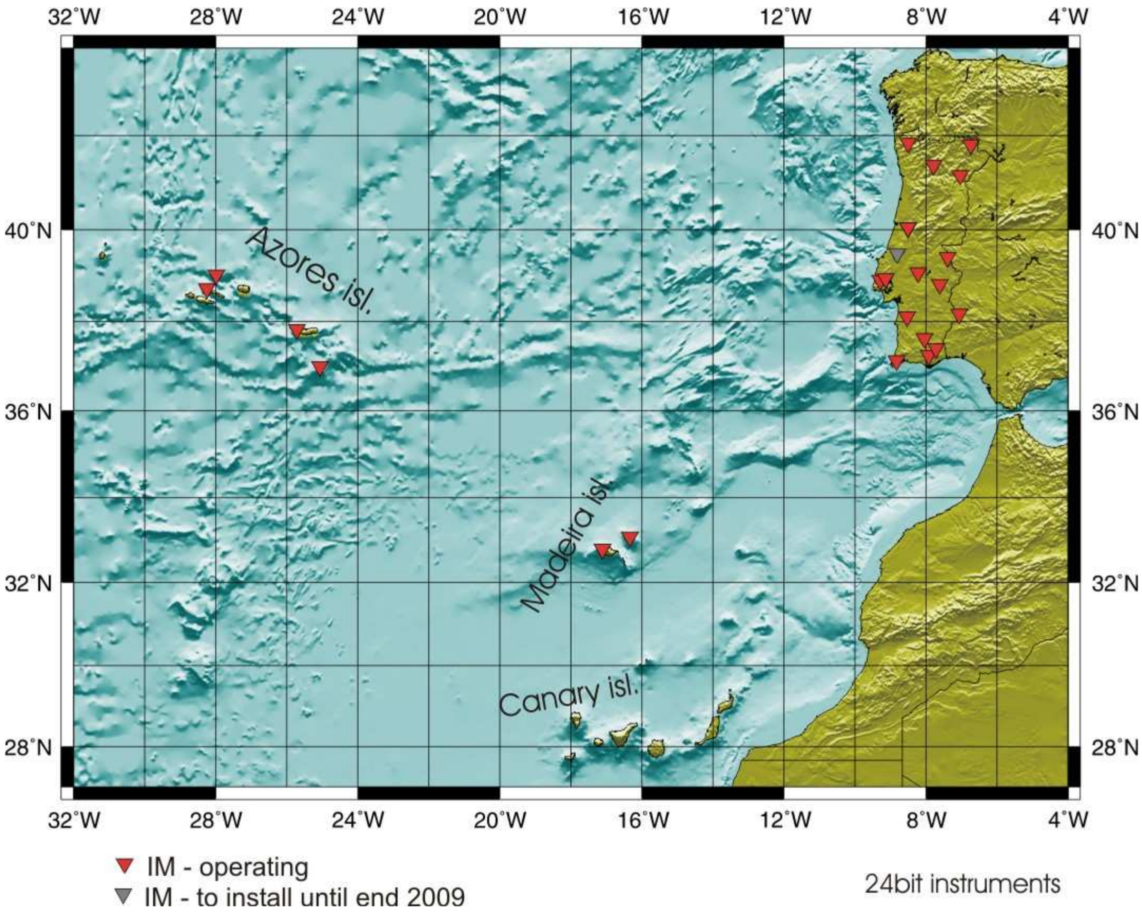


Figure 3. IM National Seismic Broadband Network

2.1.3. Data acquisition

Data acquisition was performed using very distinct processes, such as RCM software (from Lennartz Gmb), AutoDRM email protocol as well as Seiscomp 2.1, and the waveform raw data was not easily integrated into a common system. The event waveform data was then exported into SEISAN where data analysis (hypocentre location and magnitude determination) was carried out.

By that time it was not possible to receive continuous data.

2.2.- CNRST seismic network before “Nearest”

2.2.1. Telemetered network

In the eighties, the CNRST deployed a seismic network is a “ first generation digital network” type where signals in analog form are transmitted in real time to a recording central facility where data are digitized and time stamped. This network is still running and consists of about 30 short period analog seismographs distributed on 7 sub-networks. Each station of a sub network uses a double frequency modulation (audio band & UHF band) and uses UHF radio links to send data to regional sub-network center. The regional centers demodulates the UHF channels and mixes the audio frequency data before transmission to the Rabat recording centre by means of leased phone lines.

Figures 4 and 5 show respectively the spatial distribution of the seismic network and an example of a sub network.

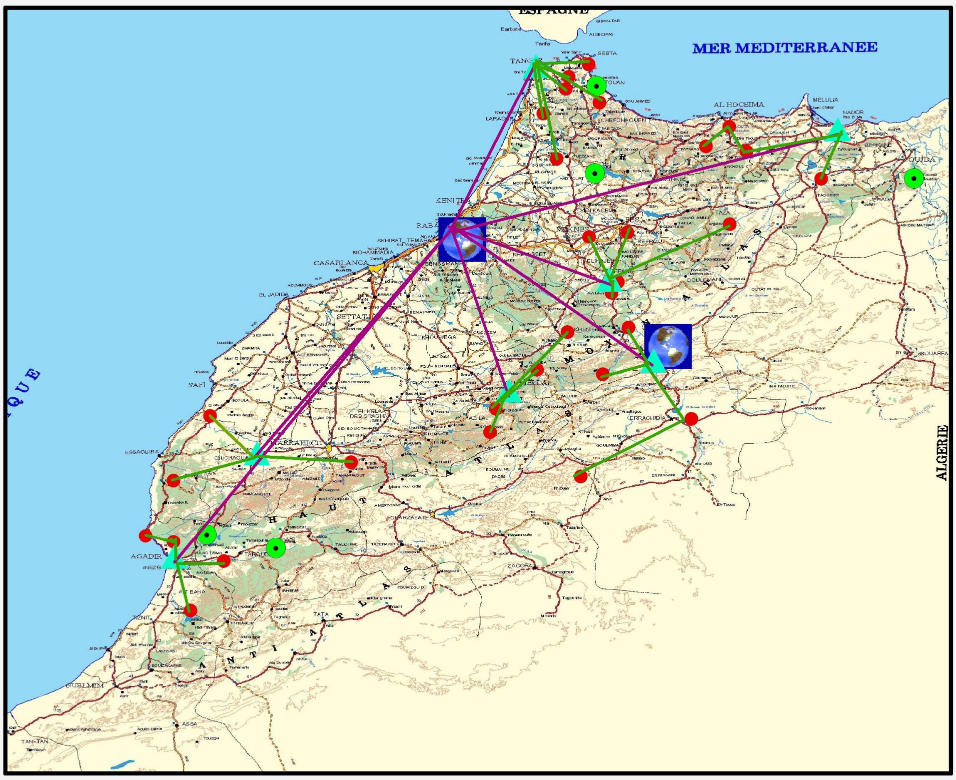


Figure 4. Spatial distribution of the Moroccan seismic network

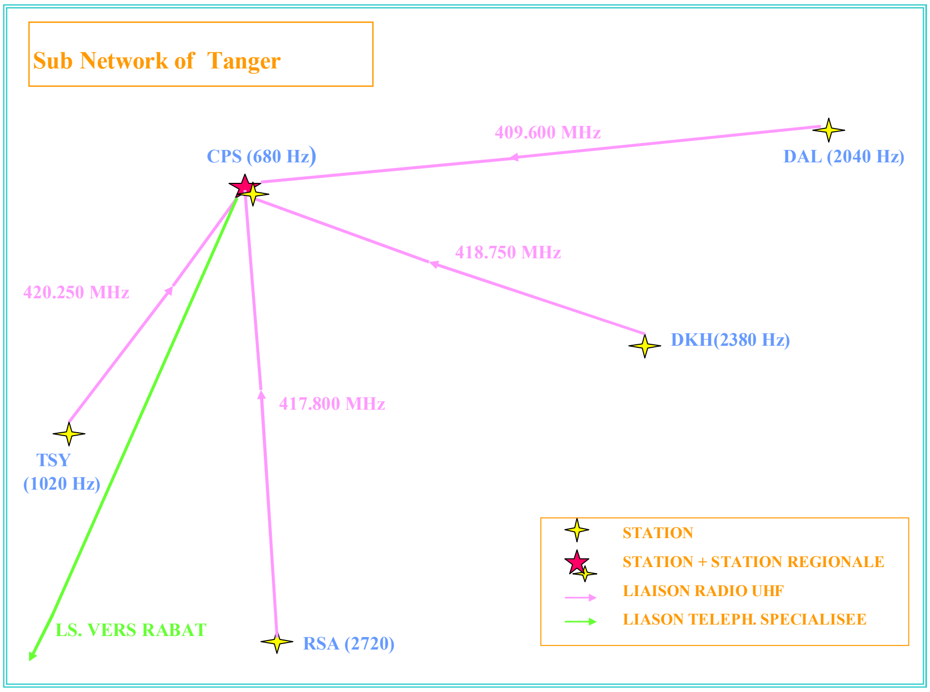


Figure.5 example of the Tangier sub-network

2.2.2 Data acquisition system:

The data received from the seven sub-networks at the Rabat recording centre is demultiplexed and demodulated using suitable electronics boards, before being sent to two different recording systems.

The first one is a continuous analog recording system that uses 32 paper drums as shown in the figure 6. The second recording system is a digital triggering system that works as follows: After an analog to digital conversion, data are processed by acquisition software called SNAP (Seismic Network Acquisition Program, from Kinemetrics Inc.). The SNAP software uses the STA/LTA algorithm for channel triggering in addition to the voting and coincidence approaches to define the overall system triggering. Channels and region (group of channels) voting and weighting parameters are manually and continuously adjusted depending on the current signal quality of different channels (stations). Coincidence applies simultaneously to both channels and regions of the Seismic Network. The recorded Data are stored on hard disk in order to be processed.

Data processing is made by various programs. The first program called SWS (Seismic Work Station) is rather primitive software which works under MS-Dos and uses Hypo71 as location software. The data processing can also be made using more sophisticated software such as SEISAN or SAC by means of a data format conversion tools.

The Moroccan real time seismic network is used to monitor the Morocco seismicity in real time. Whenever a detected seismic event is situated in Morocco or its surrounding area and the magnitude is greater than 3.5, an alert is addressed to national and local authorities dealing with seismic hazard mitigation. A duty service 24H/day and 365 days/year is established for this purpose.

The seismic data detected by the Moroccan Seismic Monitoring and warning Network (RESAS) serves also for a better understanding of the seismicity of Morocco by through scientific studies and also serves for seismic hazard assessment studies ordered by many public and private institutions.

2.2.3 Mobile Seismic Stations:

A number of equipments consisting of nine analog, six digital portable seismographs and seven digital accelerographs are kept ready to be quickly deployed in case of a significant seismic event for aftershocks recording.

Other seismographs are installed temporarily in some regions with specific interests but not covered by the telemetered network or where a greater density of seismic stations is needed.

Figure 6. Continuous recording system with GPS receiver

2.2.4 Broad band stations

In addition to the short period stations, the CNRST seismic network includes a VBB station installed in Rabat and a BB station in Midelt.

The station of Rabat (RTC) was installed in collaboration with the INGV of Italy and is part of the MEDNET network in the south Mediterranean. This station has an important role especially for the monitoring of teleseisms in the region. Below is an overview of the station and its equipments (figure 7).

Figure 7. Equipments at Rabat broad band seismic stations

A sun workstation running Seiscomp 2.1 is used to acquire data from the Q680 digitizer via RS-422 serial link. The data of this station are sent to the INGV MedNet Centre via internet.

The BB station AS066 in the region of Midelt is an auxiliary station of the International Monitoring System (IMS) implemented by the CTBT Organization to monitor underground nuclear tests. A VSAT link is used to send data to the International Data Centre (IDC) in Vienna and Moroccan National data Centre (NDC) hosted by the CNRST. Figure 8 shows the equipments installed at the Midelt site.

Figure 8. Equipments at Midelt broad band seismic stations

At the NDC, a sun workstation is running the CDtools software to acquire data. The CTBTO's GeoTools package is used to process data of the AS066 station and other seismic data available from the IDC.

2.2.5 Strong motion network

The CNRST strong motion network consists of 48 Units. All are digital instruments. The most of the network is installed in large dams for structural seismic monitoring. The rest of the network is deployed for site effect studies projects. All acclerographs data is stored locally in RAM or flash memories. Although all units support telemetred data transmission only few units are accessed remotely because of the unavailability of phones lines or because the link is not cost effective for the nature of application.

2.3- The IAG-UGR seismic network before "Nearest"

The principal characteristics of the IAG-UGR seismic network (IG international seismic code) before the beginning of the "*Nearest*" UE project can be summarized as follow.

The IAG-UGR is composed by a total of 22 seismic stations (13 broad band and 9 short period), distributed mainly in southern Spain.

2.3.1- Broad band network

The spatial distribution and configuration of the broad band seismic network is shown in figure 9. The geographical distribution and main characteristics of each station is also described in the Table 1. The broad band network consists of a total of thirteen seismic stations based on triaxial seismometers Streckeisen STS-2 (100 s of natural period). Each seismic station has a high resolution digitizer Earth Data 24 bits (PS2400), which is time-synchronised with a Garmin GPS receiver. The digitiser is connected through a serial port to the datalogger (an industrial PC with a 30 Gbytes hard disk), where the sampled signal at 50 s.p.s is stored in half-hour ringbuffers, under the control of *Seislog*, a software package (Utheim and Havskov, 2001) installed in the field stations and running under QNX operating system. *Seislog* writes continuous data files and by means of a simple STA/LTA detection algorithm also produces event files.

The figure 10 shows the typical elements configuration of a broad band field station.

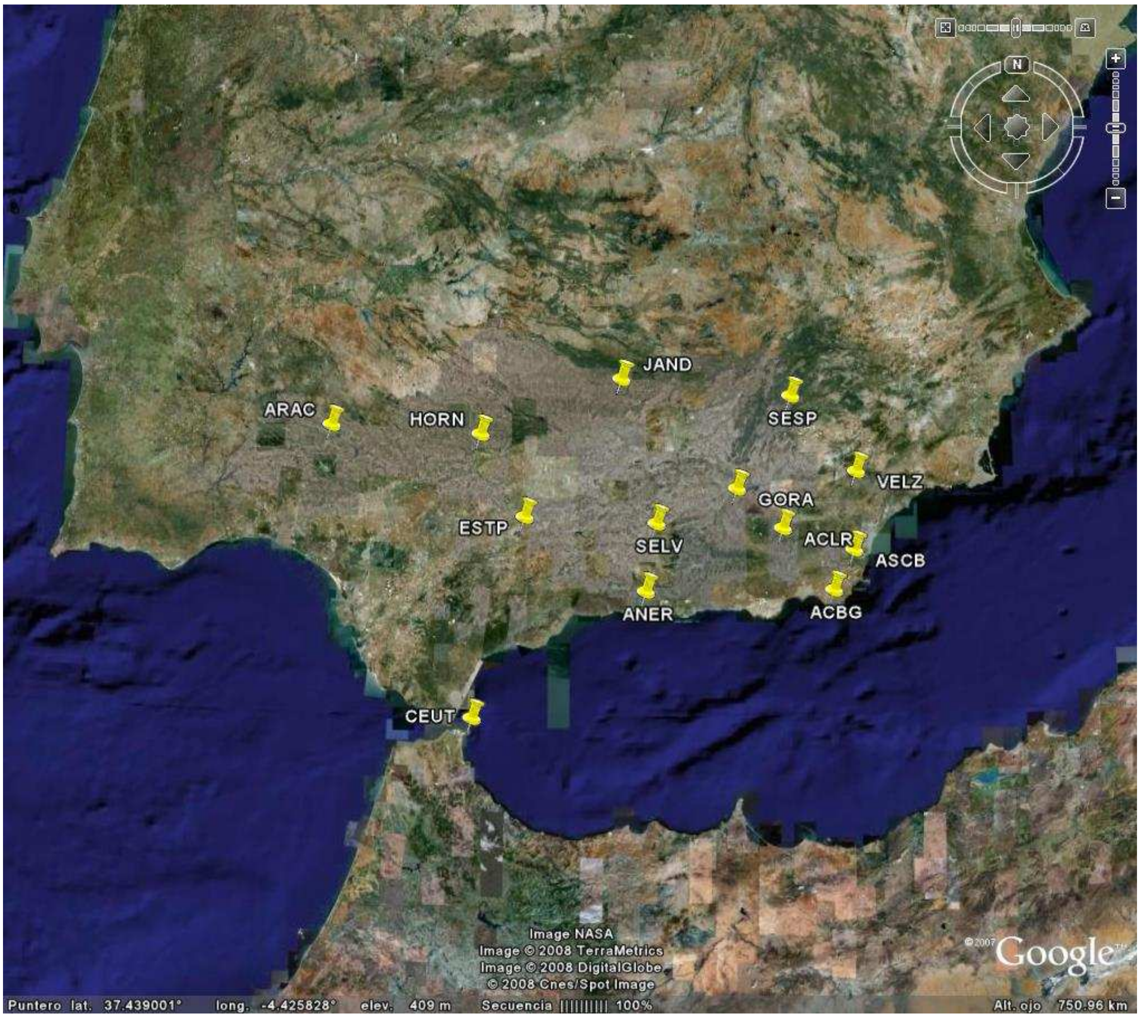


Figure 9. Google earth image where the spatial distribution of the Broad Band seismic network managed by the IAG-UGR is shown.

The data communication between the central recording site (Instituto Andaluz de Geofisica) and the seismic stations were implemented in several ways, depending of the infrastructure available in each place. GSM mobile communication for data transmission is used in VELZ, ESTP, ACLR, ASCB, and JAND. ADSL line (presently 256 kbaud) was installed at SESP, ARAC, GORA, SELV, ANER and HORN and for CEUT we use a high speed intranet line of the Granada University since this station was located at the Granada University Campus at Ceuta.

Figure 10. Field elements that conforms the broad band seismic station. Left: Earth Data 24 bits PS2400 digitizer, modem and Pc interface where the data are locally stored in at 30 Gbytes hard disk. Right: triaxial Streckeisen STS-2 broad band seismometer.

Table 1.- Geographic coordinates and installation date of the IAG-UGR broad band seismic network

	Latitude (N)	Longitude (E)	Elevation (s.l.m)	Installation (mm/yy)	Transmission
SELV	37.23	-3.72	650	05/97	ADSL*
ANER	36.76	-3.84	170	11/99	ADSL*
VELZ	37.58	-1.98	1000	10/98	Cellular/GSM
SESP	38.12	-2.54	1528	08/02	ADSL
GORA	37.48	-3.03	895	04/01	ADSL
ESTP	37.21	-4.86	893	08/00	Cellular/GSM
ARAC	37.89	-6.56	675	11/02	ADSL
HORN	37.84	-5.25	268	04/03	ADSL
ACLR	37.18	-2.58	1490	04/04	Cellular/GSM
ASCB	37.03	-2.00	550	11/03	Cellular/GSM
CEUT	35.88	-5.36	100	06/04	Intranet/Internet
JAND	38.22	-3.97	645	05/06	Cellular/GSM
ACBG	36.76	-2.19	64	04/05	Cellular/GPRS*

* The transmission was changed during the *Nearest* project

2.3.2- Short Period network

Additionally, 8 short period stations (ASMO, ACHM, ALOJ, APHE, ATEJ, AAPN, AFUE and CRT) are also operating at present around the Granada basin in south Spain (figure 11). Those stations are situated at distances of up to 60 km from the central recording site at IAG. The sensors are vertical 1 s of natural period, except for station CRT, where a triaxial extended seismometer up to 10 s. was installed. In this case the data transfer uses real-time analogue radio-telemetry where the signals are recorded continuously on drum paper in analogue format. Also an algorithm installed on a PC declared events in digital form using the STA/LTA ratio.

Figure 11. Google earth image where the spatial distribution of the short period seismic network managed by the IAG-UGR is shown.

The soft dedicated to the recording and management of the seismic data (both broad band and short period) is resumed as follow:

The *Seisnet* (Ottemöller and Havskov, 1999) package to combine seismic stations of various types with communication capabilities into a network was installed on a Sun work station under Solaris 8.0 platform. The main routines carried out by *Seisnet* are transfer of parametric data, network event detection, transfer of waveform data and automatic determination of epicentre location and magnitude. The data are stored in a central *Seisan* database.

The *Seisnet* process started up every thirty minutes. It will then collect data from short period and broad band with TCP/IP protocol (intranet or ADSL facilities). Data from BB with modem (phone or GSM) was only collected regularly at night time in order to save communication costs, except in the case of an important local or regional event, in which case the data were gathered by the operator as soon as possible. For short period and broad band stations under dial-up protocol, only data segments (event data) are transferred. Broad band stations under TCP/IP protocol provide a continuous time series of half hour data blocks. To obtain and store continuous data for those broad band stations without TCP/IP protocol, every 3 to 4 months the stations are visited, checked and all the continuous data are recovered.

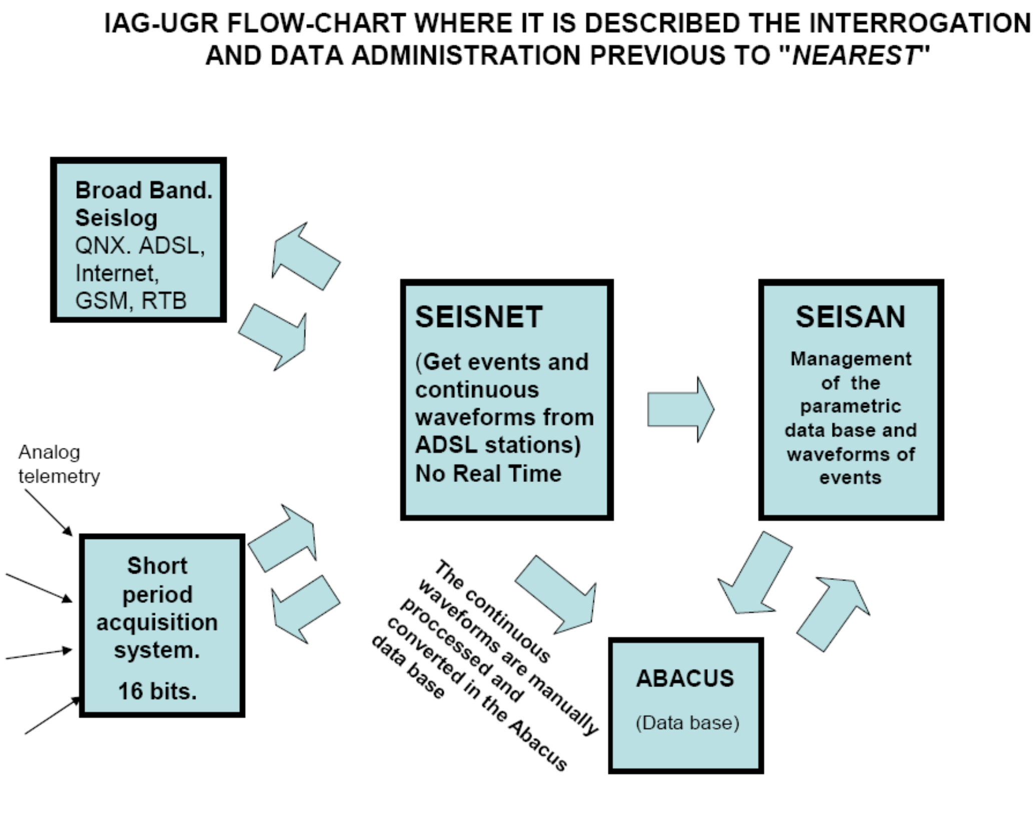


Figure 12. Operational flow chart of the IAG-UGR previous to the Nearest project.

The *Seisan* package (Havskov and Ottemöller, 1999) is used for most of the routine data analysis at the IAG. This system organizes data from all kind of seismic stations into a simple database. Seisan comprises all the tools needed for routine processing, and also conversion to other standard seismic data formats to be used in external software. The Seisan database facilitates research tasks, currently focused on regional studies of earth structure and seismic sources. In the figure 12 is shown the flow chart in the acquisition and management of the seismic data before *Nearest* project.

3.- Strategies adopted by each node for the integration of seismic data in Real Time during *Nearest* project:

3.1 Real time data integration in the IM

IM has adopted the SEISCOMP system (GEOFON, Potsdam) as the standard for data acquisition and automatic event detection.

3.1.1 Upgrade of the SP network acquisition systems

The older SP stations (Lennartz Mars88 (digital) and Lennartz (analog)) have been integrated into the new acquisition system (figure 13). Regarding the older analog stations, the data digitised at IM data center was then converted into miniSeed and exported to a Seiscomp central machine (Geo2Sei). In what respect to the Lennartz stations (extended short period stations), an upgrade on the comunication system was performed and Internet DSL connections were addopted to most of the stations. Also software tools were developped in order to request data in continuous mode from the stations to a central machine, at IM, where the information is converted to miniSeed and exported into the main Seiscomp machine. This allowed IM to have almost real-time data (data latency from 90 sec up to 2 min) from the extended SP network.

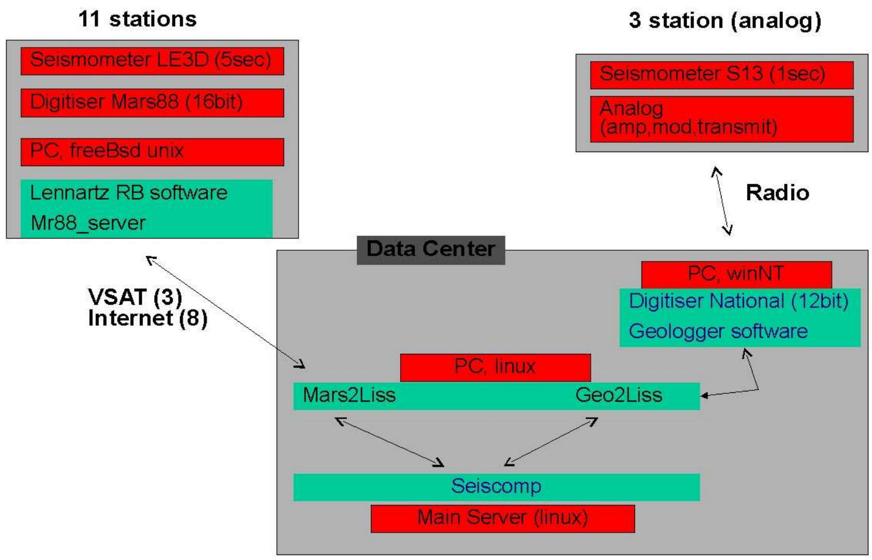


Figure 13. IM Short Period network data flow schema

3.1.2. Implementation of the main data and processing server (TREMOR)

In parallel 15 new broadband stations have installed in Portugal mainland, transmitting real-time data via VSAT links. In order to have some redundancy on the system, two distinct satellites are used making it possible to guarantee that half of the stations can be available in case of major faillure on one of VSAT systems. At station sites, Seiscomp 2.1f is used as the standard for local data aquisition and communication managment.

At the central facilities, in Lisbon, Seiscomp 2.6 was addopted for data aquisition and automatic processing. The schema implemented is as showned in figure 14. Presently 25 stations are received by VSAT and a total of 42 (21 broadband) by Internet (figure 15). Data is transferred using the Seedlink protocol into a central machine, designated by TREMOR. From this machine continuous data is archived into a Storage Area Network available at IM facilities. A second feature is the Automatic Near Real Time Processing:

- The detection phase is guarantied by the AutoPick tool (implemented in Seiscomp), that generates a list of arrivals and amplitudes to be used by further processes;
- The automatic location is performed by AutoLoc tool which, however, has some limitations, being the major one the fact that only P arrivals are used and the velocity model is the global IASP91 (not suitable for Cadiz Gulf region);
- Finally there are some StateofHealth tools, namely Seisgram display tool (*Figure 16),* data latency control (given by Seiscomp) [Figure 17, left], the StatOH tool that displays relevant information on station state of health parameters (developped at IM) [Figure 17, right] and the ContQual tool (Madureira *et al*, 2009) that computes several statistics of the station noise making it possible to evaluate the quality of the station signal along the time (developped at IM) [Figure 18].

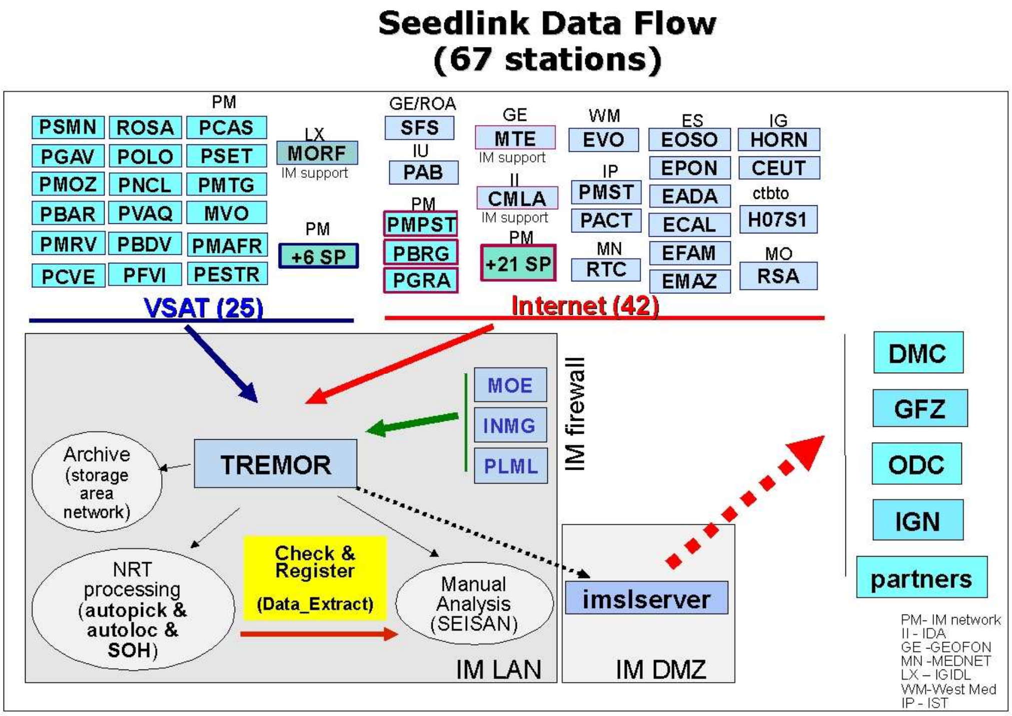


Figure 14. Seedlink data flow at IM

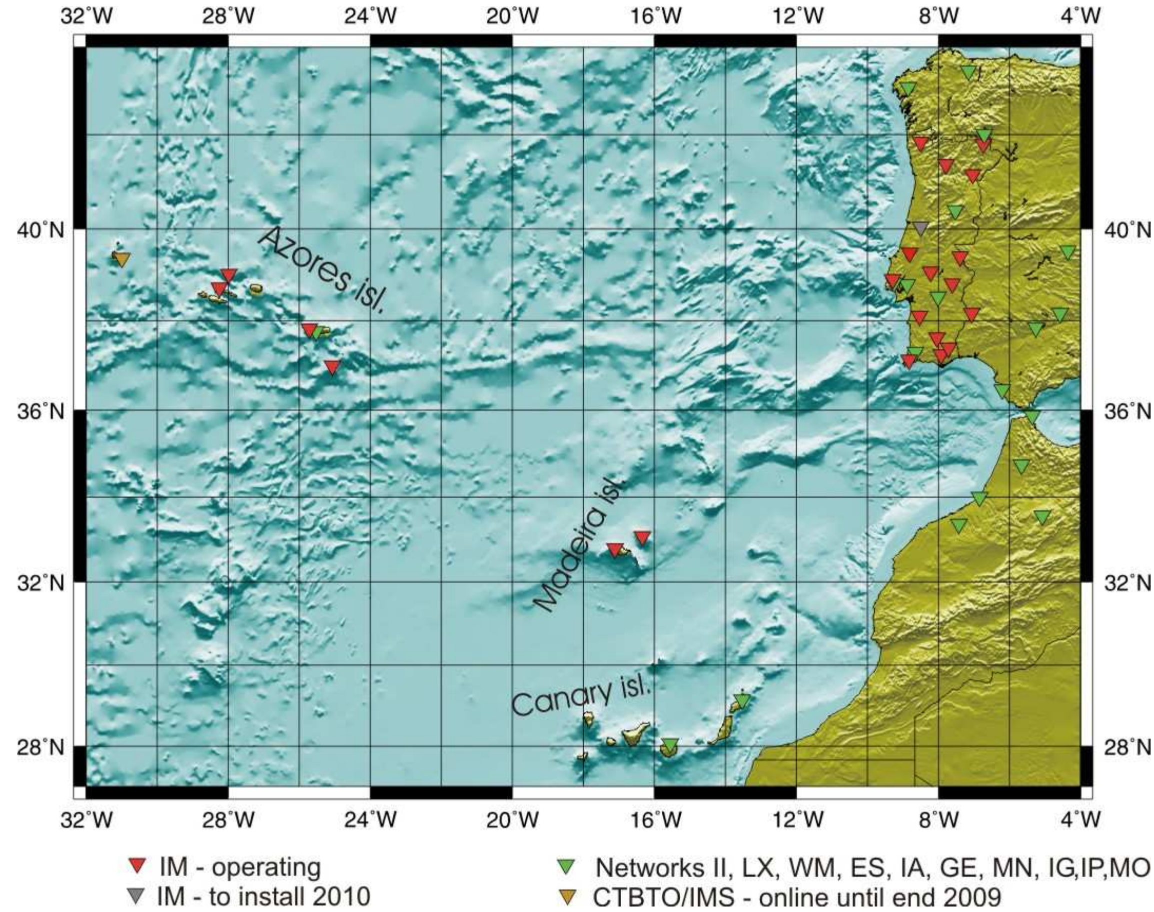


Figure 15. Broadband network presently available at the main server (networks: IM-Instituto de Meteorologia ; II-IDA (San Diego, USA); LX – Univ.Lisbon; WM – Western Mediterranean Network; ES – IGN (Spain); IA – USGS; GE-GEOFON; MN-Mednet; IG-Granada; IP-Inst.Sup.Tecnico (Portugal); MO (CNRST);

The data analysis is performed with SEISAN. The connection between the Seiscomp and the SEISAN platform is established by the DATA_EXTRACT software (developped at IM), which is used to check the triggers and to export valid events it into SEISAN data base. This DATA_EXTRACT software (figure 19) listens to the AutoPick outputs and generates alarms to the on duty analyst, which can then activate the automatic processing and validate the locations using a specific environment build around SEISAN package.

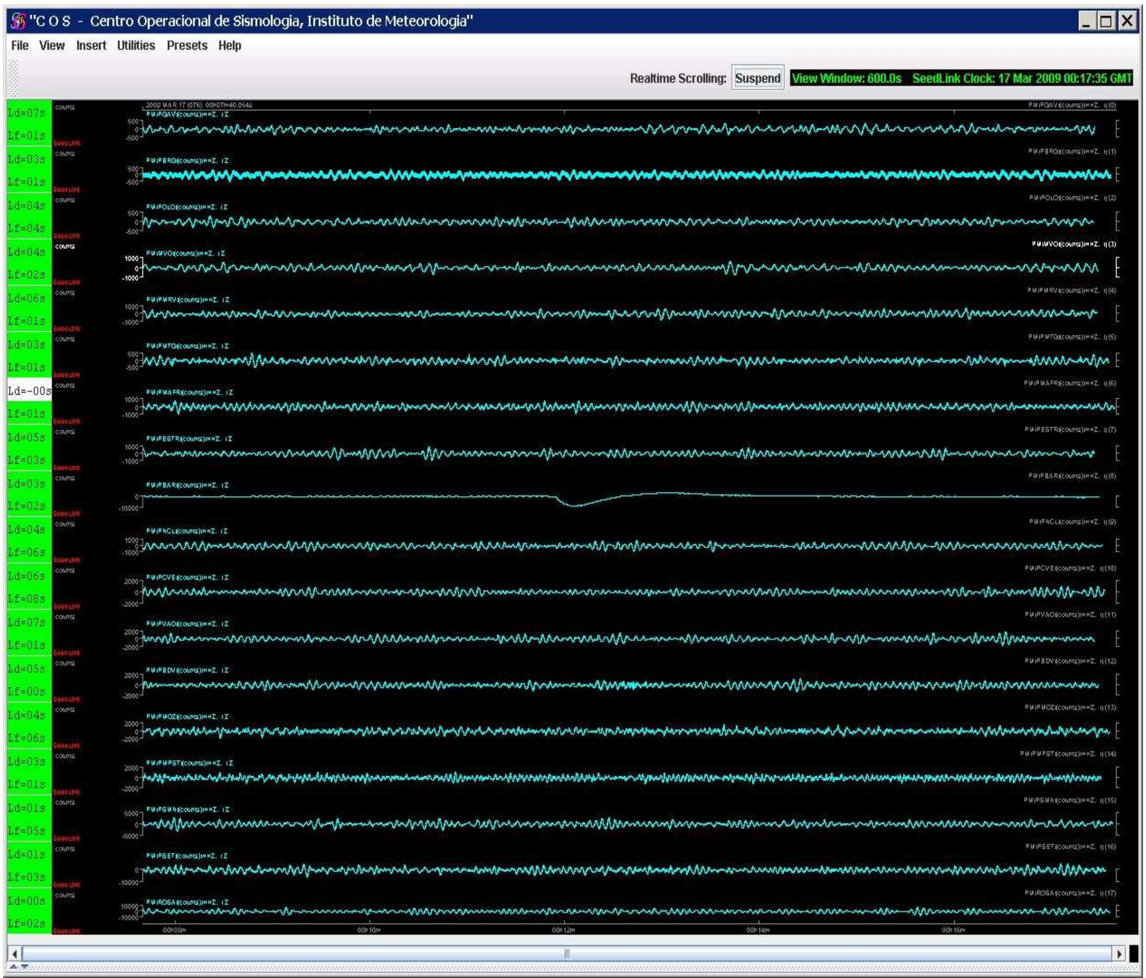


Figure 16. Real-Time display seismic data at IM operational Center (Seisgram software)

Instituto de Meteorologia, NDC Portugal SeedLink Monitor

Real-time stations

Station	Latencies		
	Data	Feed	Diff.
GE SFS	59.1 d	n/a	n/a
WM IFR	41.7 d	n/a	n/a
ES EADA	3.6 d	3.6 d	5.3 s
II CMLA	70.4 m	67.8 m	2.6 m
IU PAB	3.4 m	88.2 s	113.5 s
PM PCBR	2.3 m	8.9 s	2.1 m
PM PMAR	2.2 m	5.4 s	2.1 m
PM PBEJ	2.0 m	2.8 s	119.0 s
PM PCAB	2.0 m	9.8 s	112.0 s
PM PBAR	8.3 s	1.5 s	6.8 s
PM POLO	7.6 s	4.4 s	3.2 s
MN RTC	7.3 s	2.2 s	5.2 s
PM PMRV	6.6 s	1.6 s	5.0 s
WM EVO	6.2 s	1.2 s	4.9 s
IG CEUT	6.1 s	1.4 s	4.7 s
GE MTE	5.7 s	1.8 s	3.9 s
PM PBDV	5.7 s	1.3 s	4.4 s
PM PBRG	5.3 s	1.6 s	3.7 s
PM PMPST	4.4 s	1.0 s	3.3 s
PM PMAFR	2.8 s	0.3 s	2.5 s

Latencies:

<10 m	< 1 h	< 2 h	< 6 h	< 1 d	< 2 d	< 3 d	< 4 d	< 5 d	> 5 d

Last updated 2009/03/17 00:18:37 UTC

Instituto de Meteorologia, NDC Portugal StatOH Monitor

Estação	Data/Hora	Bateria	Drift	MassPos			Temp
PGAV	2009-03-17 00:04:59	13.8	210	0	-15	12	19.6
PBRG	2009-03-17 00:04:59	13.8	210	-4	-11	1	23.4
MVO	2009-03-17 00:04:59	13.1	214	2	-8	-5	17.6
POLO	2009-03-16 23:54:59	13.3	210	0	-18	13	19.4
PMRV	2009-03-16 23:54:59	13.4	210	-10	-7	9	24.6
PMTG	2009-03-16 23:55:00	13.3	220	-7	-3	10	23.4
PESTR	2009-03-16 23:55:00	13.8	266	-3	2	2	25.4
PBAR	2009-03-16 23:55:00	13.0	210	0	-1	3	21.0
PNCL	2009-03-17 00:04:59	13.3	269	11	8	-10	22.3
PCVE	2009-03-17 00:04:59	12.5	203	2	4	-9	21.2
MORF	2009-03-17 00:00:00	13.4	0	-			27.0
PVAQ	2009-03-16 23:55:00	13.7	209	6	1	3	19.6
PBDV	2009-03-16 23:54:59	13.2	256	4	3	4	20.1
PFVI	2009-03-16 23:55:00	12.6	276	-82	88	-11	21.4
PMPST	2009-03-17 00:05:00	12.6	232	-4	-9	10	23.4
PMOZ	2009-03-16 23:55:00	13.6	220	13	-5	8	20.4
PSMN	2009-03-17 00:04:59	14.4	210	0	2	0	24.4
PSET	2009-03-16 23:55:00	12.3	258	-4	5	7	20.5
ROSA	2009-03-16 23:55:00	13.6	186	6	-8	8	20.5

Código:

atraso > 10 h	normal	proximo do critico	valor critico	sem dados

Figure 17. Left: Data Latency control. Right: State of health parameter control (Battery charge, clock drift, Sensor mass positions and temperature inside vault)

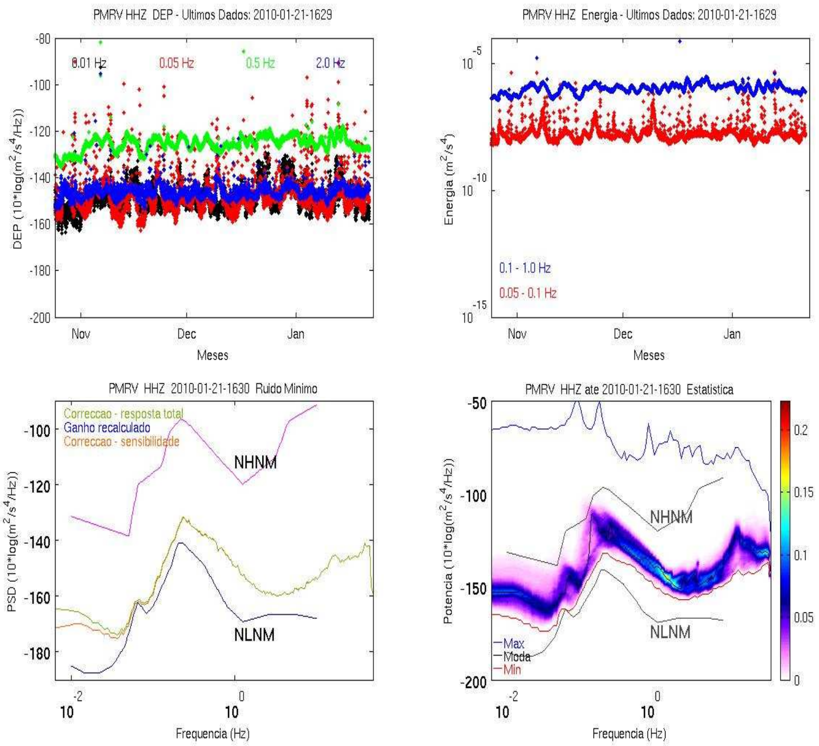


Figure 18. ContQual output for PMRV station. Top-left: signal PSD evolution along the time for 4 central frequencies (0.01Hz, 0.05Hz, 0.05Hz and 2Hz); Top-rigth: signal energy time evolution for 2 frequency bands; Bottom-left: minimum noise (PSD) compared to Peterson (1993) standards; Bottom-righ: statistics of the signal PSD

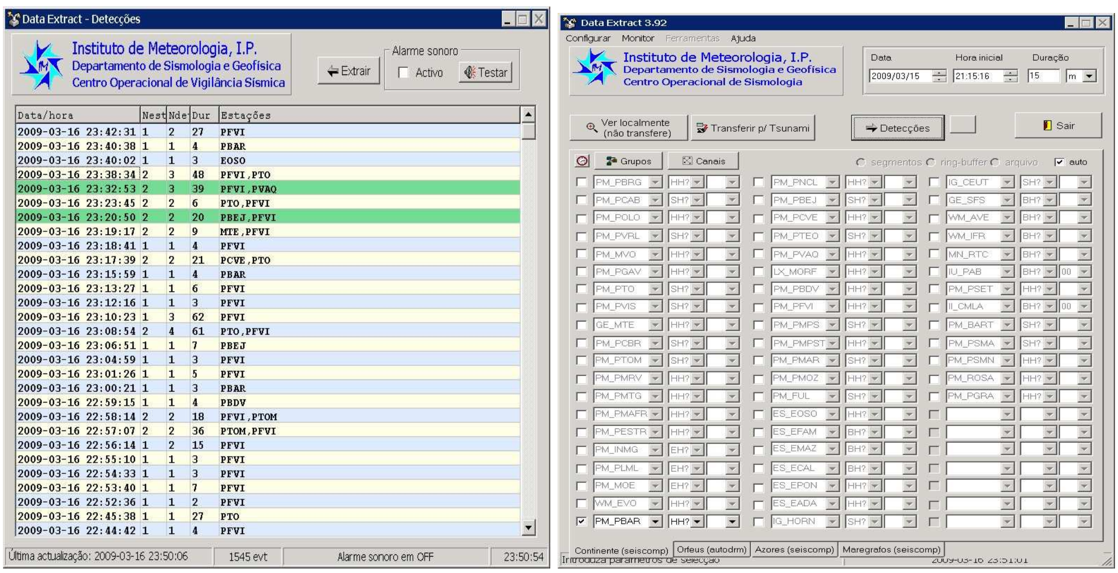


Figure 19. Data_Extract software

3.1.3. Seiscomp 3.0 at rtwc.meteo.pt server

Seiscomp 3.0 is a new version of SEISCOMP released by GFZ Group, first developped to be used within the Indonesia Tsunami Warning System. Further technical details will be given in section 3.3.3.

At IM this platform was installed in 2008, controlling more than 100 seismic stations around the Atlantic (figure 20). The idea was to monitor in real time all the seismicity that might occur in this region, particularly the one that might represent a tsunamigenic threat.

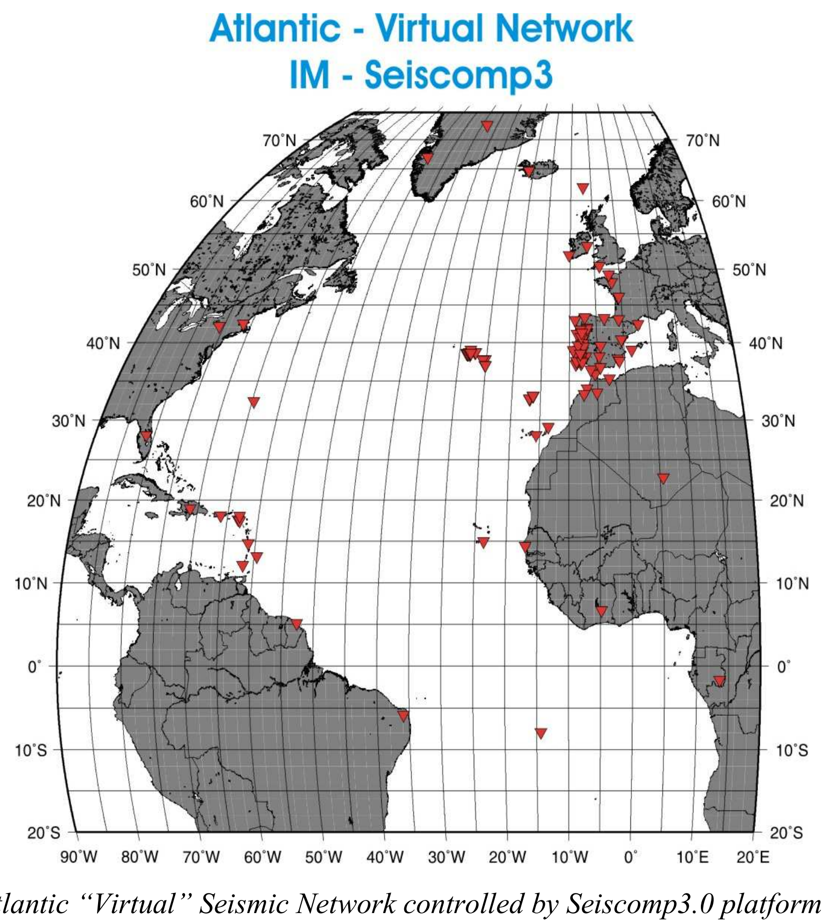


Figure 20. Atlantic "Virtual" Seismic Network controlled by Seiscomp3.0 platform at IM

One of the most interesting features is the capability to quickly estimate hypocenter parameters as well as magnitude, particularly the possibility to compute fast MW (Critical for tsunami potential assessment). However there are still some constrains which comes from the previous AutoLoc versions, namely the difficulty to properly compute travel times using more suitable regional velocity models than the global IASP91, no S arrivals are automatically detected, as well as unproper magnitude evaluation for regional smaller events (measurements are performed on velocity traces; its not possible to include proper ML regional attenuation parameters and station corrections).

3.2 Real time data integration in the CNRST

In the Nearest project, the integration and sharing of seismic data impose collecting and sharing seismic data in real time from and to different Seismic Networks. Because these networks and data format are different it was decided in the Nearest project that the 3 seismic nodes improve there seismic networks to use the MiniSeed data format and Seedlink software for real time data exchange. As described in the section 2.1**,** the CNRST seismic network transmits signals in analog form in real time to the recording central facility where data is digitized and stored in a proprietary format (Kinemetrics CDF). For this reason and to establish the Nearest Rabat seismic node, the CNRST has attempted two solutions:

The first one is the development of new acquisition software that could generate data in real time and a format compatible with other real time systems like SeedLink or Antelope. The software was developed under MatLab tools. The data acquisition and conversion to MiniSeed format works very well, but not yet the integration of the GPS signal for synchronisation. Due to the limited duration of the NEAREST project, and also the launching of the Moroccan seismic network upgrade, we stopped working in this direction.

The second approach, which is easier, is the digitizing of seismic data at the Rabat centre using adequate dataloggers that have plugins with SeedLink and Antelope. A six channels Quanterra Q330 was installed to digitize the best 6 stations of the current seismic Network. Since the NEAREST partners agreed to use SeisComp software for seismic data exchange, a workstation running SeisComp 2.6 was installed at the beginning of 2007 in order to acquire data from the Q330 (6 stations from the actual seismic network), the MedNet station RTC, and 3 stations from the IM Portugal

Node PESTR, PFVI and PVAQ. Later, three stations were added from the IG Spanish Node: HORN, CEUT and SESP.

At the same time and since 2007 the data of the Rabat VBB (RTC) station is shared in real time with the Portugal node and made accessible to the Spanish node. Later, another Moroccan BB seismic Station “RSA” is added to the system. RSA is part of the New BB VSAT Moroccan Seismic Network.

The Rabat node as what was before Decembers 2008 can be shown as below (figure 21):

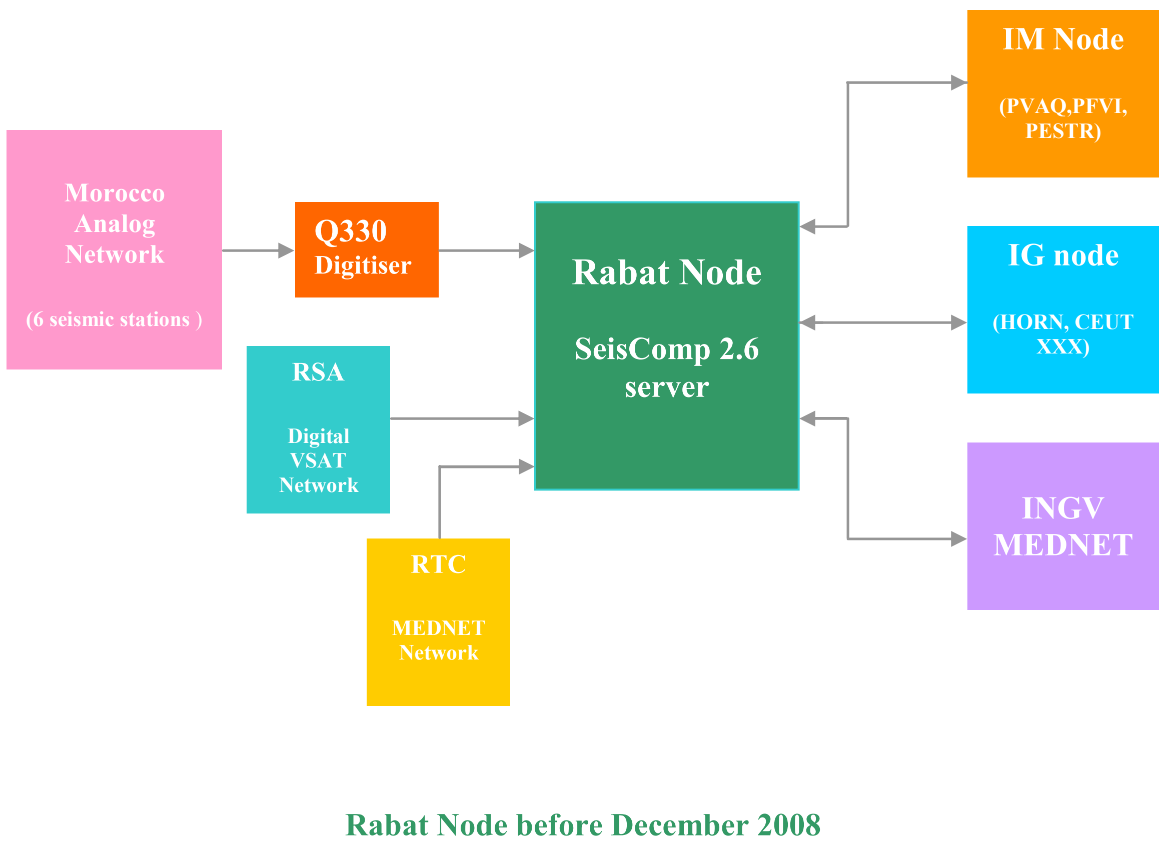


Figure 21. Flow chart of Rabat seismic node

By the end of 2008, the CNRST started the upgrading of its seismic network. A new acquisition system based on the Antelope software was installed. For the new network we will deploy in a first phase 20 BB stations and 11 SP stations using VSAT communication, and will be distributed as shown in the map below (figure 22).

Station distribution of the new telemetred seismic network (1st phase)

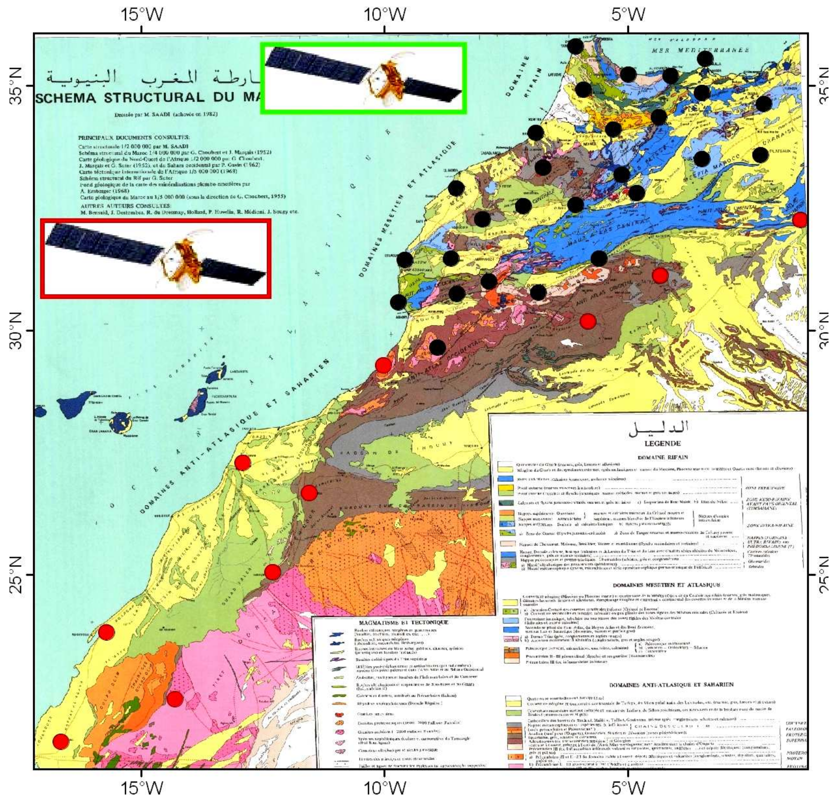


Figure 22. Spatial distribution of the new Vsat seismic network

As we can remark from this distribution, many stations will be installed near the ocean costs. Those stations can be integrated in the future national tsunami warning system in the region.

Among the suitable features of the Antelope system are the communication capabilities with other real time acquisition system as shown in the following figure 23.

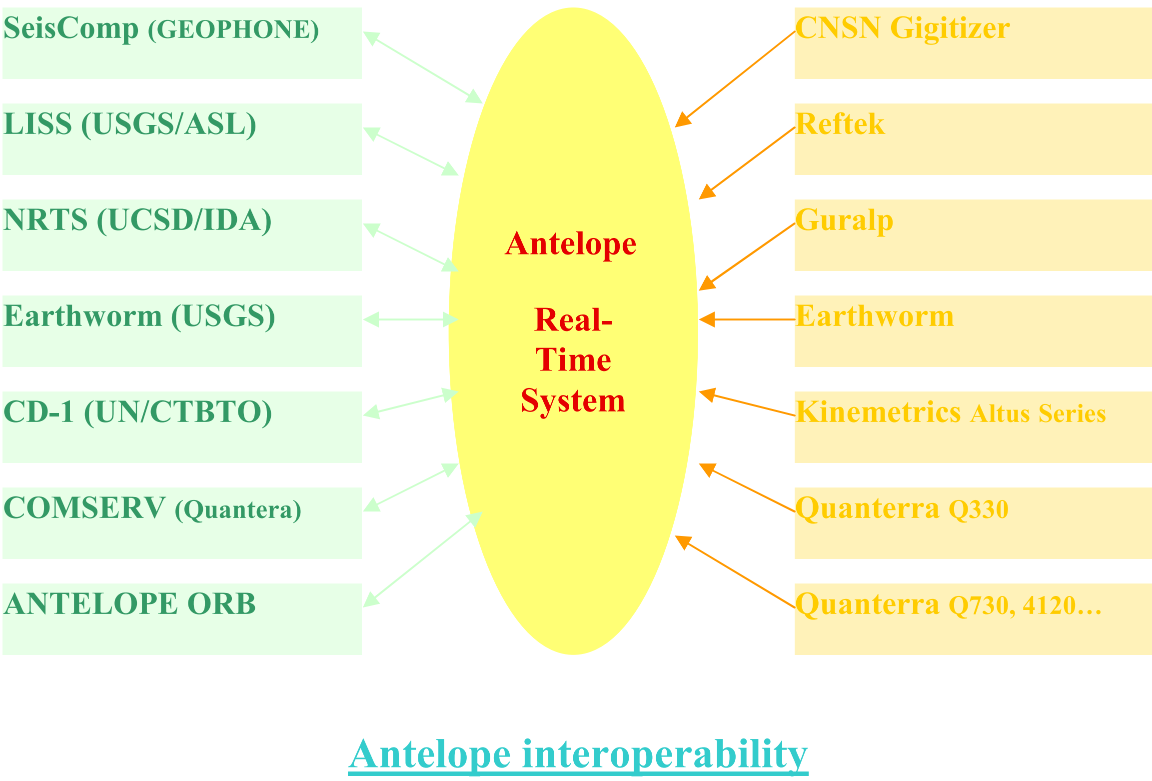


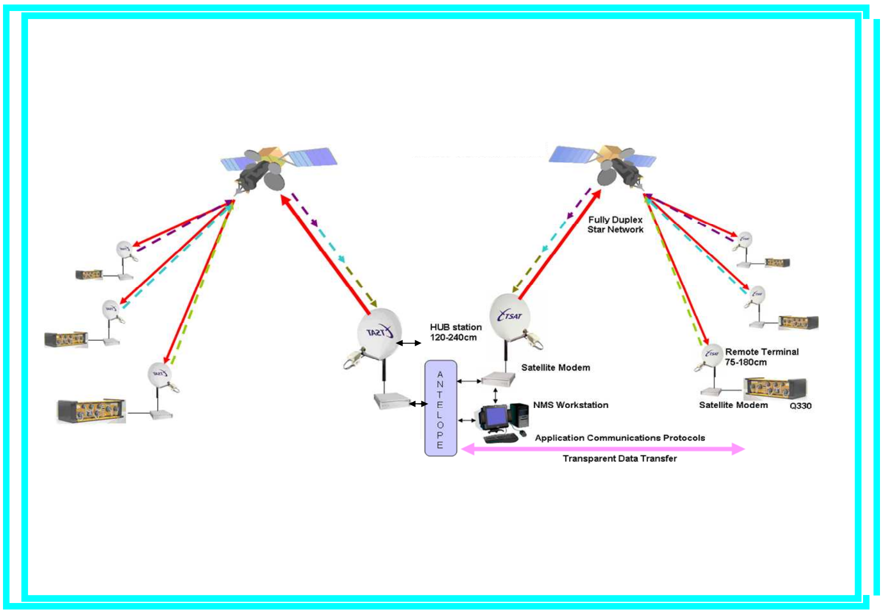
Figure 23. Scheme of the Antelope system in the Rabat node

The antelope system has more key features;

- Distributed real-time data acquisition and processing capability
- Distributed real-time system monitoring and control capability
- Comprehensive automated seismic event information in near real-time
- Information Dissemination: SMS, Web page, e-mail;
- Records data in real-time to non-volatile disk ring buffer
- Unique set of on-line and off-line processing tools
- Information system interfaces and functionality
- Offers tools with RDBMS for rapid access to earthquake information

The real time acquisition and processing part of the system is designed to be redundant, consisting of 2 workstations Sun Microsystems operating in parallel on a RAID storage module. In case of problems in the primary station, the secondary station takes over immediately and automatically restarts the real time acquisition and processing.

In addition, to avoid an interruption of the acquisition of seismic data due to a possible breakdown of the satellite, the system has been designed to provide half of seismic stations on a satellite and the other half on another, thus ensuring redundancy for inquiring the seismic data without an interruption in whole system. The VSAT system is configured as shown below (figure 24):



Dual Hub reception, acquisistion and processing system

Figure 24. Configuration of the Vsat system

Since the new Antelope package offers interesting features in terms of communication, integration and compatibility with other systems, we modify slightly the configuration for the Rabat Node (figure 25). We continue to export data with SeisComp to the Lisbon and Granada nodes. Antelope is used to import data from those nodes (Lisbon & Granada). These external data are directly merged with data of the new real time seismic data of the Moroccan National Network and used for fast detection, association, localisation and assignment of the magnitude.

New VSAT Seismic Network - Rabat Center

Figure 25. Vsat seismic network in the Rabat center

The use of Antelope instead of SeisComp for the real time acquisition and processing aims to take advantage of the broad features offered by the Antelope installed for National Seismic Network. Furthermore this helps avoid running in parallel two real time acquisition and processing systems and having to control both systems simultaneously, even though this may be perceived as attractive in terms of redundancy. However, as previously mentioned the export of data to Lisbon and Granada nodes continues to be done using a server running on SeisComp Software. The system uses three servers to manage incoming and outgoing data. The following figure gives the current configuration of the Rabat node (figure 26).

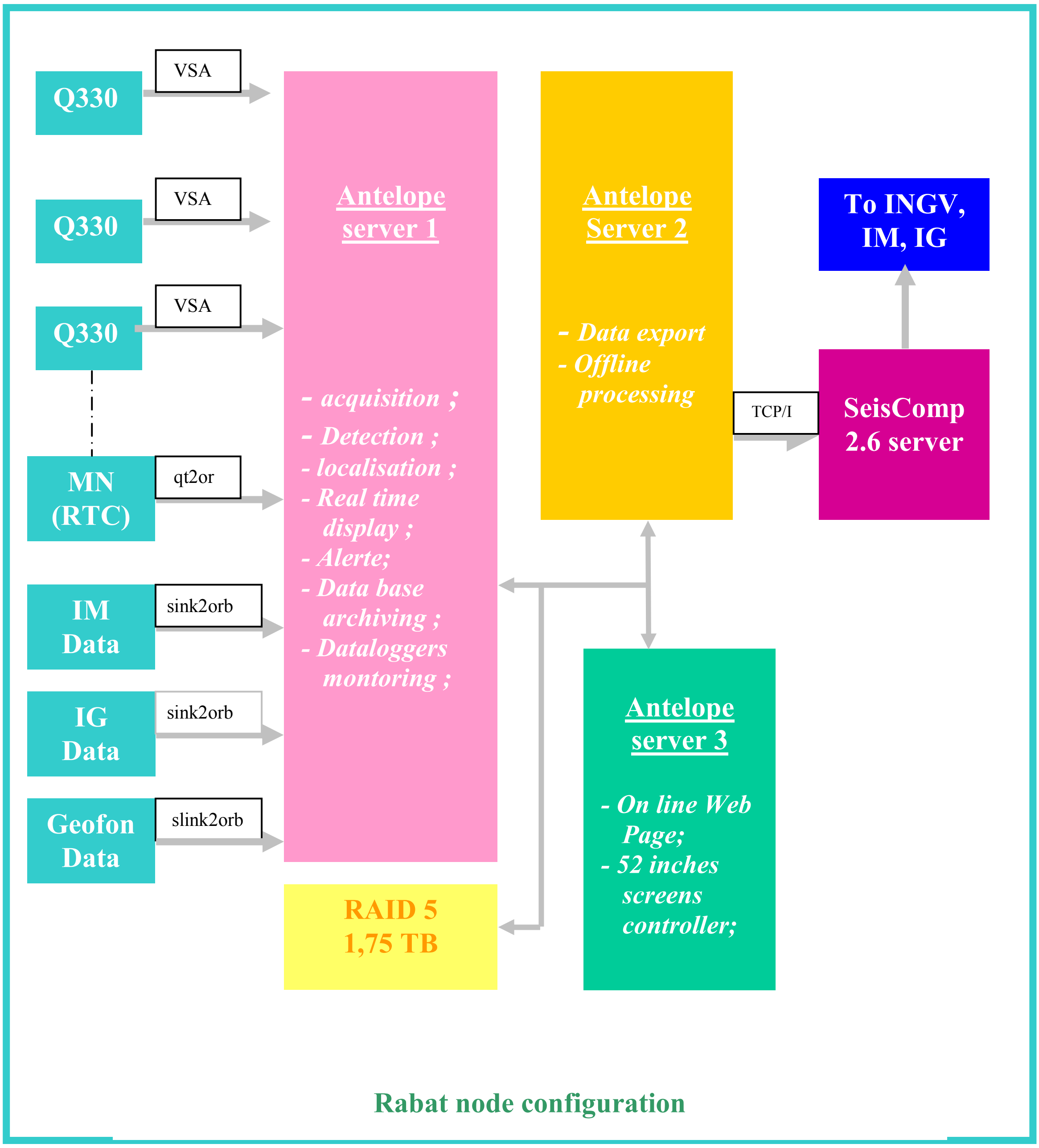


Figure 26. Actual configuration of the Rabat node

3.3.- Real time data integration in the IAG-UGR.

One of the basic elements to develop a prototype of Early Warning System is the integration in real time of the seismic data coming from the different seismic networks: local, regional or global, in order to manage the maximum number of data to do possible a fast response to a future large tsunamigenic earthquake. Such it is described in the section 2.3, the IAG-UGR seismic network was not designed to receive and to manage raw seismic data in real time due mainly because it was too expensive (satellite transmission). Therefore, the objective of being able to modify the seismic network and to adapt it to the necessities that it would require a prototype of Early Warning System (mainly a Real Time Seismic Network) needs some deep technical challenges. Among these challenges we can mention:

- To install real time communication protocols compatible with the hardware of the data acquisition system in field.
- To install software to manage the acquisition of seismic data which must to be compatible with the hardware and with the seismic instrumentation (seismometer, digitizer and gps antenna).
- To look for an operative system software to manage without problems all the resources (acquisition and transmission).
- To coordinate it with the different transmission ways (ADSL, cellular (GSM/GPRS), internet or basic telephone line).

Two of the more used protocols in the last years for the exchange of information in real time are: LISS and SeedLink. The LISS (Live Internet Seismic Server) of the Alburquerke Seismic Lab (Slad et to the., 1998) has several limitations; the main one is that in case of a loss of connection with the server, it cannot recover the data generated during the disconnected lapse time. In other hand, the Seedlink protocol was initially developed by GFZ Postdam (Heinloo, 2000; Hanka et at the 2000) as a module of SeisComP "Seismological Communication Processor" for the interrogation and intercommunication in real time of the GEOFON broad band seismic network. The SeedLink protocol is a robust data transmission intended for use on the Internet or private circuits that support TCP/IP. The protocol is robust in that clients may disconnect and reconnect without losing data; the transmission is started where it ended. Requested data streams may be limited to specific networks, stations, locations and/or channels. All data packets are 512-byte Mini-SEED records.

3.3.1.- Field module for the Broad band seismic stations

As we have described previously the field station (data acquisition system) it is formed by broad band triaxial STS-2 seismometer and EarthData PS2400 digitizer synchronized in time with a GPS Garmin. The acquisition hardware is mainly constituted by an industrial board CPU with to hard disk (Pentium to 200 Mhz with 64-128 Mb RAM and 40 Gbytes of hard disk) where the Seislog under QNX managed and saved the dates. To allow the real time communications we install the SeedLink protocol and also to substitute the *seislog* software for the acquisition for the SeisComP software, which is freely distributed by GFZ (http://geofon.gfz-potsdam.de/geofon//seiscomp/welcome.html).

The version installed in field, after numerous tests was the SeisComP 2.1 in its basic form for the acquisition: this version includes plugings to allow the acquisition of the EarthData digitizer and also include a slarchive-Seedlink client server for archiving dates on the local hard-disk using the SeisComP data structure (SDS). The recording of the data is carried out to 50 s.p.s., and the data remain 90 days stored in the disk, so the data could be recovered in case of a failure in the real time transmission.

The operative system was also changed, substituting the old QNX, incompatible with real time transmission for a Linux (Debian 3.1) compatible with the Seiscomp 2.1 module.

3.3.2.- Interrogation Data Center (Instituto Andaluz de Geofísica).

The Real Time interrogation and management of seismic data is now carrying out, in the Instituto Andaluz de Geofísica, by means of three servers connected under TCP/IP protocol: ***Dagobah, Istar and Emergencia***. Next, we describe the role that plays each server in the administration, management and automatic processes of the seismic data in time real of the IAG-UGR seismic network (broad band and short period elements), as well as, the seismic data from others external seismic networks (figure 27).

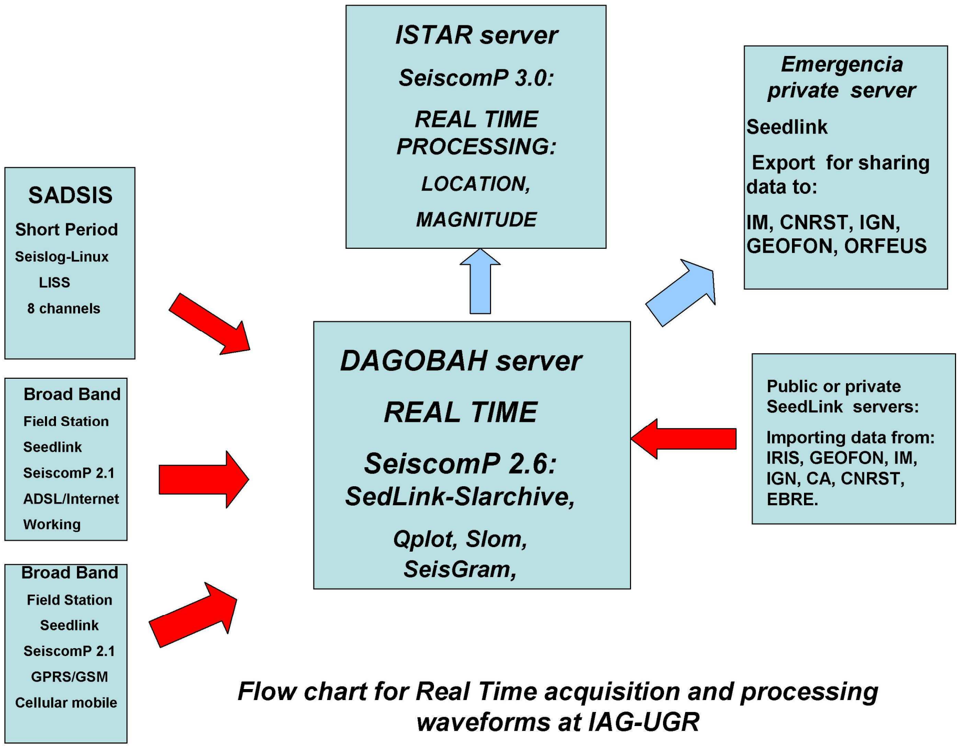


Figure 27. In this figure is shown the new Real Time acquisition and data processing scheme at IAG-UGR Red arrow indicate import data in real time from seedLink servers and blue indicate export to seedLink server for sharing data with another organisms.

The main mission of *Dagobah* server is to interrogate and to allow the communication in real time with the field server (remote seismic station), to record the data of the different broad band stations of the IAG-UGR. In this server it was installed the SeisComP 2.6 with the modules of acquisition: Seedlink-slarchive to save the waveform, the Qplot module, which generate GIF images of the seismogram in a format similar to the 24-hours drum recording (figure 28) and the Seisgram module (to monitorize the waveform in real time). The operating system installed in the server is Ubuntu 8.04.

Dagobah it is also used to interrogate other public or private servers whose waveforms (mainly of stations located in the Iberian Peninsula and surroundings areas). The seismograms collected are exported to another server (*Istar*) to be used in automatic processes as autopicking, automatic location and fast evaluation of the seismic source (magnitudes).

The *Dagobah* server is the core of the interrogation-acquisition system in the Central Recording Center in the IAG-UGR, for the seismic stations managed by the IAG-UGR and also for those that are imported in real time through other public or private servers. At this time the number of broad band stations of the IAG-UGR that are monitorized in real time, after carried out the changes in the field stations, are those that have ADSL lines or private Intranet (UGR) that support the communication TCP/IP. These are: ARAC, HORN, SESP, CEUT, SELV, NERJ and GORA. At this time we are developing several tests for the transmission of data in real time for those stations connected by cellular GSM/GPRS lines. These are: JAND, ESTP, ACLR, ASCB, and ACBG. The first tests for the transmission via GPRS have been positive for the station ACBG, which is received in real time since November 2009. It is expected that the network can be completed for its transmission in real time in few months, at least for those with GPRS-3G coverage.

Besides the stations of the IAG-UGR, the seismic server *Dagobah* obtains broad band seismic data in real time of others public or private servers belonging to institutions that manage seismic networks in the Iberian Peninsula and surrounding areas:

From the private server of the Meteorological Institute of Lisbon in Portugal (PM seismic code network) the seismic stations that are being received are: MVO, PESTR, PFVI y PVAQ.

From the private server of the Instituto Geográfico Nacional of Spain (ES seismic code network): EMUR, EBER, EMIJ, EALB y ESPR

From the private server of the Ebro Observatory server (SS seismic code network): EBRE,

From the private server of the Institute of Catalan Studies (CA seismic code network): FBR, POBL, CADI.

From the GEOFON public server (GE/WM seismic code network): MTE, MELI, CART, MAHO and MELI

From the IRIS public server (IU): PAB

From the MedNet seismic network (MN seismic code network): RTC through the GEOFON server.

From the CNRST. Morocco seismic network (MO seismic code network): RSA.

To include data from the short period network in the interrogation and acquisition in real time protocols (managed by *Dagobah* server), a different procedure was used respect to the process implemented in the broad band network, which was described previously. In this case and due to the signal transmission of the different stations that is carried out in an analogical way it has been needed to install an intermediate stage-module between the analogical reception and the communication with the *Dagobah* server. This module is an analogical-to-digital converter with 16 bits resolution (SARA SADC10 of 16 bits) with two cards of 4 channels each one. In this case the same acquisition mainboard used in field for broad band has been used (Pentium to 200 Mhz with 64-128 Mb RAM and 40 Gbytes of hard disk). However as in this case the Seiscomp 2.6 can not manage the multiplexed structure of the short period signals we have installed the *Seislog* soft (Utheim and Vásquez Casanova, 2006) under a Linux operative system (Debian 3.01) to control the digitization at 100 s.p.s and to allows the time synchronizing with the Garmin GPS. We also have tested using a low-power board TS 7260 with embedded systems. The communication in real time with *Dagobah* server is carried out by means of the LISS protocol using a intranet connection.

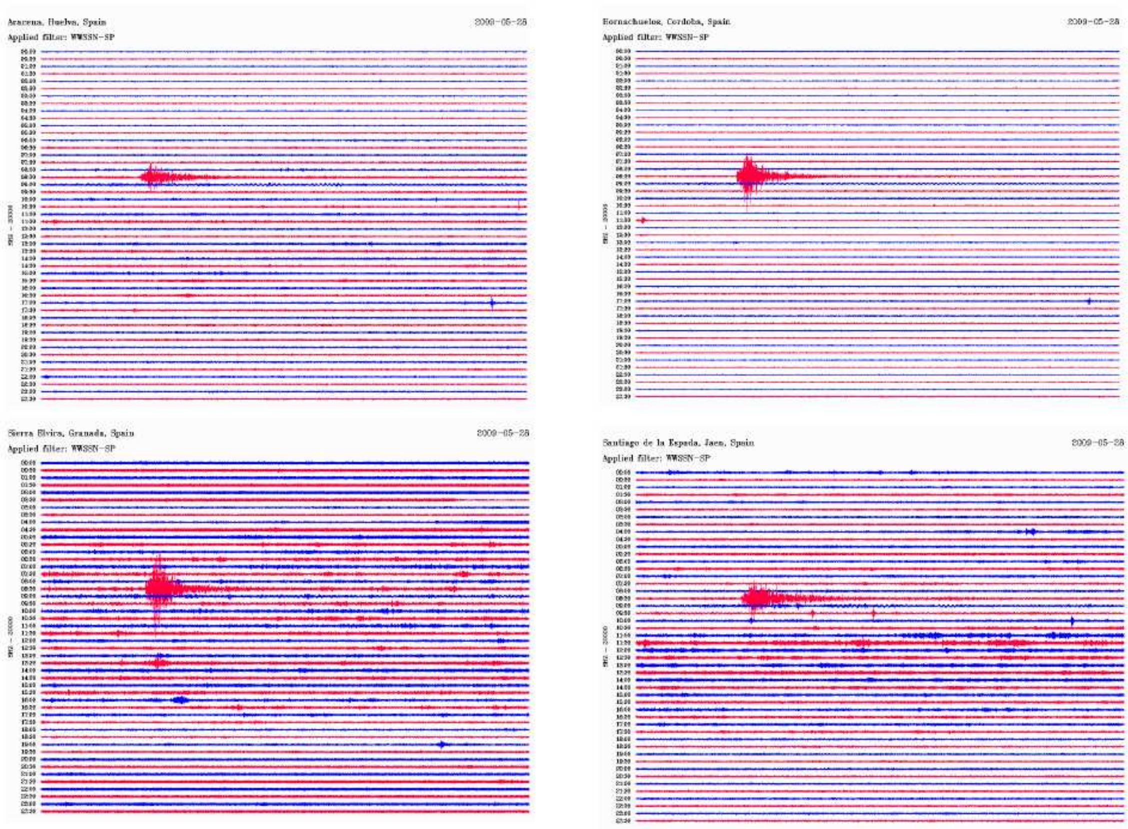


Figure 28. Gif images generated by the Qplot module for 4 broad band stations of the IAG-UGR network (SESP, SELV, ARAC and HORN) in a 24 hours drum recorded format. We appreciate the 28 May 2009 Honduras Mw=7.3 earthquake seismograms recorded.

The *Dagobah* server also exports the waveforms that that are being received in real time to another two servers (*Emergencia and Istar*) (Figure 27):

- *Emergencia*, is used as a private server of the IAG-UGR for sharing seismic data with *Nearest partners:* Meteorological Institute of Portugal and the CNRST of Morocco. Also the seismic data are offered for sharing to others institutions as for example the Instituto Geográfico Nacional (IGN) of Spain, GEOFON and ORFEUS contributing to the Virtual European Broadband Seismograph network (VEBSN). The waveforms shared are: HORN, SESP and CEUT for the Meteorological Institute of Portugal and the CNRST of Morocco. GORA, SESP and SELV for IGN of Spain. CEUT, SELV and SESP for GEOFON and ORFEUS (VEBSN). In this server it was installed a Linux as operative system (Ubuntu 8.04) with a Seiscomp 2.6 software with Seedlink-slarchive and Seisgram modules.

- *Istar* is used*,* for the management of the real time processes related with the identification and picking of the seismic phases, estimation of the location parameters (geographic coordenates and depth) of the seismic activity and the calculation of the size of the seismic source by a fast procedure algorithm that estimate mLv, mb, Mwp, Mw(Mwp), mB, Mw(mB) magnitudes (Bormann and Saul 2008). In this case we have installed the version SeisComP 3.0 (Hanka et al 2008, Saul et al 2008) under OpenSuse 10.3 as operative system*.* Futhermore this server receive in real time waveforms from *Dagobah* and also for the rest of seismic stations globally distributed belonging or managed by the public seismic server of IRIS and GEOFON:

The real Time server of **GEOFON (**geofon.gfz-potsdam.de:18000) export broad band seismograms their Virtual Global Broad Band Seismic Network and also from associated seismic Networks.

Real-time Data from the **IRIS-DMC**, runs a publicly accessible SeedLink server on the following host and port: host: rtserve.iris.washington.edu port: 18000. All open data that the DMC receives in real-time is available via this SeedLink server. Data arriving at the DMC more than 48 hours behind real-time is not exported via SeedLink.

3.3.3.- SEISCOMP 3.0 on Istar Server

Seiscomp 3.0 (SC3.0) is a new approach platform for to real time manage of seismic data (Hanka et al 2008; Saul et al 2008). Although SC3.0 has different architecture software and display it can be regarded as an extension of the previous Seiscomp 1 and Seiscomp 2.X's versions (Hanka et al 2003). SC3.0 was designed in a modular architecture that allows interactive and automatic processing using a single o several PC's connected via LAN. The SC3.0 modules allows quality control of seismograms, latency of the seismic stations, ground motion level (*Mapview, Real Time Trace View* and Control Quality modules) in each station/network (figures 29, 30 and 31) and the automatic procedures for to determine earthquake parameters as epicentral coordinates, depth and magnitudes.

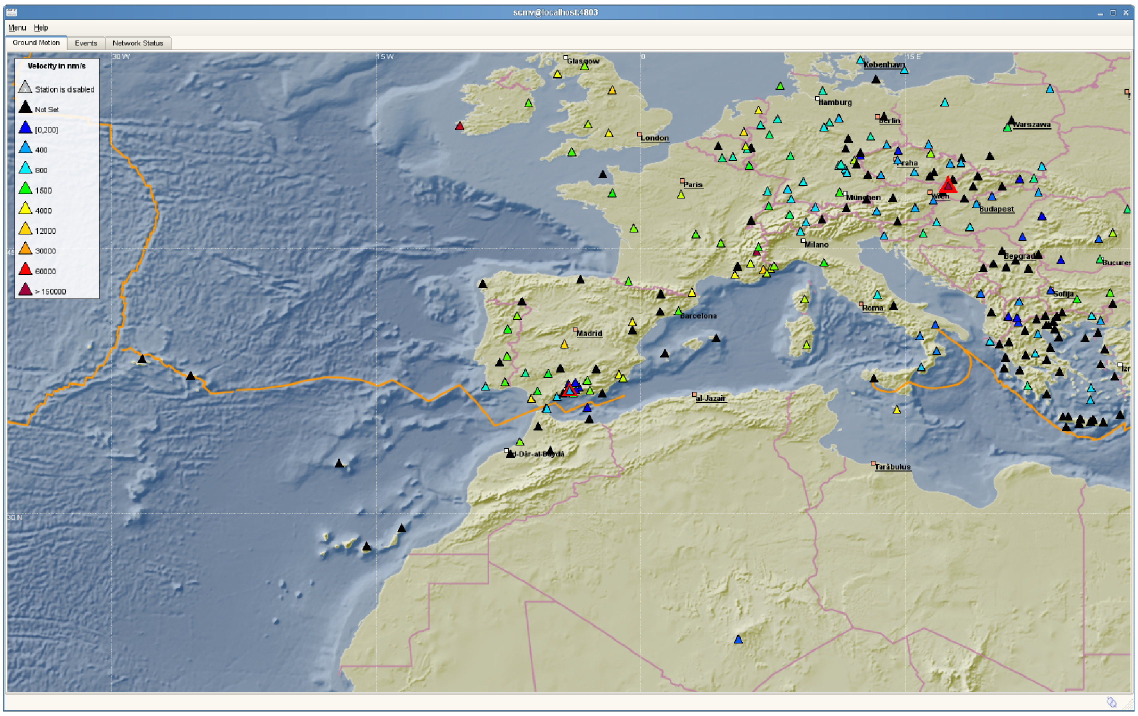


Figure 29. Screen image of the MapView module of the Seiscomp 3.0 operating in the Istar server. An image centered in the Iberian Peninsula shows the seismic stations that are being received in Real time by the IAG-UGR.

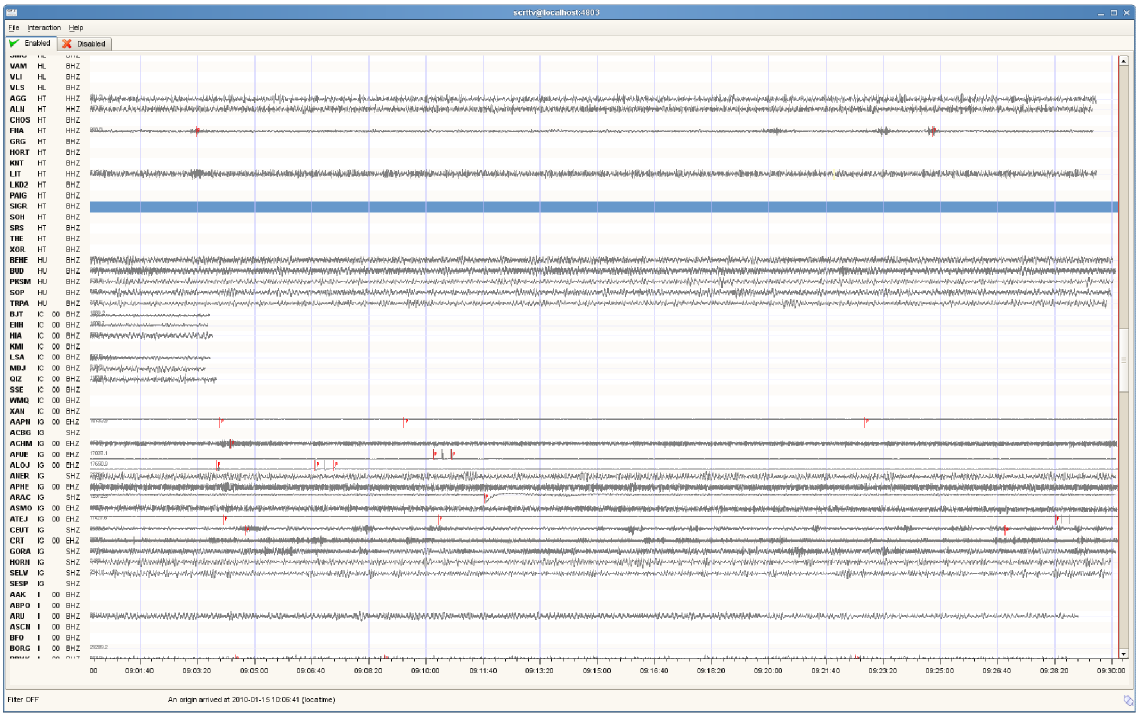


Figure 30.-. Screen image of the Real Time Trace View module of the Seiscomp 3.0 operating in the Istar server. It appreciates some of the seismograms of the different networks that are receiving in Real Time at the IAG-UGR.

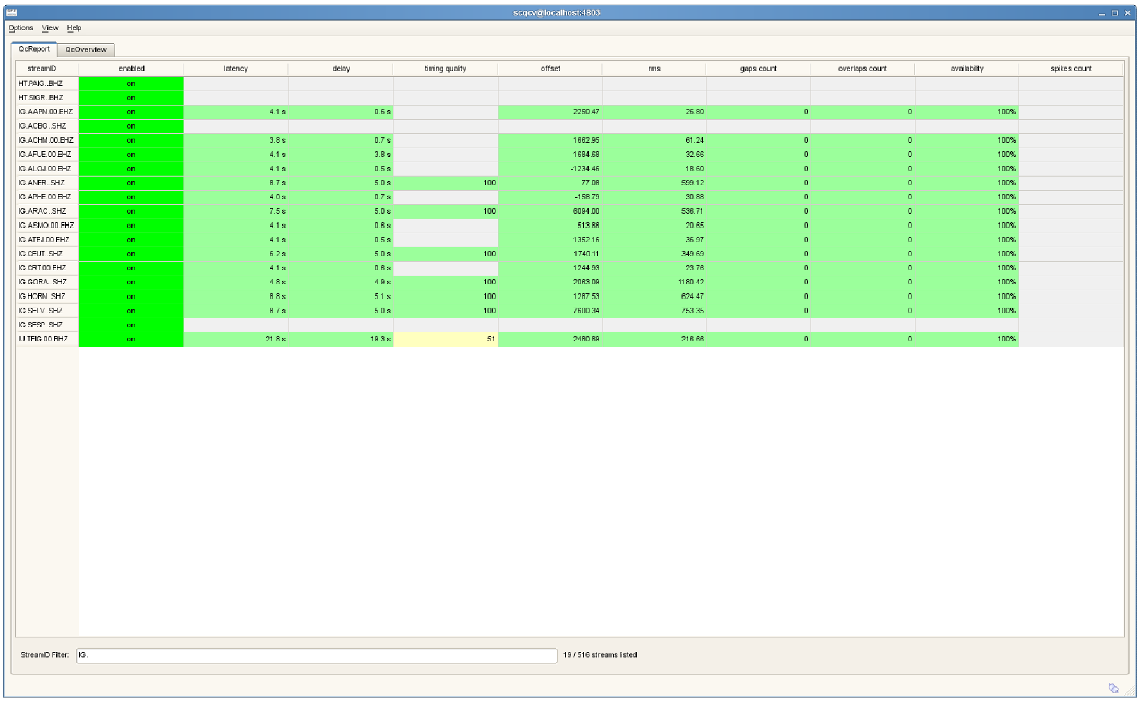


Figure 31.-. Screen image of the Qality Control module of the Seiscomp 3.0 operating in the Istar server, where the health state of the all seismic stations from the all networks received in real time. The information shows by the module include the delay, latency, rms, spike, gap, timing

At the moment, *Istar* is receiving 516 seismograms in real time from stations globally deployed around the world, with special emphasis in the deployed ones in the Iberian Peninsula, allowing that through the SC3.0 the real time monitoring of the local, regional and global seismic activity.

4.- Sharing seismic data between partners and external organisms.

4.1 IM Waveform Server for sharing data between *Nearest* partners and external agencies.

As we have previoulsy mentioned, in the section 3.1, some of the broad band waveforms belonging Instituto de Meteorologia seismic network (PM code) are exported to a private server (*imslserver.meteo.pt*), located on a DMZ, to be shared in real time with the Nearest partners (IAG-UGR and CNRST) and with other agencies: Instituto Geográfico Nacional of Spain (IGN), ORFEUS, GEOFON, DMC/IRIS and

Univ. Lisbon (LX net). This *imslserver* machine is running Seiscomp 2.5 on top of linux SUSE9.1 PC platform. Data access is controlled by IP filtering.

4.2 Server for sharing data (*Export*) between *Nearest* partners and external agencies at CNRST.

As previously stated in section 3.2, The Rabat very broad band station (RTC) which is part of MedNet Network and hosted by CNRST and a new VSAT BB station (RSA) located in the north of Morocco are sent to a special ORB in the Antelope server 2 called orb_e*xport*. The data acquired by this orb are sent to a workstation running SeisComp 2.6 in order to be shared in real time with the Nearest partners (IM, INGV, IG) using SeedLink .

4.3 IAG-UGR Seismic Server for sharing data between *Nearest* partners and external agencies.

As he have mentioned in the section 3.3, some of the broad band seismograms belonging IAG-UGR seismic network are exported to a private server (E*mergencia*) to be shared in real time with the Nearest partners (IM and CNRST) and by another institutions: Instituto Geográfico Nacional of Spain (IGN), ORFEUS and GEOFON. In this private server it has been installed the SeisComp 2.6 running under a Linux operative system (Ubuntu 8.04) with the SeedLink and Seisgram modules. The server uses the port 18000 for the connection with the external servers to export the data stream.

In the cases of the Institute of Meteorologia of Portugal and the CNRTS of Morocco the exported seismograms are: HORN, CEUT and SESP and for the Instituto Geografico Nacional de España (IGN) and GEOFON: SELV, GORA and SESP.

5.- Situation after Nearest project: advances for an Early Warning System in the Gulf of Cadiz.

As consequence of the advances carried out in the improvement and implementation of the seismic networks managed by IM, CNRST and UGR, explained with details in the previous sections we can conclude that we moved from having seismic networks designed for monitoring of the seismic activity under conditions of non real time to a situation that allows us to be in disposition to develop seismic surveillance under conditions of real time. This deep modification in the philosophy and in the management of the seismic data constitutes a clear milestone of this project. This transformation, with clear qualitative and quantitative advantages, takes also harnessed deep changes in the form of understanding a seismic network with changes in its flowchart work. Fundamentally we have passed of a quasi-static conditions in which each organism worked in an almost autonomous way with impossibility of being able a real time monitoring and surveillance in the SW of Iberia, to a situation with a dynamic and global philosophy. The autonomous character of the different agencies that operate in the region was imposed fundamentally for the different strategies that each organism had in the administration of the seismic data that generated. On the other hand, although some exchange of seismic information could exist among the partners, this was always carried out mainly after a singular earthquake (i.e last Horseshoe February 12th, 2007 Mw=6.0 earthquake) or with a research purpose. Therefore it didn't exist interconnection and/or sharing of seismic data among organisms just before to start the present project.

Independently of the specific technical characteristics of the different seismic networks belonging to IM, CNRST or the UGR, we have found a common point that have allowed to solve part of the challenges outlined in the workpackge 5 and more concretely in the task 5.1, relative to the seismic data integration. This technical solution has been based on the installation of a protocol of transmission of seismic data in real time “SeedLink”. The adaptation of this protocol for each one of the partners to modify its respective networks by means of the installation of SeisComP software package, has allowed developing a *Virtual Seismic Network* for the SW of Iberia. So, the different seismic dates collectors (seismic servers) installed in each country can receive in Real Time, waveforms from its own seismic network and also from to sub-set of seismograms belonging to others networks, allowing a best location geometry of seismic stations that facilitates a fast procedure for location and size estimation of the seismic source of the earthquake activity in the Gulf of Cádiz.

6.- Conclusions.

The real time data collection of the seismic component of a prototype of an Early Warning System for the SW of Iberia using the broad band seismic stations belonging to the different partners involved in the Nearest project mainly (IM, CNRST and UGR), was a important challenge to solve. Although, each seismic network was designed initially for seismic monitoring and surveillance it was not possible to give a fast response due mainly to the lack of, first a real time seismic data collector and second a platform for automatic processing. Although there are technologies to transmit in real time (i.e VSAT) the main challenge in this task was to be able to incorporate protocols of communication adapting them to the specifics characteristics of each seismic network.

The SeedLink system, designed by GFZ, was decided as the best tool for real time communications using TCP/IP protocol. This SeedLink protocol has client-server architecture and uses the Mini-SEED data format for the transmission. SeedLink works under a Seiscomp platform which can receive data directly from the field seismic stations and also from other public or private seismic servers.

The incorporation of this protocol of communications for each partner has allowed to begin a new stage in the administration of their own data as well as those that are being receiving in real time from other regional or world seismic networks through public or private servers. Although each partner goes carrying out continuous improvements that facilitate the automatic processed administration of the data we can conclude that the adopted system based on the protocol included SeedLink the platform Seiscomp is positively working to achieve the challenges marked in this workpackage.

The increase and progressive diffusion for the different seismic networks in the incorporation of the Seedlink protocol generating public or private servers will facilitate the exchange/share of data and it will facilitate the monitoring and fast evaluation of the earthquake activity.

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